CAA2022 OXFORD

iNSIDE iNFORMATION

8:11 AUGUST 2022

Abstract Book

Contents

Information

CAA2022 will be a hybrid event. Anyone who is unable to attend in person will be able to join us remotely on Teams. We strongly encourage remote delegates to use the Teams app rather than using a web browser. The Teams app can be downloaded from: https://www.microsoft.com/en-gb/microsoft-teams/download-app. Links to Teams meetings for individual sessions will be provided in the final conference programme (coming soon).

Sessions

The timings in the programme include 15 minutes at the beginning of each session for an introduction, 15 minutes at the end of each session for concluding remarks and wider discussion, and 5 minutes between papers for handover and questions.

Papers

Standard papers should last 15-20 minutes.

In Person: Windows laptops running PowerPoint are provided in all rooms. **You will not be able to use your own laptop to present**. Please bring your presentation with you to the session on a USB stick. You should save your presentation in both PPTX/PPT and PDF formats. Wifi is provided in all rooms. If you intend to use an online presentation, please bring a backup version with you on a USB stick.

Remote: You will need to share your display using the Teams app in order to present live. We recommend that remote presenters join the meeting 15 minutes before the start of the session block in which they are presenting. If you wish to pre-record your presentation please email your presentation to the session chair at least 1 week before your session.

Lightning Talks

The length of lightning talks varies between sessions – if in doubt, check with your session chair.

In Person: Windows laptops running PowerPoint are provided in all rooms. **You will not be able to use your own laptop to present**. Please bring your presentation with you to the session on a USB stick. You should save your presentation in both PPTX/PPT and PDF formats. Wifi is provided in all rooms. If you intend to use an online presentation, please bring a backup version with you on a USB stick.

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Posters

Posters will be displayed in North Schools. Please bring/send the printed version of your poster to the registration desk in the Great Hall on the morning of the first full day of the conference (Tuesday 9th August). Poster presenters should be available to answer questions about their posters at lunchtime on Wednesday 10th August (12:30 – 13:30).

Posters should be no larger than A0 (841 mm x 1188 mm) if printed in portrait orientation and no larger than A1 (841 mm x 594 mm) if printed in landscape orientation.

Poster presenters will also be given the opportunity to present a 1 slide, 2 minute presentation of their poster in the main session. If you wish to take advantage of this opportunity, please notify your session chair and follow the presentation guidelines for Lighting Talks (above).

If you are unable to bring/send your poster to the conference, please email the conference organiser (caa2022@caaconference.org) to make alternative arrangements.

Scientific Programme

Monday 8th August

Seminar Room	Lecture Theatre	Teaching Room
W1. Building chronologies with ChronoLog 13:30 – 15:00	*W2. How to navigate the coding archaeology world* 13:30 – 15:00	*W3. Global Virtual Access Library implementation* 13:30 – 15:00

Tuesday 9th August

Great Hall
Registration 09:00 – 10:00

South Writing School
Opening Plenary 10:00 – 10:30

East Writing School	Room 6	Room 7	Room 9	Room 11	Room 14
S07. Cultural heritage data across borders 11:00 – 15:00	*S25. Engaging the public with archaeology and cultural heritage* 11:00 – 15:00	*S08. Are you my type?* 11:00 – 15:00	*S10. Digital archaeology in the Gulf* 11:00 – 15:00	*S14. Large-scale and intensive computational workflows in archaeological remote sensing* 11:00 – 14:20	*S04. Hic sunt dracones!* 11:00 – 15:00

South Writing School
CAA @ 50: Looking to the future 15:30 – 17:00

Wednesday 10th August

South Writing School	East Writing School	Room 06	Room 7	Room 9	Room 11	Room 14
S01. iN Deep (Other) 09:00 – 15:00	*S13. Machine and deep learning methods in archaeological research* *(Part 1)* 09:00 – 15:00	*S20. Investigating and/or modelling ancient paths* 09:00 – 14:35	*S18. Exploring further the possibilities of 3D spatial analysis* 09:00 – 14:35	*S16. Reaching across the digital divide* 13:00 – 15:00	*S11. Mountains of data* 09:00 – 14:10	*S05. Our little minions IV* 09:00 – 12:15
						S12. Formal modelling and models of social complexity *(Part 1)* 13:30 – 15:00

South Writing School
AGM 15:30 – 17:00

Thursday 11th August

North Writing School	East Writing School	Room 6	Room 10	Room 11	Room 14	Room 15
S06. Towards an open platform for computer simulations of past socio-ecological systems 09:00 – 10:30	*S13. Machine and deep learning methods in archaeological research* *(Part 2)* 09:00 – 14:20	*S27. Modelling prehistoric maritime mobility* 09:00 – 14:20	*S03. Quantitative approaches applied to lithic studies* 09:00 – 14:35	*S21. Inter-disciplinarity in digital archaeology* 09:00 – 14:10		*S09. Archaeology and digital humanities* 09:00 – 10:30
S12. Formal modelling and models of social complexity *(Part 2)* 10:30 – 17:00		*S23. Computational archaeology & seafaring theory* 15:30 – 17:00		*S15. Workflows and experiences on collaborative working and community building using digital tools* 15:30 – 17:15	*S22. Traces of digital archaeological practises* 11:00 – 16:10	

Venues


Walton Manor
Norham Manor
Jericho
School of Archaeology
Ashmolean Museum
Gloucester Green
Railway Station
Oxford
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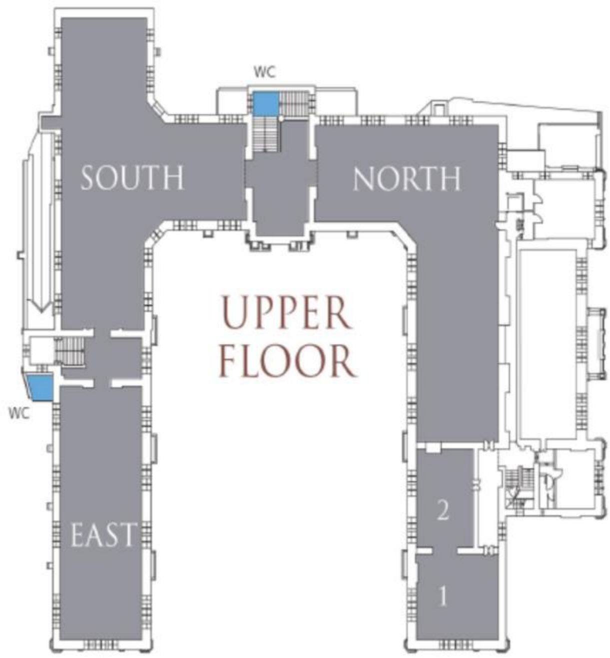
Examination Schools



Workshops (Monday)

Workshop 1. Building chronologies with ChronoLog: A practical introduction

Eythan Levy, University of Bern

This workshop will present the foundations of ChronoLog, a free tool for building chronological models, testing their consistency, and computing tight, checkable, chronological estimates. These models consist of a network of entities (e.g. archaeological strata, ceramic periods, historical reigns) connected by a set of synchronisms. The tool allows users to modify the data in the model and assess on-the-fly the impact of these updates on the overall chronology. ChronoLog also allows users to add radiocarbon determinations to their models, and to convert the model automatically to an OxCal Bayesian radiocarbon model. This feature allows archaeologists with no knowledge of the OxCal specification language to build complex Bayesian models on their own, with just a few clicks of the mouse. The workshop will start with a general introduction to ChronoLog, its basic principles, and its main functionalities. The main part of the session will then be devoted to practical modelling exercises, which users will do on their own laptops. In these exercises, users will first learn how to build chronological models by themselves, based on a wide set of archaeological and historical data. They will then explore how ChronoLog can serve as a useful tool for archaeological cross-dating. Finally, they will learn how to use ChronoLog as a front-end to OxCal for building Bayesian radiocarbon models. ChronoLog is freely available for download at https://chrono.ulb.be . For more details on ChronoLog, a user manual is available on the ChronoLog website. For additional details, see the bibliography below.

The workshop has no formal requirements. Participants should bring their laptop, and have an internet connection to download the ChronoLog app at https://chrono.ulb.be or, alternatively, download the app before the start of the workshop. For the last part of the workshop, users are also encouraged, if possible, to create an OxCal account on https://c14.arch.ox.ac.uk/oxcal/.

References

E. Levy, I. Finkelstein, M.A.S. Martin and E. Piasetzky, 2022: "The Date of Appearance of Philistine Pottery at Megiddo: A Computational Approach." Bulletin of the American Schools of Oriental Research 387, pp. 1-30.

E. Levy, E. Piasetzky, A. Fantalkin and I. Finkelstein, 2022: "From Chronological Networks to Bayesian Models: ChronoLog as a Front-end to OxCal." Radiocarbon 64, pp. 101-134.

E. Levy, E. Piasetzky and A. Fantalkin, 2021: "Archaeological Cross-dating: A Formalized Scheme." Archaeological and Anthropological Sciences 13, pp. 1-30.

E. Levy, G. Geeraerts, F. Pluquet, E. Piasetzky and A. Fantalkin, 2021: "Chronological Networks in Archaeology: a Formalised Scheme." Journal of Archaeological Science 127, pp. 1-27.

G. Geeraerts, E. Levy and F. Pluquet, 2017: "Models and Algorithms for Chronology", in S. Schewe, T. Schneider and J. Wijsen (eds), Proceedings of The 24th International Symposium on Temporal Representation and Reasoning (TIME 2017), Dagstuhl, pp. 13:1-13:18.

Workshop 2. How to navigate the coding archaeology world: An introduction to scientific co-creation using Git and Github

Sophie C Schmidt, Free University Berlin, Germany

Clemens Schmid, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany

Florian Thiery, Römisch-Germanisches Zentralmuseum, Mainz, Germany

The archaeological community is moving beyond the traditional modes of scientific communication, such as research papers, monographs and conference talks, and interacts online on a daily basis. Especially for archaeologists, who use and develop advanced, computational tools, a new kind of platform increasingly extends mailing lists and social media here, and has proven invaluable for collaborative work: Version control systems to develop, share and test manuscripts, figures and code.

But not just coding archaeologists collaborate online to co-create. And co-creation is riddled with pitfalls and challenges – for anyone. Ensuring that datasets are unified and tidy, that details in projects are documented reproducibly, and that each colleague is indeed working on the latest version of a text or script is neither trivial nor easy. Proper version control can simplify the collaborative process for small teams, larger research networks and the community as a whole – and is also helpful to back up single-author work.

In this workshop we will demonstrate how archaeologists can concretely profit from code sharing platforms and version control software, guide the participants to navigate these digital spaces and tools confidently, and showcase how they can streamline and improve common (research) tasks. We will give a practical introduction to some of the most popular systems: Git, a powerful command line software handling and documenting changes in (text)files, and the platform GitHub, where projects can be stored and shared online.

- The following topics will be covered
- The markup language Markdown for writing text collaboratively
- The software Git and how to use it for day-to-day work
- The GitHub website and how to set up projects for collaboration and sharing
- Community interaction with Issues and Pull Requests
- How deviating document versions can be merged

We will close with a real-world example from the Linked Open Data community – the SPARQLing Unicorn QGIS Plugin by the Research Squirrel Engineers – for which Git/GitHub is the basis of collaborative software development. This ties in with the proposed session "Workflows and experiences on collaborative working and community building using digital tools". Both session and workshop are organized by the CAA Special Interest Group for Scientific Scripting Languages in Archaeology in cooperation with the CAA SIG on Semantics and LOUD in Archaeology (Data-Dragon).

The workshop will be online and open for up to 18 participants without any prior knowledge. It should be streamed, so non-participants can follow along. We ask participants to submit a very short motivational statement with their current knowledge on the subject instead of an abstract.

Workshop 3. Global Virtual Access Library implementation: Using the template to create a working, interactive experience for your ancient manuscript

Lynn Dodd, University of Southern California

Sabina Zonno, The Huntington Library, Art Museum, and Botanical Gardens; USC

Mats Borges, Independent Technical Designer

Have you ever been standing in front of a rare, handmade, handwritten book in a glass display case with a desire to reach in and turn the pages yourself? Now you can do this in virtual reality!

The University of Southern California's Archaeology Extended Reality (XR) Lab will host a workshop on their "The Global Virtual Access Library" template which was created with support from the USA National Endowment for the Humanities.

The Global Virtual Access Library is a template that allows anyone to create virtual reality experiences of ancient books on parchment…or any book, really.

You'll start with 2-D photographs of your book's pages and text files containing translations. After following the instructions, you will have an immersive virtual experience in which you can turn the pages of the book with high realism and display it in a virtual reading space. This can be displayed in an 3-D, immersive, interactive Oculus Quest 2 headset or on a flat 2-D screen. The project allows customization of the virtual space, context, content, and more.

This is an innovative humanities resource that affords wide audiences access to virtual, high-realism, interactive experiences of ancient books. The initial prototype virtual reality experience focused on a rare, handmade, hand-written prayer book now at USC Special Collections, which was produced in the Southern Low Countries in the second half of the 15th century….and this ancient book has been joined by others, a beginning of a Global Virtual Access Library.

The goal of this project is to offer open, global, virtual access to ancient books in worldwide collections, delivering rich humanities content through interactive, multi-sensory, embodied learning experiences of these ancient books.

The virtual reality experience template is a portal to ancient manuscripts that makes them available to anyone, anywhere, at any time. This template also enables any global institutions that are preserving and exhibiting ancient manuscripts to create fully interactive, immersive virtual reality experiences of any book so that general audiences can engage as long as they wish and with every page of the book.

Join development team members for this half-day workshop in which users of any skill level can learn how to use the template with any book to make their own VR experiences. The topics we will cover are:

1. Intro to The Global Virtual Access Library and the template
2. How to put scans from any book into the project
3. Creating a virtual setting/context for your reading experience
4. How to export and share customized experiences

Attendees may watch or follow along as we go from downloading the Unity game engine to exporting a file that can run on an Oculus Quest 2 headset.

Advanced users can stick around to discuss the inner workings of the project, learn how to create more complex functions like custom interactive annotations, and more about The Global Virtual Access Library.

Attendees are encouraged (but not required) to download Unity version 2020.3.1 to their computer prior to the workshop to save time and bandwidth.

Sessions (Tuesday)

Session 04. Hic sunt dracones! Real-world data-driven knowledge modelling resulting in Semantics and FAIR-LOD based tools and workflows

Florian Thiery, Römisch-Germanisches Zentralmuseum, Department of Scientific IT, Mainz, Germany

Brigit Danthine, Universität Innsbruck, Department of Archaeologies, Innsbruck, Austria

Mag. Nicole High-Steskal, University for Continuing Education Krems Department for Arts and Cultural Studies

Dr. Valeria Vitale, The Alan Turing Institute

Dr. Allard W. Mees FSA, Römisch-Germanisches Zentralmuseum, Department of Scientific IT, Mainz, Germany

Dr. Karsten Tolle, Frankfurt Big Data Lab, Institute of Computer Science, Goethe-University, Frankfurt am Main, Germany

Dr. David G. Wigg-Wolf, Römisch-Germanische Kommission (RGK) des Deutschen Archäologischen Institut (DAI)

Room 14

Introduction	11:00 - 11:15
81. A glitch in the Matrix? - How FAIR and re-used is the stratigraphic data we record, analyse or synthesize? *May*, Taylor and Binding*	11:15 - 11:40
111. Linked Open Time: Reproducible LOD-driven workflows and research tools for validating Roman Limes and Hadrian's Wall relative time intervals based on Samian (Terra Sigillata) *Mees*, Thiery and Schmidt*	11:40 - 12:05
112. Challenges and opportunities from real world archaeological datasets in the community-driven LOD ecosystem *Thiery*, Mees and Wigg-Wolf*	12:05 - 12:30
Lunch	
148. Connecting 3D-environments with LOUD: The use case of the consumer landscapes of Monte Iato, Sicily *Danthine*, Dauth, Hiebel, Kistler and Öhlinger*	13:30 - 13:55
155. ArchaMap: A web-based application for integrating archaeological data and part of the CatMapper family *Bischoff*, Hruschka and Peeples*	13:55 - 14:20
171. Approaches to FAIR transformation of the Texas Archaeological Sites Atlas *McKee* and Yuan*	14:20 - 14:45
Discussion	14:45 - 15:00

41. A FAIR future for archaeological survey: The SEMAFORA project Poster

van Leusen, de Haas, Bruseker, Siebinga and Nenova*

Introduction

In historical maps, the phrase *"Hic sunt dracones"* (here be dragons) is used to describe areas which were unknown to the map creator. Today the WWW offers researchers the possibility of sharing their research (data) and enables the community to participate in the scientific discourse and create new knowledge. But much of this shared data is not findable or accessible, thus resulting in modern 'unknown data dragons'. Often these 'data dragons' lack connections to other datasets, i. e. they are not interoperable, and in some cases also lack usability. To overcome these shortcomings, Linked Open Data (LOD) techniques can be used (Hyland et al., 2013). In 2006 Berners-Lee introduced the concept of LOD (Berners-Lee, 2006), in 2018 Sanderson instigated the "Usable" aspect at EuropeanaTech (Sanderson, 2018). Additionally, in 2016 the FAIR principles were introduced: Findable, Accessible, Interoperable and Reusable (Wilkinson et al., 2016).

The Semantic Web offers a variety of vocabularies, ontologies and reference models that can be used for archaeology-related LOD modelling: CIDOC-CRM, SKOS, PROV-O, FOAF, GeoSPARQL, Wikidata, etc. The Linked Data Cloud already provides FAIR and LOUD research data repositories, data hubs and domain-specific ontologies for specific archaeological and humanities domains such as: Nomisma, Kerameikos, Pelagios, OpenContext, Portable Antiquities Scheme, ARIADNE, Linked Open Samian Ware, Linked Open ARS, Linked Open Ogham, and the Ceramic Typologies Ontology. Beyond them, many other networks for graph modelling in the digital humanities, such as the Pelagios Network, Linked Pasts, Graph Technologies / Graphs and Networks in the Humanities offer methods and resources that could be used and further developed for digital archaeological research.

The development of ever more repositories poses challenges in handling the complex facets of data quality and completeness. This is especially true for archaeological data, which are based on complex networks of concepts from different domains and linguistic backgrounds. Moreover, it is necessary to include means of assessing uncertainty in the data models to produce and publish transparent FAIR and LOUD data that can also describe specific stratigraphy or the (archaeological) context of objects.

To enable non-experts to engage with FAIR and LOUD data, research tools – little minions – were created for different purposes, such as modelling relative chronologies in RDF (e.g. Alligator), modelling and reasoning on vague edges in graph data (e.g. Academic Meta Tool), creating annotated texts and images (e.g. Recogito, Annotorius), and sparql, as well as enhancing Geo-Datasets using the SPARQLing Unicorn QGIS Plugin. In addition, community-driven knowledge bases like Wikidata not only offer data, but also provide a number of tools for using and interacting.

The positive feedback on the LOD sessions on data quality, FAIR and LOUD at CAA 2017-2021 encourages the pursuit of the debate. The goal of our online session is to bring together both experts and colleagues interested in learning about FAIR and LOUD data-driven publishing and applications, as well as to collect research application scenarios to jointly promote research domain specific solutions. We would like to discuss application-oriented and data-driven investigations into how to improve technologies for FAIR and LOUD data models as a basis for reproducible and

CAREful research and exchange in the Semantic Web, as well as solutions related to one or more of the issues listed below:

- application of semantic web technologies, such as ontologies (e.g. CIDOC-CRM) or RDF, to the archaeological domain modelling of archaeological artefacts, archaeological context, including the specificity of stratigraphy, uncertainty, and vagueness
- development of research tools producing or using FAIR and LOUD data
- identifying sources and dangers of incorrect or ambiguous LOD, e. g. duplicates across different LOD sources
- keeping track of the provenance of data as a means of solving errors and identifying their source
- setting up research-question based methodologies and tools in order to label or assess datasets based on their quality
- dealing with ambiguities resulting from multiple links in the LOD cloud
- computer vision or machine learning applications built upon controlled, semantic data
- modelling comprehensible / reproducible workflows and data flows as "Linked Pipes" using RDF for documentation and reproducible research (Thiery and Homburg, 2021).
- use of Linked Open Data related tools in archaeological research, their implementation and/or enhancement
- possibilities, challenges, benefits and risks of the Wikimedia Universe in archaeological research
- implementation of reference models such as CIDOC-CRM in real-world datasets and ways to achieve LOD
- graphs of facts, beliefs, and/or assertions as a digital archaeological method
- reasoning with heterogeneous and real world archaeological data in graphs
- granularity in LOD/graphs/networks
- graph and RDF representation of specific networks of persons, objects and information relating to research questions
- interacting with graphs and graph interaction design
- LOUD techniques as a solution for information and data annotation on objects / artefacts in 2D and 3D (e.g. cuneiform tablets, ogham stones, samian ware, books, texts, ...)
- semantically modelling geospatial data FAIR and LOUD
- implementation of GeoSPARQL as a geospatial standard in archaeological data
- things as a concept, such as places (e.g. Pleiades Place/Location), persons (e.g. "potters" as Actors) and events in archaeological LOD
- overcoming linguistic barriers and increasing accessibility through LOD
- implementing the CARE-principles through thoughtful LOD application
- development of educational or Open Educational resources (OERs) to increase use of LOD

We encourage presenters to derive the problems addressed from real-world datasets and to formulate proposals for solutions, preferably demonstrating (prototypes of) realised data-driven (web-) applications. Due to the thematic relevance, we target a broad and diverse audience and the challenges described should also be integrated into an archaeological context (excavation, museum, archive, etc.). Only those papers will be taken into consideration which offer the data and tools involved as FAIR data and Open Source tools in Open Science repositories (e.g. Zenodo, OSF, GitHub, GiRetLab). Exceptions to this principle (e.g. dissertation in course) should be explained.

This session is organised by the CAA SIG on Semantics and LOUD in Archaeology (SIG Data-Dragon). The core aim of this SIG is to use the SIG format to raise awareness for Linked Data in archaeology by creating a friendly and open platform to discuss and further develop semantics, and LOUD and FAIR data in archaeology.

References

Wilkinson, M., Dumontier, M., Aalbersberg, I. et al. (2016). The FAIR Guiding Principles for scientific data management and stewardship. Sci Data 3, 160018. https://doi.org/10.1038/sdata.2016.18.

Berners-Lee, T. (2006). Linked Data. URL: https://www.w3.org/DesignIssues/LinkedData.html.

Thiery, F., Homburg, T. (2021). Linked Pipes @ Linked Pasts 7: Introduction. Linked Pasts VII, Ghent, Belgium. https://doi.org/10.5281/zenodo.5781275.

Hyland, B., Atemezing, G., Pendleton, M., Srivastava, B. (2013). Linked Data Glossary, W3C Working Group Note 27 June 2013. URL: https://www.w3.org/TR/ld-glossary/.

Sanderson, R. (2018). Shout it Out: LOUD by Rob Sanderson, EuropeanaTech Conference 2018. URL: https://de.slideshare.net/Europeana/shout-it-out-loud-by-rob-sanderson-europeanatech-conference-2018-98225909.

81. A glitch in the Matrix? - How FAIR and re-used is the stratigraphic data we record, analyse or synthesize?

Keith May, Historic England

James Taylor, GB

Ceri Binding, University of South Wales

Stratigraphic laws and principles underpin the archaeological records from excavated sites and are essential for integrated analysis, wider synthesis and accessible digital archiving of the growing body of archaeological data and reports generated through the commercial archaeological sector in the UK and internationally. On most excavated sites, the stratigraphic record, most often visualized, and to a degree quantifiable, in the form of a stratigraphic matrix, acts as a primary, if not the primary piece of evidence for how, and in what order, the site was excavated. As such the stratigraphic record is the key mechanism that enables anyone less familiar with the site, to re-visit the excavation records, understand what data is most relevant for any research questions, or problems encountered, and piece together the underlying details of how the interpretations by the excavator(s) were arrived at.

However, such primary records are often only held on paper or scanned copies of matrix diagrams that cannot easily be re-used with associated data. Often the key phasing data needed for re-use in synthesis work and interpretive understanding, let alone Bayesian Chronological modelling (Dye & Buck 2015), is not consistently documented, if at all, in written reports. This results in key records being unsearchable or remaining unconnected and lacking interoperability with other data (unFAIR).

The focus of digital archives and museums is now switching from simply providing better access to digital records, to questions of how users in commercial units, curatorial organizations and academia, along with the general public, are going to make best use of this growing body of digital information and data.

This paper will present work undertaken by The Matrix project [AH/T002093/1] which is addressing some of the current problems caused by the lack of standardized approaches to analysis and digital archives of archaeological stratigraphic and phasing data.

The paper will also discuss challenges in handling the complexities raised by issues with data quality in archaeological records and uncertainty in dating evidence along with practical experiences of re-using data from digital archives deposited with the Archaeology Data service (ADS). The presentation will include demonstration of a prototype matrix and phasing analysis tool based on previous Semantic Technologies for Archaeological Resources (STAR) project research (Tudhope et al 2011) that enables cross-comparison of stratigraphic and temporal records using Allen temporal operators (Allen 1983).

The Matrix project aims to address 2 major research questions:

1. How can we encourage the sharing, linking and interoperability of archaeological data and information, particularly information derived from the commercial development funded archaeology sector in order to maximise public value and enhance the research potential of archaeological data?
2. How can we ensure the consistent development, application and enforcement of existing technical information and data standards and their promotion to others?

Areas for investigation by the project include enhancing the recording of implicit and explicit spatio-temporal and temporal relationships in the analysis of digital stratigraphic records from archaeological investigations (May 2020) and the practical use of LOD vocabularies to deduce or make explicit dating and phasing records derived from temporal Periods and/or other types of reference data (e.g. LOD periods from Perio.do and HeritageData.org). The project also reviews current stratigraphic matrix analysis activities, including stratigraphic and temporal recording and analysis processes, digital stratigraphic data archiving, and requirements for reuse of archaeological data by chronological modellers.

The paper will cover the following topics:

- Introduction and background to The Matrix project
- Stratigraphic Standards: Need for interchange and archive formats for stratigraphic data derived from Analysis and phasing processes
- Modelling for Analysis: review of existing processes for digital stratigraphic recording and analysis
- Phaser: prototype web based software tool developed to explore the user needs for stratigraphic analysis and suitability for converting and migrating legacy stratigraphic matrix data via JSON and CSV export

- Use of LOD vocabularies: e.g. Linked Open Data (LOD) terminologies from Perio.do for temporal data to improve the interoperability of resulting digital archives.
- Phasing methodologies: use of the prototype Matrix tool for analysis of dating records along with spatio-temporal and temporal matrix phasing
- The Matrix project outcomes aim at improving the re-usability of stratigraphic data for Bayesian chronological modelling and increasing the FAIR-ness especially for interoperability and reusable synthesis of archaeological data.

References

Allen, J.F. (1983) 'Maintaining Knowledge about Temporal Intervals'. Communications of the ACM 26, 11, 832-843.

Dye, T.S. & Buck, C.E. (2015) Archaeological sequence diagrams and Bayesian chronological models. Journal of Archaeological Science, 63. 84 - 93. ISSN 0305-4403

May, K. 2020 The Matrix: Connecting Time and Space in Archaeological Stratigraphic Records and Archives, Internet Archaeology 55. https://doi.org/10.11141/ia.55.8.

Tudhope, D., May, K., Binding, C. and Vlachidis, A. (2011) 'Connecting Archaeological Data and Grey Literature via Semantic Cross Search', Internet Archaeology 30. https://doi.org/10.11141/ia.30.5.

111. Linked Open Time: Reproducible LOD-driven workflows and research tools for validating Roman Limes and Hadrian's Wall relative time intervals based on Samian (Terra Sigillata)

Allard Mees,RGZM

Florian Thiery, RGZM

Sophie C Schmidt, FU Berlin

Introduction

The handling of relative time intervals, including vague and uncertain relations between them, is a major challenge in modelling chronologies in archaeology. Underlying dating mechanisms such as circular argumentations or dependencies on open end time intervals require tools for verification and visualisation of the underlying reasoning process. We are working with algorithms to combine relative time intervals with absolute dates by using quantitative parameters, resulting in a machine readable representation and a pipeline of tools using Semantic Web technologies to enable reproducible research. The consecutive phases of the Roman Limes have always been thought to be a cornerstone in establishing chronologies in archaeology. However, since there are only very few absolute dates attached to the Limes sections, many Limes parts are - if at all - only describable as relatively vague time intervals.

Methods and materials

In order to tackle the issues mentioned above, we developed two methods which are built on one another: the Alligator, and the Academic Meta Tool (AMT) approaches. As their starting point, an _.agt file is used which includes the values name, xyz-coordinates, start / end dates (if available), as well as uncertainty information (e.g. a "fixed" absolute dates or floating endings). This file is generated from the correspondence analysis (ca) output (based on a CSV comprising Limes intervals, potters, number of occurrences) in which the quantitative relations of the euclidean distances between finds and proposed time intervals are calculated. Following the "horseshoe paradigm", the ca result may provide a measure of (possible chronological) overlap between the Limes intervals. It is important to note that a ca does not start with any pre-known dating information. Therefore, the _.agt file contains dating metadata (e.g. start / end dates, uncertainty information) from a separate file. The Alligator approach starts with (i) a 3D distance calculation using the coordinates of the first 3 ca dimensions (xyz) in the *.agt file. Then the "Alligator Algorithm" will be applied by (ii) calculating undated wobbly floating periods (e.g. terminus post quem points, derived from a historical sources, or terminus ante quem points derived from dendrochronological dates) by finding the next 3D ca neighbour. Following this step (iii) the new virtual time intervals are calculated and the resulting "virtual fuzzy years" are generated based on Allen's interval algebra. Any resulting "virtual fuzzy year" is then (iiii) transformed into relative intervals and stored in RDF format \[1]. The AMT approach is applied by using the AMT library. It uses a specific AMT ontology for relative time intervals \[2], in which temporal reasoning can be applied.

Each relation contains a degree of connection that is based on the rules of vagueness. In our use case, the estimated Allen intervals and the potters' overlap of the Limes parts is (j) described with the (normalised) Pearson correlation coefficient. In the case of the AMT approach, we (jj) have to transform the intervals into the AMT format and include the degree of connection as a (normalised) Pearson correlation coefficient. This RDF file serves as input for the AMT. With AMT (jjj) temporal reasoning according to the specific ontology can be calculated and afterwards (jjjj) exported and visualised. As a use case, this Linked Open Time workflow validates Roman Limes and Hadrian's Wall relative time intervals, based on the Samian (Terra Sigillata) found on these Limes sections. The data stems from the online database "Samian Research". Several Limes time intervals can be defined convincingly (e.g. Elisabethenstraße: AD 74-104, Wetteraulimes: AD 110-260), others are less certain. Although there is only a vague possible starting date known during Hadrian's reign (after AD 122), we neither know the precise starting date nor its end date. As for the North Sea foundations, we assume that Hadrian founded them AD 120 (emperor Hadrian gave his name to the newly founded town Forum Hadriani), but we do not know what their end date was.

Results and discussion

The approaches are resulting in research tools: the *.agt file format, an AMT ontology for temporal reasoning, the R-based research tool "Alligator CA" (in cooperation with the CAA SIG SSLA), the JAVA-based "Alligator", the Python-based "Alligator-AMT-Transformator", and the JavaScript-based "AMT time" have been implemented. In combination as a Linked Pipe \[3], they are able to base the mechanisms of Limes-dating on specific material find-categories more comprehensible. As an example, it is possible to analyse and visualise the dependencies within the dating arguments of individual Limes sections when using the Terra Sigillata found on their Limes sites. "Virtual timelines" show the position of the "Elisabethenstraße" and the "Wetterau Limes" in "virtual fuzzy years" as a fundament for a relative Limes chronology. The results of this use case seem to confirm the widespread assumption that Hadrian's Wall, the North Sea Coast foundations and the Wetterau Limes were founded in the same decades. Based on very similar Samian consumption profiles, they are all located on the right ("late") side. However, the process of nearest neighbour findings also suggests a somewhat earlier starting date of Hadrian's Wall, similar to Wetterau Limes. There may have been a number of reasons for this phenomenon: a) the quantities involved are causing volatility, b) the amount of Samian Ware available on the British/Scottish or German markets were different, causing supply differences c) although it is possible with Samian as a find category to establish relative chronologies (especially when there are no absolute dates available), it has no reliable capability for yielding absolute dates. This method of dealing with uncertain time intervals opens possibilities for comparisons with other timeline-oriented methods used to date Limes sites, such as series of coin dates. When applying the workflow, there are some issues which still need to be discussed and implemented: a) including weights from dating metadata, e.g. dating method, b) refine the algorithm to add wobbliness to the calculated virtual fuzzy years, c) weighing of factor loads in different ca dimensions, d) taking quality values of individual ca units and types into account.

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[2] https://doi.org/10.5281/zenodo.1157985 and https://doi.org/10.5281/zenodo.1160350; https://github.com/mainzed/academic metatool-viewer/blob/master/time/ontology_time.ttl.

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112. Challenges and opportunities from real world archaeological datasets in the community-driven LOD ecosystem

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Introduction

Building sustainable research communities around archaeological research subjects requires domain-specific common standards. By linking data to other communities using Linked Open Data (LOD) and so-called Community Hubs, reciprocal community development can take place. In order to attain such research community dynamics, data must be semantically modelled following the FAIR principles (e.g. using CIDOC CRM) and be part of the LOD ecosystem. This leads to the research question as to which methods can be used to enrich and/or contextualise data with community work.

Methods and materials

Real world archaeological datasets are usually evolutionary projects. In the case of Samian Ware / Terra Sigillata, incorporating new (ceramic) material groups from other periods or regions requires adapting data schemes. The same is the case with coins: including new (coin) material from other periods or regions requires adapting the ontology and community-standards in agile processes. Methodologically, when extending the material scopes of these domain-specific projects, the participation of a much larger community is necessary in order to use LOD. An approach that is either Citizen Science driven or based on Community Hubs is able to enhance properties and classes.

This paper is based on use cases comprising ceramics (ARS3D, Samian Research) and coins (AFE-RGK, NAVISone), as well as the iconographic / epigraphic elements involved (e.g. figure types, inscriptions), that demonstrate the challenges and opportunities of their semantic modelling. Within AFE-RGK, 16,957 coins are recorded, in ARS3D 325 African Red Slip Ware vessels describing 1173 man-made features (e.g. figure types). Samian Research comprises 252,342 (sic) recorded information carriers (potter's stamps) and 8,425 actors as a concept (potters), NAVISOne contains 613 coins and 17 ARS objects.

Results and discussion

Whereas enhancing the domain specific research aspects themselves is expected to remain largely within the specific research community, the results of these projects confirm that potentially the more general aspects of the data (geospatial information, chronology) can - on an LOD basis - indeed successfully be outsourced into a broader user community. Community standards for the semantic modelling of ceramics and coins, as well as iconographic / epigraphic elements such as LADO (Linked Archaeological Data Ontology as a common semantic data model for archaeological artefacts, e.g. ceramics) or NUDS (Numismatic Description Schema) can be a basis for publishing data in domain-specific hubs like DANTE, a data hub for authority data and terminologies, or archaeology.link.

Using Wikidata as a Community Hub, as shown in the WikiProjects Archaeology, Linked Open Samian Ware [1], or African Red Slip Ware digital [2], in which Wikidata entries are enriched with backlinks to the specific research domain resources, leads to new opportunities, but also challenges: (i) new Wikidata properties have to be created in order to lock backlinks to the home repository. This is carried out in sometimes unpredictable active discussions within the Wikidata community, e.g. ToposText place ID (P8068), Arachne entity ID (P10510) or Nomisma ID (P2950); (ii) the often volatile discussion which data is considered relevant or not is entirely in the hands of the Wikidata community; (iii) creating an import / export strategy to identify own resources, e.g. by using the properties "part of" (P361) or "instance of" (P31) for updating the home repository with Citizen Science data; (iv) creating common data modelling schemes for entities, such as findspots, production centres or potters, e.g. using the Wikidata:Cradle tool, and (v) creating and applying strategies for modelling of different point of views, e.g. coordinates derived from Geonames or real excavations/ surveys.

The domain-specific numismatic hub nomisma.org faces very different challenges, aiming as it does to extend its coverage to such a wide chronological, geographical and (inter)national range of sub-fields (Celtic, Mediaeval and Modern, Oriental, etc.)[3]. These sub-fields can have very different descriptive conventions and standards (e.g. NUDS), so that care must be taken to ensure that there is sufficient conformity across the broader discipline to achieve full interoperability, and contradictory solutions are not adopted. Overlap between sub-fields, particularly for periods and regions that underwent constant redefinition such as mediaeval and early modern Europe, can lead to conflicts of claims of (perceived) responsibility. Here the coordinating role of the steering committee is of paramount importance. On the other hand, the pre-existence of clearly defined semantic concepts in the form of nomisma PIDs greatly enhances the ability to incorporate citizen science driven data, as is demonstrated by the recent launch of the Celtic Coin Index Digital (CCID) which holds 72126 records.

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148. Connecting 3D-environments with LOUD: The use case of the consumer landscapes of Monte Iato, Sicily

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The project "Narrative consumer landscapes between modernity and traditionality"

The project, funded by the Austrian Science Fund (FWF), intents to visualize the research and excavation results for the broad public of the FWF projects "Between the Temple of Aphrodite and the Late Archaic House" I-III conducted from 2011 till 2021 (Kistler et al., in press).

The central cult site of the indigenous settlement at Monte Iato (Sicily) of the 6th/first half of the 5th century BC is in focus. This period is characterized by intense contacts between the local population and Greeks and Phoenicians, who began to settle on the coasts of Sicily from the 8th/7th century. Through this emerging entangled situation foreign goods, technologies and practices found their way into local communities. This increasing flow of new forms is also reflected in the material culture of ritual feasting in the area of the central cult building - the so-called Aphrodite-Temple and the adjacent banqueting house - the so-called Late Archaic House leading to different consumption practices oscillating between the maintenance and reshaping of traditions and the integration of "modern" or cosmopolitan elements.

The project goals can be divided into the following points:

1) Visualize the archaeological site as 3D-environment. Since the archaeological situation is quite complicated, it was decided not to use the photogrammetric 3D models, but to reconstruct the original situation on the basis of plans.
2) Model the information and the resulting interpretations of the artifacts signaling the different consumption landscapes at different zoom levels. For this purpose, the event-based CIDOC CRM (Bekiari et al. 2022) with its extensions is used. CIDOC-CRM is an ISO standard for Cultural Heritage Information with different extensions for specific purposes like the CRMarchaeo for archaeological excavations or the CRMinf to represent argumentations leading to interpretations.
3) Connect the resulting semantic network with the 3-dimensional visualization of the site. At the end, viewers should not have to follow a linear story, but are offered different access points, whether it may be multiple story lines, different starting points, different zoom and knowledge levels or the virtual environment generated by the archaeological data.

Semantic modelling

One of the best ways to convey a historic reality, is to tell a story, what is specifically the aim of the project. For this, the story of the "Narrative Consumer Landscapes" was divided in story parts to allow an individual navigation. Story parts relate to historic events as interpretations of the archaeological data they are based on. The CIDOC CRM ontology offers a big potential to model that through Conceptual Objects (E28) as story parts related through Temporal Entities (E2) as historic events to the Physical Things (E18) and Places (E53) where they happened.

The parts of the story of the project are modelled as Information objects (E73) that relate with refers to (P67) (or sub-properties documents (P70), represents (P138),...) to the events of the historic interpretation that the project tries to present to the public.

The implementation of this model in a semantic network will be realized through the mapping of the archaeological documentation consisting of a database for finds and stratigraphic units and excel sheets for historic events based on stratigraphic units. For the story parts an excel sheet will be created that holds the information of the story part, its relation to other story parts, to historic events and existing archaeological documentation.

For the mapping to CIDOC CRM Karma (https://usc-isi-i2.github.io/home/), a tool from the semantic web community is used. The resulting knowledge graph, which represents the information of the structured data with the concepts of the CIDOC CRM, is implemented in RDF (W3C 2021), a data format able to relate logical statements within a network.

The connection to LOUD and the importance for archaeological documentation

The connection of the project to LOUD and thus to the topic of the session is that the data generated in the process will be interoperably modelled with CIDOC CRM. They will then be published and made available in such a way that they are freely available at any time and can be integrated into other systems and queried and used for other questions. On the other hand, already existing data of the LOUD cloud are to be used, e.g. links with further information from Wikidata, Wikipedia, Pleiades, geonames and other already existing resources like Getty AAT and Perio.do vocabularies.

The difficulty here is to integrate the data accordingly. While there are solutions for text-based data or in the meantime also in the GIS area through the Sparqling Unicorn Plugin for QGIS to integrate and analyse data by means of Sparql queries, the possibilities for this in 3D environments are quite limited. Nevertheless, in archaeology, 3D data are now recorded routinely, either by structure from motion/photogrammetry or by laser scanning. Due to the limited further possibilities, however, 2D derivatives are often processed instead of working directly with the 3D models.

The project presented here is intended to be a pilot project in this direction, connecting 3D data, LOUD data, GIS, databases etc. It is hoped that this will form a basis for future larger projects.

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155. ArchaMap: A web-based application for integrating archaeological data and part of the CatMapper family

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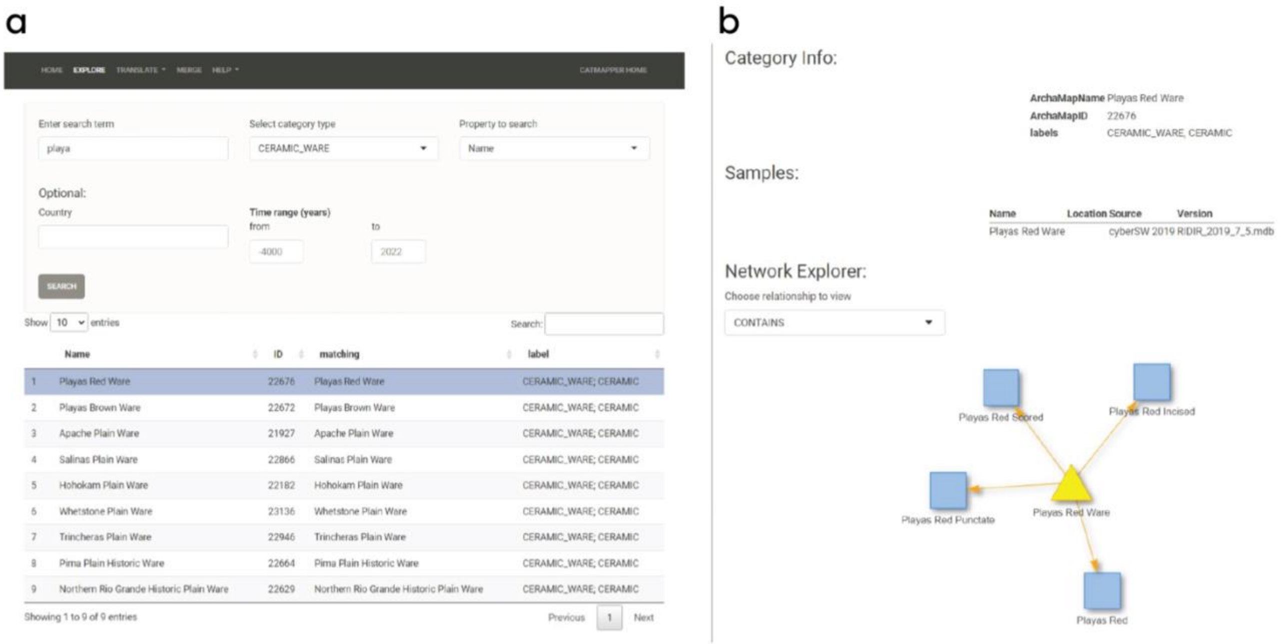

Figure 1. Screen captures of the ArchaMap application: (a) demonstrates searching for a specific category; (b) demonstrates the explore page.

Archaeological data are accessible via the internet at ever-increasing rates. This is a boon to archaeologists and the general public. Data synthesis is a productive avenue of research and has tremendous future potential, but datasets can be difficult to discover and access. Furthermore, integrating datasets is a labour-intensive process that tends to promulgate errors and minimize reproducibility, as researchers must make many decisions when merging data due to discrepancies in naming conventions and fundamental categorization schemes (i.e., ontologies). This problem is not unique to archaeology, and the fundamental challenges remain the same across many disciplines.

At the most basic level, datasets cannot be easily translated because the same category is encoded in different ways. For example, different datasets may encode the same period as the Late Glacial Maximum, the Last Glacial Maximum, or the LGM. Some knowledge is needed to verify that these are the same, but this only becomes a major challenge when hundreds or thousands of periods need to be checked. Once completed, has each decision been documented? Can another researcher reproduce the work? Often the categories are more complicated, particularly when they are created ad hoc (e.g., lithic scatter/quarry. Categories may be a partial match, a many-to-one match, or a one-to-many match. Only after all of these cases have been examined can the appropriate ontological/semantic relationship be determined. What is needed is a tool to utilize full-text index searching of synonyms and contextual metadata to make matching categories faster, more accurate, and more transparent. The CatMapper tools are designed to accomplish this.

CatMapper

The CatMapper tools [catmapper.org; Hruschka et al. (2022)] are designed to fill in the gap between creating and reusing data that is not filled by data repositories. CatMapper is a family of web-based applications sharing a fundamental structure designed to tackle four core challenges: (1) explore existing categories (e.g., types of ceramics, lithics, culture areas, time periods) using non-sensitive contextual information such as rough location, time period, or related culture areas (no legally protected or culturally sensitive data will be stored in any CatMapper database); (2) translate categories between datasets; (3) generate novel dataset integrations that includes auto-generated syntax (e.g., R, Stata, SPSS); (4) share merging templates for reproducibility and open science principles. CatMapper was inspired by a desire to save time and effort finding and identifying matches across datasets and to increase the accuracy and reproducibility of merging datasets. The applications currently use the open-source R Shiny platform, and the databases are stored in a free Neo4j community edition graph database. The archaeological implementation of CatMapper is called ArchaMap.

ArchaMap

ArchaMap is a CatMapper tool specific to archaeological categories. It is currently populated primarily with data from the cyberSW project [cybersw.org; Mills et al. (2020)]. This database contains ceramic, lithic, and architectural data from the Southwest/Northwest United States and Mexico. Initial targets for expansion include PeriodO, People 3000, CARD, and DINAA. We seek to increase the representativeness of ArchaMap's data by inviting global partners to participate. Populating ArchaMap with these datasets will make it easier for other users to match their own datasets. The database is still in its beta stages, but at the time of writing it contains 936 datasets, 20,664 site names, 1,480 ceramic type and ware names, and 215 projectile point type names. The following is an example of how ArchaMap serves the four purposes of CatMapper applications described previously: (1) any archaeology site or ceramic type in the database can be easily searched for and matched including search terms that use alternate names, partial matches, or misspellings; (2) a new dataset with site names and ceramic types can be uploaded and matched automatically to existing sites and types in the database (questionable matches are flagged for the user to verify); (3) the user may then select any number of datasets that connect to the same sites and ceramic types and export a merging templates that allows the user to merge those databases together; (4) the user can share the merging template they used as supplemental data in the resulting publication which makes the entire process transparent and reproducible.

Discussion

One essential element of CatMapper is that it does not require the use of standard ontologies. The graph database is inherently flexible and allows an infinite number of competing standards and typologies. The user simply determines which approach is appropriate for their needs or creates their own. Standards are helpful for interoperability, but much of the archaeological data in existence was produced before such standards were developed. Furthermore, standards are often developed with a particular area in mind. Frequently, these standards are pushed by well-intentioned archaeologists in the Global North, who are unaware that the standards are ill-suited for archaeologists working elsewhere.

ArchaMap and other CatMapper tools will be freely accessible and are designed to grow through the user community. Each user who translates and stores a translation of a database will add to the database. If there are no existing categories, then new categories will be created. This means that the database can immediately grow in new areas without relying on additional funding.

Besides the tremendous amount of time that can be saved through the automatic matching of datasets and the scientific benefit of permanently storing merging templates, each dataset that is saved in ArchaMap can point to either a unique url for the entire dataset or each node (site, ceramic type, etc.) can point to a unique database. Each node in ArchaMap will have its own unique url. This allows the linking of databases through the semantic web. Furthermore, a dataset may specify that it is a physical repository. It can often be an enormous challenge to identify the location of physical objects extracted from archaeological sites. Thus, ArchaMap can point users to the virtual or physical locations of the data they wish to use. In this way, ArchaMap can serve as a bridge between the islands of archaeological data and direct users to the information they need without the need for technical skill.

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171. Approaches to FAIR transformation of the Texas Archaeological Sites Atlas

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Archaeologists new to a region or subject need to verify access to the most relevant studies, identify comparable sites, and acquire available datasets to generate comparative data. The research need prevails across many disciplines and pushes for FAIR data principles (Wilkinson et al. 2016). This paper presents the ongoing work to enable open and FAIR spatial data tools on the Texas Archaeological Sites Atlas (TASA). Few spatial databases are available for locating archaeological journal articles, gray literature Cultural Resource Management reports, and local professional and avocational society. For archaeological sites in Texas, TASA is the single largest repository for reports as pdf files and is the only official repository, jointly managed by the Texas Historical Commission and the Texas Archaeological Research Laboratory, for site and project spatial data. TASA contains diverse schemata of site forms submitted by both professionals and avocationals. TASA also includes scanned and electronically filed documents. While searchable metadata allow users to retrieve information based on limited keyword searches or through specifying locations on an interactive WebGIS map, the metadata structure lacks capabilities to explore connections of the most relevant secondary (or tertiary) items to a target feature. This project aims to provide multiple means to search for related sites and projects to a target feature. Specifically, the study proposes a methodological framework that utilizes Natural Language Processing combined with Machine Learning classifiers to construct a semantic graph of sites and projects. The semantic graph organizes TASA resources to represent archaeological site knowledge and allows searching for related items and projects across sites through archaeological connections among these sites. Our TASA case study will share codes and semantic graphs in Github to demonstrate the feasibility of FAIR archaeological resources.

Methods and materials

The TASA database is hosted on a restricted SQL server on the Texas Historical Commission's website. The database consists of spatial data layers (points and polygons) of over 85,000 archaeological sites and over 20,000 project locations, as well as a library containing over 7,000 pdf documents. Within the spatial layers, only official trinomials are recorded at individual sites, and limited bibliographic information is noted with feature classes on these spatial layers. A keyword search for data at a given site may evoke 139 linked tables in different schemata from site forms prior to digitization in the mid-1990s in Texas. Currently, TASA lacks many necessary data links to sites and other documents, and 7% of the sites lack tabular data that characterize the locations. With the inherent "messiness" of the various legacy data formats, as well as the fact that the database is growing by up to100 sites and 50 reports per month, TASA represents a spatial Big Dataset (Evans et al. 2014), so approaches to analyses of these data should be thought of in this regard.

The proposed framework for FAIR transformation focuses on enriching metadata with relationships among data items. A table of linked abstracts (henceforth, a linked abstract table) captures complete bibliographic information, including linkages among archaeological references (including peer-reviewed publications, project reports, etc.) and linkages among site types mentioned in a document. Both linked abstracts and linked site types form semantic graphs, which can serve as searchable metadata for projects and reports. To-date, we implemented machine reading 7,244 documents in TASA. We identified 33,945 sites mentioned in the documents and started the initial examination of the nearly 500,000 site citations. Additionally, we used site citations in each document to build a semantic graph of 2.6 million site connections (i.e., edges in graph terminology). We implemented the case study in Python 3.9 with popular python libraries, including NLTK (natural language toolkit), pandas, geopandas, network, and pybis, and used the open-source software Graphia to visualize semantic graphs. We plan to host these analytical datasets and Python codes through Jupyter notebooks on a Github repository, though (as of the abstract submittal date) primary spatial filtering for TASA is ongoing and is not made public.

Results

The site citations retrieved from the full-text search expectedly yielded a highly skewed distribution, with approximately 99% of the sites having been referenced in fewer than 20 documents. The remaining 1% of sites were mentioned in up to 459 documents. Examination of these frequently cited sites revealed a predictable list of the most intensively studied and important sites in Texas. A further examination of a co-citation network graph (Figure 2) showed that statistical groupings of co-cited sites could often follow natural spatial patterns. Sites in a region focusing on a particular archaeological culture or time period, such as the East Texas Caddo (represented as orange nodes in Figure 2), were often cited together and formed a distinctive branch on the graph. Important sites with available comparative analytical data, such as Oak Hill Village in East Texas or Wilson-Leonard in Central Texas, had high PageRank values while plotting in the centre of well definable regional clusters. Highly important sites, such as the Caddo Mounds State Historic Site and the Aubrey Clovis site, took node positions that bridge multiple regional clusters. These sites were critical in Texas for they contained cultural significance that extended far beyond their specific cultural region.

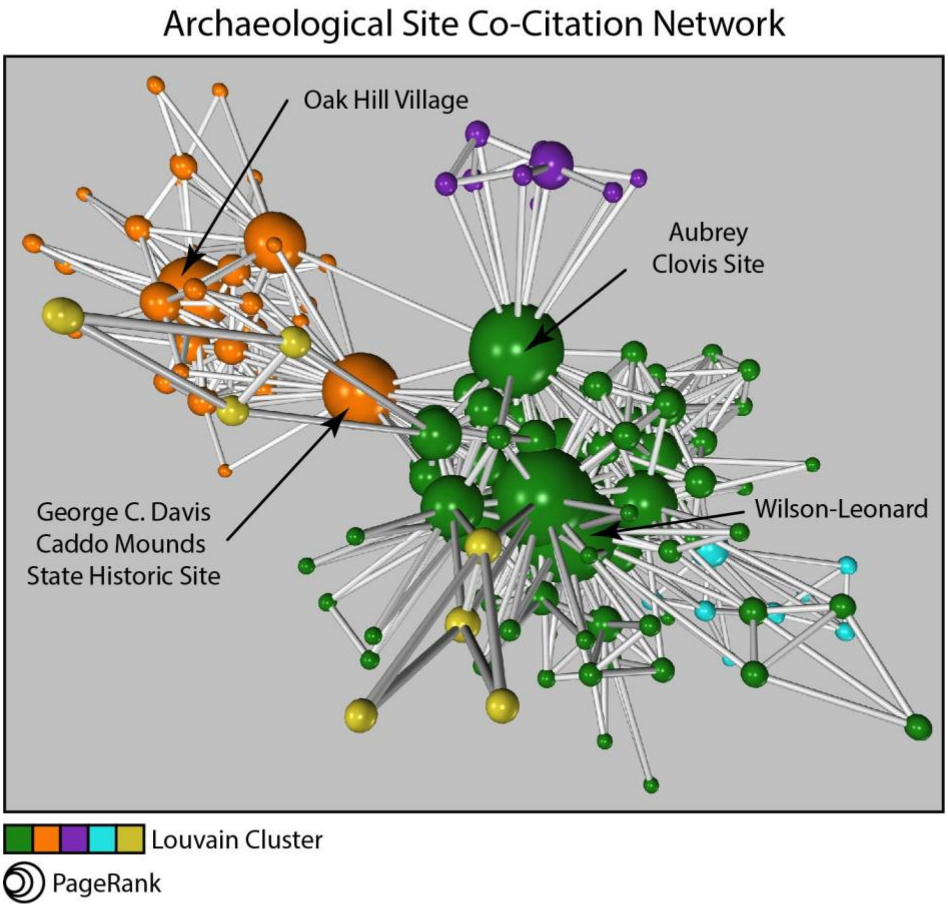

Figure 2. Archaeological site co-citation network.

Discussion

Our initial analysis promises a new avenue for populating metadata within TASA to improve site search and retrieval of the relevant reports mentioning these sites. Furthermore, enabling users to search semantic graphs allows exploration of new insights through visual analytics and retrievals of possibly relevant sites reported in documents. Our efforts continue to convey these network clusters in the semantic graphs on interactive geographical maps through R-tree and Geohash spatial indexing for the intra- and inter-regional importance of highly cited sites. Additionally, we are developing a supervised Machine Learning algorithm to classify the types of citations for individual sites in all the report documents. This classification analysis should enable the identification of types of citations that are more robust and contain significant comparative datasets within the document from those that make only passing or fleeting references to sites. We hope to present the findings of these analyses in the upcoming session.

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41. A FAIR future for archaeological survey: The SEMAFORA project

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Archaeological research is in the position of both benefiting and suffering from its long-term success at data generation. While analytic research in the field over many years of evolving methodologies and technological advancements has created a wealth of data, this same data is extremely difficult to interpret and reuse owing to the changes in methods and tools over this time and the lack of agreed solutions for documenting such information. The resulting plethora of datasets often cannot be externally accessed, in the best-case scenario, until publication - and when accessed it often lacks interoperability, which hampers our ability to use these datasets for advanced research.

In recent years there is a serious effort toward overcoming this issue using formal ontologies such as CIDOC CRM (Bruseker et al., 2017). These ontologies have been, in turn, specialised further with extensions such as CRMarchaeo which have been developed to serve archaeological information management needs via specific concepts and relationships. In this sense, many aspects of archaeological excavations, artefact curation and archiving can already be semantically modelled. However, a major segment of archaeological research data remains semantically unrepresented: that of archaeological field survey. Field surveys have, since about 1970, been the main method by which archaeologists discover and record 'sites' and individual finds at the earth’s surface. Such surveys may give rise to archaeological excavations but more frequently form the basis for regional analysis and/or site preservation strategies. Within the Mediterranean area alone the documented finds already run in the millions, but the lack of an effective high level semantic model to represent and unite this information effectively prevents researchers and heritage managers from using this extant data resource to conduct large-scale, integrated analyses (Attema et al., 2020).

The SEMAFORA project is a Netherlands Foundation for Scientific Research (NWO) funded Open Science project running from March 2022 to March 2023, in which survey specialists from the Groningen Institute of Archaeology collaborate with SME’s with expertise in semantic data modelling (Takin.solutions) and semantic data mapping and transformation (Delving). The project seeks to build a showcase software toolkit that will allow researchers to map, transform and query distributed survey data in an integrated semantic data format (de Haas et al., 2020), based on a new high level semantic model for fields surveys. We present the background, aims, goals, current status and expected deliverables of the SEMAFORA project, with examples taken from the semantic model and user interface under development. Testing of the software toolkit will begin in September 2022, using the very diverse datasets generated by the Tiber Valley Project, Rome Suburbium Project, and Pontine Region Project (Attema et al., 2021), and will extend to other major and minor survey projects in the Mediterranean world and beyond.

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Session 07. Cultural heritage data across borders: Web-based management platforms for immovable cultural heritage in the global south

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Crystal El Safadi, University of Southampton

Bijan Rouhani, University of Oxford

Ash Smith, University of Southampton

East Writing School

Introduction	11:00 - 11:15
125. Surveying the steppes and beyond: Transmethodological data integration and the endangered cultural patrimony of Mongolia *Fisher*, Jamsranjav, Jurkenas and Jambajanstan*	11:15 - 11:40
160. Overcoming the digital divide: documenting the maritime archaeological resource in Pakistan *Khan* and Hashmi*	11:40 - 12:05
82. Interoperability of online heritage resources *Richards* and Zoldoske*	12:05 - 12:30
Lunch	
109. Outlook geospatial platform to integrate climate change scenarios on cultural heritage conservation *Fino* and Abedalhaleem*	13:30 - 13:55
87. Remote sensing data in an armed conflict zone: A new approach for the detection of the destruction of cultural sites using spatial images *Mobaied*, Lapierre and Rudant*	13:55 - 14:20
140. Temporal analysis of disturbances to cultural heritage during the Syrian conflict *Almohamad, Hopper, Huet and Deadman**	14:20 - 14:45
Discussion	14:45 - 15:00

Introduction

Cultural heritage is a "shared heritage" (UNESCO, 1945), and managing it globally - at a large scale and over a longue durée - requires gathering information from heterogeneous and disparate sources, involves the integration of different software (databases, search engines, etc.), semantic data interoperability (open international standards, multilingual thesauri, etc.), and publishing policies (URI-based names, licenses, etc.). Nowadays, such aims require IT based on the semantic web (Bikakis et al., 2021), structured as a stack of technologies (Berners-Lee, 2013), supported by the concept of FAIR principles (Findable, Accessible, Interoperable, and Reusable, Wilkinson et al., 2016) and described in Data Management Plans (DMP) along the following streams of application:

- Data (re)use: use and reuse of data and metadata, describing sources, methods (remote sensing, ground surveys, etc.), software, format, and volume;
- Data register: describe data and metadata by controlled vocabularies (thesauri), based on ontologies (CIDOC-CRM, XML-TEI) and presented in information placeholders like dropdown lists;
- Data storage: database technologies (SQL, NoSQL), access policies, data versioning, backups and snapshots for short-, mid-, or long-term archives;
- Data analysis: analyses routine and data-driven documents, database auditing, machine learning (automatic site and change detection, etc.), knowledge discovery in databases and knowledge representation;
- Data sharing: access to publishing supports of raw or processed data or dataset through working papers, data paper (versioning), scientific papers referenced by URI-based names, how-to-cite documentation, licenses, GeoSPARQL and SPARQL endpoints.

Achieving these objectives is per se a challenge. But additionally, new challenges arise when the concerned region is the global south. Such challenges are opportunities for geospatial semantic web-based purpose-built platforms (IT capacity vs digital gap), data access rules (ethical considerations, intellectual property, etc.), multi-linguism protocols, ground/remote sensing data quality control, recording condition assessments and threats over time (Rayne et al. 2017; Andreou et al. 2020; Fisher et al. 2021).

This session welcomes papers addressing and demonstrating a successful workflow on collecting, registering, storing, analysing, and sharing knowledge on immovable cultural heritage in the global south, especially for condition and risk assessment of archaeological sites, using standard ontology. Papers should address one or more aspects of these topics, the entire workflow, or emerging issues such as web3D, image annotation, heritage BIMs. Participation is encouraged for institutional projects at the supranational and national levels, or over multi-paradigm, to inform the upcoming emerging challenges of geospatial semantic web-based purpose-built platforms over the borders.

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125. Surveying the steppes and beyond: Transmethodological data integration and the endangered cultural patrimony of Mongolia

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The Mongolian Archaeology Project: Surveying the Steppes (MAPSS) draws on a variety of methodologies to document the archaeological and ethnographic landscapes of Mongolia. The overarching goal of the project is to generate the first open-access, semantically interoperable, reproducible, and comprehensively populated geospatial database of immovable Mongolian cultural heritage. This work is 'transmethodological' in that it integrates several distinct approaches in order to address questions in both the archaeological and cultural heritage disciplines. MAPSS combines archival field data with the results of manual remote sensing, Machine Learning detection, ground-truthing survey, and digital imaging to record tens (and potentially hundreds) of thousands of sites and their conditions. Our research uses these data to explore topics such as palaeohydrology and human-environment interaction, diachronic patterns of nomadic mobility, development of an early nomadic state, large-scale prehistoric funerary practices, community archaeology, and cultural heritage vulnerability.

Among the issues that MAPSS considers in the design of its data collection and management systems are breadth versus depth of data, modelling uncertainty at scale, multilinguality, multivocality, and interpretive multiplicity. Thus, the project balances capture of metadata, paradata, resource relationships, site conditions, and archaeological interpretation with the scope, ambition, and inclusivity of populating a national cultural heritage database. In this paper, we demonstrate how our design principles reflect this balance. We present an argument for the interrelationship between reproducibility, sustainability, and inclusivity. Finally, we discuss the challenges associated with working at a national scale while the ancient cultural landscapes of Mongolia extended beyond modern state boundaries. Numerous migrations in and out of the region over millennia–resulting in non-linear extra-regional distribution patterns of otherwise Mongolian archaeological and cultural features–add further complexity.

As Mongolia is the least densely populated nation on earth, risk factors for immovable cultural heritage are also significantly different there than in many other parts of the world. In fact, due to the primacy and perdurance of nomadic lifeways throughout Mongolia's past and present, traditional models of archaeological mapping and cultural heritage preservation are not applicable in their entirety, and must be rethought in accordance with the Mongolian cultural landscape. For this reason, MAPSS combines remote sensing of archaeological and ethnographic remains with rock art survey, camp settlement survey, high-resolution drone mapping, and excavation in order to both capture the complete palimpsest of immovable Mongolian cultural heritage and begin to untangle it.

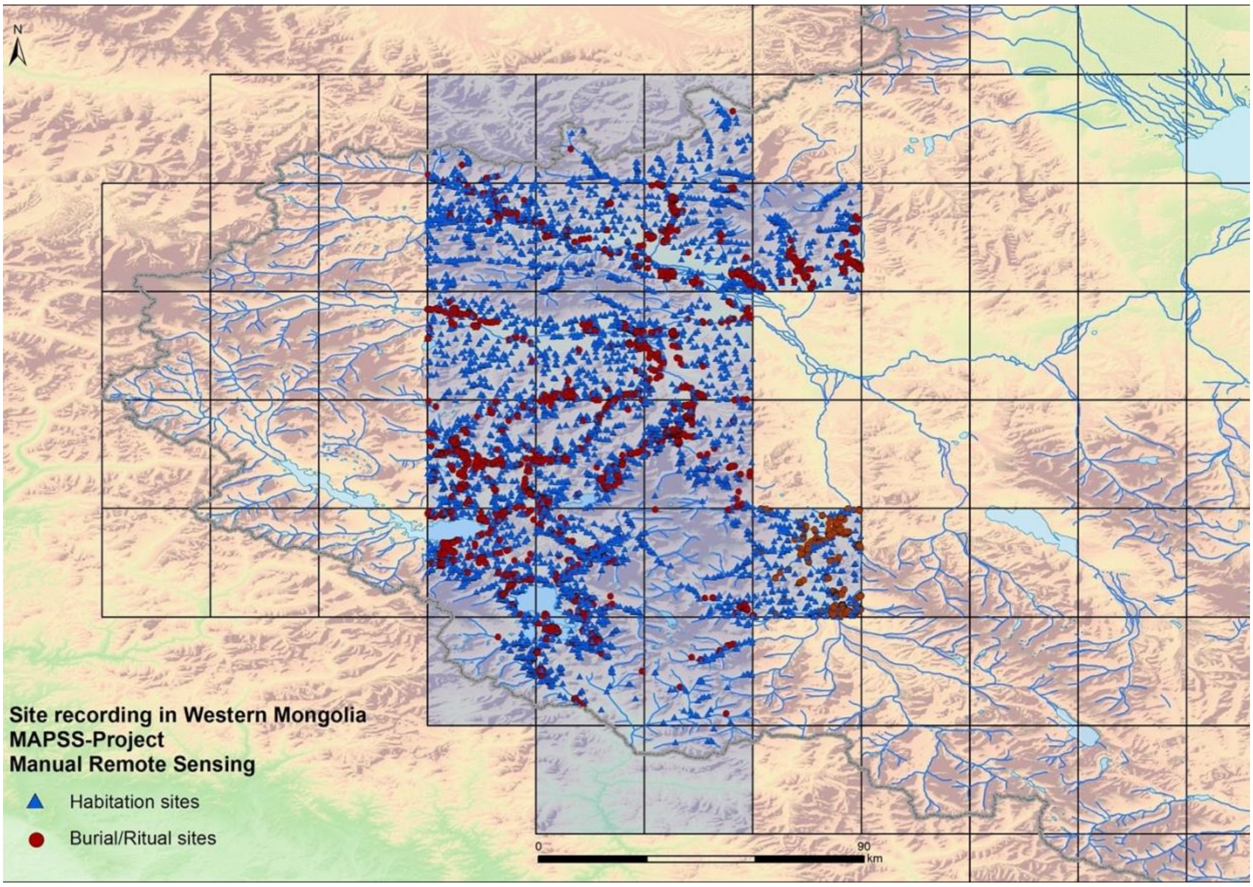

Figure 3. Site recording in Western Mongolia.

Mongolia opened its doors to the western world after the collapse of the socialist state, and began collaborating with international scholars on cultural heritage research to form new perspectives. Over the past two decades, this has resulted in a series of marquis discoveries and major data collection efforts. However, economic collapse, the rapid expansion of legal and illegal mining, limited access to cultural heritage information, and a loss of control over immovable heritage threaten Mongolia's archaeological sites and sense of its own history. Furthermore, climate change, especially global warming, severely impacts both archaeological heritage and traditional nomadic lifeways. Organic archaeological remains preserved in the large glacier mountains and permafrost regions will become especially at risk in the coming years (Taylor et al. 2021).

Although the MAPSS project is still largely in its data collection phase, early results have been promising (Figure 3). A systematic analysis of Late Bronze Age 'Deer Stone' and Khirigsuur monuments has provided the earliest evidence to date for the initial appearance of state governance among Inner Asian nomadic societies. This evidence, drawn from both excavated sites and remote sensing data, points to the existence of a complex socio-political system occurring almost 1,000 years before the Xiongnu empire, which had generally been regarded as Mongolia's earliest nomadic state. The archaeological evidence acquired by MAPSS team members demonstrates that this was not a simple association of tribes, a chiefdom, or a loose socio-political framework, but rather a state-like organisation that was ethnically mixed but culturally and religiously united in a complex pastoral political economy.

Remote detection of archaeological sites is at the core of the project's methodology, working at a pace of approximately 25,000 sq. km per year using manual remote sensing methods to detect burials, ritual sites, and campsites. The spatial interaction between those three groups is particularly interesting. But in order to cover a greater percentage of Mongolia's 1.5 million sq. km within the 5-year timeframe of the project, MAPSS is additionally developing Machine Learning methods for remote sensing, which use Object Detection to discover potential funerary and habitation sites. By training the system with Deep Learning Models such as MaskRCNN, YOLOv3, and Single Shot Detector, we run a selected model against an input raster image to produce results according to each object class.

MAPSS is also starting to generate data in order to better understand palaeohydrology and human-environment interaction in the Mongolian Great Lakes Depression. Documenting environmental characteristics of the sites through remote sensing and field survey, while integrating archival datasets, will allow us to understand the impact of human lifeways on both the climate and cultural heritage, and vice versa. Site selection was and continues to be conditioned by several factors, both at micro and macro-regional scales, including hydrology, topography, fertility, and climate change. The location of archaeological sites and features in permafrost regions, on present-day flood plains, directly beneath bodies of water, in areas affected by solifluction, and in erosion channels resulting from seasonal precipitation and meltwater, indicates the ongoing alterations to the local palaeohydrology and climate. Furthermore, the documentation of such environmental elements is of particular importance to assess the threat to heritage resources and to evaluate the actions to be taken in order to ensure their long-term preservation.

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160. Overcoming the digital divide: documenting the maritime archaeological resource in Pakistan

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Heba Hashmi, Maritime Archaeology and Heritage Institute

The Inventory of Maritime Archaeology of Pakistan (IMAP) project, undertaken by the Maritime Archaeology and Heritage Institute (MAHI) and supported by Arcadia - a charitable fund of Lisbet Rausing and Peter Baldwin, is the first systematic documentation of coastal and underwater maritime heritage sites in Pakistan.

Working in the Global South and in a country with zero infrastructure in the discipline of Maritime Archaeology has presented innumerable challenges, especially those emerging from poor archival practices, IT constraints, and local security concerns over access to information.

IMAP has been designed with the intention of systematically overcoming some of the core challenges, of raising the standard of heritage data collection, storage and analysis, and ensuring public access to the data. By plugging in an international heritage database platform like Arches, IMAP ensures that the quality of data collected and stored is of an internationally accepted standard. Data collection workflows involve a multi-method approach, which includes analysis of legacy data (historical documents, survey maps, environmental datasets etc), remote sensing using aerial imagery and marine geophysical surveys, ground truthing of identified sites and diver-based surveys. Such documentation efforts can greatly improve site condition assessments and threat evaluations to enable evidence based heritage management responses. By using a variety of open source tools IMAP is also employing computational methods to analyse various datasets in order to determine areas of high archaeological potential along the Sindh coastline (for example viewshed analysis and leeward shadow analysis) in order to maximise the efficiency and productivity of manual surveys.

As IMAP is still a new project, the efficacy of these methods is still being assessed, however, the project benefits greatly from the experience and hindsight of other Arcadia-funded projects using Arches, and the resulting environment of support, knowledge-sharing and innovation.

82. Interoperability of online heritage resources

Julian Richards, Archaeology Data Service

Teagan Zoldoske, Archaeology Data Service

The European research infrastructure ARIADNE provides a portal search across 1.8m data resources and 22 countries. The second phase of development of the ARIADNE Portal (https://portal.ariadne-infrastructure.eu/), the ARIADNEplus Project (https://ariadne-infrastructure.eu/), is now coming to a close. The Archaeology Data Service (ADS) is the national archive for archaeological data in the UK, and has been a primary partner in this initiative throughout the development, and a key partner in this research.

This paper will discuss and reflect on the latest developments and lessons learned, as the 41 international partners work to expand and improve the inclusivity and interoperability of the ARIADNE Infrastructure. ARIADNEplus touches upon and represent many facets of computer applications in archaeology, including use of the CIDOC CRM ontology (https://www.cidoc-crm.org/), the Getty Art and Architecture Thesaurus (https://www.getty.edu/research/tools/vocabularies/aat/), Periodo (https://perio.do/en/), Linked Open Data technologies and methodologies, along with data stewardship and preservation best practice.

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109. Outlook geospatial platform to integrate climate change scenarios on cultural heritage conservation

Nazih Fino, Global Nomad GIS Services

Haifaa Abedalhaleem, Global Nomad GIS Services

The purpose of this geospatial-based platform is to link climate change impacts and potential consequences such as flooding, fire, and cyclones (hurricanes) to significant cultural and natural sites, as well as to establish an early preparedness system for identifying those sites that may be more vulnerable to these potential climate change issues and assisting site management authorities in developing risk preparedness plans. The platform's objective is to understand better how climate change may affect and alter heritage for example sea level rise. Such a platform can assist in comprehending or anticipating these potential changes and, if necessary, develop an early reaction, mitigation, or adaptation measures linked with scientific research and planning measures.

Background

The planet's climate is changing faster than at any other time in modern civilization's history, primarily due to human activity. Global climate change has already resulted in a wide range of consequences across all regions, and many cultural and economic sectors are likely to intensify over the next few decades. Weather and climate-related catastrophes have escalated internationally. Spatial computing is essential for evaluating and synthesizing data using geographic information systems technology to demonstrate how the world has evolved through time, forecast future changes, and share their impacts on cultural resources with decision-makers and the general public.

Objective

The platform's objective is to understand better how climate change may affect and alter heritage for example sea level rise. Such a platform can assist in comprehending or anticipating these potential changes and, if necessary, develop an early reaction, mitigation, or adaptation measures linked with scientific research and planning measures.

Methods

The platform approach is to link climate change impacts and potential consequences such as flooding, fire, and cyclones (hurricanes) to significant cultural and natural sites, as well as to establish an early preparedness system for identifying those sites that may be more vulnerable to these potential climate change issues and assisting site management authorities in developing risk preparedness plans. The geospatial web-based platform development and implementation on the ArcGIS Server-AWS. the cultural and climate change resources geodatabase hosted (cloud-based) ArcGIS portal. The GIS web applications' primary function is to support the organization's users in accessing the Site Record, Reports and studies, and project areas (area of Interest AOI) hosting approximately 350,000 records by querying, selecting, displaying on a map, and hyperlinking to other documents (e.g. SharePoint). All services (GIS Layers) are published, maintained, managed, and communicates via ArcGIS Server with a web-based login secure platform for the organization’s members and design-makers.

Results

Global Nomad GIS Services LLC. has developed this platform. The web-based GIS application's direct benefits and desired outcomes are to improve security, quality, productivity, cost-saving, and support decision-makers. but also accomplish:

1. A Global Reach
2. A large number of users
3. Better cross-platform capability
4. Low cost as averaged by the number of users
5. Easy to use

6. Unified updates
7. Diverse applications
8. Support decision-makers as a cost/benefit analysis.

87. Remote sensing data in an armed conflict zone: A new approach for the detection of the destruction of cultural sites using spatial images

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Luc Lapierre, Société Française de Photogrammétrie et de Télédétection (SFPT)

Jean Paul Rudant, Univ Gustave Eiffel, ENSG, IGN, LASTIG

The main idea of the existence of the world heritage is based on the value of this heritage as a legacy of the past that we enjoy today and that we must transmit to future generations. In this context, the destruction resulting from armed conflicts must be considered as one of the most serious threats because it does not only concern the region impacted by the conflict but the whole of humanity and its cultural and natural heritage. Despite the importance of these unique and irreplaceable properties as defined in the 1972 United Nations Convention, many deficiencies concerning their conservation in conflict areas can be revealed:

- The destruction of cultural and natural heritage during armed conflict goes unpunished, despite the presence of legal and regulatory provisions in international law that prohibit and limit harmful actions on the environment and heritage during wartime.
- The destruction of cultural and natural heritage is not included in the inventories of damage that determining factor of the armed conflict barometer. To classify this damage affecting civilian populations, it is usual to distinguish four categories of degradation: destruction of infrastructure (civilian and military), destruction of habitats, degradation of the economy/self-sufficiency and identity assets (HIIK, 2021).
- Currently, intervention in World Heritage sites is limited to damage assessment in the post-conflict period, due to the limitations inherent in the situation of armed conflict, such as the difficulty of accessing the site to assess the damage and attempt to safeguard it by alerting the relevant archaeological services.

These difficulties in accessing information need to be taken into consideration in order to evolve strategies and tools for monitoring and actively protecting world heritage. Geographic information technologies, remote sensing and spatial modelling, currently offer new potentialities to understand and analyse observations related to the impacts of armed conflicts in these areas and to better prepare the post-conflict period. These tools can also be used to document violations of regulations in real time.

In this context, this study aims to propose an approach to detect the destruction of cultural sites in areas impacted by armed conflict in Syria using spatial images. In Syria, damage to archaeological sites is due to several kinds of action, direct bombing of sites, intentional destruction by armed groups and clandestine excavations. In this study, it is the clandestine excavations that have been observed and monitored.

Syria is considered as one of the richest regions in the world for historical sites and archaeological heritage. Conflicts have caused considerable damage to the Syrian heritage park (Bouvier, 2019). In this study we analyzed the impact of armed conflicts on the archaeological site of Apamea on the Orontes River in western Syria. The objective of this study is to establish a method of spatio-chronological analysis for the quantitative monitoring of the damage caused by the looting of archaeological sites in conflict zones.

The results of the spatio-chronological analysis obtained using Pleiades and SPOT5 imagery detected clandestine excavations extending over 95% of the Apamea site between 2011 and 2019 as well as over 60% of the adjacent fields affected by excavations during the same period using a semi-automatic classification (Table 1 and Figure 4). For long-term monitoring of clandestine excavations Sentinel 2 images have been used, with a resolution of 10 m and a regular revisit frequency, Sentinel 2 images, provide a very effective tool for detecting reflectance changes associated with new excavations in areas at risk.

Table 1. Apamea semi-automatic classification 2011 and 2019.

	Percentage	2019					
		Intact Site	Intact Fields	Erased Clandestine Excavations	Ancient Clandestine Excavations	Recent Clandestine Excavations	Other
2011	Intact Site	5%		10%	62%	23%	
2011	Intact Fields		40%	13%	26%	21%	
2011	Other						100%

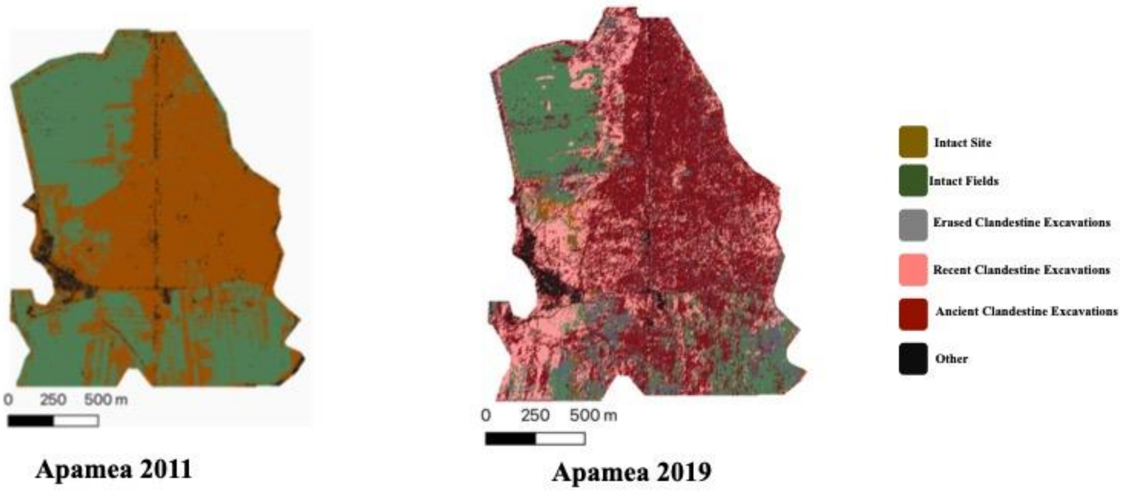

Figure 4. Apamea semi-automatic classification 2011 and 2019.

The use of high-resolution satellite images is proving to be very effective in detecting the appearance of clandestine excavations and the quantitative monitoring of the damage caused by these excavations in archaeological sites. Indeed, the SPOT 5 satellite images with a resolution of 2.5 m and Pleiades ones with a resolution of 70 cm (images sampled at 50 cm) are more suitable with an advantage for the Pleiades images, because they allow to observe the excavations whose dimensions vary between 50 cm and 3.5 meters. For this application, Pleiades images have an advantage over SPOT 5 because they can locate structures four times finer.

The detection of new excavations using Sentinel 2 images are based on a threshold on the green channel which triggers an alert. These alerts then require more in-depth analysis, which can be carried out using finer resolution images or, in the best case, by means of an inspection in the field.

Apamea has been investigated and used as a case study for many methods to assess damage and detect looting (Tapete et al., 2016; Tapete et al., 2018), the method we presented aims to establish a long-term monitoring using accessible multi-source satellite images and can be applied to other areas of armed conflict. The results show that the site Apamea underwent clandestine excavations in an intensive way between 2011 and 2019, this phenomenon leads to two remarks: firstly, it reflects the lack of intervention of the state, state that should be responsible for compliance with the provisions of international legal instruments for the protection of cultural heritage, while in Syria, these sites have been instrumentalized in a political context (Mobaied, 2020).

Secondly, this phenomenon shows the lack of collective responsibility of citizens towards cultural heritage sites in Syria. These sites have long been considered as sources of tourist and economic activities without any awareness of the universal value of cultural heritage sites and the consideration of these sites as a support of identity and as a witness of the urban civilizations that were born in Syria, in which the local populations could find their roots.

These sites, seen by most of the local population only as an economic source, have suffered the impacts of armed conflicts but also the consequences of a long social and cultural policy in Syria that has neglected the importance and the development of the Syrian heritage and its links with the world heritage.

140. Temporal analysis of disturbances to cultural heritage during the Syrian conflict

Adnan Almohamad, Durham University

Kristen Hopper, Durham University

Thomas Huet, University of Oxford

William Deadman, Durham University

The archaeology of the Middle East has international significance, but it is under intense pressure from a wide range of threats including agriculture, development, looting and conflict (Bewley et al. 2016). Nowhere is this more readily apparent than in Syria, where the ongoing conflict is causing significant damage to cultural heritage (Gibbons 2017). In an earlier study, five years' worth (2014-2019) of condition assessment data for 19 archaeological sites in the northwest of the country was collated, combining information from ground-based Syrian volunteer networks with modern high-resolution, multi-temporal Google Earth imagery. The dataset followed the schema of the database of the Endangered Archaeology in the Middle East and North Africa (EAMENA) project. This is based on the open-source Arches geospatial semantic graph management platform (Bewley et al. 2016); the condition assessment data utilised CIDOC-CRM ontologies (ISO 21127:2006) . Analysis of the disturbances demonstrated a clear correlation between the temporal patterning of different types of damage and the changing political situation across the study area (Almohamad et al. under review).

Figure 5. Tel Dabiq.

This paper introduces an improvement to the resolution of the data analysis. The temporal dimension of each disturbance has been adapted to comply with the Extended Date/Time Format (EDTF, ISO 8601-2:2019). EDTF provides a standard syntax for fuzzy dates, very precise (timestamp) dates, negative years, intervals, and a number of standardised formats. We developed an R script to routinely carry out temporal analyses, ensuring their replicability, and allowing integration with the Arches/EAMENA platform.

We will present our refined analysis of disturbances patterns for our Syrian dataset, demonstrating how it can be integrated with Arches/EAMENA for further future analysis of the wider project dataset, and how other projects can make use of our work in compliance with an open science rationale and FAIR framework.

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Session 08. Are you my type? Network analysis and the study of material culture

Arianna Sacco, Austrian Academy of Sciences, Austrian Archaeological Institute

David Laguna Palma. University of Granada, Department of Prehistory and Archaeology

Room 7

Introduction	11:00 - 11:15
45. Network analysis of the political control system in Liangzhu archaeological sites, China *Yuan* and He*	11:15 - 11:40
106. Shrinking the scale of social network analysis in the North American Southwest *Allison**	11:40 - 12:05
107. The Use of Network Cartography for Visualizing Large Prehistoric Relationships *Sommer*, Kandel and Hochschild*	12:05 - 12:30
Lunch	
35. "Interlinking exchange" *Hilpert*, Strohm and Kerig*	13:30 - 13:55
21. Social network analysis, community detection algorithms, and neighbourhood identification in Pompeii *Notarian**	13:55 - 14:20
Discussion	14:20 - 15:00
32. Social network analysis of ancient Japanese obsidian artifacts with reduced sampling bias *Sakahira* and Tsumura*	Poster

Introduction

Network analysis started from sociometry, which studies the social, economic, or cultural ties of an individual, as well as how individuals link into groups and how these groups connect into a society. (Scott 2012, 7–16). Network analysis is based on the belief that interpersonal relations, as well as relations between organisations and countries, are important because they are means of transmission of behaviours, information, and goods, which travel between and because of the entities. Therefore, to understand the role and behaviour of entities (i.e. individuals, organisations), it is important to study how they interact and what relations they establish in the network (Collar 2014, 99; Collar et al. 2015, 6; Scott 2017, 2–3; Sindbæk 2013, 72–73). The network is visualised as a graph; mathematical algorithms allow us to study the role of entities and the structure of the network (e.g. Bolland 1988; Bonacich 1987; Borgatti 2005; Freeman 1979).

Archaeological studies have recently started using network analysis. It has shed new light by giving the possibility to focus on human relations and social groupings demonstrated by objects, because these relations are seen as means that allow material and non-material resources to flow between groups (Brughmans 2013, 632–33; Collar et al. 2015, 6; Mills et al. 2013, 181–82; Östborn and Gerding 2014, 76). Specifically, network analysis has been used to study relationships between individuals and groups of individuals (as in Knappett 2011, Terrell 2010), or places (as in Gjesfeld 2015; Östborn and Gerding 2014; Sindbæk 2007; Sindbæk 2013), the circulation and distribution of (types of) objects (e.g. Brughmans 2010; De Groot 2019) or even decorative features (e.g. Östborn and Gerding 2015), to understand the flow of resources (e.g. Golitko and Feinman 2015; Peeples et al. 2016), to study regionalization phenomena (e.g. Blake 2013; Coward 2010; Coward 2013), and even to study ethnic identities (e.g. Collar 2013; Collar 2014).

New ways are constantly introduced to apply network analysis to archaeological research (most recently: Brughmans 2021; Carrignon et al. 2020; Rawat et al. 2021; Sacco 2019; Sacco 2021; Van Oyen 2016; see Rivers 2016 and Mills 2017 for most recent summaries of different ways network analysis has been used in archaeology). But contrary to other disciplines, where one can observe the connections creating a network while they are still ongoing in the present day, archaeologists need to reconstruct these connections based on material remains, like examining the data from a black box (Brughmans 2010, 282; Knappett 2013, 7–8; Sindbæk 2013, 72, 76). This means that when using network analysis and its algorithms to explore archaeological material, one needs to be aware of issues that can arise from the limitations of the source material.

The first issue is defining the geographic and chronological boundaries of the study. Expanding or contracting these boundaries changes the perspective of the study, as well as its results (Brughmans, Collar, and Coward 2016, 10-2; Knappett 2016, 25-6; Scott 2017, 46–8). Second, the fragmentary nature of the material, part of which is still unexplored, inaccessible, or unstudied and unpublished, even though models have been created to reconstruct missing links (e.g. Tsirogiannis and Tsirogiannis 2016). This creates a risk of bias, which can make some entities (e.g. archaeological sites or types of objects) either over-represented or under-represented in the study only because more or fewer data respectively are available (Brughmans, Collar, and Coward 2016, 10-2; Knappett 2013, 7–8; Knappett 2016, 28-9; Östborn and Gerding 2014, 81–3; see Düring 2016 and Gjesfeld 2015 for examples of how to reduce the bias). Thirdly, the archaeological remains represent points in time, hence diachronically reconstructing the processes that created them can be problematic (Brughmans 2010, 288; Golitko and Feinman 2015, 217; Knappett 2016, 27-8; Mills et al. 2013, 182; Östborn and Gerding 2014, 80–1). Lastly, especially when examining material culture, the classification of objects and the definition of a type are important. What features are considered relevant to differentiate objects? What objects are included in the analysis? Or which ones are excluded and why? Different answers to these questions can lead to different results (Brughmans 2010, 285; Sindbæk 2013, 73).

The described issues will be the topic of the papers included in this session. The papers will present case studies, i.e. applications of network analysis to the study of material culture from any region of the world and any period. These papers will explain how network analysis is applied in archaeology, how the mentioned issues affect the case studies and, most importantly, how the issues are tackled, making it possible to get results and shed light on particular aspects of the past. The issues explored in the session are among the topics regularly explored in the Connected Past conferences, as well as in Knappett 2013 and Brughmans, Anna Collar, and Fiona Coward 2016. However, the mentioned publications and conferences do not focus only on material culture, but explore more ways of applying network analysis, e.g. also to landscapes. On the contrary, the proposed session focuses on artefacts, on how they are collected and classified, on how network analysis is used to examine them, and what research questions can be answered. The aim is to discuss and propose ways of solving issues relevant to when one applies network analysis to archaeological objects.

The issues discussed in the proposed session are already well known in archaeological research that applies network analysis. Attendants of CAA are most probably familiar with them. However, this session gives the opportunity to showcase the most up-to-date research and the latest projects that use network analysis, but which have not yet been presented at the CAA or Connected Past. While younger researchers will have the opportunity to introduce themselves and their research to the community, more experienced researchers will have the opportunity to show the latest advancements in their research, such as new projects or updated results of ongoing projects. The wide chronological and geographical scope of the proposed session will also allow us to include researchers and projects from diverse regions of the world and concerning diverse historical periods. The diverse backgrounds in expertise, historical period, and geographical areas will provide the occasion for networking and fruitful comparisons and discussions, which will help advance the field.

This session will be of interest to different groups of researchers. Firstly, to researchers that are already familiar with, or even experts in, network analysis and want to stay up to date, learning about the latest developments in the field. Secondly, to younger researchers that want to make their research known and get in contact with other researchers engaged in the field. Thirdly, to researchers that plan to apply, or are curious about, network analysis and want to learn more about its most recent state. Furthermore, this session aims to demonstrate the potential and usefulness of network analysis in archaeological studies to scholars who may still be sceptical about it, and to introduce this methodology to researchers that are still unaware of it. Lastly, this session will be of use not only to archaeologists, but also to other scholars, such as ancient historians, who are faced with similar problems to most of the ones described.

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45. Network analysis of the political control system in Liangzhu archaeological sites, China

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Liangzhu settlements with more than 135 archaeological sites are located in Zhejiang Province, 160km west of Shanghai, dating from 3300-2300 BC. Recent research at Liangzhu documents the settlements accompanied by an impressive system of earthen dams for flood control and irrigation. An earthen platform in the centre of the town probably supported a palace complex, and grave goods from the adjacent Fanshan cemetery include finely worked jades accompanying high-status burials. These artefacts were produced by a complex society more than a millennium before the bronzes of the Shang period (年代). The large-scale public works and remarkable grave goods at Liangzhu are products of what may be the earliest state society in East Asia (Renfrew and Liu 2018). Our research focuses on how to establish and explain the political control system of Liangzhu state society with the relationship of material culture and geographical space.

First of all, jade objects are considered as the symbol artefacts for the elites of China. These artefacts have a special significance. As Zhang (Zhang 2012) said, people in Liangzhu buried with the jade Bi and the jade Cong control the rights to talk with God in their culture. The jade axe is the symbol of holding supreme military. And people with stone axe are the ordinary soldiers or the craftsmen. The only people buried with ceramics are the agricultural laborers. Therefore, a series of archaeological reports of Liangzhu Sites are introduced as our data sources. According to different styles of artefacts in graves, the owner can be classified into four social divisions including ancestor worship, military commanders, and agricultural labour. Under network theory, we use the matrix of relationships to build a two-mode network of sites. This two-mode network then can be reduced into two one-mode networks which show how different sites participate into social divisions. For one-mode site to site network, we further choose the similarity of artefacts to find out cross-class relationships among sites.

Secondly, the structure of geographical space can strengthen the political position of different sites. Inscribed as a World Heritage Site in 2019, Liangzhu Ancient City is a prehistoric city with a clear triple centripetal layout. Not as the centre status of the settlements in politics, the Ancient City located in the southwest of the sites group. So, it hasn't been noticed whether there is a spatial preference in the geographical layout of each site. Because of the huge differences between modern geographical environment and the Chinese Neolithic times, this study chooses the height of the unearthed sites as the basic data instead of other modern data. Based on Foucault's theory (Foucault 2012) of the relationship between space and vision. The study calculates the intervisibility in QGIS to recognize the spatial relationship of Liangzhu sites. We can find out visual control by the structure of network; the role of each site and the group of well-connected sites.

Finally, the geo-spatial network and the social network of artifacts are constructed by the same sites according to different relationship, which conveys the political control formation modes from the above-mentioned two perspectives. Comparing these two networks, we can identify different site groups in two networks.

The study finds out the Ancient City has obvious regional control function covering 135 settlement sites. Intervisibility relations among sites are evenly distributed, and the structure of spatial network is highly stable. However, the material cultural network illustrates a multi-centre political network structure.

Through this study, the organizational form and characteristics of political controlling in prehistoric society in Liangzhu capital area are further discussed, which provides a reference for further understanding of the complexity in society. At the same time, it provides support for the protective practice of Liangzhu cultural relics in this area or even in a wider range. On the other hand, this study explores the optimization of spatial and material relationship analysis methods in a specific regional environment. Furthermore, the approach of integrating spatial analysis on human-landscape relationship and social network analysis on data organization also provides an innovative interdisciplinary methodology for archaeological interpretation and cultural heritage value evaluation.

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106. Shrinking the scale of social network analysis in the North American Southwest

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Social network analysis has made important contributions to the archaeology of the North American Southwest (e.g., Mills et al. 2013, 2015; Borck et al. 2015). These approaches have used similarity in ceramic assemblages at large sites as the basis for social network analysis linking sites across vast areas and have convincingly shown that network approaches provide important information about large-scale transformations in social relationships over a period of several centuries. The nodes in these networks are villages with populations in the hundreds, and it is difficult to know the nature of the social relationships the networks represent. Network approaches have not been used in Southwestern archaeology to explore the relationships of smaller groups at smaller scales of space and time, and there has been only limited use of data other than ceramic assemblage composition as the basis for linking nodes. This paper uses a case study based on work by the Animas-La Plata Archaeological Project to explore the use of network approaches to link households using a variety of data types within a relatively small area and a short time span.

Between 2002 and 2005, the Animas-La Plata Archaeological Project excavated 34 Ancestral Pueblo habitation sites near Durango, Colorado (USA) that dated to the late 700s or early 800s AD (the early Pueblo I period in the local archaeological classification). With one exception, these sites are all small, with one to four pit houses each, and even in the one larger site (which has 22 pit houses) structures are spatially separated in a way that allows artifact assemblages to be associated with a single household or a small group of households.

These sites all date to approximately the same time period and the most distant sites are only about ten kilometres apart. Yet the sites exhibit substantial variation in architecture, artifact assemblages, and (where burial data are available) biometric variables, suggesting variation within the community in technological choices, activities, and social identity (Potter and Yoder 2008). Project reports analyse data on ceramic design, ceramic raw material use, faunal remains, architecture, and overall assemblage composition (Allison 2010; Potter 2010), all of which provide information about differences or similarities in technological choices or activities among households within the project area. These technological choices and habitual differences in activities are plausible proxies for strength of social relationships among households.

In the previous analyses of the Animas-La Plata data, a variety of methods were used to look at the data, although Allison (2010) and Potter (2010) both rely heavily on Correspondence Analysis. In this paper, I apply network analysis to the detailed artifact data available from the Animas-La Plata project. Networks are formed in several different ways to explore how choices in the type of material culture used as the basis for network ties influence the results. For example, networks based on similarities in (highly visible) ceramic design attributes differ somewhat from networks that are based on (relatively invisible) similarity in ceramic raw materials. I also compare the network analysis to results from Correspondence Analysis to contrast the strengths of each analysis method.

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107. The Use of Network Cartography for Visualizing Large Prehistoric Relationships

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The ever-growing record of digital archaeology allows us to construct increasingly complex networks of ancient human relationships. However, the more extensive the networks are, the more difficult they become for humans to interpret. This is where cartographic methods from the field of big data can help.

The ROCEEH Out of Africa Database (ROAD) is one of the most comprehensive data collections containing archaeological, anthropological, paleontological, and environmental data with >15,000 assemblages from >2,100 sites with relevance to the physical and cultural evolution of hominins between 3,000,000 and 20,000 years ago. For this study, we queried a dataset representing the Middle Stone Age and Middle Palaeolithic in Africa and Eurasia, respectively. The query includes localities, dating information, cultural categorization, and 32 further attributes, such as lithic tool groups, organic tools, symbolic behaviour, personal ornaments, materials like ochre and egg shells, or the use of fire. Based on this data, we calculated the cultural similarity of temporally close assemblages and created a weighted network. In this network, assemblages whose age ranges overlap are represented by nodes, and cultural similarity is represented by weighted edges.

To represent the 3.5 million edges, we used a cartographic method related to flow maps, an idea which is used for the visualization of big data. A well-known example is Paul Butler's Facebook Friendship Map (2010), which shows the global spread of the social network and confirms this method as suitable for mapping centres and peripheries, natural and artificial boundaries, and connectivity and isolation. In contrast to classical cartographic methods of generalization and abstraction that tend to simplify representation, this variant allows patterns to emerge from the totality of the connections to illustrate the overall picture. This effect is the result of a minimalist design and a carefully calculated symbology that results from the weighting and length of the edges.

We present results for the cultural similarities within the Middle Stone Age and Middle Palaeolithic separately as well as between them. As further examples, we show a selection of technocomplexes like the Acheulean, Mousterian, Aterian, Howiesons Poort and Initial Upper Palaeolithic. Furthermore, we discuss alternative ways to estimate cultural similarities and conceptualize temporal overlap. We also present ideas to further develop this approach, such as an interactive web app that allows researchers to adjust parameters and thus explore ancient cultural networks on their own.

35. "Interlinking exchange"

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Far-reaching, interregional exchange networks have been in the focus of archaeology for over 150 years. We present a collection of important trans-Eurasian datasets (Neolithic to Bronze Age) of specific raw materials with a clearly determinable source. Network analytical methods allow quantification of network properties and their correlation in time and space with proxies of social evolution.

Here we focus on large-scale exchange networks which fulfil very different demands, from daily lithic tools to very rare objects in the diplomatic sphere. Examples are networks of Neolithic flint and ground stone raw materials like e.g. Actinolite-Hornblende schist, Rijckholt and Grand Pressigny flint, Jade, but also spondylus shells, ochre, and early copper objects. During the Bronze and Iron ages many luxury materials seem to have been of highest social significance, at least for a short period. Especially gold, silver, ivory, amber, ostrich shells, faience, glass, different gemstones and lapis lazuli but also textiles, high valued foodstuff and special ceramics as well as other exotic items were collected and exchanged – probably sometimes between kinspeople and sometimes to connect peers in an economic and political sphere of elites.

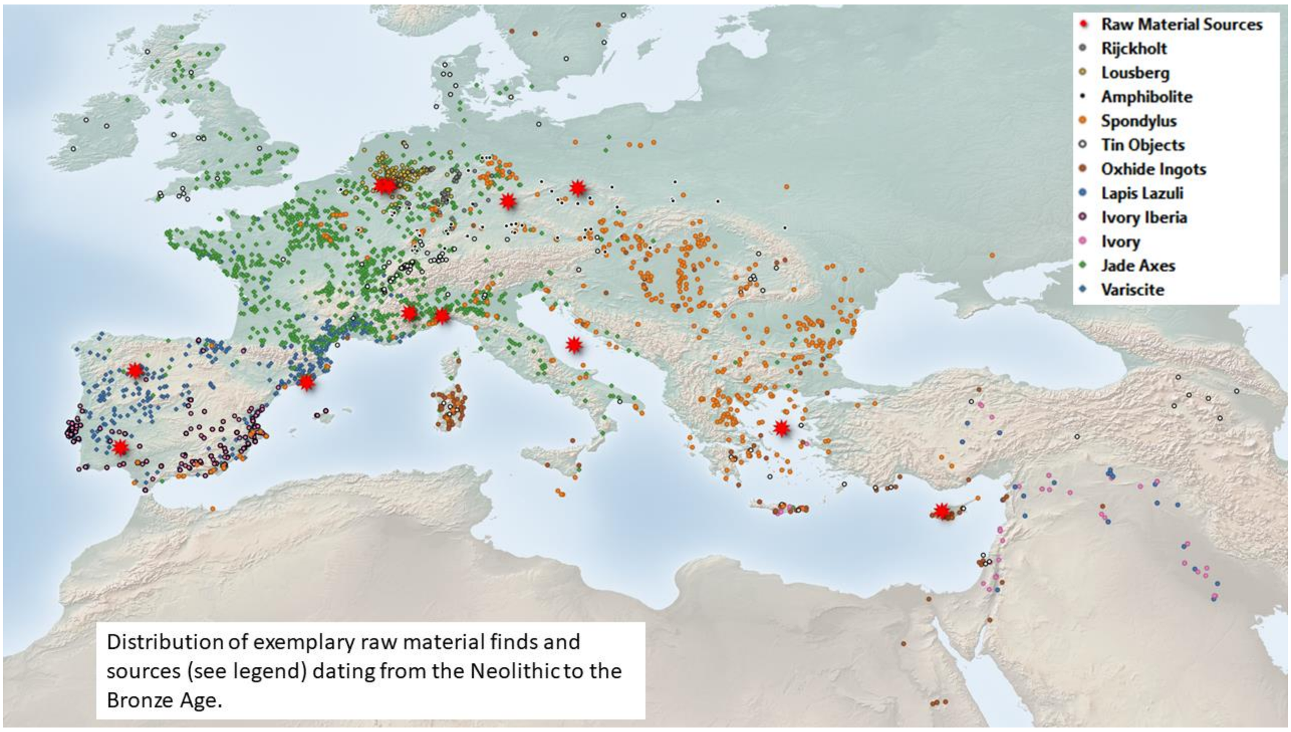

Figure 6. Distribution of exemplary raw material finds and sources.

Here we focus on large-scale exchange networks which fulfil very different demands, from daily lithic tools to very rare objects in the diplomatic sphere. Examples are networks of Neolithic flint and ground stone raw materials like e.g. Actinolite-Hornblende schist, Rijckholt and Grand Pressigny flint, Jade, but also spondylus shells, ochre, and early copper objects. During the Bronze and Iron ages many luxury materials seem to have been of highest social significance, at least for a short period. Especially gold, silver, ivory, amber, ostrich shells, faience, glass, different gemstones and lapis lazuli but also textiles, high valued foodstuff and special ceramics as well as other exotic items were collected and exchanged – probably sometimes between kinspeople and sometimes to connect peers in an economic and political sphere of elites.

Recently, booms and busts of prehistoric exchange networks could be shown to be interrelated thus especially indicating subsequent networks for the supply with prestige items. It can be expected that changing production volumes and demands turn those former prestige items into mass products (from type 2 networks of small numbers with high economic utility to type 1 networks with large numbers of items of low economic utility sensu Kerig 2018).

The joint consideration of different raw material distributions under a network perspective allows the recognition of temporal and spatial patterns that have not been recognised in this clarity so far. We will present a case study where settlement at the beginning of the Neolithic in Central Europe is explained by a process of directed percolation. Different raw material exchange networks are connected to form a single network. We focus on raw material sources located outside of the areas settled by the first agriculturalists. At this level, the formation of cliques can be observed. These cliques do not necessarily coincide with local ceramic groups. External arguments (violence, environment, ...) are considered to interpret these exchange relations and group formation.

In the current project "Interlinking Exchange", different networks in regard to material and time horizon are brought together by collaboration of the respective researchers. The interdisciplinary project is a cooperation between prehistoric archaeology, geo- and material sciences as well as data-sciences. It connects archaeologists from all over Europe and works as a moderated but basically open platform for the cooperation of interested parties.

Data brought together in this cooperation is also used as a case study of integrating data from different sources, with a focus on automation potential, domain requirements and upcoming challenges in the process.

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21. Social network analysis, community detection algorithms, and neighbourhood identification in Pompeii

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Neighbourhood archaeology has seen increasing interest in recent years (e.g. Pacifico and Truex 2019 and associated articles in the same volume). The definition and identification of neighbourhoods, however, both theoretically and within archaeological data, remains complex and problematic. Are neighbourhoods primarily top-down administrative units, organic bottom-up household agglomerations, or something in between? Is face-to-face interaction an important prerequisite or can larger districts exist at a more dispersed level of contact? Crucially, as constructs with both social and spatial characteristics, their detection through material culture alone remains elusive, especially within large settlements that are incompletely excavated or preserved.

Thanks to its focus upon relationships, archaeological network analysis offers a profitable path towards untangling the complexities of urban neighbourhoods. As in all such applications, the definitions of edges and nodes must be carefully considered. Mazzucato (2019), for example, used the co-occurrence of domestic material features at Çatalhöyük to form edges between units. Clusters of units that share denser ties with each other than surrounding sub-communities may correspond with neighbourhoods. Various community detection algorithms (e.g. Louvain and Leiden) offer mathematical solutions for partitioning large graphs into communities, but these should not be applied without careful interpretation. Mazzucato used statistical measures of modularity to prove the existence of spatially clustered household groups but did not vary the algorithm's resolution parameter which controls the size and number of identified clusters. Recent advances in the quality and efficiency of community detection algorithms, and new methods for assessing their outputs, offer new modes of archaeological analysis that have yet to be put to widespread use.

Main argument

This paper examines Pompeii's public fountains as centres of social interaction and plausible proxies for definable neighbourhoods, given their certain daily frequentation by nearby inhabitants. The excellent preservation of the city's streets and domestic units permit the creation of a detailed social network. This is derived from a GIS spatial network walking model that connects all 2000+ external doors in the city to its 43 public fountains along streets. Three theoretical one-mode social networks are compared, using shared fountains as edges connecting units. The first network connects units by the closest fountain to any door. Since many properties had side doors within reach of different water sources, these represent potential interconnections between communities. The second and third networks use incrementally larger time to fountain thresholds (30-second and one-minute walks to any fountain, respectively) to map potential choices to collect water, expanding social integration.

Although spatial data underlie its structure, this study's focus is topological relationships using social network analytics. As with most archaeological network analysis, initial parameters must be set that ultimately impact the calculated metrics. About a third of the urban plan is unexcavated, which means several fountains and hundreds of domestic units are missing. These lacunae distort the topology of the network in specific regions. A small number of fountains are also excluded from the networks since these were likely not functional in 79 CE, the phase most clearly represented in the extant unit divisions across the city. Unit boundaries and typologies are also subject to different interpretations. There is no standard plan of architectural divisions despite centuries of study.

Specifically, this paper concentrates on the contributions of community detection algorithms towards understanding Pompeii's fountain-based communities or neighbourhoods. These equations seek to identify clusters of nodes which are more densely connected to each other than others in the network. Using R-igraph, the Leiden algorithm (Traag, Waltman and van Eck 2019) is run using both the Constant Potts Model (CPM) and modularity as quality functions. Modifying the resolution parameter (gamma) in each equation partitions the network into greatly varying numbers of neighbourhoods of different sizes and compositions. Higher gammas produce smaller but more interconnected communities in which densities approach 100%, meaning almost every included household met face-to-face at a fountain. Smaller gammas result in fewer, larger, and more sparsely connected neighbourhoods centred around multiple fountains. In the latter, face-to-face interaction was less guaranteed, but neighbouring households nonetheless shared stronger ties with each other than the rest of the network.

To determine the optimal number of communities, Leiden was iterated at multiple gammas 25 times each. The number of partitioned communities was plotted against their gamma values to analyze their stability, assuming that more stable community divisions were also more robust. The chosen gammas were then iterated 1000 times to examine the internal stability of community partitions, which should be considered in interpreting the results. Modularity favours fewer, large, and relatively stable partitions, while CPM produces numerous small clusters that are highly volatile. Variable partitions likely suggest that the boundaries and cohesiveness of the resulting smaller communities were very fluid. We should perhaps read competing dense "face-to-face" communities at the level of individual fountains, which, surprisingly, often cross the boundaries of the larger more stable districts identified by modularity.

Implications

The results of this study demonstrate, on the one hand, that the Leiden algorithm holds great promise towards analysing very complex networks. Thanks to its widespread availability in multiple packages (e.g. R, Python, Gephi) and computational efficiency, it can handle even the most demanding networks that defy simple visual analysis. On the other hand, it should be carefully applied if used to interpret the results of archaeological network analysis. Practitioners should not rely upon the default resolution parameter for either modularity or CPM as this controls the characteristics and number of detected communities. Furthermore, using an iterative analysis run at multiple resolutions provides rich data for interpreting the neighbourhood structure of archaeological networks.

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32. Social network analysis of ancient Japanese obsidian artifacts with reduced sampling bias

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We performed a social network analysis of obsidian artifacts from the Jomon Period (15,000–2,400 years ago), a hunting and gathering period in Japan. Analysis of obsidian sources provides important clues to information and logistics networks among sites and regions in ancient times. In particular, the analysis of obsidian sources in the southern Kanto region of Japan is significant in terms of both quality and quantity. However, few studies have quantitatively investigated trends in the dynamics of logistics networks among consumption areas during the Jomon period, and the actual situation remains unclear. Based on these data, Tsumura and Tateishi 2013 attempted to reveal the pattern of obsidian source and consumption site combinations using statistical analysis methods. Their analysis is based on the source perspective. Analysis from the consumption site perspective, on the other hand, has recently employed methods of social network analysis among sites (Golitko and Feiman, 2015, Ladefoegd et al., 2019), using relatively small data (thousands of obsidian), although not from southern Kanto, Japan.

Subject

This study will also perform social network analysis using obsidian source data, which include more than 21,000 obsidian items from more than 270 sites, to explore information and logistics networks among sites and regions during the hunting–gathering period. When analysing obsidian data, however, some issues are unique to archaeology. That is, not all artifacts produced during the examined period have been excavated and analysed. As with obsidian artifacts, not all excavated obsidian has been subjected to source analysis. Therefore, we cannot ignore the possibility that the compositional ratios of sites in the results of the obsidian source analysis for each site may be subject to sampling bias. To reduce the risk of bias, we took the following precise steps. To begin with, we assumed that spatially neighbouring sites share some information and logistics and have similar obsidian source composition ratios. Based on this assumption, we adopted the density-based spatial clustering of applications with noise (DBSCAN) method to increase regional representativeness and reduce sampling bias by clustering neighbouring sites (within 10 km) and summarizing the number of obsidian artifacts in regional aggregate values, rather than aggregating values for each site. The DBSCAN method determines a region as a cluster based on the number of points in a certain radius. Provided that the density around the region exceeds a certain threshold, the cluster will grow continuously. However, if there are no nearby points within a certain radius, the points are considered as noise in this clustering method. Then, social network analysis was performed using these regional unit data. we used the cosine similarity of obsidian source composition ratios between clusters as a proxy for connection strength in the social network analysis. The cosine similarity (Sim) is expressed by the following equation.

$$Sim(A,B)=\cos\theta=(\vec{a}\cdot\vec{b})/|\vec{a}||\vec{b}|$$

Here, Sim(A,B) denotes the similarity between A and B clusters. Furthermore, $\vec{a}$ denotes the vector of A, and $\vec{b}$ denotes the vector of B. The values of Sim(A,B) range from 0 to 1. If the obsidian composition ratios of A to B are similar and the $\vec{a}$ and $\vec{b}$ are along the same direction, $\cos\theta$ approaches 1. Conversely, if they are not similar, the value approaches 0.

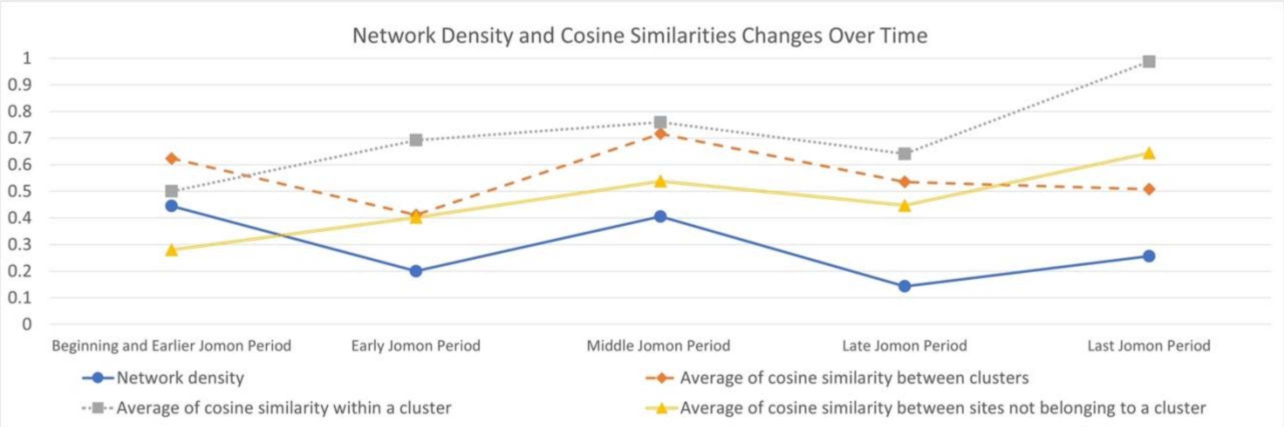

Figure 7. Network density and cosine similarities.

Discussion

Clustering results using the DBSCAN method showed that, for any cluster in any period, the average cosine similarity of the source composition ratios between sites within a cluster was higher than that between sites not belonging to that cluster (Figure 7). These results indicate that neighbouring sites have information about obsidian and obsidian logistics and that it is reasonable to compile aggregate values by region and analyse them in terms of regional representativeness. Furthermore, the network density among clusters and the cosine similarity among sites within clusters during the Middle Jomon Period were higher than those before the Early Jomon Period and after the Late Jomon Period (Fig.1). Regarding the logistics network among consumption areas, the details of which had been unknown, these results indicate the possibility that an obsidian distribution network was formed throughout the southern Kanto region during the Middle Jomon Period, but it was no longer functional in later periods.

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Session 10. Digital archaeology in the Gulf: New solutions to old problems

Jennifer Swerida, Penn Museum, University of Pennsylvania

Eli Dollarhide, New York University Abu Dhabi

Selin Nugent, Oxford Brookes University

Robert Bryant, University of Pennsylvania

Room 9

Introduction	11:00 - 11:15
136. What can mustatils tell us? Spatial analysis of the monumental ritual landscapes of Saudi Arabia *Hatton**	11:15 - 11:40
62. Monitoring land change and erosion for cultural heritage landscape of Bat, Oman *Nugent*, Swerida and Bryant*	11:40 - 12:05
17. The ArchaeoTrail app: Insights on a digital public archaeology project from Al-Khashbah, Oman *Döpper*, Loges, Ludwig, Gurjanow and Oehler*	12:05 - 12:30
Lunch	
55. Accuracy of photogrammetric excavation data capture in Oman: A time-saving methodology of acquiring traditional archaeological data at comparable precision and accuracy *Bryant* and Swerida*	13:30 - 13:55
25. Integrated archaeological surveys across large areas: The use of digital methods to obtain wide-reaching results from limited datasets *Smith**	13:55 - 14:20
29. Project: Economy and character of the Early Iron Age in south-eastern Arabia *Yule**	14:20 - 14:45
Discussion	14:45 - 15:00

Introduction

The archaeology of the Gulf Region of the Middle East presents unique challenges to researchers in the 21st century. This area, including Arabia, southern Mesopotamia and Iran, and the Indus Valley, is home to some of the world's first cities, states, and most iconic archaeological sites. This situation has made the Gulf backdrop to the development of many traditional fieldwork methods, including broad-scale landscape survey (Braidwood et al. 1983), settlement pattern analysis (Adams 1965), and the use of aerial photography (Kennedy and Bewley 2004; Stone 1991). In the years since these foundational achievements, geopolitical challenges and deteriorating environmental conditions have resulted in inconsistent access to on-the-ground research and limited the implementation of some digital archaeological approaches common to other regions. This disjointed development has resulted in uneven states of the field and limited interactions between scholars working in these different countries.

This session addresses these challenges by inviting scholars working throughout this region into conversation with each other about these challenges and the strategies they have developed to overcome them. The papers presented here will bring traditionally divergent groups of regional specialists together. Potential topics include the use of geophysical prospection (Herrmann 2013; Khan et al. 2021), drone-based survey and mapping (Smith 2020), applications of satellite imagery (Harrower 2013; Sivitskis et al. 2018; Ur 2013), digital approaches to preservation and conservation management (Rayne and Bewley 2016; Zerbini 2018), agent-based modelling (Angourakis et al. 2020), and the application of artificial intelligence (Orengo et al. 2020; Nugent in prep) in contexts across the Middle East. Audience members may include researchers with active field projects in Gulf states, digital archaeological innovators, and the heritage community of the greater Middle East.

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136. What can mustatils tell us? Spatial analysis of the monumental ritual landscapes of Saudi Arabia

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Human occupation has occurred in Arabia since at least the Middle Pleistocene, often during periods of increased rainfall. The most recent period of increased rainfall, the Holocene Humid Period took place from 10 to 6 thousand years ago. There were major cultural changes during this period, with the expansion of Neolithic populations and a transition from foraging to herding and pastoralism. Thousands of prehistoric stone structures cover the landscape of Arabia, although their chronology is still not well understood. Prominent in recent discussions are mustatils, a type of large rectangular stone structure, which have only been formally recognised in the last decade. Based on a few dated examples, mustatils are understood to be ritual structures constructed in the late 6th to early 5th millennia BC and are likely linked to a cattle cult phenomenon (Thomas et al. 2021). They are some of the oldest large structures in the world, indicating an extensive monumental ritualisation of the landscape. While our understanding of mustatils has grown significantly over the last few years there is still much to learn and understand, particularly about their location on the landscape. Spatial patterning of mustatils may shed light on their purpose and on population dynamics given that they are potential territorial markers linked to the cattle cult during a period of time where Arabia was becoming more arid. Groucutt et al (2020) found that mustatils were relatively evenly distributed across the landscape, although due to the local-topographic complexity they were unable to identify any landscape patterns. This paper aims to expand our knowledge of mustatils by conducting spatial analysis on mustatils in the southern Nefud to better understand their patterning.

I conducted surveys of Bing and Google satellite imagery over an area of approximately 45,000 km2 covering the southern margins of the Nefud desert. This area was chosen to as it incorporates mustatils previously studied by Groucutt et al. (2020) while expanding the study area to the south. This was done to include a wider variety of types of landscape, which now includes the desert and jebels within it as well as lava fields (harra) towards the south. 170 mustatils are now known in the study area, which has increased the sample from the 104 that were reported by Groucutt and colleagues (2020).

Spatial analysis of the mustatils is being conducted to investigate their relationship to one another, the underlying geology, proximity to water sources, and topography. Mustatils are often found in groups, and understanding the orientation, size and other aspects of mustatils within and between these groups will shed light on their usage. The underling geology varies across the chosen area; the north is covered by sand dunes, with sandstone outcrops forming jebels, where mustatils are often located. In the south of the study area there are basalt lava fields. Mustatils, and other stone structures, are built using locally sourced stone and so there is a possibility that construction style is affected by the underlying geology. Analysis of mustatil location in relation to water sources is also be conducted, by modelling modern occurrences of seasonal water sources. Topographical analysis of their position includes viewshed analysis, since mustatils are often located in areas where they have good visibility (edge of escarpment) or where they are highly visible on the landscape (on the slope of inactive volcano's).

Because mustatils have received such little attention, spatial analysis of them at a landscape scale sheds light on their use and on processes of demographic and cultural change. This adds to our understanding of these structures which represent one of the earliest monumental building traditions identified in the world. The abundance of mustatils in North Western Arabia makes them uniquely well placed for spatial analysis offering insights into Late Neolithic society.

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62. Monitoring land change and erosion for cultural heritage landscape of Bat, Oman

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Jennifer Swerida, University of Pennsylvania

Robert Bryant , University of Pennsylvania

This paper presents the design process and prototype for an semi-automated, remote-sensing workflow developed to monitor land change and erosion risks, which threaten to damage archaeological monuments, as part of the Bat Archaeological Project. Located on the piedmont of the Hajar mountains in Oman, the archaeological site of Bat is one of the most important heritage centres in southeast Arabia (UNESCO 1988), comprising an oasis settlement and necropolis occupied from the Neolithic through the present. The increasing climate variability, extreme precipitation, and flash flooding events in the region (Ahmed and Choudri 2012) have generated concerns among community members and heritage professionals over their impact on the preservation of this site and the ability of researchers and heritage officials to rapidly monitor and mitigate damage risks. This project involves multiple phases, which aim to ultimately integrate prototype development with participatory design through community engagement. In this initial phase, we focus on evaluating current cell-based raster approaches to continuous monitoring of land change and reliability for the landscape in the Bat archaeological landscape.

Methods

Our analyses use open source Sentinel-2 satellite imagery and cloud-based computing in Google Earth Engine. Change detection analysis is performed on point data of archaeological monuments and features from the Bat Archaeological Project database. We apply established methods (Hussain et al. 2013) for per-pixel change detection analysis by using a layer change detection algorithm that calculates the difference between each spectral band in image composites. Further we apply a Continuous Change Detection and Classification (CCDC) algorithm to test land changes continuously as new images are integrated. Until on-the-ground validation can be undertaken at Bat, change detection results will be compared against a spatial assessment for erosion risk based on landcover, slope gradient, and hydrology using the application of the Revised Universal Soil Loss Equation (RUSLE) model.

Results

Analysis for this project is ongoing and validation results will not be possible before comparing results to on the ground observations. We present initial results from both per-pixel change detection analysis and erosion risk mapping. By comparing these two results, we are able to evaluate erosion vulnerabilities that can be tested against detectable changes in imagery. Moreover, we aim to identify areas of higher risk that do not correspond to detectable changes, which can inform on the robustness of this approach. This modelling will help us identify areas of heightened risk and help prioritising monuments for conservation.

Discussion

As the effects of climate change increasingly impact communities and the landscape of Southern Arabia, it is becoming increasingly critical to also consider strategies for monitoring and mitigating its impact on cultural heritage. Further, these strategies should carefully consider and integrate stakeholder perspectives and accessibility of monitoring tools. Although this presentation focuses on the initial prototype phase of work in this research, we also aim to discuss adapting participatory design strategies and user-research approaches in supporting closer connections between communities and their cultural heritage.

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17. The ArchaeoTrail app: Insights on a digital public archaeology project from Al-Khashbah, Oman

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Matthias Ludwig, Johann Wolfgang Goethe University Frankfurt

Iwan Gurjanow, Johann Wolfgang Goethe University Frankfurt

Deng-Xin Ken Oehler, Johann Wolfgang Goethe University Frankfurt

Archaeological sites can offer valuable insights into the past for visitors and local audiences if they are presented well. Often, however, more information is needed than easily available to communicate this knowledge. This is especially true for less widely known and more remote sites that lack proper signage and knowledgeable guides, which is the case for many archaeological sites on the Arabian Peninsula. To fill this gap, and make local heritage accessible to people around the world, the ArchaeoTrail project based at Goethe University Frankfurt (www.archaeotrail.org) has developed a web portal for archaeologists and other people responsible for archaeological sites to generate self-guided, informative tours of their site using a smartphone app. Some of the first tours, or “trails”, have been generated at the site of Al-Khashbah in Central Oman, where we were able to test the application and receive feedback on the trails from local residents. The same is planned for several other sites in the Sultanate of Oman that members of the team have worked on.

The Project

In recent years, the use of mobile applications has become increasingly widespread within the field of digital public archaeology, as smartphones have become a ubiquitous means of accessing knowledge (Bonacchi 2012; Richardson 2014). They are used to transport information on and interpretation of archaeological sites, and to engage larger and more diverse audiences. They help raise awareness of the economic, social and political importance of cultural heritage and to create interest and motivation for its protection, especially through the integration of local communities in archaeological research and discovery.

The ArchaeoTrail project aims to do just this: It is a system that facilitates the communication of information about archaeological sites, consisting of a web portal and an app for mobile phones. The portal provides people who care for archaeological sites with the technical toolkit to generate "trails", i.e., informative tours of their site. No specific requirements are made to the creators, making the portal explicitly open for all. For each trail, stations at the archaeological site can be generated and filled with text, images, or short audio and video files, as well as different types of quizzes, especially targeted at younger visitors. To make the trail publicly available, it has to undergo a peer review process.

The app itself allows visitors to conduct a self-guided tour at the site. They are navigated by GPS to each station, where they get the information provided by the trail’s creator. This creates an experience not unlike being guided through by an archaeologist or a museum guide, pointed at the most important features and provided with relevant information. Added digital replications or photos can also provide a reconnection of archaeological objects that are normally only displayed in museums, with their original context. Here, as with the web portal, broad accessibility is a key goal of the project. To be suitable for as broad an audience as possible, the app is available in several languages, including Arabic, and is also suitable for non-left-to-right scripts. Translations in more languages can be added at any stage of the project and will be available with the following update of the app.

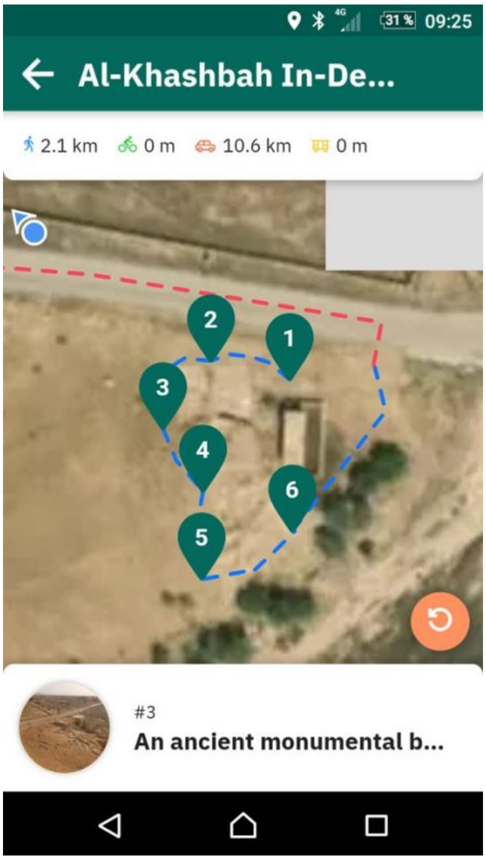

Figure 8. The ArchaeoTrail app.

Drawbacks of using a mobile app are mainly technical issues, such as problems with GPS signals, network connection, and memory space of the phone. Arguably more important are concerns about the cost of developing and maintaining such a project. For the latter, ArchaeoTrail provides a solution as both app and portal can be used free of charge and no own digital infrastructure is needed. The challenge of future sustainability is mitigated, albeit not ultimately solved, as funding for infrastructure costs and maintenance for ten years are included in the project's budget.

Case study: Al-Khashbah

The first site for which trails were created is Al-Khashbah in the Sultanate of Oman (Schmidt et al. 2021). Most archaeological sites in Oman, including Al-Khashbah, lack on-site interpretation panels, visitor orientation centres and guides, although increasing efforts are made by the Ministry of Heritage and Tourism to change this situation. Al-Khashbah is situated in central Oman off the more densely populated areas and far from major tourist attractions. This results in low numbers of visitors, most of them coming from Al-Khashbah itself or neighbouring villages. The interest in the archaeology from those who visit, is, however, quite high, often resulting in visitors coming back with friends and family. To generate engaging tours that meet the needs of our target audience, we decided to focus on local and national visitors including school children. With the widespread use of smartphones and an internet user rate of 92 % of Oman's population, a smartphone application is a suitable approach for the local needs.

This resulted in the generation of three different trails for Al-Khashbah, available in Arabic, English and German. These are an in-depth trail featuring most of the archaeological structures at the site, a highlight trail allowing to visit the most important of the structures in a shorter time, and a family trail, which provides information in a more child-friendly way, including interactive quizzes. An online feedback questionnaire is linked at the end of each tour, available in English and Arabic. During the excavation season in Al-Khashbah in the spring of 2022, the trails were tested by the project team as well as volunteers from local schools. Feedback was also sought from the Ministry of Heritage and Tourism of Oman, who supported the project from the beginning. In our talk, we will share the insights gained during this testing phase, as well as the consequences it resulted in for these and future trails.

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55. Accuracy of photogrammetric excavation data capture in Oman: A time-saving methodology of acquiring traditional archaeological data at comparable precision and accuracy

Robert Bryant, University of Pennsylvania

Jennifer Swerida, University of Pennsylvania

With the growth of digital technology and methodology in our field, we must remain cautious of over-relying on their implicit objectivity. Interpretation certainly occurs at the trowel's edge, as much as it occurs at the setup and positioning of a total station, the reflection of a laser from a prism rod, remotely sensed imagery, and especially the photographs taken for a photogrammetric model.

The goal of digital technology is about increased data accuracy and precision, but the interpretation of that data is no less subjective. Digital methodologies should serve two purposes: increasing efficiency or efficacy in capturing data for the current archaeologist, and increasing the density or resolution of data for future archaeologists to re-interpret and contextualize.

It's important when making photogrammetric models to understand them as constructions rather than reconstructions (Clark 2010). They are approximations of a moment in excavation and the drawings and data they seek to replace. There is a tendency to attribute higher objectivity to these models when we should rather recognize them as a more efficient and resilient means of obtaining the same sought after interpretive information.

Work has already been done in detailing the photogrammetric concerns and methodology behind selecting the proper camera, how to take photographs, and the setup control points (Sapirstein and Murray 2017). Additionally, work has been done by De Reu et al. (2014) and Douglas et al. (2015) in thoroughly proving the effective accuracy of photogrammetric recording over more traditional hand-based sketching and recording of archaeological trenches and features.

Building on this established photogrammetric methodology for the systematic photogrammetric capture of excavation trenches, our effort is to increase the efficiency of obtaining contextual surface data such as: elevations, plans, trench photographs, section drawings, and a virtual phenomenological experience, by testing the limits of this particular methodology in data capture and how far the range of error can be responsibly pushed and remain useful. Although Sapirstein and Murray (2017) argue for maximum accuracy and point toward the degree of error in total stations being problematic when sampling control points from trench nails and rebar--these control targets must also be shot in with a total station with the same margin of error.

Using a simple test sounding in Oman, excavated at arbitrary lot depths, we explore how many targets are necessary to achieve a reproducible and acceptable margin of error in the construction of 3D trench data using only the initial set of total station points.

We outline a step-by-step methodological plan of how to accurately, and reliably extract both orthographic overhead and profile images that are properly scaled from Agisoft Metashape, how they can be imported into QGIS, and exported into ready to utilize base images for accurate drawings of plans and stratigraphic sections. We focus particularly on the complex geometric transformation necessary to produce the most accurate rendering of a section. Even if exporting an orthographic planar view of a section in Agisoft, this is only available for excavations that work exclusively in cardinally aligned grids, and may be subject to human error in the trench's original layout. We explain a short Python script and the math necessary to quickly apply this transformation to established control points to prepare for QGIS image rectification.

Our results show that there is, we argue, an acceptable margin of error through a rapid deployment of photogrammetric data capture in the field using easy to access equipment compared to traditional means of capturing the same data. These constructed models can be gleaned with little additional effort when taking existing trench photographs, processed the same day in the field to provide scaled and georeferenced visual guides for producing publication quality plans and section drawings, and provide a more robust dataset for future archaeologists, (including ourselves on subsequent seasons), to access the past. We hope to invite others to reproduce these results with their own projects and open the conversation to criticism and suggestions.

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25. Integrated archaeological surveys across large areas: The use of digital methods to obtain wide-reaching results from limited datasets

Stefan Smith, ANEE, University of Helsinki

Archaeological surveys across large areas of landscape typically require many seasons of fieldwork and significant human, time, and financial resources to obtain data at a sufficient breadth and depth to be used for comparative and holistic studies. This often poses a problem to projects of limited time, limited resources, or particularly large geographical remits. However, employing a variety of integrated digital techniques, both in the field and in the lab, can greatly improve this dilemma, allowing less to go further in terms of data collection, processing, and analysis. This paper will present such techniques using the examples of two fieldwork projects, the Western Harra Survey (WHS) of north-eastern Jordan and the Bat Archaeological Project (BAP) of central Oman, and illustrate how each benefit from the methodology in different ways.

The WHS, a co-directed project between the author and Marie-Laure Chambrade, (CNRS Archéorient, University of Lyon, France) is a project conceived to study a 36 by 32 km area of the interior of the Harra desert, a basaltic plateau that stretches from southern Syria to the northwestern corner of Saudi Arabia (Smith 2020). While archaeological projects over the last few decades, and in particular the last few years, have identified a dense prehistoric site distribution, much of the landscape remains unknown. In particular, the geographic relationships of sites to each other and the issue of movement are poorly understood. The latter is particularly crucial the Harra due to the extreme access difficulties of traversing the dense scatter of basalt rocks that cover almost its entire surface, something that also renders modern investigation tricky. Indeed, there are limited areas within this desert that are accessible today, even by 4x4 vehicle, meaning that all investigations are necessarily keyhole snapshots of a wider landscape. However, by a combination of intense satellite imagery analysis, the flying of drones across the landscape to map otherwise inaccessible sites, and the processing of this data through the lens of targeted surface investigations designed to encompass a representative sample of site and landscape types, a relatively holistic view was achieved in only 4 fieldwork seasons of 2-3 weeks each. Amongst other results, it was determined that certain site types previously lumped together can in fact be subdivided into further categories, that some “buildings” in fact consist of a palimpsest of structures, and that a dense network of anthropogenic paths criss-crosses the landscape, mainly connecting sites to resources and natural accessways (Smith and Chambrade 2018).

The BAP, currently co-directed by Jennifer Swerida (Penn Museum, Philadelphia, PA, USA) and Eli Dollarhide (NYU Abu Dhabi, UAE), is a longstanding project investigating the large site of Bat, encompassing a total area of at least 15 by 4 km. As a holistic project comprising of archaeological excavations and surveys, geomorphological and environmental surveys, and local outreach programmes, it promotes an integrated combination of these various aspects of research to build towards a complete picture of the area, past and present (Swerida, Cable, and Dollarhide 2020). The survey portion of the project, which the author co-directed in 2019 and directed in 2022, is thus required to be intensive enough to match the depth of data acquired by other investigation methods, while at the same time encompassing a large area. To achieve this, an integrated approach was again utilised, but the relative ease of access of the landscape when compared to the Jordanian Harra enabled a more systematic use of the digital methods to be possible. Thus drones were first used to not only get views of the landscape as with the WHS, but to map regions in detail in advance of surface surveys, allowing these to be specifically planned as required. The results of the detailed surveys along 20 by 100-metre transects were then analysed through the lens of the processed drone data, allowing for example in one instance for discrepancies in artefact density to be explained by surface wash which was easily visible on Digital Elevation Models (DEMs) created from the aerial imagery. Drone-derived DEMs were also used to plan a structural survey of potential Iron Age buildings at the site of al-Khutm which were difficult to see on the ground. Finally, the BAP survey utilised a number of digital data input methods in the field on tablet computers and mobile phones, enabling a rapid processing of collected data at the end of each working day, thereby greatly reducing backlog and allowing for quicker interpretations to be made, which could in turn be used to plan subsequent data collection procedures.

Together, these presented methodologies will not only showcase how integrated digital methods benefited the WHS and BAP projects, but also provide a potential framework for other projects attempting to build towards holistic views of a particular landscape, particularly those without the benefit of large-scale resources.

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29. Project: Economy and character of the Early Iron Age in south-eastern Arabia

Paul Yule, Heidelberg University

Our research during the past few years on the Early Iron Age (EIA) puts digital methods to use in different ways. It may present solutions to old problems, but often opinions differ on the exact one to be attacked first. Needed are an agreed-on nomenclature for artefacts, sites and phases not to omit a desire to come to a consensus in basic ways. Several solutions can be presented to improve the situation for both fieldwork and archiving.

Since 2000 I began to develop an archaeological site gazetteer first for the entire Gulf, but later just for the Early and Late Iron Age (LIA) of south-eastern Arabia. In its latest form the list of EIA and LIA sites amounts to 313 and 214 sites, respectively, which can be mapped in various ways. Simple plotting programmes such as ExpertGPS produce good first results. QGIS offers more options for topological mapping of the entire region. Two challenges present themselves: first to find a date format usable for different purposes and second, to have the flexibility to update the results as new data become available.

In 2006 heidICON, the image bank of the Heidelberg University Library began to scan and upload images regarding the archaeology of Oman, South Asia, Yemen and Ethiopia. In the meantime, this database-driven open access archive contains over 11.000 images which can be downloaded at no cost. This is an excellent solution, the all too common alternative being that the slides are simply discarded after retirement, of a given colleague, as known in several cases. Whereas we began archaeological mapping in the 1980s by means of 1:100.000 maps, this changed in May 2000 when the US government turned off GPS 'selective availability' in SE Arabia. More importantly, Google

Earth site revolutionised site prospection especially when high-resolution imagery became available for larger parts of Oman after 2006. Where greater resolution is needed, programmable drones provide the best results, producing enormous amounts of data: A flight in the al-Salayli valley of a surface 1300 x 700 m produced some 300 GB of data including the landscape model and high-resolution imagery (DJI Matrice M300 and a DJI Zenmuse camera). Flight altitude: 250 m above the surface (670-780 m relief). Flight time: 55 minutes. A Leica Viva CS15 GNSS served for the geo-positioning of some 50 targets in DIN A2 size placed in the topography. Getting a radio license in order to use the instrument in Oman effectively ended this initiative.

We also map with a new Garmin hand-held GNSS receiver. This is not a major improvement over the GPS, but does provide a more stable resolution, maximally at 3 m radius, since it draws on both GPS and Galileo satellites. The coordinates, date and photo direction in the metadata of this instrument are basic for understanding archived photos in heidICON. This is important for the documentation of encroached archaeological sites in a constantly changing environment.

Other digital applications for our project are far simpler. A database application is used to store and sort morphometric classification of EIA so-called red-metal artefacts. A protracted data search preceded the classification and evaluation. This shows that the south-eastern Arabian EIA by far out-produced the BA in terms of metal artefacts. Thus, economically the EIA clearly overshadows the BA.

Our main result this season – the archaeological mapping of the al-Salayli valley – shows it to be mostly an early Islamic instead of an Early Iron Age one.

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Session 14. Large-scale and intensive computational workflows in archaeological remote sensing: from big data to data science

Francesc C. Conesa, Catalan Institute of Classical Archaeology

Arnau Garcia-Molsosa, Catalan Institute of Classical Archaeology

Hector A Orengo, Catalan Institute of Classical Archaeology

Room 11

Introduction	11:00 - 11:15
65. Scaling Up: Results from an automated search for hillforts across the whole of Britain *Maddison* and Landauer*	11:15 - 11:40
176. Harnessing the benefits of a much improved cost-benefit ratio for proven remote sensing techniques in developer-led 'commercial archaeology' *Tomiak**	11:40 - 12:05
108. Application of machine learning algorithms on satellite imagery for the detection of potential new prehistoric sites in the Egyptian Western Desert *Brucato*, Masini, Scardozzi and Lucarini*	12:05 - 12:30
Lunch	
78. Assessing desertification in the cultural landscape of Southern Morocco using Google Earth Engine *Rayne* and Brandolini*	13:30 - 13:55
Discussion	13:55 - 14:20

Introduction

The last few years have seen an unprecedented advance in the application of computational approaches for the remote analysis of archaeological landscapes, sites and features. This progress is mostly related to improvements in availability, diversity and quality of remote sensing data acquired from multiple platforms (ranging from satellite imagery to UAVs) and sensors (e.g. multispectral, radar, lidar, thermal) but also to increased access to high performance computing. This is partly related to the development of multi-petabyte catalogues of geospatial datasets linked to cloud computing environments accessible through web-based application programming interfaces associated to interactive development environments. These have granted the research community unparalleled access to geospatial data and computing power, and facilitated the development of large-scale, multi-temporal and multi-sensor analyses of the Earth's surface. These environments have also been instrumental in the implementation of intensive computational processes, such as machine learning-based data classification, multi-scale topographic analysis, long-term time series analysis, and so on. Many computing platforms have recently gain some popularity and are boosting a fast-growing number of applications. Among those, we highlight the of Amazon Web Services or the Data and Information Access Services that are run by the Copernicus satellite program. In particular, Google's Earth Engine have been integrated into the archaeologist toolkit in a wide range of topics such as site detection and the long-term monitoring and management of cultural landscapes (see for instance Agapiou 2016; Rayne e al. 2017; Orengo and Petrie, 2018; Orengo 2020, Agapiou 2021).

This session will aim at showcasing and discussing new computational workflows for the treatment and analysis of large or complex remote sensing and other geospatial datasets. The adoption of cloud-computing platforms and other reproducible processing operations ultimately leave more time and resources for data interpretation and compared studies. We therefore encourage submissions that highlight innovative remote-based archaeological applications in the following or similar topics:

- Implementation of high-performance computing workflows
- Application of cloud-based computing platforms to archaeological remote sensing problems
- Use of multi-petabyte repositories of geospatial datasets
- Complex computing or multiplatform workflows
- Remote sensing analysis of large areas
- Landscape analyses over time-series
- Geospatial data cleaning and preparation
- Synergistic use of multispectral and radar satellite imagery
- Integration of multi-sensor or complex types of remote sensing data

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65. Scaling Up: Results from an automated search for hillforts across the whole of Britain

Simon Maddison, University College London

Jürgen Landauer, Landauer Research

The rapidly increasing availability of remote-sensing data such as LiDAR and aerial imagery and its improving image resolution have the potential to revolutionise landscape archaeology, as previously unknown archaeological features can potentially be identified. By using some degree of effective automation this could even be achieved on a region or country wide scale with a manageable effort.

Hillforts are amongst the most obvious and iconic archaeological sites in Britain. Usually associated with the Iron Age, they can date from the Neolithic to early Medieval times. The Atlas of Hillforts project (Lock and Ralston 2017) provides a comprehensive and up-to-date record of these sites, over 4000 in total, and an invaluable database for further research (e.g., Maddison 2022). Nonetheless a new site has been recently discovered (https://www.bbc.com/news/uk-england-beds-bucks-herts-53741441) with the application of citizen science to LiDAR, demonstrating the potential for further discoveries from the growing extent of this LiDAR dataset.

Finding British hillforts

Since 2020 we have been developing a software tool for the automatic detection of hillforts using LiDAR, based on modern Machine Learning and Artificial Intelligence technology. The methodology and the workflow were presented at CAA 2021 in Limassol (Landauer and Verschoof-van der Vaart 2022). By contrast, the research presented here reports the results based on a substantially improved workflow and extended database. Hence, we can now show the effectiveness of the approach not only on select test regions in England, but over a substantial part of Britain as a whole. We have obtained all available LiDAR data as Digital Terrain Models (DTM) for England, Scotland, and Wales. Using these, we have been able to generate detection results at a country-wide scale, and present and discuss these here.

Results and outlook

LiDAR for Britain comprises some 400 GB of data and hence processing this for hill-fort detection takes approximately 30 hours of computation on a reasonable performance PC (ca. 1000 € with good graphics hardware).

The output is a set of thousands of patches of land in a 500 m x 500 m grid. Each patch has a confidence score between 0 and 100 percent which can be interpreted as the likelihood of this patch containing the remains of a hillfort. With this "raw" output a variety of research questions can be addressed, including:

- Relationship between detection and landscape types: What (statistical and other) impact have differences in topography on detection quality? For example, are highland hillforts detected more easily?
- Detection quality and hillfort types: Are hillforts of different types detected uniformly, i.e. all with the same likelihood? Or are there differences between less common sites such as promontory forts and more widespread forms?
- Regional variations: there is significant variation in the density and nature of hillforts across Britain, e.g. southeast Scotland, southwest England. How is this impacted by the selection of training data, or is it necessary to run the detection on a regional basis?

- And in our view, most importantly is the question of interpretation: Even a high confidence score could be a False Positive, hence it is essential to have an efficient process to analyse promising hillfort candidates, e.g. via manual inspection of other remote sensing data such as satellite imagery, field prospection and checking the Historic Environment Record, as the detected site might be of a different category. A bigger question still is who would undertake this work and how it could be organised. This is perhaps the biggest question in this new era of Big Data.

In our opinion these results on hillfort detection quality are also likely to be applicable to other types of archaeological features. As a long-term objective, findings of this project (and similar automatic detection projects) could therefore serve as the basis of a future quality benchmark for the automation of archaeological feature identification from remote sensing data.

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176. Harnessing the benefits of a much improved cost-benefit ratio for proven remote sensing techniques in developer-led 'commercial archaeology'

Michael Tomiak, WSP

Whilst the application of remote sensing in archaeology is not new, commercial, developer-funded applications have been, and to an extent still are, considered too costly.

However, these barriers are rapidly vanishing; dataset costs are decreasing, geographic and temporal data availability widening, more affordable hardware to process and view the information, and digital skills now more integrated within the discipline. Commercial archaeology should be seeking to apply these techniques as standard to desk-based assessment and early phase planning.

From a number of example, but discussing a recent mid-sized pipeline project, this presentation seeks to highlight the recent changes: the positive cost-benefit ratio now available due to falling data and hardware costs, and the growing prevalence of GIS skills and software in the industry.

Context

Remote sensing applications are not yet applied in the industry as a standard part of the desk-based assessment/planning stage. The 'National Mapping Programme,' and Aerial Photo archives make good steps towards shedding new light on the archaeological resource. But these are limited to select areas of the UK, and are assessed at a single point in time, often before new remote sensing techniques were available.

There are a number of barriers that seemingly have deterred implementation of application of remote sensing techniques at these early stages: Developers are deterred from 'add-on' pieces of assessment; Developers do not typically understand the added cost-benefit of these assessments if applied correctly in appropriate situations. Furthermore trained heritage specialists with remote sensing skills were fairly uncommon, which would mean it is not always practical.

Case study

A case study reviewed the application of remote sensing techniques as part of the identification of the baseline heritage receptors within 250m of a planned 22km water pipeline corridor. The proposed pipeline route had previously been subject to limited archaeological investigation and there was minimal baseline information available to inform the scope of further archaeological works. Historic Environment Records (HER), the National Mapping Programme (NMP) and other sources were consulted, but had considerable limits; the HER denoted features using points, or if an area, a polygon 'containing' the feature - the National Mapping Programme study was undertaken in 1996, and since then new remote sensing technology has provided new methods of identifying potential archaeological.

The approach used both multi-spectral imagery and LiDAR (Light Detection and Ranging) techniques to better understand and quantify archaeological features present. Using a GIS, datasets were 'streamed' into the GIS software for visualisation allowing for the viewing of large datasets without the need for large amounts of available storage space on local devices. Both the LiDAR and the multispectral dataset were then reviewed in the context of existing heritage information. New or additional information was then transcribed into the baseline.

In the study's multispectral analysis the Normalized Differential Vegetation Index (NDVI) was applied. This technique, exaggerates how buried archaeological features affect the quality and health of the crops and other vegetation growing around them – especially during periods of drought. This study acquired imagery from a commercial aerial imagery provider, which came under a cost of £100 for 12.5cm resolution, for an area of 1km2. This was almost triple just 5 years ago. A number of temporal datasets were available and so specifically selected imagery, captured during 2018,2019 and 2021 summers was acquired.

LiDAR data was acquired from the Environment Agency (EA). Until the systematic wide-spread capture of LiDAR data by the EA began in 2018, (EA national LiDAR surveys are usefully recorded through this webmapping dashboard), freely available 1 or 2m resolution data was patchy. The data was visualised as a Digital Terrain Model (DTM) and analysed to identify archaeological features. The Digital Terrain Model was run through a composite hill shade algorithm before being visually analysed.

Benefits

Through the case study, use of remote sensing provided important new insights and detail into buried archaeology and enabled a better quantification of the archaeological resource. The assessment led to 49 either new, or new detail to existing, features. Out of the 49 anomalies identified, approximately 50% of the features were identified through the multispectral dataset with NDVI applied (24 features) and 50% from the LiDAR dataset (22 features), with the remaining three features identified using open-source imagery.

The study however led to eight identified anomalies of particular risk to the project, that were unknown before the study. As a form of potential risk to the project, these were flagged and considered for targeted surveys at a later stage.

The assessment benefitted:

- Developers and commercial archaeologists - allowing a greater reduction in the unknown resource, more targeted surveys and less risk in planning and costs.
- The HER; a more detailed and consistent resource (assuming guidelines, agreed schemas and best-practices are used) entered the baseline database, funded thorough developer-led archaeology.
- The wider archaeological community by providing a detailed resource which can lead to better targeted research.

The method described above is applicable to large-scale project too. Remote sensing studies have also been undertaken using this approach, such as HS2 Phase 2a and East West Rail. Whilst the data cost is proportional to the larger area, once schema, thesauri and processes have been created, is minimal – as templates can be reused.

In sum, proven remote sensing techniques can provide a wealth of archaeological information to support early assessment and planning and should become part of the standard paradigm. With the costs in the last few years becoming demonstrably less restrictive (coupled with digital data skills more readily available in the discipline), the cost-benefit ratio is clearly now of interest to developers and effort to encourage this type of a study should made.

108. Application of machine learning algorithms on satellite imagery for the detection of potential new prehistoric sites in the Egyptian Western Desert

Alessia Brucato, UNIBA - CNR ISPC

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In recent years, the increasing availability of large open access datasets coming from different sources and the development of automated approaches and algorithms to discover and classify archaeological evidence, has offered researchers interesting new possibilities and perspectives on historical investigations. Especially for aerial and cosmic remote sensing, the released datasets of optical and multi-sensory images and the diffusion of new digital approaches have led to extraordinary results in the discovery of previously unknown archaeological and paleo environmental markers. They have also helped us understand connections and complex patterns of large-scale phenomena from a more comprehensive point of view.

In this study we applied an automated approach to satellite multi temporal and multisensory imagery for the detection and classification of archaeological features and patterns related to the hunting-gathering, and later pastoral groups, occupying the Egyptian Western Desert (hereafter EWD) during the Early and Mid-Holocene. This period was characterized by major environmental changes and repeated climatic oscillations, which triggered cultural and economic transformations, and mobility strategies, especially with regards to contacts with the Nile Valley.

In particular, between the 7th and 6th millennia BC, the area of Wadi el Obeiyid in the Farafra Oasis witnessed the presence of semi-sedentary settlements, possibly related to a phase of increasing demographic pressure. The groups dwelling in the area were characterized by a mixed economy based on hunting activities, wild plant gathering, ostrich exploitation, and caprine herding. Similar kinds of evidence are present in other areas of the EWD, like Dakhla (Masara C), Kharga (Midauwara), Great Sand Sea (Abu Ballas), Gilf Kebir, Karkur Talh, and Jebel Uweinat. This paper aims to investigate the real extent of these groups' mobility and settlement distribution, especially with regard to the contacts between the Eastern Sahara and the Nile Valley.

Materials and methods

This study focuses on a specific archaeological feature visible from lower orbit satellites and related to changes in the mobility of the Early- Mid-Holocene local communities. This is a type of hut foundation (slab structures) made of stone slabs vertically stuck in the silt layers and arranged in circular or oval shapes. They are believed to be foundations of huts/shelters probably supporting covers in perishable materials. They can be isolated or grouped forming these proto villages.

The methodological approach developed for this project includes the application of: 1) a selection of algorithms to enhance the archaeological proxy indicators (Spectral Indices, PCA on multispectral imagery - Res. 10-20 m); 2) a machine learning algorithm for the automated processing and classification of very high resolution optical imagery (Unsupervised Classification through ISODATA Clustering on RGB – Res. 0,2-10 m), and different modalities of acquisition. The satellite dataset derives from different sources (Hexagon KH-9, Corona KH-4B, Bing Satellite, Google Satellite, Sentinel 2), and were assembled and processed through computing platforms for satellite imagery and other geospatial and observation data analysis (GIS, Google Earth Engine, USGS and other repositories).

The selected input data for the application of the Spectral Indices for the identification of the settlements proxy indicators and the region of interest comes from the RGB composition, and the bands NIR, SWIR1/2 of Sentinel-2. In particular, the Spectral Indices selected were: ARVI, NDVI, NDWI, OSAVI, GVI, NDMI, EVI, DWSI.

The selected input data for the application of the ISODATA Clustering algorithm comes from the Bing Satellite, Google Satellite, KH-9, KH-4B collections pre-processed with PCA. The ISODATA Clustering parameters for the classification of the proto villages and their slab structures are as follows: Distance Threshold 0.01, Number of Classes 20, Max Number of Iteration 20/30, ISODATA Max Standard Deviation 0.2, ISODATA minimum class size 10px; Random and from band values seed signatures; Minimum Distance Algorithm.

Results

The resulting classification on a sample area of 2.845 km2 showed 19 classes. These were reclassified in 4 useful classes of interest and vectorized through an automatic GIS process (GDAL Polygonize). The Class1 vector, in which most of the structures appeared, was compared with a manual classification of the same pre-processed imagery and it showed a match of 78 ISODATA polygons on the 84 archaeological features manually identified. The comparison also revealed 10 more features not previously identified.

The early results of this study have shown that the combination of the selected areas of investigation through multispectral imagery analyses and unsupervised classification of pre-processed high-resolution optical imagery is able to highlight the presence of slab structures in previously not surveyed areas.

Discussion

This study will offer an effective approach to overcome many difficulties of ground-based surveys, especially in Egypt where, after 2015, access to the EWD was reduced and denied by the Egyptian Authorities due to security and safety concerns. In fact, despite the efforts of several international research groups to identify and assess the distribution of these features, right now it is impossible to bring new sites to light or study the known ones via traditional ground-based surveys. The application of a remote, automated, precise, and cost-effective methodology for feature detection and analysis will help us overcome these obstacles and open new lines of investigation.

In the future, further analyses will pe performed: 1) to enrich the existing archaeological datasets about the hunter-gatherer/early herder groups populating the EWD during the Early and Mid-Holocene; 2) and to provide essential information about the human mobility patterns between the Eastern Sahara and the Nile Valley during the same period, shedding new light on the contribution of these communities to the emergence of the Egyptian late prehistoric and Predynastic cultures.

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78. Assessing desertification in the cultural landscape of Southern Morocco using Google Earth Engine

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The impact of anthropogenic climate change and pressures on water resources will be significant in the oases of the Northern Sahara but there is a paucity of detailed records and a lack of knowledge of traditional cultivation and water management approaches in the long term.

Remote sensing technologies are increasingly being recognised as effective tools for documenting and managing landscape heritage including water management systems, especially when used in conjunction with archaeological data. However, proprietary software licenses limit access to broader community growth and implementation. Conversely, FOSS (free and open-source software) geospatial data and tools represent an invaluable alternative mitigating the need for software licensing and data acquisition, a critical barrier to broader participation. Freeware cloud computing services (e.g. Google Earth Engine - GEE) enable users to process 'big data' and create outputs without significant investment in the hardware infrastructure. The GEE approach used in this research aims to assess the desertification rate in the oasis-dominated area of the Ourzazate-Drâa-Tafilalet regions of Morocco, aiming to identify areas of former cultivation as distinct from active cultivation and from other types of land cover with similar spectral properties.

Methods

The free and open-source Copernicus Sentinel 2 satellite dataset and freeware cloud computing offer considerable opportunities for landscape heritage stakeholders to monitor changes. In this paper, a complete FOSS cloud procedure was developed to map the degree of desertification in the Ourzazate-Drâa-Tafilalet traditional rural landscape between 2015 and 2021. We adapted a methodology which used 1 Sentinel-2 image covering part of the Draa Valley (Lamqadem et al, 2018).

Instead, we took advantage of the processing power of Google Earth Engine (GEE) to apply this to a large collection of over 200 Sentinel-2 images covering our AOI south of the Atlas. The GEE platform combines a multi-petabyte catalogue of geospatial datasets and provides a library of algorithms and a powerful application programming interface (API). The highest resolution available in GEE (up to 10 m/pixel) is offered by the Copernicus Sentinel-2 satellite constellation, which represents an invaluable free and open data source to support sustainable and cost-effective landscape monitoring.

The Google Earth Engine script uses the technique tasselled cap to determine areas of desertified fields and visually assess the effect of climate change on the landscape heritage features in the area. All bands of the Sentinel-2 collection images were used. The collection was filtered to remove the affects of clouds using the image metadata. A median composite was generated by calculating the median of values at each pixel across all bands. A set of coefficients was then applied and the result separated into the components of brightness, wetness and greenness. The difference between the wetness and brightness components was also calculated (TCW-TCB).

We compared this data to the location of archaeological sites. High-resolution imagery (e.g. through Google Earth) and a standardised image interpretation workflow was used for digitising sites. The region was investigated on the ground and the data validated in the field in November 2021. A sample of relict and active oases were visited near Ourzazate, in the Draa and the Tafilet.

A student internship project will be undertaken to classify the desertified areas using the tasselled cap outputs and the Sentinel-2. An error matrix will then be produced to assess accuracy. The results of this will be presented in the paper.

Results

Areas of desertified traditional fields were distinguishable in the tasselled cap image and in the difference between the wetness and brightness (TCW-TCB) index, allowing them to be delineated accurately using unsupervised classification. A small number of false positives were detected, representing areas of disturbed sediment beside streams.

When combined with archaeological data, these algorithms allowed us to detect both areas of fields which were recently desertified, and those which may have been abandoned during the medieval period.

The field visit confirmed the status of areas identified as desertified by the script, and built on work we have been doing in collaboration with the Middle Draa Project since 2015 (Mattingly et al 2017). For example, we found dry irrigation networks and preserved field systems, many of which had been abandoned prior to the earliest satellite imagery available (1960s-80s), but others had begun to desertify in the last 5 years.

Discussion

Desertification is an environmental problem worldwide and is one of the most decisive changing factors in the Moroccan landscape, especially in the oases in the south-eastern part of the country. This region is well known for its oasis agroecosystems and the earthen architectures of its Ksour and Kasbahs, where oases have been supplied by a combination of traditional water management systems including 'seguia' canals and 'khattara' (groundwater collecting tunnels) since at least the medieval period. The survival of the unique and invaluable landscape heritage of the region is threatened by several factors such as the abandonment of traditional cultivation and farming systems, overgrazing and increased human pressure on land and water resources.

The development of FOSS-cloud procedures such as those described in this study could support the conservation and management of landscape heritage worldwide. In remote areas or where local heritage is threatened due to climate change or other factors, FOSS-cloud protocols could facilitate access to new data relating to landscape archaeology and heritage.

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Session 25. Engaging the Public with Archaeology and Cultural Heritage: Exploring and Assessing Outreach during the COVID-19 Pandemic

Lisa Fischer, Independent Researcher

Room 6

Introduction	11:00 - 11:15
73. YouTube as historical process: The transfiguration of the Cerro Gordo mines through Ghost Town Living *Emmitt**	11:15 - 11:40
181. Geoinformatics technologies for heritage preservation and public outreach at Egmont Key, Florida *Harrison**	11:40 - 12:05
64. People and places: People-centred approaches to cultural landscapes *Tenzer**	Poster
Lunch	
172. Today is tomorrow's history: Documenting street art in the aftermath of the murder of George Floyd *Bradshaw Kmitch, PorterT* and Zellner-Smith*	13:30 - 13:55
28. Bearing (digital) witness: COVID-19 and virtual visits to sites of violence *McKinney**	13:55 - 14:20
72. ChronoMB: Synthesizing a chronological framework for Manitoba archaeology and providing a basis for Indigenous engagement *Cable*, Wren, Fowler and Collins*	14:20 - 14:45
Discussion	14:45 - 15:00
123. The Ashwell Project: Creating an online geospatial community *Talks**	Poster

Introduction

The COVID-19 pandemic has disrupted many facets of life over the past two years. As a result, museums, universities, and historical sites have had to grapple with closures, budget cuts, and protecting the health of staff and visitors while trying to fulfil their educational missions. During lockdowns, heritage organisations had to focus their outreach and engagement efforts almost exclusively on online channels. This led to a push of new educational offerings, from zoom lectures to circulating lists of online archaeological resources for schools. While many of these digital assets were made available freely on the internet, some cultural heritage organisations experimented with monetizing virtual content to try to counter revenue losses caused by the lack of in-person visitors. Posting educational materials on the web and social media was not new, but many organisations and individuals increased their output to engage the public stuck at home and to provide educational resources to students as well as teachers engaged in virtual learning. At the same time, staff were also challenged to develop this new content, often while working from home without access to their sites, objects, and office resources.

Museums and historical sites, as they were able to re-open to the public, were suddenly faced with new challenges regarding how to create a safe on-site visit. High-contact, embedded touchscreens and hands-on activities were suddenly seen as potential virus vectors. Interpretative approaches—like video screens and immersive technology experiences—that may have previously encouraged guests to cluster in groups, had to be adapted to new physical distancing measures or face temporary shuttering. Organisations, especially those that rely on ticket sales for revenue, had to find ways to foster visitation while offering programs that met new health and safety guidelines.

Challenging situations, like Covid-19, can often spur creativity and offer the opportunity to analyse old and new ways of working. This session invites authors to discuss and assess current technology-based approaches created during the pandemic for engaging the public, teachers, and students with cultural heritage. Papers can examine digitally-based educational approaches through any channel, including the web, social media, in the classroom, or on-site. What have we learned during the pandemic about how to effectively deliver information about archaeology and sites online and/or in-person? How do we evaluate digital resources and determine whether they are meeting the needs of the intended audience(s)? What approaches that worked well before and/or during the pandemic should continue and what new challenges are being faced now? What lessons have been learned from approaches that did not go quite as planned or even failed? Can a glut of online resources result in oversaturation and how should organisations assess the effectiveness of outreach approaches, especially in the face of limited budgets? How do we balance the costs of developing and maintaining technology-based educational resources while making them as accessible to audiences as possible?

This session will appeal to cultural heritage practitioners interested in how technology can be used to effectively educate and engage non-specialist audiences with archaeology. Papers are invited from authors who would like to explore some of these questions in the context of their own research. This can be done by presenting new applications, resources, projects, and strategies "born" during the pandemic to illustrate how organisations adapted their interpretive approaches. Example projects can be in any stage of development, including planning, in progress, or completed. Authors can also focus on the bigger picture to evaluate pandemic-related trends—across institutions and/or platforms—in technology-based outreach and education focusing on cultural heritage topics. Papers may also examine future directions and the potential long-term impact that the pandemic may have on technology use, both online and on-site.

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73. YouTube as historical process: The transfiguration of the Cerro Gordo mines through Ghost Town Living

Joshua Emmitt, University of Auckland

YouTube is now a common public face for archaeology and history. Professionals and amateurs alike make videos, whether it be for monetary gain, outreach, or a combination of the two. The channel Ghost Town Living is no exception and features the town's current owner, Brent Underwood, modifying the settlement from an 'abandoned' mining town into a tourist destination. During this process, as is documented in the videos, it becomes clear that Underwood is not only conserving the town but also transforming it into something else.

The YouTube channel Ghost Town Living was started on 13 April 2020 by Brent Underwood as a way to record his daily life, exploration, and reconstruction of the old mining town of Cerro Gordo in California. The success of the channel has also, over time, generated some revenue towards its reconstruction. As of December 2021 the channel had 1.39 million subscribers with 57 videos posted. In September 2021 a secondary channel Ghost Town Two was started which hosts shorter less formatted content. The main channel hosts videos ranging from 10 minutes long to over an hour, with weekly releases when possible.

Throughout the videos Underwood outlines his motivations for restoring the town. While a tone of enthusiasm and passion is conveyed, the practices of Underwood are in many case far from best-practice. However, given the town does not have a legal historical status, there is no obligation for the practices there to be up to a professional standard.

Underwood is not an archaeologist, and this may be a good thing. Archaeology can be viewed by non-archaeologists and amateurs as an esoteric field, and often professional archaeologists are seen as 'by-the-book' individuals who will not step out of their disciplinary norms. Working with private individuals and collections is still treated with scepticism by some in the discipline. However, as others have suggested (e.g. Shott 2014; Douglass et al. 2017) is through such collaborations with private individuals that archaeology will be able to increase its exposure to the public in an accessible way. Similar arguments are made for other forms of public engagement such as podcasts, which readily make archaeological content accessible and understandable to the general public (e.g. Slotten 2021).

This paper will examine reflexive relationship between Cerro Gordo and YouTube through the work of Underwood. The role archaeologists could play in the town is explored, in addition to comments on the relationship between archaeologists and amateurs.

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181. Geoinformatics technologies for heritage preservation and public outreach at Egmont Key, Florida

Laura K Harrison, University of South Florida

In 2019, the Florida Trust for Historic Preservation listed Egmont Key as one of the state's 11 most endangered heritage sites. The 2 km^2 barrier island has lost nearly half of its landmass in the last 150 years, submerging several heritage sites, and endangering numerous others. Few of the island's 200,000 visitors per year are aware of the island's rich history or the threats it faces, due to inadequate tourist interpretation and visitor infrastructure. This presentation discusses the process behind creating high-resolution simulations of the projected impacts of rising sea levels on coastal heritage, with a novel combination of terrestrial lidar, aerial lidar, and GIS. These analyses help advance communication between academic researchers and local land managers, who must decide if, when, and how to address the problem of beach erosion and historic preservation, despite limited resources. These simulations – and recommendations about the development of living shorelines, green infrastructure, and targeted beach renourishment - will be incorporated into the next edition of the Egmont Key Comprehensive Conservation Plan, published by the U.S. Fish and Wildlife Service. The goal is to promote sustainable tourism and protect the island's natural and cultural heritage in accordance with the UN Sustainable Development Goals (Targets 8.9 and 11.4).

In addition, detailed sea-level-rise simulations are a powerful public science communication tool, providing a visual illustration of how overlapping natural and anthropogenic factors threaten to wash away history. These results are communicated to the public as part of an interactive virtual reality (VR) tour of the island's Spanish-American War forts and eroding western shoreline, built for the Oculus Quest. A user-experience evaluation of 80 participants demonstrates that more than 75% of users feel that this app increased their knowledge of Egmont Key's history and the environmental threats it faces. Additional outreach programs launching in 2022 include: (1) a Heritage Monitoring Scouts citizen science program that trains members of the public how to take and upload site photos to a statewide database to aid in site monitoring, and (2) a *Guardians of the Gulf* augmented reality app for middle school students (ages 11 to 13) that uses animated trackers to teach students how to become “champions of the coast” by addressing erosion, caring for sea turtles, and protecting the island’s heritage sites. Together, these public heritage tools weave together geoinformatics with broader digital storytelling projects that will live on, even if the island itself disappears.

64. People and places: People-centred approaches to cultural landscapes

Martina Tenzer, University of York

Starting a research project at the beginning of the Covid-19 pandemic, focused on practical applications of people-centred approaches to data collection and engagement, forced researchers to rethink research designs, especially with respect to tools and methods applicable in times of restrictions to social contact and movement. Commonly used ethnographic methods, such as focus groups, face-to-face interviews and community projects, became impossible (Chitty 2016; Jones 2017). However, exploring new approaches and techniques to overcome this challenge did not only lead to stopgap solutions but rather to opportunities for pursuing new paths for data collection, analysis, and visualisation. This project aims to identify what matters most to people in the landscapes of their daily life (Gombini 2020). Places, buildings, landscapes, landmarks, traditions and beliefs form the parts of the “everyday heritage” that creates a sense of belonging and identity rather than the exceptional, outstanding heritage assets defined by heritage professionals, which form the grand narrative of a nation.

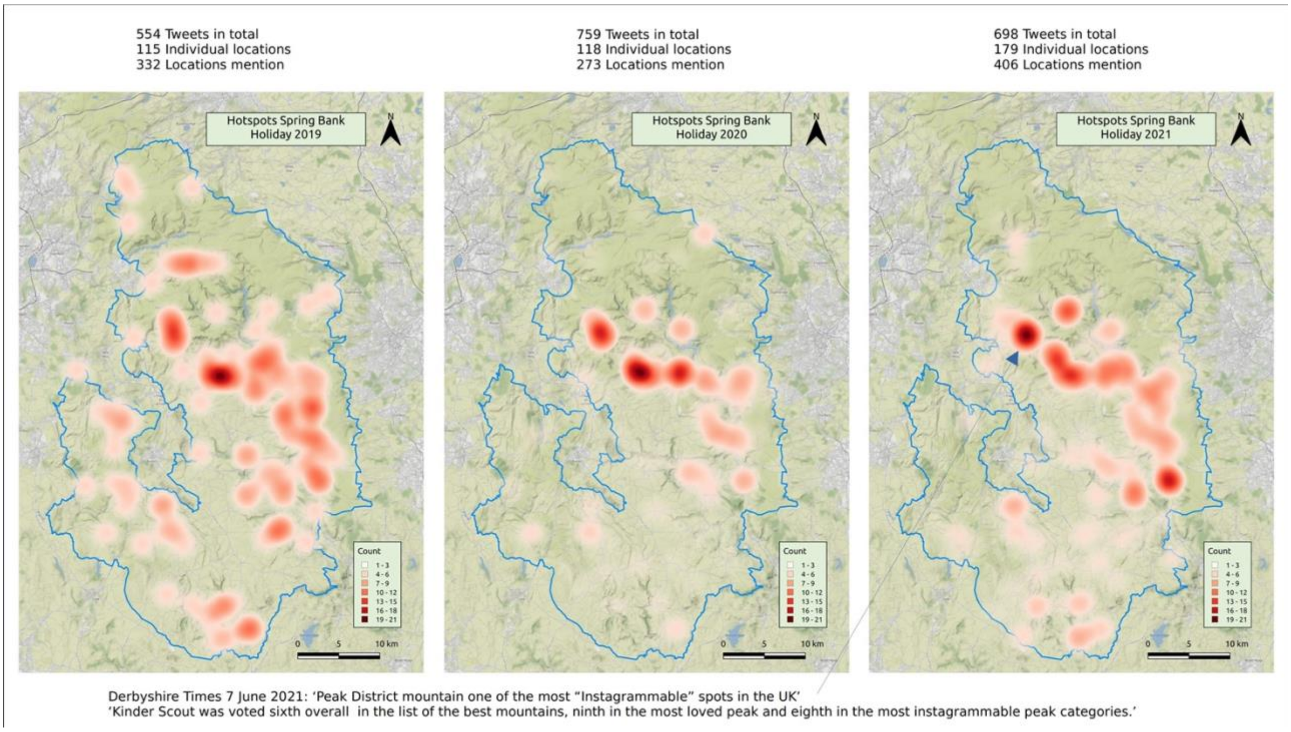

Figure 9. Results of the Twitter analysis based on algorithm using a fine-grained, area specific location dictionary for location entity recognition developed by the author and visualised in QGIS.

Using social media data, socially-distant interviews, and online surveys allowed to gather data from a wide variety of sources while adhering to the restrictions. Both the format of this qualitative data and the increase in the volume of available data require exploring methods and tools applied in other fields and disciplines. Existing and new techniques were developed for this project, such as Natural Language Processing (especially Named Entity Recognition), license-free map questionnaire applications, and interactive web maps to address this significant change of data quality, format, and volume.

The insights gained from social media research undertaken during three phases of Covid-19 restrictions in the Peak District National Park and a project exploring the connection between modern pilgrimage and sites associated with Anglo-Saxon female saints present just two examples of how people-centred approaches may look like going forward. Results of the former show that the tensions between visitors and residents of the national park were high during the pandemic. Moreover, locations shifted notably from "chocolate box" villages towards natural features going into the restriction phases. A turn towards historical sites in the year following the pandemic points to greater importance of local heritage after lockdown restrictions were lifted. Data sets resulting from these new methodologies will provide a background of local knowledge and people's perceptions of cultural landscapes for inclusive and sustainable planning and decision-making and engage the public through interactive deep maps as a form of immersive storytelling.

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172. Today is tomorrow's history: Documenting street art in the aftermath of the murder of George Floyd

Kassie Bradshaw Kmitch, Save the Boards Minneapolis

Samantha Porter, University of Minnesota

Emma Sheperd, Save the Boards Minneapolis

Kenda Zellner-Smith, Save the Boards Minneapolis

On May 25, 2020 George Floyd was murdered by former police officer Derek Chauvin in Minneapolis, Minnesota. The murder, captured on video by bystander, Darnella Frazier, went viral and was disseminated widely via social and mainstream media. In the following days, weeks, and months, protests and social uprisings occurred throughout the Twin Cities area of Minnesota and across the United States, all occurring against the backdrop of the global COVID-19 pandemic. A very visible part of this movement In Minneapolis and Saint Paul Minnesota was the creation of public works of art and public protest works. People began boarding up their homes and businesses with plywood panels to protect against the rioting and looting during the civil unrest. These boards became a living canvas; an opportunity for street artists, taggers, activists, ordinary people with no art background, and muralists to express themselves in the trauma of the moment. Themes present on these works include but are not limited to police violence and racial injustice against the Black community.

Figure 10. Living canvas.

In this paper, we outline a grassroots effort to both physically collect and digitally document as many of these ephemeral works as possible, due to their cultural value as manifestations of grief by the communities who created the works, and also for these works' cultural and historical value within the greater context of the historic miasma of 2020 civil rights movement. This effort brought together diverse members of the community, including some with vocational expertise. We discuss both the technical aspects of the work, including utilizing photogrammetry and data curation skills acquired through experience as archaeologists and heritage professionals, and the fraught reality of balancing identities as 'experts' and community members.

Furthermore, we discuss challenges raised by grassroots efforts of this kind in searching for both recognition and resources, including funding to continue this community-led work. For example, many grants require legal 501(c)(3) non-profit status for application, which can take years for an organization to acquire. This problem is exacerbated by the fact that there can be a very real and rational reluctance by communities to work with established cultural organizations. This is because established cultural organizations historically–and sometimes presently–have caused / are causing harm against BIPOC and minoritized communities.

While archaeology is inherently the study of the past, it is important archaeologists remember that today's events are tomorrow's history. We hope our story can serve as a case study in how heritage skills can be used in moments of cultural reckoning as tools of emergency conservation. We hope to open a discussion about the ways in which systemic barriers can be dismantled to make more work like this possible.

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28. Bearing (digital) witness: COVID-19 and virtual visits to sites of violence

Sierra McKinney, Université de Montréal

Within the context of archaeological sites of violence, museums act both as an educator and a memorial. Heritage institutions and museums located at sites of violence seek to educate visitors on the tragedies of the past, remember those lost, and build empathy to prevent similar acts of violence and hate. In order to fulfil these aims, museums frequently rely on the emotional resonance of the site itself. The visitor is called to learn and remember the past through the embodied and phenomenological act of bearing witness.

Due to COVID-19, museums, heritage institutions and memorials, around the world were forced to shut their doors. In response to these closures and limited visitor access to the physical archaeological sites, museums turned to digital tools to continue their educational outreach. One such tool is the virtual visit. This has primarily taken the form of virtual guided tours or digital 'google-map' style walkthroughs. Examples of the former include a pre-recorded tour of the 9/11 Memorial Museum, and live ZOOM tours of the former Shingwauk Residential School and the Mohawk Institute Residential School led by the Shingwauk Residential School Centre and the Woodland Cultural Centre respectively. The digital walkthrough format has been adopted by numerous museums related to the Holocaust and the Second World War including the Dachau Concentration Camp Memorial Site, the Leistikowstrasse Memorial, the Auschwitz-Birkenau State Museum, the Canadian National Vimy Memorial, and the Anne Frank House Museum.

As demonstrated by numerous memorial museums remembering slavery, genocide and victims of war, bearing witness does not require a physical presence at a physical site of harm. Nevertheless, with the increasing number of virtual tours, digital walkthroughs and VR experiences for sites of violence, the physical is being replicated virtually. Thus, exploring Wilson's notion of the 'radical witness' (2021), this paper will reflect on the act of embodied witnessing and its relationship to the digital sphere. In reviewing the content and format of existing and publicly accessible digital tours, I will examine how the sector is currently translating the phenomenological experience of visiting violent archaeological sites and memorials. Furthermore, I will discuss the ethical and practical implications of the work to reflect on whether the act of bearing witness to physical remains of violence can, or should, be made digital.

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72. ChronoMB: Synthesizing a chronological framework for Manitoba archaeology and providing a basis for Indigenous engagement

Brandi Cable, University of Manitoba

Colin Wren, University of Colorado, Colorado Springs

Kent Fowler, University of Manitoba

Benjamin Collins, University of Manitoba

The province of Manitoba in Canada encompasses diverse ecologies, including prairie, woodlands, and arctic environments, and demonstrates a rich archaeological record that extends back to the early Holocene concurrent with the melting of glaciers. However, this extensive archaeological archive lacks a strong chronological framework, critical for understanding and contextualising major changes in culture history and landscape use. Moreover, the accessibility of this archive to the public, and especially to Indigenous communities and Indigenous youth is underwhelming. To address these two major issues, we initiated the ChronoMB project. This lack of chronological data for Manitoba's archaeological record is reflected in the Canadian Archaeological Radiocarbon Database (CARD), where of the over 9,400 dates from Canadian archaeological contexts, only 256 are associated with pre-contact archaeology in Manitoba (Gajewski et al. 2011). ChronoMB uses ArcGIS and the data from CARD to map out the distribution of pre-contact radiocarbon dates across Manitoba through time to better inform our understanding of past settlement strategies and improve the current chronological framework, which relies heavily on culture history affiliations and lacks resolution. In this respect, we test the current data set for geographic bias, as well as use Bayesian modelling to explore potential periods of population pulses.

Outreach and dissemination are crucial components of the ChronoMB project and will be the main focus of this paper, which describes preliminary results from the strategies we are using to make our results accessible and engaging to the public across the province. To provide context, I am a Cree woman from northern Manitoba, Canada. The historical relationship between Indigenous peoples and anthropologists and/or archaeologists has not always been a positive one, as described by Anthropology and Nostalgia (Angé and Berliner 2016, 22). By making our research accessible to and inclusive of Indigenous populations, we aim to establish and maintain positive working relationships between Indigenous peoples and archaeologists. Our hope is that we can make conversations surrounding archaeology comfortable for Indigenous peoples and better engage with Indigenous communities to develop community-focused and community-driven projects. We also aim to contribute to breaking down barriers for Indigenous youth to study archaeology and emphasize how important their voices and perspectives are in the field.

Our first method of outreach and research dissemination is to provide our findings in various formats (e.g., posters, academic articles, presentation power points) that can then be translated into the traditional languages of the nations living in present-day Manitoba. Among the First Nations living in present-day Manitoba, there are five linguistic groups comprised of Cree, Ojibway, Dakota, Oji-Cree, and Dene (Government of Canada, 2021). First Nations reserves in Manitoba are widely dispersed and are primarily situated in the northern half of the province, with some communities being inaccessible by land travel. To accommodate the distance, as well as mitigating potential COVID-19 risks, we are utilizing Zoom to present research to northern Indigenous communities. However, as a result of the remote geographic location of some northern reserves, a stable internet connection is not always possible to hold Zoom events. To accommodate these particular communities, a pre-recorded presentation will be sent to communities alongside a physical copy of the poster to be posted in community centres.

Our second method of outreach and research dissemination focuses specifically on the youth in Indigenous communities. Taking into consideration the age range of Indigenous youth in these communities, as well as the often-remote locations of their communities, this demographic makes substantial use of social media platforms. Our approach to disseminating our research to this demographic, as well as increasing their interest in the field as a whole, will focus on the utilization of the social media platforms Instagram and TikTok. These two platforms allow for the posting of content, as well as the option to livestream, and they are widely used among youth in northern Manitoba communities. Preliminary results from this approach will be discussed, including engagement metrics, as well as the attitudes of the social media users interacting with the content.

Disseminating research in an inclusive and meaningful way to northern Indigenous communities already exhibits barriers. The COVID-19 pandemic has severely impacted northern Indigenous communities and exacerbated these barriers. It is with these barriers in mind that our project seeks to increase the accessibility and inclusivity of the Manitoba's rich archaeology to the public, and especially to Indigenous communities and Indigenous youth.

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123. The Ashwell Project: Creating an online geospatial community

Alphaeus Talks, University of York

As the world becomes increasingly digital, so too must the way in which archaeologists engage with the public (Morgan and Eve, 2012, 521). This was particularly pertinent during the COVID-19 pandemic, and many outreach and engagement efforts began moving online. One such project was The Ashwell Project. This project was similar to that of Layers of London (Cullum, Jarvis, and Unitt, 2020, 5) and Know Your Place West of England (Streich 2017, 3), as it combines aspects of participatory GIS and crowdsourcing of datasets, yet also utilises web application functionality of geolocation and navigation to move from one narrative to the next. The project's main area of study was how to include anecdotal datasets within local heritage education, and how to engage less technically competent users with inherently complex digital systems.

Subject

The project's aim was to function as a proof of concept, collating local narratives from the village of Ashwell, North Hertfordshire. The demographic of the village is a combination of the aging and many commuter families. As such, it was vital to ensure the design considered the different needs of these groups. The project was created using the design thinking process of empathising with the users, ideation, development, and testing. The result was a free to access geospatial web application. The project was co-developed by Ashwell Museum and the University of York and aimed to capture previously excluded datasets in one digital resource, educating the public about local narratives, and creating a digital community and so tackling the issue of isolation. The datasets involved within the project included anecdotal and intangible heritage alongside formal tangible heritage datasets, forming a 'living digital record'. The application has since been taken down, yet there are several lessons that can be learned from this project. Firstly, how to encourage older generations to use these applications. Secondly, how important design is in encouraging wider participation with such technologies. Thirdly, how progressive web applications can encourage further use. From user case study analysis, the project was shown to be effective across a wide range of demographics, particularly those targeted. It also revealed the wide range of narratives and stories individuals consider important, thus providing opportunities to reassess what we consider as significant heritage.

Discussion

This paper provides interesting opportunities and lessons in all aspects concerning digital engagement of diverse communities. It considers how to best encourage wider uptake of participatory GIS and crowdsourcing datasets, alongside how users' own devices can be utilised to increase engagement with both tangible and intangible heritage. Within this poster, it will argue that such approaches should be considered on a much wider scale, encouraging wider communities to engage with such platforms. The project revealed that the process of design thinking with iterative testing is imperative in designing heritage assets. Crucially for this session, it shows how it is possible to engage the public with archaeology throughout a global pandemic.

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CAA@50: Looking to the future

Lisa Fischer, Independent Researcher

Marta Lorenzon, University of Helsinki

César González-Pérez, Incipit (Institute of Heritage Sciences) of the CSIC (Spanish National Research Council)

Rachel Opitz, University of Glasgow

South Writing School

Special Session	15:30 - 17:00

CAA turning 50 next year offers an important opportunity to reflect on the organisation's history as well as how it should continue to evolve in the digital age. Please join us for this special session to share your thoughts on CAA's future. The session will be structured around three main topics: 1. Who are we or who should we be as an organisation? What should our aims and values be? 2. What do we do as an organisation? How do we implement our aims and values? and 3. What should our priorities be as we embark on the next half-century of CAA? The session will begin with three speakers, Lisa Fischer, Cesar Gonzalez-Perez, and Marta Lorenzon, offering brief remarks to help spark a dialogue. The remainder of the session will be a discussion facilitated by Rachel Opitz. The audience, both online and on-site, will be invited to share thoughts about how CAA should evolve to meet the needs of the membership and to ensure that the CAA is well-positioned to continue fostering cutting-edge research within the discipline. This preliminary discussion will lead to subsequent conversations at the CAA 2023 conference as we plan for the future.

Sessions (Wednesday)

Session 01. iN Deep: Cultural presence in immersive educational experiences

Elaine A Sullivan, University of California Santa Cruz

Sara Perry, Museum of London Archaeology

Paola Derudas, Lund University

South Writing School

Introduction	09:00 - 09:10
6. Veterans' voices: Place, objects, and memory in virtual reality *Donald*, Brown, Locke and Scott-Brown*	09:10 - 09:25
147. The cultural construction of place: A VR-enabled pedagogy *Herckis**	09:25 - 09:40
168. Social VR for heritage: Designing care and affect into multi-user virtual reality *Perry*, O'Connor, Katifori, Lougiakis and Roussou*	09:40 - 09:55
Discussion Group 1	09:55 - 10:15
43. Can archaeologists tell the truth? Using VR as a means to visualise uncertainties at the Celtic "Princely Site" of the Glauberg *Posluschny*; Beusing and Grellert*	10:15 - 10:30
101. VETERA VR: A cyberarchaeological VR prototype about the Vetera I legionary camp *Cruz, Matheus M**	10:30 - 10:45
152. Transcending virtuality? Multi-modal and multi-media experimentation in VR *Day and Richards-Rissetto**	10:45 - 11:00
80. Bath Abbey Footprint Project: From 4D photogrammetric recording to virtual reality *Marziani**	11:00 - 11:05
Discussion Group 2	11:05 - 11:25
128. Deriving meaning through engagement with a sustainable, immersive, interactive reading experience in a virtual global library *Dodd*, Zonno, Borges and Hanson*	11:25 - 11:40
8. A virtual 'return to the tomb': The rejoining of a 26th Dynasty sarcophagus and its burial at Saqqara *Sullivan**	11:40 - 11:55

177. Learning from the past: XRchaeology and web-based experience *Sharp*, Raj Paudel and Kambhatla*	11:55 - 12:10
Discussion Group 3	12:10 - 12:30
Lunch	
Demonstrations	13:30 - 15:00

Introduction

Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (XR) technologies are increasingly incorporated into university classrooms and public education in the GLAM sector (galleries, libraries, archives, and museums). The potential to use these technologies to engage students and the public with archaeological knowledge (such as site reconstructions, artefacts, or re-imagining the activities of past peoples) is exciting, but these forms of representation, including the use of individual headsets, tablets, and personal mobile phones, come with particular challenges. In his book Critical Gaming (2015), Eric Champion argued that virtual realities should express 'cultural presence,' the meaning and significance of a time, place, or object to people of the past. Hyper-reality, photogrammetry, and ever-increasing levels of 'accuracy' in 3D models do not inherently convey aspects of cultural significance and meaning, and many VR/AR/XR experiences fall dramatically short of the goal of expressing the importance of past places and things to their original communities. Emphasis on technological and (especially) hardware innovation often deflects attention from critically engaging with questions of meaning-making. This panel asks those creating or intensely using Archaeology VR/AR/XR to focus NOT on software, hardware, or the latest technical innovations, but on how we as archaeologists can better design, create, or curate experiences that inspire and educate students and the public on the cultural importance of archaeological spaces, objects or themes.

What are successful techniques to aid a visitor to better understand the original context of an object now placed in a (often far off) museum or gallery? How can university instructors incorporate the (problematically individual) headset or mobile experiences into pedagogy to provide meaningful and active student learning? How can complex data be usefully layered or curated so that multiple types of museum visitors or classes could find it informative and emotionally resonant? How can we turn these increasingly popular technologies into serious spaces of cultural learning and curiosity, moving beyond the initial 'wow' factor

Instead of traditional 20 minute talks, we request that participants present 8-10 minutes in depth on one VR/AR/XR experience they have designed and/or utilized in a university or GLAM setting (not a general review of multiple types of work). We ask participants to present and explain aspects of design and interaction and their intent in that experience; or, if the content was not designed by the presenter, how content was incorporated, curated, or enhanced for the classroom or GLAM experience. Specifically, we ask presenters to think thoughtfully and critically about how we might collectively learn to use these technologies in more informed ways, including: What types of interactions with students or the public have shown promise, and how might we build on those successes? What practices have not worked, and how might we learn from our failures? What particular aspects of archaeological and cultural heritage knowledge are best emphasized in the

VR/AR/XR experience? What is key to re-using content created by others, including content created by non-archaeologists?

The session will be divided into four sections:

- 1st group of presentations (10 minutes per presentation)
- 2nd group of presentations (10 minutes per presentation)
- 3rd group of presentations (10 minutes per presentation)
- a 90 minute 'hands-on' period** where participants and the audience will be able to engage/interact directly with the presented content

We hope this format will allow the audience to engage directly with the content before opening up the session for questions and comments. The goal is to turn this session into a workshop that helps all present work more critically with VR/AR/XR content and improve how we communicate scholarly information at the university and GLAM setting.

**We therefore ask participants to commit to bringing their discussed content uploaded or downloadable in some format that can be shared directly with others: including (but not limited to) VR headsets, Google cardboard, AR apps pre-installed on tablets or smart phones, etc.

References

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6. Veterans' voices: Place, objects, and memory in virtual reality

Iain Donald, Abertay University

Gordon Brown, Abertay University

Ryan Locke, Abertay University

Kenneth Scott-Brown, Abertay University

Their Memory explores cultural presence in an educational context through the co-creation of a virtual reality (VR) project. Examining how memory, identity and place are inter-connected for young people, schools, and families through the narratives of Scottish veterans and the veterans' charity, Poppyscotland. The VR project demonstrates how new immersive experiences can extend the access, interpretation and reach of memory-based institutions to different audiences. Going beyond entertainment to consider how game design techniques and game technologies can inform real world narratives. The project aimed to answer the following research questions:

- How can co-design facilitate the development of a VR application that is to engage audiences with cultural heritage?
- Does utilising immersive technology such as virtual reality increase engagement and create a more appealing engaging tool than traditional methods?
- Will an immersive experience better shape attitudes to memory and memory-based institutions?

These were addressed through the design and delivery of a polished VR experience, Their Memory, which depicted Lady Haig's Poppy Factory in Edinburgh. The environment is fully realised and recreates the character and detail of the real-world factory. Within VR, players can explore the desks of the different veterans who work at the factory. On each desk are mementos and artefacts unique to each veteran. The player can pick up and explore each object, as the objects are interacted with they play an audio clip. Each audio segment is a memory that relates to the object. The memories are retold by the veterans who own the object. The decision to use the personal objects that each veteran kept on their desk was to aid the narrative as each object was unique to the veteran and they reflected many different aspects of their time in service and throughout their life. These objects became central to the storytelling and were something that a wide range of people could relate to (Auslander and Zahra 2018).

Figure 11. Lady Haig's Poppy Factory.

Framework, methods and materials

The core output of the project was to produce a narrative-driven representation of the experiences of veterans that Poppyscotland support. The project undertook an exploratory sequential mixed-method design approach with several co-design sessions, the development of a VR experience and an evaluation at a public event with young adults. The framework consists of four core components: (i) co-design with both the audience and memory owners, (ii) virtual environment design, (iii) user experience design, and (iv) evaluation of the co-created application. The overarching aim was to explore how commemoration is changing. The project objectives included an evaluation of the potential that VR has to be used as a medium to facilitate cultural learning. The project also explored how games design and technology can be adapted to evolving memory models such as antagonistic, cosmopolitan or agonistic (Bull and Hansen 2016). The methods used were primarily participatory. Co-design sessions were conducted with young adults in Secondary Education, adults in Tertiary education and Scottish veterans from across the armed services. These sessions informed the creation of an interactive narrative experience in VR. The application was developed using the Oculus Rift, but final delivery was made to the more accessible Oculus Go platform, and the output has been evaluated through a range of events with the target audience of young adults.

Results

The initial evaluation of the VR experience was conducted at an educational event advertised to schools. Participants from Scottish Schools were invited to attend an event at the National Museum of Scotland. Ninety young adults (approximate age range 14–16 years) undertook two surveys, pre and post the VR experience, to examine whether the application facilitated their understanding of the impact of war (Donald and Scott-Brown 2019). These initial findings were followed up with additional evaluation events for young adults at several Museums and more recently through the inclusion of Their Memory as part of Poppyscotland's new project that explores the contemporary understanding of remembrance. Overall the evaluation results demonstrated that Their Memory was an effective tool and that an immersive experience raised awareness, engaged the audience and encouraged a change in the perception of veterans and Poppyscotland. The project is currently part of the Poppyscotland's Learning and Outreach programme and displayed through their interactive learning space, an 18-tonne truck known as 'Bud', that travels to schools and events across the country.

Discussion

This paper focuses on the design, development and evaluation of virtual reality environments and experiences. Examining what game design techniques were successful and how immersive technology can be better used to enhance existing historical research, enrich narratives and bring expansive experiences to hard-to-reach audiences. The project further demonstrates the importance of co-design and academic-industry collaborations in shaping project direction. The original concept was to place people in a VR environment that only a veteran could have seen. The concept was a melding of the interviews in the Band of Brothers TV series with the visual imagery of games like Verdun or Battlefield 1 to present a prototype that was expected to be similar to a virtual battlefield tourism application. Co-design was fundamental in changing that direction. The creation of a 1960s factory that plays as a desk simulator does not have the same resonance. Their Memory is a more multi-layered experience because of that. It is an archive of an archive, that attempts to navigate the complex relationship that exists between history, memory, and the stories that people tell about their experiences. The project has notable design successes in that it can provide a very short but powerful immersive experience and it allows people to play with the virtual artefacts without impacting upon the story being told. Most importantly the project provides an opportunity for the veterans that we support in the present to tell their stories for future generations in order to understand the past both in the context of recent conflicts and the organisations that supported veterans after the First World War.

Additional information

AHRC Immersive Experiences: Their Memory: Exploring Veteran's Voices, Virtual Reality and Collective Memory https://gtr.ukri.org/projects?ref=AH%2FR009589%2F1

Their Memory Trailer: https://youtu.be/zCQFmmKOJgo

Their Memory Gameplay: https://youtu.be/mQA1aaXwNnM

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147. The cultural construction of place: A VR-enabled pedagogy

Lauren Herckis, Carnegie Mellon University

A course entitled "Unreality: Immersive and Spatial Media" was offered for the first time in the Spring of 2021, serving first-year students who had been accepted to University in the Spring of 2020. First-year undergraduate students enrolled in the 2020-2021 academic year began their college experience in a novel educational context, selected Unreality as their freshman seminar experience in a moment during which remote instruction was enjoying unprecedented adoption and attention in the international press, and engaged with the course during its first instantiation. Among course learning goals were that students would learn to (10 Identify characteristics of human perception and experience that play a role in the cultural construction of place; (2) Critically analyse representations of cultural places in immersive and spatial media environments; and (3) Discuss the ethics of representation in immersive experiences.

The mandate for rapid experimentation with novel pedagogies and the unique needs of students in the Spring of 2021, combined with the opportunity to teach across multiple platforms which offer diverse levels of immersion, resulted in a suite of experimental pedagogies incorporating immersive media which proved central to small group work, enhanced students' sense of community, and showcased the affordances and limitations of the technologies at hand. The course was offered for a second time in the Spring of 2022, which offered the opportunity to reflect on what worked in 2021, refine and iterate effective pedagogies, and redeploy the most promising active learning experiences.

At several points in the semester, synchronous group work required students to collaborate in virtual environments to solve problems, generate ideas, and deconstruct complex concepts. These sessions usually took place concurrently, while the instructional team was on hand to answer questions and support problem-solving. This short talk will describe student engagement with two immersive experiences, "The Peacock Room" in Google's Arts & Culture app, which was employed in 2021, and "Industry in the Victorian Era: Letterpress Printing" in Google's Expedition app, which was employed in a parallel exercise during the 2022 instantiation of the course, as well as their pedagogical integration into the course context. We will demo these exercises during the session using Google Cardboard and walk participants through elements of the student experience. Further, we will discuss how this commercially available content was curated and enhanced by the course developers and collaborators for the classroom experience and aligned with the learning objectives described above. This approach shows significant promise for use in archaeology course contexts, and may be readily adapted for a variety of pedagogical ends to support student mastery of diverse methods and bodies of theory.

168. Social VR for heritage: Designing care and affect into multi-user virtual reality

Sara Perry, Museum of London Archaeology

Kristen O'Connor, Independent Researcher

Akrivi Katifori, National and Kapodistrian University of Athens

Christos Lougiakis, Athena Research & Innovation Center

Maria Roussou, University of Athens

Despite decades of research, development methodologies for heritage virtual reality (VR) experiences remain relatively stagnant. The consensus within the scholarship suggests that heritage VR's primary goal is typically to educate the public about cultural objects, sites, or groups. This focus likely contributes to developmental efforts that disproportionately prioritise accurate representation to the detriment of the actual human experience. Indeed, applications of virtual reality in heritage tend to underutilise and oversimplify the affordances of modern VR technology more generally. For instance, few projects provide opportunities for social interaction, often leading to isolating user experiences. In some cases, rigid storylines and limited interactivity within certain virtual environments may diminish people's agency. More recently, in the context of "VR 2.0," naïve reliance on the visceral qualities of virtual reality privilege "emotional feeling," manifesting dangerous, oppressive expressions of what Nakamura (2020) calls "toxic embodiment."

Here we present a novel social VR design approach for heritage which prioritises perspective-taking, affective engagement and the ethics of care (Endacott and Brooks 2013; Noddings 2003) as part of an overarching objective to achieve more complex, critically reflective outcomes in people's experiences with virtual reality. Social VR involves two or more individuals interacting with one another in the same virtual environment. While social VR for cultural heritage is not a new concept, we are among the first to focus on sociality specifically for achieving complex, affective and care-oriented outcomes.

We validate our design approach through an immersive virtual reality experience in which pairs of remotely located participants collaborate in a virtual reconstruction of the UNESCO-listed archaeological site of Çatalhöyük in modern-day Turkey. Together, participants enact some of the social practices inferred to have been common at Çatalhöyük in the Neolithic period through archaeological research, from artistic expression of group identity to home repair and burial customs, while engaging in guided exploration and conversation. We evaluate our design approach with 34 individuals (17 pairs) across multiple locations in Europe. Our findings confirm that social interaction design for perspective-taking, affect and care in heritage VR can meaningfully progress the field and help confront the methodological and practical shortcomings of many traditional heritage VR projects.

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43. Can archaeologists tell the truth? Using VR as a means to visualise uncertainties at the Celtic "Princely Site" of the Glauberg

Axel Posluschny, Keltenwelt am Glauberg

Ruth Beusing, Landesamt für Denkmalpflege Hessen

Marc Grellert, Technische Universität Darmstadt, Department Digitales Gestalten

In the field of virtual reality (VR), improved displays and simple creation of VR worlds have inspired museums to make greater use of VR glasses in exhibitions and to explore boundary conditions for their use (Grellert 2018). Evoking a sense of space, of size and of embeddedness is now possible in a simple way. At the same time, new forms of interaction exist. For a profitable use of this feeling of presence in the context of archaeology, a careful selection of topics, spaces, buildings or settlement facilities must be made.

Using these potentials, a virtual reality application has been developed for the Keltenwelt am Glauberg (KWG), which uses digital forms of mediation to present the latest research to the public in an innovative way and aims to appeal to a young audience in particular. The Glauberg is an Early Iron Age ("Celtic") hillfort with accompanying rich burials on its slopes, surrounded by a gigantic ditch-/rampart system surrounding roughly 200 ha of its environs (Posluschny/Beusing 2019). Though the famous Glauberg burials present a wide range of affluent accoutrements nearly no visible remains of dwellings and settlement structures have survived. (Re-)Constructions of the hillfort and its environs need to respect these issues. The VR application of the KWG therefore deliberately does not want to follow the widespread trend towards hyper- or pseudo-realistic reconstructions of archaeological features and instead sets its own accents and goes new ways. The aim is not to achieve unambiguity, but rather, in accordance with a fuzzy state of knowledge, to show different solutions for reconstructions and to present background information on the sources and the scientific path that led to the creation of these reconstructions. In this way, the viewers receive similar information that the archaeologists also used to approach this past world. Regarding the general challenges of reconstructions in archaeology see Miera 2020, Schreg 2013.

The presentation of the VR application for Oculus Quest 2 devices will be focussing on both the 'honest' presentation of knowledge as well as on aspects of the use of such application/devices within a museum context.

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101. VETERA VR: A cyberarchaeological VR prototype about the Vetera I legionary camp

Matheus Cruz, University of São Paulo

In recent years, the academic community, including archaeology professionals, has shown great interest in the relationship between digital games (and/or simulations), research, education, and extroversion. Archaeology aims to study material culture and its physical, functional, and symbolic aspects, through specific research methodologies. Digital applications are nothing more than human products, recorded in physical or digital media and created from the fusion of four elements: programming codes, texts (computational linguistics), audio, and art (graphic design) (Copplestone 2017), being, therefore, a part of contemporary material culture loaded with meanings produced from subjective interpretations of reality by groups of people. On the other hand, games can also be defined, more broadly, as playful means of learning that go back hundreds of years, capable of providing complex approaches to the past and present, through their interpretive frameworks correlated with a contextualized use of technology. Thus, the relationship between archaeology and digital games/simulations has been the concern of several disciplines within Digital Archaeology, among them Cyber-archaeology (Forte 2010).

Based on the concepts and practices of Cyber-archaeology and the possibilities that the discipline offers for the extroversion of archaeological knowledge, this paper aims to present the interactive simulation application called VETERA VR: a low-poly walking simulator, whose scenario takes place in the Vetera I legionary camp, built in 16 BC during Drusus' campaigns against the Germanic tribes from west-central Europe. Located in the region of the modern Xanten (Germany), in the ancient Roman province of Germania Inferior, Vetera I was one of the main Roman camps in the limes germanicus, having been completely destroyed between 69 and 70 AD during the Revolt of the Batavi.

The main objective of the application is to test the feasibility of the project for the future development of a more complete digital game, which will be one of the final products of my master's research entitled "The amphorae of Vetera I: contacts, frontiers, and Roman military supply in the limes germanicus", under development at the Museum of Archaeology and Ethnology (MAE-USP) at the University of Sao Paulo (Brazil), which aims to collaborate in the extroversion of research results and fundamental themes and concepts for the study of the Ancient Mediterranean to a wide audience, including students from Basic Education.

Methods and materials

For the elaboration of this prototype, an initial version of the scenario was built with only some of the main buildings that were part of the camp. The first step in the development of the project was the writing of texts for the points of interest in the scenario, characters, buildings, and objects, based on the study of the dense and specialized historical and archaeological literature on the subject. After the conclusion of the layout and writing of the narrative design, the three-dimensional modelling of the scenarios, characters, buildings, and objects was carried out using the Blender software and a technique called low-poly modelling, which proposes the use of a low number of polygons to the elaboration of stylized models. The third stage was the animation of the characters through the Mixamo platform, from Adobe Systems. Finally, scenes and interactions were programmed using the Unity software and a set of independent assets.

Discussion

For an initial testing of the prototype, VETERA VR was introduced among the digital and audio-visual materials used in the Minimus project, a university extension project aimed at teaching Greek, Latin, philosophy, history and archaeology classes for students from a public school in São Paulo (Brazil) by a group of university student monitors (including the author of this paper).

The use of digital games and simulations by teachers and students of (public or private) Elementary and High schools allows not only to increase the daily activities in the classroom but also to engage students and the public with archaeological knowledge, improving communication between Basic Education and the university, in addition, to provide a product based on archaeological research that can be critically analysed, promoting an accurate process of learning historical knowledge at school.

As pointed out by Erik Champion (2015), these digital products offer a learning potential through tools focused on non-textual visualization, in addition to their ability to convey stories and meanings. Although games are socially received, above all, as commercial products, they also assume the role of disseminators of a certain knowledge shaped and programmed by their developers, and can be worked from an educational perspective, and, therefore, must be understood as sources, primary or secondary, to be analysed with the criticality required by scientific practice.

Understood as a new type of media (Copplestone 2017), these applications should be examined as critical opinion-forming vehicles. It is therefore necessary to reflect on the possibilities presented by this tool of convergence between the production of scientific knowledge (specifically, the interpretations and representations of the past and its material culture) and specific practices of development of these games guided by interdisciplinarity.

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152. Transcending virtuality? Multi-modal and multi-media experimentation in VR

Zachary Day, Bureau of Land Management

Heather Richards-Rissetto, University of Nebraska-Lincoln

Over the past fifty years, digital technologies have become a mainstay of archaeology. Geographic Information Systems (GIS), statistical software (e.g. SAS, SPSS), and other computational software allow us to investigate quantitative data in ways not previously possible leading to new questions, hypotheses, and interpretations. In the 21st century, digital data acquisition such as laser scanning and photogrammetry is replacing manual mapping and drawing—both in the field and lab. While Virtual Reality (VR) has seen use by a few archaeologists since the mid to late 1990s, only in the last decade have archaeologists more avidly pursued applications of VR. Free to low-cost consumer-based 3D gaming development software such as Unity and the Unreal Engine has allowed new ways to reconstruct and present the past for archaeologists. Along these lines, recent consumer versions of immersive headsets such as Oculus Rift and HTC Vive as well as Augmented (AR) and Mixed Reality (XR) technologies are creating a public buzz. They are often heralded as bringing in a new era of education and public outreach for cultural heritage. There's no doubt these technologies draw audiences, but their potential for archaeological education is in its infancy, and moving slowly. While immersion and interactivity is possible in new ways, we're still struggling to employ VR, AR, or XR for effective teaching. One reason for this struggle, centres on affordance—specifically, to what degree can VR, AR, or XR afford embodiment and cultural presence?

In this talk, we experiment with multi-modal and multi-media approaches in two virtual reality settings and compare student learning experiences in these environments. The case study is the ancient Maya using artifacts, buildings, and architectural complexes from the UNESCO World Heritage Site of Copan, Honduras. We design two VR environments, with one designed as a traditional museum with photogrammetric models of artifacts placed on pedestals, and another VR that situates these same artifacts in the ancient buildings and architectural complexes of Copan. We beta-test these two VR environments with students from various disciplines using survey methods.

Our objective is to address the question: What are successful techniques to aid "visitors" to better understand the original context of an object now placed in a (often far off) museum or gallery? In our attempt to answer this question, we explore the relationship between embodiment and cultural presence with tiered multi -modal and multi-media experiences. Such a tiered approach allows us the opportunity to evaluate the impact of turning on/off layers of data on learning. We investigate the impact on student learning/experience based on different modes of data, such as visual (image vs. video), auditory, or "haptic" interaction (via touch controllers) and different combinations of these multi-modal data. Additionally, we evaluate student "reaction" to reality-based (photogrammetric/laser scanning) buildings in comparison to CAD reconstructions including transitioning in the VR from the present (extant ruins) to a simulated past. In particular, we are interested in the potential use of transitions to multiple simulations as a means to teach students and the public about process, critical analysis, and interpretation in archaeology. By comparing student experiences and take-away points using the same artifacts, but one set situated in a traditional museum setting and the other placing these artifacts a simulated cultural context, we seek to contribute to studies of the role VR can play in fostering respect for diverse cultural heritage.

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80. Bath Abbey Footprint Project: From 4D photogrammetric recording to virtual reality

Roberta Marziani, Wessex Archaeology

In May 2018 Wessex Archaeology began the excavation under the floor of the Bath Abbey as part of a sustainable renovation project. The peculiar nature of the site and the need for splitting the excavation into parcels to allow refurbishment works has led to some experimentation with 4d Photogrammetry recording. In this instance, 4d recording is meant as a type of recording carried out not simultaneously. Ultimately, this led to the building of a composite model, which offered the chance to see the archaeology exposed in its entirety, and a great opportunity for the creation of a virtual reality space. As the project developed a VR concept, two types of audiences were identified as possible end users: the archaeologists, as a tool to aid post-excavation research and publishing, and the Abbey's visitors. Our client became interested in this product and commissioned the full production of the media to be installed at the Abbey's visitor centre.

Figure 12. Bath Abbey Footprint Project.

Consequently, the need to incorporate historical and archaeological content within the VR space became prominent so to add cultural significance to the whole experience. Following consultations with leading archaeologist on site, the archaeological and historical contents were fed into the VR.

The Virtual Reality product has been delivered as an interactive media station for the visitor Centre at the Abbey early this year. In this immersive space, the user is projected in the "past", under the abbey's floor, where they can walk in the site of the excavation, explore, and observe the features that have been uncovered, and experience firsthand the archaeological dig that took place, hence delivering a true immersive archaeological experience. The surrounding abbey's architecture is rendered in transparency to suggest the "present" level above the floor. The user can choose to activate key historical information for each feature which enhances the cultural presence and the learning experience.

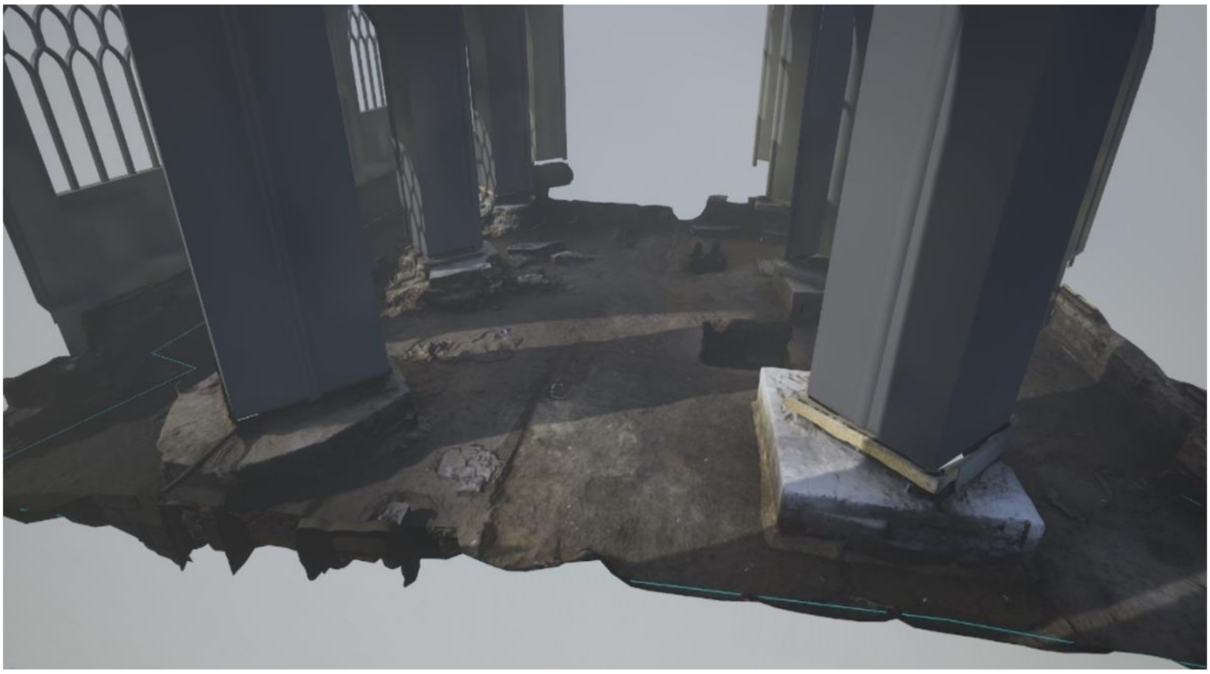

Figure 13. Bath Abbey Footprint Project.

This project has been truly pioneering for the Wessex team and a new challenge for the ones involved. We intend to highlight the journey that got us to the final digital product as a research process in its own merit and offer a retrospective look on the reception of this digital asset. In addition, we would like to instigate a fresh discussion on its scopes and investigate what can we learn, as a team, from this experience. Particularly, we would like to present this as a form of digital heritage, explore topics surrounding its use in post-excavation analysis other than an immersive experience offered for the Abbey's visitors centre and understand how we can move forward and deliver more immersive and research-worthy Virtual Realities experiences.

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128. Deriving meaning through engagement with a sustainable, immersive, interactive reading experience in a virtual global library

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Mats Borges, University of Southern California

Eric Hanson, University of Southern California

Sustainability is a key concern in the GLAM sector worldwide as practitioners aim to succeed in their linked, complex responsibilities of protecting and preserving tangible heritage, such as manuscripts and rare books, while also encouraging audience engagement and appreciation with the ineffable content that is embedded in their pages and accessible through dynamic handling (Campion and Rahman 2019).

Through this research and virtual production, we aim to undermine and defeat the violence of separation that decouples the body and soul of books and manuscripts, and that disarticulates the artifact from its resonant ancient context. In this presentation of a working virtual reality project that we developed from 2020 through 2022 at the University of Southern California (USC), with funds from the National Endowment for the Humanities, we share an ongoing experimental effort to richly enfold the experience of reading real, ancient texts in places that are resonant with their original production or use. In this virtual experience work, we provide opportunities for the expression of personal agency, exploration, reading, translating, transliterating, and reflection in original contexts of reading, expressed virtually.

Figure 14. Page turning.

Our research has been motivated, in part, by the frustration that so many have experienced so often as optimistic visitors to exhibitions and collections. The object of personal pilgrimage lies beyond our reach temporarily, entombed in a clear vitrine, tantalizing us with one static view of its potential, but frozen beyond reach like the stuffed denizens of the natural history diorama displays. Our research aims to defeat the sadness that is provoked simultaneously in that moment of hoped-for revelation and engagement.

In this research, we ask how to unbind both artifact and explorer in an experience of reading virtually. We experiment with answers to this question by creating an experience that is intended to surpass the experience of reading in the real world by attending to the varying frames of curiosity, commitment, and preparation that both readers and GLAM curatorial staff diversely invest. We also investigate the possibilities of unconstrained exploration in an immersive experience as a gateway to provoke greater investment by readers traditionally unable to access materials or traditionally un-invested or even repelled by issues of language, translation, and preservation concerns from accessing ancient manuscripts.

In the workshop portion of this session, we will provide Quest 2 headsets, downloadable apk files of multiple 360 immersive embodied experiences of ancient manuscripts that can be engaged in specific places, some with aural environments specific to their moment of production and use. We also provide 2-D video excerpts on flat display screens of each immersive experience for those whose access is better facilitated in that mode.

This experience has been developed (and continues to be developed) by an interdisciplinary team (archaeologists, art historians, curators, 3-D modelling specialists, film-makers, game designers, and music specialists). The initial experiment that we created is an embodied, immersive, interactive 3-D experience of a 15th-century illuminated manuscript kept by USC Libraries' Special Collections. Through a Unity-based, headset-accessible experience, users access the 3-D model of the original manuscript placed in a 3-D modelled church space. Immersed in this virtual sacred space and while listening to period- and spatially-appropriate music, people gain a more connected experience of the manuscript, virtually touching the manuscript and learning about its proper handling and its content without damaging the original. Interactives are designed to make the manuscript more accessible to non-specialists and to engage people in exploring materiality, images, and texts. In the virtual realm, this costly book can be used carefully as it was when its owners, beguines (female, lay members of a woman-only community) in fifteenth-century Ghent, Belgium, would have read it in the beguinage church of Old Saint Elizabeth and its nearby residential buildings.

This virtual reality experience is replicable, as it was designed as a preliminary template to be used by any museum, library, or archive. The template itself is an object of research, as it is a provocation for learning and public awareness about manuscripts and books that fascinate but which also contain the seeds of their demise as direct access poses threats to the future preservation of these ancient artifacts.

Through our template, we are able to replicate the reading experience in vastly diverse places and ways. We provide access to multiple examples of its use with manuscripts from collections that lie in distant places worldwide. Through this virtual reality experience, manuscript owning institutions are able to:

1. preserve ancient manuscripts;
2. make them accessible for research and public access;
3. encourage proper handling;
4. provoke appreciation for owning institutions as sustaining the shared cultural heritage of humanity.

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8. A virtual 'return to the tomb': The rejoining of a 26th Dynasty sarcophagus and its burial at Saqqara

Elaine A Sullivan, University of California, Santa Cruz

Immersive visualization technologies (VR, AR, and XR) are poised to provide transformative capabilities across many sectors of our society. Within higher education in general and the humanities and arts in particular, these innovations have an especially high potential to provide new avenues for scholarship, teaching and learning, and public engagement. Archaeology and History are especially productive arenas for this kind of work and offer alternative models of publication that demonstrate the potential of applying digital technologies to the study of the past as well as to the present.

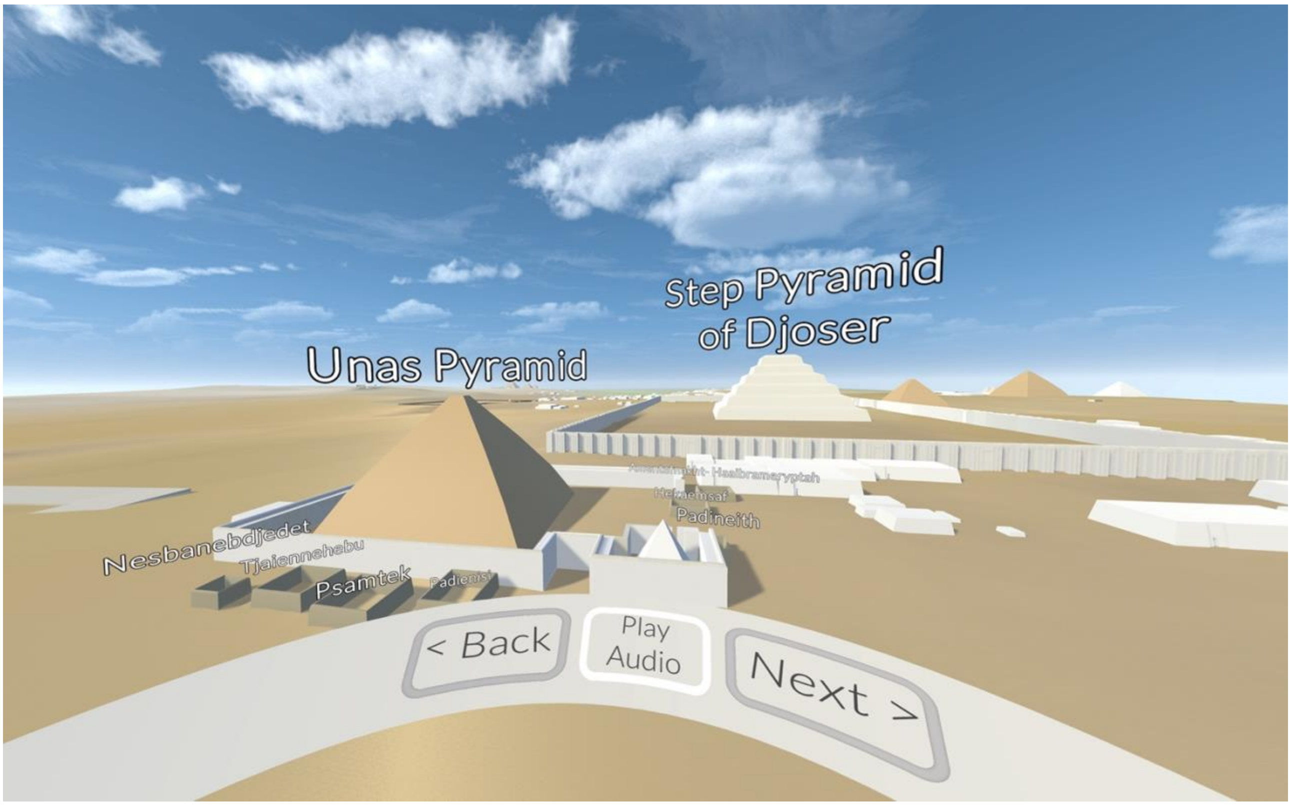

Figure 15. Return to the Tomb.

Project summary

The project Return to the Tomb, an immersive VR headset experience under development, offers an educational virtual heritage environment integrating different scales of archaeological and historic information at an ancient Egyptian cemetery. The application will allow the user to experience a visualization of the Saqqara cemetery in the first millennium BCE, enter a model of a tomb's burial chamber, interact with the sarcophagus inside, and read translations of the object's funerary texts. The project combines detailed archaeological information on the site of Saqqara with a photogrammetric model of the Late Period inner sarcophagus of "chief physician" Psamtek, now on public display in the Phoebe A. Hearst Museum of Anthropology in Berkeley, California (PAHMA 5-522). Like for many museum artefacts (Ellenberger 2017), the modern display of the sarcophagus cannot adequately replicate aspects of its original archaeological context: originally in a deep rock-cut shaft, nestled among hundreds of impressive elite tombs at the necropolis. Today, the museum visitor has little opportunity to understand the meaning and original placement of the object, either within the tomb or in the larger cemetery. The project virtually re-places the sarcophagus in a 3D model of the tomb, based on the early 20th century publication by Barsanti and Maspero (1900), and situates this tomb in a larger reconstruction model of the entire site in Dynasty 26, the period in which Psamtek's tomb was constructed. Users can interact with the sarcophagus, displaying translations of individual lines of hieroglyphic text. The application has been designed in collaboration with students, librarians, and technologists at UC Santa Cruz and UC Berkeley.

Project education and learning goals

The goal of the project is to experiment with how new immersive 'virtual reality' headset technologies can be used by Egyptologists to better express to the public the complex histories and layered meanings of archaeological objects, especially those removed from their original sites of deposit. We will discuss the ways in which the project attempts to create a 'culturally significant place' in a virtual world, layering cultural information about the landscape, objects, and religious beliefs to express the unique cultural aspects of this Egyptian cemetery (following the ideas of Champion, 2011). We have already presented the prototype application at a number of academic events to receive initial feedback on design, and have future plans to test the next iteration with Hearst museum visitors and undergraduate students. While ease of use and enjoyment are relatively easy to assess, we also hope to gauge how such immersive experiences can aid in education about the artefact, and to assess whether such digital techniques can be effective for transmitting 'cultural presence,' or the importance of the object in its original cultural context.

In this presentation, the authors will demo the VR headset application (under development), very briefly discuss the base data for the 3D models, and describe the technological and intellectual challenges of combining multiple types and scales of data in the application. We will focus primarily on our learning goals for museum visitors and undergraduate students, and discuss how our educational goals impacted our design decisions. We will also comment on the ethical questions involved in working with Egyptian material during an era of archaeological reckoning with the colonial past. Finally, we will solicit feedback for improving the educational content and sense of 'cultural presence' of the project.

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177. Learning from the past: XRchaeology and web-based experience

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How can complex archaeological data be used to engage a broad range of learners in accessible ways? Is it possible to mobilize the 'wow'-effect of new AR/VR/XR technologies into useful tools of critical inquiry and problem-solving? How can cultural presence be incorporated? Our XRchaeology apps immerse users in archaeological field experiences using an array of data resources that can be [re]combined in a series of interactive hypothetical scenarios that encourage data exploration, critical thinking, and hypothesis testing.

This project began with the broad intent to overcome obstacles that arise from the inability to access museums, and remote archaeological collections (i.e., those stored in permanent museum collections or curatorial archives around the world), and the more specific aim to emphasize the contextual associations of systematically excavated objects. While traditional archaeological exhibits often focus on the most beautiful and complete exemplars of past societies and civilizations, such objects are often presented out of context, losing their connections to the social and physical settings from which they were derived. In contrast to traditional museum experiences, our XRchaeology app emphasizes artifact context while maintaining elements of uncertainty the are omnipresent in the archaeological record. Within the XR framework, it is possible to share rich archaeological data from a variety of contexts and engage in fruitful exchange with experts and virtual informants in one part of the world, with learners and investigators in another, transforming the way objects and information about them is transmitted and used. The incorporation of a virtual assistant guides users in the process of archaeological inquiry and helps learners to construct and reconstruct the experience of life an extinct community and explore the factors that influenced it.

As discussed at last year's CAA meeting, we encountered several critical roadblocks in our design that challenged us to find solutions and pivot as technological innovations continued to force periodic maintenance and modifications. For example, although highly engaging, 3D objects deployed as .obj or .fbx files are not ideally compatible with classroom learning management systems (or LMS) packages without an interface (e.g., Sketchfab or ThingLink) to make them interactive, but this technology is changing rapidly. This technological fluidity led us to design an independent WebApp for content management and dissemination. Another caveat we encountered concerns the availability of VR headsets. While it is possible to agree that content delivered in 360 immersive environments significantly enhances the simulated archaeological experience we wished to convey, deploying content to headsets for all students in a large classroom simultaneously was not a feasible or economical option. Finally, with the growing adaptability (interoperability) of heterogeneous platforms like traditional computers, mobile devices, and VR headsets – each of which continues to run a different operating system – it has become more challenging to develop digital learning tools that are widely cross-platform compatible. In the presence case, we decided that interactivity must not be restricted any one platform.

To move beyond these limitations, designing a web-based application was our solution for achieving cross-platform functionality while maintaining opportunities for immersive engagement (Agugiaro et al., 2011, Doyle et al., 1998). Our immersive learning tool is designed to be accessed as a stand-alone web-based experience, but due to its web-based deployment, it can also be accessed immersively inside VR headsets and wearables and on a range of personal devices. Through immersive and non-immersive VR, the profound moment of discovery and critical inquiry required to link past and present, reaches learners of various levels and abilities, in ways that are engaging, insightful and substantive.

With the above in mind, we argue that emerging media techniques are useful, if not the best option for teaching learners as well as the broader public, the relevance and importance of linking material culture to cultural context. To create more enriching experiences with cultural presence, we apply the three principles of Universal Design for Learning, or UDL, which urges the use of multiple means of representation, expression, and engagement (Rose and Meyer 2002) in the development of our multi-dimensional learning media. Like their in situ archaeological counterparts, our virtual learning modules are object-based and experiential, as well as interactive and didactic. In a field context, object-based learning not only transforms “how students think about archaeology, history, and the past”, but also leaves a lasting impression upon those who experience it (see Henderson and Levstik 2016). By creating corollary virtual experiences, we contend that similarly long-lasting impressions are made when data are enhanced through dynamic 3-dimensional and spatial media, and through the incorporation of cultural presence (see Champion 2016) in the form of a virtual AI assistant and objects with socially-contextualized biographies. Teaching WITH archaeology using combined AR/VR/XR techniques creates new opportunities to both learn from and experience the past. Our immersive approach is unconventional in that it teaches the importance and significance of even mundane items of material culture while using multi-dimensional experiential media to make real-world connections among the past, present, self and community.

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Session 05. Our little minions IV: Small tools with major impact

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Moritz Mennenga, Lower Saxony Institute of Historical Coastal Research, Wilhelmshaven, Germany

Ronald Visser, Saxion University of Applied Sciences, Deventer, Netherlands

Brigit Danthine, Universität Innsbruck, Department of Archaeologies, Innsbruck, Austria

Room 14

Introduction	09:00 - 09:15
3. CyprusArk: A multi-institutional content management system for small museums collections online *Avgousti* and Papaioannou*	09:15 - 09:30
10. BERT's little minion: A tool to normalise time periods extracted from Dutch text *Brandsen**	09:30 - 09:45
71. From OXALID to GlobaLID: A substantial upgrade of a well-known data pool of lead isotopes for metal provenancing using R and Shiny App *Hsu**	09:45 - 10:00
77. Learning to play FAIR-ly with large spatial datasets *de Gruchy*, Clarke, Welton, Hammer and Lawrence*	10:00 - 10:15
85. Your (gpkg) relations matters *Lowenborg*, Jansen, Pálsson and Dawson*	10:15 - 10:30
Tea/Coffee	
110. Linked Pipes: A little minion for reproducible research *Thiery* and Homburg*	11:00 - 11:15
120. On the search for invariants in corpora of archaeological artifacts *Levy**	11:15 - 11:30
127. Currycarbon: A Haskell library and command line tool for radiocarbon calibration *Schmid**	11:30 - 11:45
157. QGIS-plugin "CRS-Guesser" *Danthine**	11:45 - 12:00
Discussion	12:00 - 12:15

Introduction

In our daily work, small self-made scripts (e.g. Python, R, Bash), home-grown small applications (e.g. GIS Plugins) and small hardware devices significantly help us to get work done. These little helpers -"little minions" (Thiery et al., 2021) – often reduce our workload or optimise our workflows, although they are not often presented to the outside world and the research community. Instead, we generally focus on presenting the results of our research and silently use our small tools during our research, without even pointing to them, and especially not to the source code or building instructions.

This session will focus on these small helpers – "little minions" – and we invite researchers to share their tools, so that the scientific community may benefit and – perhaps – create spontaneously "special minion interest groups".

As we have seen in last year's "minion talks" since 2018 there is a wide range of tools to be shared. These may be perfect examples for your own minion creation. You can find an overview on https://littleminions.link.

At the virtual online conference CAA 2021 a lot of little minions of various research domains were published to the research community (see Cyprus University of Technology, 2021 pp. 53-55), e.g.:

- Democratization of Knowledge from Small Museums Online Digital Collections Reusable Human and Machine-Readable Content Models by A. Avgousti, G. Papaioannou, N. Bakirtzis, and S. Hermon
- ChronochRt –make chronological charts with R by T. Rose, and G. G. M. Girotto
- re3dragon – REsearch REsource REgistry for DataDragons by F. Thiery, and A. W. Mees
- geoCore - A QGIS plugin to create graphical representations of drillings by M. Mennenga, and G. Bette
- Grading minion to the rescue by R.M. Visser
- Introducing a stature estimation tool for human skeletal material to the public by M. Koukli, V. Sevetlidis, F. Siegmund, C. Papageorgopoulou, and G. P. Pavlidis

This session invites short presentations, lightning talks – aka "minion talks" (max. 10 minutes including very short discussion) – of small coding pieces, software or hardware solutions in any status of completion, not only focusing on field work or excavation technology, associated evaluation or methodical approaches in archaeology. Each "minion talk" should explain the innovative character and mode of operation of the digital tool. The only restriction is that the software, source code and/or building instructions are open and are or will be freely available. Proprietary products cannot be presented, but open and freely available tools designed for them. In order to support the subsequent use of the tools, the goal should be, that they are open available to the scientific community (e.g. GitHub, GitLab, etc).

We invite speakers to submit a short abstract including an introduction into the tool, the link to the repository - if possible - to get access to the source code and an explanation which group of researchers could benefit from the little minion and how. The tools may address the following issues, but are not limited to: data processing tools and algorithms, measuring tools, digital documentation tools, GIS plugins, hands-on digital inventions (for excavations) and data driven tools (e.g. Linked Data, CSV, Big Data). After previous years (pt. I CAA 2018 Tübingen, pt. II CAA 2019 Krakow, pt. III CAA 2021 Limassol/virtual) spontaneous success of "Stand-up-Science", you will also have the opportunity to spontaneously participate and demonstrate what you have on your stick or laptop. If you want to participate without an abstract in the spontaneous section of the session, please send an email to us (even shortly before the conference). Please come and spontaneously introduce your little minion!

The minion session is designed for interested researchers of all domains who want to present their small minions with the focus on the technical domain and also for researchers who want to get ideas about what kinds of little minions are available to help in their own research questions. All of us use minions in our daily work, and often tools for the same task are built multiple times. This online session gives these tools that are considered too unimportant to be presented in the normal talks, but take important and extensive steps in our research, a home.

As an outcome of the session, we try to give support, that all presented tools and links to code repositories will be available for the research community in a "CAA little minion catalogue" (http://littleminions.link) available for the public and extended in the future on a GitHub repository at (https://github.com/caa-minions/minions).

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3. CyprusArk: A multi-institutional content management system for small museums collections online

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Nikolas Bakirtzis, The Cyprus Institute

Feliz Ribeiro Gouveia, University Fernando Pessoa

This article highlights the challenges small museums have in publishing their collections online for human and machine consumption. It showcases a work-in-progress solution named CyprusArk. An open-source web content management system for small museums' online collections. It is based on the idea that if you're not online, you do not exist, and if you're online and search engines or other machines cannot find you, you only exist in part.

CyprusArk is developed using an open-source stack consisting of the leading-edge Django, a high-level Python Web framework, MySQL Database, Bootstrap, an open-source CSS framework, and running on virtualized Docker containers.

Furthermore, encapsulating Semantic Markup using Schema.org is an ontology supported by all major search providers, cultural heritage aggregators, and other machines and can be considered a component of the Semantic Web. CyprusArk differs from other comparable systems in focusing only on small museums in Cyprus. Further, it follows the KISS principle, "Keep it simple, stupid"

According to the KISS principle, most systems work best when they are maintained simply rather than convoluted.

Introduction

Cultural heritage digitization and online accessibility offer an unprecedented opportunity to democratize museum collections. Museum collections presented usually via institutional websites are more than just an adaptation to keep up. They represent the world's culture. They form an increasing trend toward a world where information is digitally preserved, stored, accessed, and disseminated instantaneously through a global and concatenate digital network. However, while the Web has enabled cultural heritage organizations to democratize information to diverse audiences, many small museums do not enjoy the fruits of this digital revolution. The majority of small museums are underfunded, understaffed, and lack technology infrastructures (OECD, 2020).

As a result, many small museums do not have their collections online (publishing content for human consumption). Furthermore, nowadays, our consumers include machines that must be able to comprehend and utilize the content in the same way as humans (publishing content for machine consumption). In addition, small museums that manage to publish their collections online usually do not have structured or linked related content. In other words, the human-readable words of traditional web pages are not associated with any specific machine consumable syntax or structure. As a result, the information provided by museum's collections online may be ambiguous to search providers and other machines.

Due to the problems above, digital versions of small museum collections are mainly inaccessible and hidden. Subsequently, humans have less access to information that can lead to new knowledge.

What is CyprusArk

CyprusArk is an open-source web content management system for small museums' online collections. Designed to meet the needs of Cyprus's small museums. CyprusArk is developed using an open-source stack consisting of the leading-edge Django, a high-level Python Web framework, MySQL Database, Bootstrap, an open-source CSS framework, and running on virtualized Docker containers. At the same time employs Schema.org, a semantic vocabulary or ontology that enables the embedding of structured semantic markup (metadata) into web pages for direct consumption by significant search providers, web crawlers, cultural heritage metadata aggregators, and other machines and can be considered a component of the Semantic Web (Willis et al., 2017). Moreover, Schema.org is suitable for describing cultural heritage objects and is widely used in the cultural heritage domain (Ronalo, 2012). Further, it follows the KISS principle, "Keep it simple, stupid" According to the KISS principle, most systems work best when they are maintained simply rather than convoluted (U.S. Navy,1960)

Related work

A Similar system is the ViMuseu content management system, which constitutes a project dedicated to the needs of small Finnish museums and has been developed by the Department of Arts and Cultural Studies at the University of Jyväskylä in Finland in collaboration with the same university museum. The ViMuseo CMS can be regarded as an online multimedia presentation tool mainly used for virtual exhibitions and projects. ViMuseu content management system's utility is related to digital-free institutions that wish to be more active on the Internet. The tool can be described as a web application (Web CMS) content management system co-developed by programmers and graphic designers. However, as Zamojska (2011) has commented upon, the specific tool's use is a significant challenge.

Additionally, a similar project is related to the work carried out by The Cyprus Institute (CyI) and the considerable development of the OpeNumisma content management system. According to Avgousti et al., (2017), the OpeNumisma content management system can be perceived as a reusable web-based platform that does constitute a kind of merge of digital imaging and content that offers tremendous opportunities for research as well as for the dissemination of knowledge and Data. The platform's development seeks to create a digital web framework concerning online numismatic collections. This kind of content management system has been implemented and used by small museums in Cyprus. It is available as a distribution software that can be used only by small numismatic museum collections.

Further, (Daradimos et al., 2015) presented the significant problem of small museums that are considered unable to reach the public through the Web. In line with the above, as Daradimos et al., (2015) have mentioned, certain of these reasons are related to the cost of commercial products and the complexity of such application development and customization. In this paper, a different approach is recommended, along with the development of a general-purpose plugin (module) that will extend the functionality of the open-source Drupal CMS for small museum collections online.

Furthermore, the Getty Foundation Online Scholarly Catalog Initiative (OSCI) is helping museums to make web-based publications available to the public with the use of technology and the internet (Marrow, 2017). The development of ChicagoCodeX can be regarded as the basis of the tool since this kind of toolkit leaves the margin for institutions to deploy microsite's digital collections. However, based on the OSCI report in 2017, parameters relative to the toolkit's complexity combined with its augmented cost on account of its technical expert requirements can be regarded as certain of its disadvantages.

Accordingly, the WissKI content management system platform can be regarded as one other illustration that is aimed at the production of a virtual research environment as regards the digital humanities (Scholz, 2012). The platform is based on the open-source content management system Drupal and on installing about thirty contributed plugins to implement the system. However, limitations of considerable importance concerning the WissKI system can be regarded not only as of the default installation of the software, which in many cases leads to difficulties with upgrading to new versions of the system (Vilios, 2016) but also the sustainability challenges which can render the system highly problematic (Dombrowski, 2016).

Additionally, the GLAMkit content management system or web framework is designed specifically for small museums (Weakley et al., 2009). It has tools for managing and displaying collections online and complex events. Mostly focused on small institutions with limited technical staff. GLAMkit is developed using the Django Framework and the Wagtail content management system focusing on common museum needs (Mansfield, 2020).

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10. BERT's little minion: A tool to normalise time periods extracted from Dutch text

Alex Brandsen, Universiteit Leiden

In the context of building a search engine for Dutch excavation reports, we extracted time period entities from these texts using a BERT (Bidirectional Encoder Representations from Transformers) language model (Brandsen et al., 2021). When inspecting the entities, we encountered the problem that time periods in text are extremely varied in their form, and we needed a way to normalise these varied expressions to a common format. This way it would be possible to search across all different types of time periods and return relevant results, i.e. a search for "500 - 1500 CE" would return results containing "Middle Ages", "Merovingian", "1000 AD", "second half of the 10th century", etc..

We created a Python script that uses a time period ontology (based on Perio.do, Rabinowitz et al., 2016) and extensive rules to convert just about any expression of an archaeological time period to a list containing the start and end year, e.g. "[500,1500]". We then indexed all these dates in the AGNES search engine (Brandsen and Lippok, 2021), allowing for far more effective search than previously available. We also analysed all the year ranges extracted from our entire document collection, giving an insight into which time periods are encountered most in Dutch archaeology.

The code is available on Github: https://github.com/alexbrandsen/timeperiod2daterange

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71. From OXALID to GlobaLID: A substantial upgrade of a well-known data pool of lead isotopes for metal provenancing using R and Shiny App

Yiu-Kang Hsu, Deutsches Bergbau Museum

Lead (Pb) isotope geochemistry is an approved key method in archaeological sciences to reconstruct the resource provenance of metals and trade networks of the past civilisations. Successful application and interpretation of Pb isotope signatures of metal artefacts rely crucially on the published ore data, which are partly only available from pre- or re-digitalised publications. Most Pb isotope reference data collections were compiled by individual working groups, usually focusing on their projects and regions of interest. A great step towards a large-scale collection of Pb isotope data came with the release of the OXALID database in the early 2000s, which has benefited the scholars in the natural science discipline as well as the more untrained users from the archaeological community. Still up today, OXALID is the most used and cited source for reference data, despite the accumulation of many additional data sets since then. All of them are set up as static data collections, limiting the possibilities to expand, correct, and modify them with the publication of newer results or analyses. Additionally, not all of them are easily available for people from across the world and only recently compilations for regions outside of Europe and the Mediterranean became widely available.

Riding the wave of open science and new data infrastructures, the authors are endeavouring to digitalise and construct a global Pb isotope data base using the statistical environment R and Shiny App. The presentation will showcase this highly promising application for the modernisation of archaeometry as an applied geoscience discipline

Resources

Web App: https://globalid.dmt-lb.de/

GitHub Repository: https://github.com/archmetalDBM/GlobaLID-App

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77. Learning to play FAIR-ly with large spatial datasets

Michelle de Gruchy, Durham University

Alison Clarke, Durham University

Lynn Welton, University of Toronto

Emily Hammer, University of Pennsylvania

Dan Lawrence, Durham University

The PAGES Landcover6K network challenged researchers to map global land use in several temporal snapshots across the Holocene. Archaeologists have long been interested in land use, estimating site catchment areas and calculating field extents or determining how much pasture would have been required to support animals at a site. Landcover6K required archaeologists to move beyond abstract calculations and individual site models to categorise the dominant land use in every 8x8 km square of land around the world based on archaeological evidence (Morrison et al. 2021). On the Southwest Asia team, we found that our data could support a much higher resolution map, modelling land use at 30x30 meter resolution (Welton et al. forthcoming), but computing the map has been a challenge. We wanted our method to adhere to FAIR principles and we wanted to use R to maintain consistency with other teams, but R is not very efficient with large spatial datasets and producing such a high-resolution map requires a lot of memory. For this reason, we sketched out preliminary models using GIS software on a good workstation with 64GB RAM, but scripting and running those same models in R required a supercomputer (Durham University's Hamilton8). This work has highlighted an area for improvement in software, the need to combine the reproducibility of R with the computational efficiency of GIS software. Here one possible solution is presented: a tool that aims to enable reproducibility for work done in QGIS's GUI.

Methods and materials

To determine potential land use we used data from a 30m SRTM dataset, a soil depth dataset from SoilGrids.org, and a hindcasted rainfall dataset for 5976 B.P. (Hewett et al. forthcoming).

To transform the potential land use map into a model of actual land use at 6000 B.P. we used settlement data from 101 archaeological surveys and ethnographic data from the region (e.g. Thalen 1979).

Methods follow the classification system outlined in Morrison et al. (2021).

Results

A land use map/model for the entirety of Southwest Asia at 6000 B.P.

Development of a tool that will increase the computational efficiency for working with large spatial datasets while adhering to FAIR principles in the future.

Discussion/Wider significance

The land use map is one of a series that will provide empirically-based datasets of past anthropogenic land-cover change to facilitate palaeoclimate modelling of the impacts of global land use on climate.

The QGIS tool will make large spatial projects more accessible to researchers around the world who wish to adhere to reproducibility but who may not have access to the latest supercomputers.

Specifically, it will enable QGIS users to produce a script that can be used to allow others to reproduce their analysis, improving reproducibility even for users who are not used to scripting.

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85. Your (gpkg) relations matters

Daniel Lowenborg, Uppsala University

Jane Jansen, Arkeologerna, Intrasis

Gísli Pálsson, Uppsala University

Nyall Dawson, North Road

This presentation is of an early stage work-in-progress of making it easier to work with database relations in QGIS (and more). The Geopackage (gpkg) format today cannot hold definitions of what relations exist between layers and tables included in the gpkg, making it complicated, time-consuming and error-prone when relations need to be defined manually. For a project where we are working with a large number of databases of excavations, created with the program Intrasis using a relational database structure, we want to make it easier to work with the relations in QGIS. Together with the company North Road, we are currently working with an update to the GDAL library definitions for the gpkg format, so that relation definitions can be stored inside the gpkg, and recreated in QGIS with the click of a button. Since the enhancements would be already at the GDAL level, however, this function could be implemented in any software using the gpkg format. In the presentation we wish to present the current stage of this development, and look ahead to how to take this further in working with GIS relations for analysis of archaeological excavations in an open source software environment. With a simplified process for getting the relationships set in your GIS this can hopefully inspire further improvements on how to make use of relational databases for excavations.

110. Linked Pipes: A little minion for reproducible research

Florian Thiery, RGZM

Timo Homburg, University of Applied Sciences Mainz

At Linked Pasts IV in Mainz 2018, the Linked Pasts Network had a session on "Linked Data Tools and Pipelines": As a result, the Linked Pipes Working Group was born. The goal: creating so-called Linked Pipes as semantically modelled pipelines for (not only) LOD related workflows using the help of the WWW, and existing research software solutions such as JavaScript based little minions. Currently Linked Pipes are developed by the Research Squirrel Engineers Network (Timo Homburg and Florian Thiery), and is part of the Pelagios Network Annotation Activity as well as the Linked Pasts Network.

Digital Workflows (as known as Linked Pipes) exist in mind, but researchers should visualise and semantically model them using well-known ontologies such as the Provenance Ontology (PROV-O) and the Dataflow Ontology (DFD) to create a part for reproducible research. Additionally, research workflows are usually not published in interoperable formats, such as RDF. It would be an improvement for archaeology if researchers could document Liked Pipes e.g. for a research publication and share the workflow with colleagues. Linked Pipes consists of tools, which can be easily part of the so-called Linked Open Data Cloud and therefore interlinked with other tools by using Wikidata [1] where you can create or edit existing items (research tools) with the property "used by" (P1535) "Linked Pipes" (Q73897190), e.g. SPARQLing Unicorn QGIS Plugin (Q74005133), Recogito (Q74692524), Annotoriuos (Q110585388). Linked Pipes should be reusable once defined in Linked Data. Creating a "Linked Pipe Registry" will help to share Linked Pipes in a central repository. But how? a) a registry file in a git repository which links to Pipe RDF files published elsewhere save, e.g. Zenodo -> DOI or Solid Pod -> access control, and b) visualisation of these pipes on demand in JavaScript in a Linked Pipe Viewer [2].

This minion talk focuses on the Linked Pipe Viewer published on Github [3]. The viewer is based on JavScript and the flowchart.js library. Currently this framework does not support the "Yourdon / DeMarco" notation, as DFD visualising backbone. We currently adopted the syntax, to model digital data(-stores) (subroutine|data|blue), not digital resources (inputoutput|toolwd|purple), tool in Wikidata (subroutine|data|yellow) and local (maybe unpublished) tools (inputoutput|tool|yellow) and started to model use cases:

- Digital Text -> Recogito Geo Annotation -> QGIS Map
- Book Text -> Recogito Townland Annotation -> QGIS Map
- Ogham CIIC Book -> R based Density Map
- Samian Research Data -> Samian Ware in Wikidata
- 3D Scan of clay tablet -> Machine Learning Data

References

[1] https://www.wikidata.org/wiki/Wikidata:WikiProject_LinkedPipes

[2] http://viewer.linkedpipes.xyz

[3] https://github.com/Research-Squirrel-Engineers/LinkedPipes

120. On the search for invariants in corpora of archaeological artifacts

Eythan Levy, Bern University

This paper presents a new methodology and software for identifying logical relations (invariants) among a corpus of archaeological artifacts. In this setting, a corpus is seen as a table where each row represents an artifact, and each column a characteristic of the artifact. These columns are assumed to represent categorical variables (e.g., material, color, provenance) or Boolean variables (e.g., inscribed/uninscribed, iconic/aniconic). The goal of our methodology is to automatically discover logical relations between this set of variables, some of which might be overlooked when examining the dataset with the naked eye, especially in cases of variables which are usually not considered as being correlated with each other. Examples of such invariants could be linked to a geographical origin, say "all artifacts from the northern region are iconic", or to material aspects, say "all artifacts made of metal are inscribed", among many others. The discovery of such invariants might hint at clusters, possibly related to specific workshops, or at other types of interesting relations that call for an archaeological (or art historical) explanation. We first formalize the exact kind of invariants we wish to search for, using Boolean logics. We then present Python code that takes as input a CSV file representing a corpus of artifacts, and searches for all invariants satisfying a certain set of user-defined parameters. We propose a case study consisting of an automated invariant search in the corpus of provenanced Iron Age Hebrew seals. We show the usefulness of our approach through the discovery of several meaningful invariants, some of which seem to have been overlooked by previous studies on Hebrew seals.

127. Currycarbon: A Haskell library and command line tool for radiocarbon calibration

Clemens Schmid, Max Planck Institute for the Science of Human History (MPI-SHH), Max Planck Institute for Evolutionary Anthropology (MPI-EVA)

Currycarbon is a small library written in the programming language Haskell for fast intercept calibration of radiocarbon dates. It includes a command line executable for simple access to the features of the library: https://github.com/nevrome/currycarbon.

Figure 16. Currycarbon.

There are already multiple excellent and broadly applicable implementations of radiocarbon calibration (OxCal, CalPal, Bchron, rcarbon, calibrator, ...), and there was no immediate need for yet another one. Three specific reasons caused me to write this library anyway, which, I would argue, also qualify it as a useful "little minion":

- Currycarbon was an educational exercise to understand intercept calibration. Writing it was a valuable learning process and my way to understand this crucial algorithm, which forms a foundation for so much of modern, archaeological research.
- Currycarbon is a Haskell library. I'm personally working on other software tools in Haskell and missed a way to directly interlink calibration with other code. This renders currycarbon a useful minion for myself.
- Currycarbon provides a command line interface with a precompiled executable. That allows for a very quick and intuitive user experience for the common task of recalibrating dates encountered in the literature or a live presentation. The CLI tool might help colleagues, whose current workflow for this case involves logging into c14.arch.ox.ac.uk to run OxCal.

In my lightning talk I will quickly walk through the inner workings of currycarbon, explain why I created it and demonstrate how it can be used by archaeologists on Linux, Windows or macOS, who are only ever so slightly comfortable with the command line.

157. QGIS-plugin "CRS-Guesser"

Brigit Danthine, University of Innsbruck

Frequently, the situation arises that survey data or GIS layers are available, but without the information in which coordinate system the data are located. Especially in Austria this situation is aggravated by the fact that there are not only three different zones, but each of them is defined by several different coordinate systems. Up to now, the coordinate system of the layer had to be changed manually by trial and error in order to find out which coordinate system is the correct one. To make this easier, the QGIS plugin "CRS-Guesser" was written. With this it is possible to enter a coordinate or a layer with an unknown coordinate system and automatically search a list of possible coordinate systems. While with the manual determination different coordinate systems are attributed to a layer, the plugin assumes that the data are in the coordinate systems to be searched one after the other and converts these in each case to a layer with a coordinate system to be defined in the plugin. The result is a layer with different points that were transformed from the respective coordinate systems, whereby these are written into the attribute table. After the plugin has finished reprojecting, this layer is loaded automatically. The user can now load a basemap (e.g. via the Quick Map Service plugin), zoom to the appropriate location where the data must be and query the correct coordinate system through the attribute table.

It needs to be mentioned in this context, however, that this is not the correct procedure for determining coordinate systems! The plugin is only intended to provide automated assistance for these situations, in which there is no other way to determine the coordinate system than to guess.

The plugin can be found under the following link: https://github.com/brigitdanthine/crs-guesser.

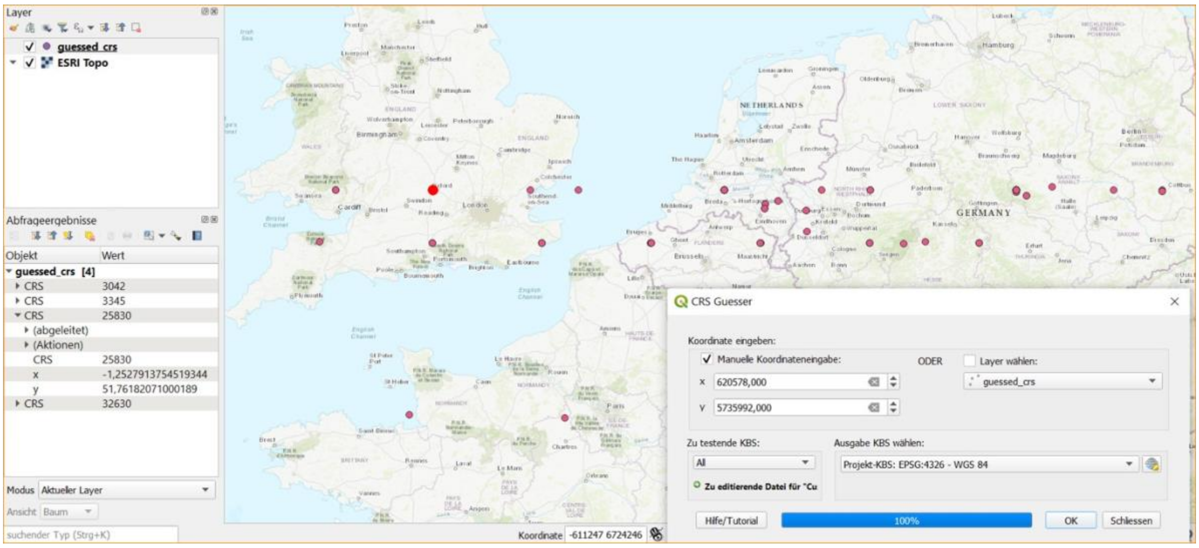

Figure 17. CRS-Guesser.

Session 11. Mountains of data: Digital mountain archaeology in global perspective

Cinzia Bettineschi, University of Augsburg (Germany)

Luigi Magnini, Department of History, Human Sciences and Education, University of Sassari (Italy)

Room 11

Introduction	09:00 - 09:15
12. High mountain archaeology in central South Norway *Uleberg* and Matsumoto*	09:15 - 09:40
88. Archaeological predictive modelling of alpine pastoralism: A case study in the Orobie Alps, Italy *Croce*; Carrer and Angelucci*	09:40 - 10:05
103. Detecting and interpreting fossorial marks in mountainous environment: From ground surveys to UAV prospections *Magnini*, Bettineschi, Michielin, Chiarini, Venco and De Guio*	10:05 - 10:30
Tea/Coffee	
113. Continuity and discontinuity: Creation of a predictive model for the study of the landscape from Middle Age to the Great War in Valsugana Valley, Trento, Italy *Pedersoli* and Azzalin*	11:00 - 11:25
117. Valmaron Valley: A First World War logistics centre above the Venetian Prealps, Italy *Azzalin**	11:25 - 11:50
151. Rescuing Rosalila: 3D scanning of complex archaeological tunnels for conservation efforts in Honduras *Richards-Rissetto*, Wood, Wittich, Agurcia Fasquelle, Garza Roldan and Tuarez*	11:50 - 12:15
Lunch	
164. Non-invasive approach to Ancestral Pueblo settlement studies: Results of archaeological investigations in the Canyons of the Ancients National Monument, Colorado, USA *Szczepanik*, Zych, Palonka and Przybyła*	13:30 - 13:55
Discussion	13:55 - 14:10

Introduction

According to the United Nations Environment Programme – World Conservation Monitoring Centre, mountains cover more than one quarter of the Earth’s land surface (Rodríguez-Rodríguez et al., 2011). The fragility of these ecosystems and their exceptional historic-archaeological potential are constantly threatened by natural hazards, human-induced climate changes (Fort, 2015), and by an increasing loss of biocultural diversity (Agnoletti & Rotherham, 2015).

On one side, modern socio-economic pressure is causing the abandonment of wide mountainous areas, their pastures, and of long-established forest management systems, which are seldom replaced by adequate monitoring strategies (Dax et al., 2021). On the other, mass tourism and the economical attractivity of mountain resources are leading to an uncontrolled exploitation of the local environment (Taczanowska et al., 2019), increasing the risk of destruction both for traditional landscapes and archaeological remains.

Despite the enormous variability in mountain environments, archaeologists working in such contexts have to face specific challenges, including – as applicable – dense afforestation, inaccessibility, significant erosion, altitude and temperature-related technical issues which require proactive mitigation and contingency measures (Carrer et al., 2020; Caspari, 2021; Pelisiak et al., 2018).

In this framework, the opportunities offered by digital methods constitute a fundamental help for contributing to a sustainable identification, documentation, monitoring, and management of the montane cultural record (Brogiolo et al., 2012). The recent advances in hardware solutions, and sensor typology, resolution, and portability are constantly improving the potential of remote/ near sensing and 3D modelling for earth observation and field prospection of mountainous areas (Lambers, 2018; Reinhold et al., 2016; Stek, 2016). Artificial intelligence is further pushing the computational power of such approaches, offering an efficient system to process huge amounts of data in relatively short timeframes (Chen et al., 2021; Magnini et al., 2017; Sărășan et al., 2020). Furthermore, the development of dedicated predictive models using advanced spatial methods and ontological reasoning is contributing to identify and protect endangered archaeological contexts (Magnini & Bettineschi, 2021; Märker & Heydari-Guran, 2010; Stirn, 2014; Visentin & Carrer, 2017).

This session constitutes an opportunity to disseminate the most promising results of the digital heritage community in the field of mountain archaeology and welcomes case studies, methodological developments, and position papers. The main topics can include (but are not limited to):

- Aerial and satellite remote sensing from local to global scale, including advanced image enhancing & data processing techniques, and spatial analyses for site detection and settlement pattern identification;
- UAVs and other autonomous vehicles in extreme mountain environments;
- Predictive and Agent-based modelling for the spatio-temporal modelling of human/ landscape interactions;
- Artificial Intelligence (broadly defined) and big data;
- Digital methods for risk management, heritage protection, land use/ land cover/ land change assessment;
- 3D modelling for the documentation and communication of mountain cultural heritage, including design of Augmented/ Virtual, and Enhanced Reality experiences.

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12. High mountain archaeology in central South Norway

Espen Uleberg, Museum of Cultural History, University of Oslo

Mieko Matsumoto, Museum of Cultural History, University of Oslo

This paper address peoples' movement and Stone Age site distribution based on high mountain archaeology and results and challenges connected to modern human activities. The high mountains in central South Norway are today the areas above the forest limit, at 1000 m a.s.l. Large-scale systematic archaeological investigations started in 1958, as an effort to collect as much information as possible from sites to be destroyed by hydroelectrical power constructions. Surveys located large numbers of archaeological sites around lakes, and the following excavations and natural science investigations provided a lot more knowledge about prehistoric, especially Stone Age, activity (Indrelid 2009).

Methods and materials

This work reuses published archaeological artefact data, and combines it with investigations on vegetation, especially the forest limit. It is a Big Data approach that uses Geographic Exploratory Data Analysis (EDA) as a method to identify activity focal points, also called attractors, in the Stone Age.

Archaeological artefact data are taken from the National archaeological database (MUSark) and the Norwegian National Heritage Environment Register—Askeladden. Norwegian university museums collaborate since the 1990s in a series of projects to digitise and create common database solutions, and one outcome is the national database that can be downloaded as georeferenced datasets from unimus.no. Presently there are more than 1.2 million georeferenced entries in MUSark. Several sites found during surveying are registered without any material being included in a museum collection, so the entry in Askeladden is essential to understand the distribution of activity areas.

The earliest sites in the mountain areas appear shortly after the Ice Age, ca. 10000 BP, but most of the human activity in South Norway was close to the coast, where recent archaeological investigations of a large number of Stone Age sites have made it possible to define different culture groups. The sites in the central mountain areas on the other hand do not show any clear relations to any of these specific groups in the lowland. The occurrence of raw material—flint from the coast that has been used in the high mountains—indicates, however, that there have been contacts between the central mountain areas and the coast both to the East and West.

The scarcity of dateable material, both organic and lithic artefacts, is one aspect of the high mountain sites. Dating of a site often relies solely on typology of stone tools. Lithic material may have been used as late as the Early Iron Age, and sites may have been revisited several times and include material from the Stone Age, Bronze Age and even early Iron Age. This, combined with the general lack of stratigraphy, is a main reason why the site distribution has been described as a four-dimensional dataset projected on a three-dimensional hyperplane. The distribution can be observed in the three-dimensional space, but the distribution in time is practically lost.

A recently emerging source to understand the exploitation of the high mountain areas are finds from permanent snow patches. Snow patches that have existed for around 5000 years are now melting due to climatic changes. Organic material well preserved in the ice patches—arrow shafts and other items related to hunting and transport across the mountains—reveals a hitherto unknown aspect of prehistoric life in these areas (Pilø et al. 2021).

Subsistence is an important factor to understand the site distribution. Reindeer comes first to mind, but there is also discussions around the importance of fishing. The topography of the terrain leading up to several of the lakes indicates that fish could not have followed the rivers to get there; there are too high waterfalls blocking the way. However, fish bones found at several sites show that fish was a part of the subsistence in some areas.

A special site type—stone quarries—have also been focal points of activity, often at long distances from the lakes and other sites. The dating of the activity is very difficult as the overwhelming parts of the material is scattered debris, but estimates indicate use over long periods. A quarry can also be a marked landscape feature that has played a significant role in experiencing the landscape.

The analysis will focus on the spatiotemporal distribution of Stone Age sites in relation to more recent sites, lakes, forest limit and quarries. Unclear site boundaries, and varying precision of site location, will be taken into consideration. The temporal site-distribution is sometimes based on C14-dates, but more often based on typology. This will give rather fuzzy chronological limits. The distance to water should be the shores of the original lakes and not to the present shores, which are a result of dam constructions. The forest limit is also changing through time, and the climatic conditions are reconstructed partly on macrofossils like tree trunks. These variables will be presented and studied in a GIS.

Discussion

Identification of focal points in the landscape can be based on the georeferenced finds and registered sites, including the quarries. Such a dataset can be seen as archaeological Big Data, but it is essential that the approach is theory-based, even though EDA can be seen as an inductive method. The site distribution in the high mountains appears to be concentrated around the lakes. This is a self-sustaining statement, as the surveys are concentrated around the lakes.

The changing forest limit encourages certain subsistence strategies (Matsumoto & Uleberg 2018), and the chosen subsistence strategy influences the understanding of what constitutes the most favourable positions in the landscape; the hunter will have other preferences than the pastoralist. However, the interpretation of the sites should take into account that a higher mean temperature allowed a higher forest limit through most of the Stone Age. The same site may therefore have been used for varying purposes through time.

The presentation will reflect on the spatiotemporal extent of human activity on and between possible focal points in the landscape. The main research objects are the sites at Lake Vavatn, and other sites in the surrounding mountain areas, Lærdalsfjellene, are included in analyses at larger scales and as comparative material.

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88. Archaeological predictive modelling of alpine pastoralism: A case study in the Orobie Alps, Italy

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The study of ancient mountain landscapes has always been difficult due to the low visibility of archaeological sites, especially of those associated with pastoralism. In order to tackle this issue, a new approach to pastoral landscape, based on the integration of inductive predictive modelling and ethnoarchaeology, has been recently proposed for the Italian Alps, in Trento province (Carrer 2013).

The new modelling protocol was tested on a different context in the Orobie Alps (Bergamo province, Italy). A GIS-based inductive model was implemented using modern pastoral sites in the area of Carona (Bergamo, Italy) as training sample. The selected pastoral structures, locally called Monti or Alpi, have been in use until the end of the 20th century (Marengoni 1997) for cow herding and cheese making; some of them are still used today, but mostly by shepherds.

We apply binary logistic regression to investigate whether the selected environmental variables are reliable predictors to explain the distribution of sites and random locations. The underlying assumption is that sites with similar functions (pastoralism and cheese making) are more likely to be located in areas with similar environmental variables. The main variables selected by the model are the altitude and slope value.

The model returns a probability surface, where the value for each pixel corresponds to the probability of being a site. The model is then used to infer the function of known sites mapped during extensive field surveys. Spatial distribution of human evidence in the area is overlaid to the aforementioned probability surface. Since the model is created using pastoral sites, structures located in areas with high predictive potential can be tentatively interpreted as related to pastoral activities.

The field survey in the area of Carona assessed the presence of a complex landscape, with pastoral evidence, iron mining facilities and charcoal production sites, dating from Middle Ages to XIX century. The application of an ethnoarchaeological quantitative methodology, originally developed in a more homogenous context, gives a deep insight into its real interpretative capabilities. The most of known pastoral structures have higher predictive potential than mining related structures, which are also significantly distributed under the calculated predictivity threshold. We can thus assess that the model is performative at predicting pastoral sites but cannot predict other types of functions, confirming the original aim of the model itself. Nevertheless, the high values of charcoal production sites on the probability surface, very similar to that of pastoral sites, might cast doubt upon the assumed strict relation between the selected association of environmental variables and a single productive function.

The results of the case study can shed light on both the strengths and biases of the current application of predictive models to Alpine cultural heritage, stressing the importance of the testing procedure in order to assess their actual representativeness (Verhagen and Whitley 2020).

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103. Detecting and interpreting fossorial marks in mountainous environment: From ground surveys to UAV prospections

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Since the very beginning of aerial archaeology, surface anomalies like soil, vegetation and shadow marks have always been the main elements for the identification of the buried archaeological record through remote sensing.

The increasing resolution of passive sensors and the introduction of active sensors (such as Lidar and SAR) have enabled a substantial step forward in the detection and interpretation of such anomalies. Furthermore, the advent of UAVs (Unmanned Aerial Vehicle) has given an outstanding contribution on the acquisition of remotely sensed data with ultra-high spatial resolution; this, in turn, resulted in an even more efficient identification of surface traces with archaeological significance. The technological contribution of these methodologies has triggered new challenges and new analytical and interpretative possibilities for the study of archaeological landscapes.

This paper aims to explore a peculiar type of surface anomalies which is usually associated by the archaeologists with post-depositional bioturbation processes: the molehills or, more generally, small piles of soil created by burrowing animals. It is indeed undeniable that the excavation of tunnels affects the buried archaeological record and compromises the stratigraphy causing a loss of information (Wilkinson, Richards, and Humphreys 2009). But despite disturbing the stratigraphy, these actions can also bring to the surface evidence of what is lying underneath the ground; for this reason, such traces – identified and recognized thanks to aerial and ground surveys

– can be used to identify and define the extension of archaeological sites and sometimes even those of specific structures. Anthropogenic layers are indeed the ideal ecosystem for the proliferation of micro-mammals, because of the lower compactness in the sediment and the greater supply of organic matter useful for their subsistence. Previous works have provided a very clear evidence of the usefulness of molehills and similar structures as a precious source of information during ground surveys (Sapir and Faust 2016; Trachet et al. 2017). However, in this presentation we want to focus on the potential of UAVs for investigating the surface patterns of these structures and their relevance in the archaeological interpretation of buried archaeological remains. Also, distinguishing the burrowing species involved case by case represents an exceptional source of information, as ethological studies can help in reconstructing the average dimension and penetration of the tunnelling, thus offering improved data regarding the maximum depth of the resulting material, both soil sediments and archaeological remains.

For this purpose, three case studies belonging to different chronological periods, but all located in mountainous areas, have been selected: the protohistoric site of Monte Corgnon in the municipality of Lusiana (Vicenza), a group of Great War trenches in the Laiten area – Asiago (Vicenza) and a series of charcoal pits distributed along the Prealps of Veneto. By analysing the results obtained in these sites, the presentation will illustrate the potential of UAV imaging for analysing the pattern of surface traces left by fossorial mammals, mostly moles and voles, but also including badgers, rabbits, and foxes.

From a methodological point of view, an approach combining qualitative analysis with quantitative data was adopted. The study involved a systematic application of field survey, UAV-derived imagery, historical aerial photographs (which proved particularly helpful as a validation strategy for the case study relating to the First World War), and distribution analysis. The process pipeline varied according to the case study, but included in all cases field observations, analysis of the exposed stratigraphic windows, and acquisitions with UAVs, and GPS.

Two different commercial UAVs of the DJI company, a Phantom 2 and a Mavic 2 pro, were used for drone acquisitions. The flight altitude was always quite low, between 5 and 10 m, to grant an adequate spatial resolution.

Historical aerial photographs were only employed for the validation process in the case study of the Laiten of Asiago. These are frames taken by the French Air Force between 16 March and 7 October 1918, during the last year of the First World War.

Only for the protohistoric settlement of Monte Corgnon, we collected and quantified the artefacts discovered on each of the molehills. This allowed us to produce distribution and density (both point and kernel) maps concerning the quantification of artefacts.

The use of multiple of methodological approaches is of course dependent from the research questions and the type of archaeological structure investigated.

Finally, it is important to underline that this reappropriation of anthropogenic layers and structures by the fossorial fauna fits very well in the framework of site formation processes caused by a continuous alternation of natural and anthropic interactions with the archaeological record. Yet their study – not only from a terrestrial, but also from an aerial perspective – can provide very important clues to interpret the extent and preservation rate of subsurface archaeological structures, offering a time and cost-efficient method to guide archaeological surveys.

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113. Continuity and discontinuity: Creation of a predictive model for the study of the landscape from Middle Age to the Great War in Valsugana Valley, Trento, Italy

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In the early 2000s, predictive modelling represented a pioneering field of research for the study of human communities interfacing with and exploiting the local area (Wescott and Brandon 2003). In recent years, the improvement of user practices and a greater archaeological sensitivity in the exploitation of data have made this practice particularly successful. Predictive modelling has revealed particularly useful for the study of mountainous areas, whose archaeological research is hampered due to the difficult access to the contexts. The aim of the research is the creation of a predictive model for the detection of control places (Magnini and Bettineschi 2021) in the Valsugana area, an important and strategic valley in south-eastern Trentino, with the purpose of defining the continuity of exploitation of such sites between the medieval and post-medieval ages and the First World War; the further goal is to test the parameters of the model in different areas for the identification of possible unknown sites. The model is developed from available archaeological data such as medieval castles and hillforts, and military data coming from historical cartographic maps such as forts, artillery emplacements and observation outposts. The data-driven methodology - used to develop the predictive model - calculates settlement probability on environmental statistics of already identified sites (Verhagen 2018). The starting data comes from two geodatabases: the first of which is owned by Autonomous Province of Trento, that stores archaeological finds in the Trentino territory, and the second one concerning the First World War features mapped starting from historical cartography. LIDAR data were also taken into account, from which slope, local dominance, cumulative visibility and aspect were processed, in order to get a general picture of the orography and visibility of the whole area. The initial data package was implemented with land use shapefiles, hydrography and isohypses for the definition of the height range, in which the military features are developed. In the overall development of the model only a half of the sites are used as a starting point for the analysis. Then the processed data were reclassified since the output data did not have comparable values making pairwise comparison difficult. The reclassification of the raster data was made on the basis of ten classes in order to have whole numbers and thus to be more manageable and intuitive for the subsequent weighting of the variables. The maps created, once evaluated through pairwise comparison, defined the importance of each environmental variable through a correlation matrix. The variables taken into consideration and considered most important on a statistical basis were the slope (expressed as a percentage), the dominance of individual artillery positions (particularly those associated with small-calibre guns), geographical exposure, elevation and the cumulative visibility of the single raster. For the creation of the model, all the elaborations carried out have been correlated with the average of the values obtained for each individual map and finally summed up to create the predictive map. Then, to validate the result, the map has been tested by taking into account sites and locations not included in the first analysis. The additional areas, identified by the predictive model, were subject to sample verification through ground truth in order to assess the reliability of the model on unknown land. Among these, potential artillery and observation posts and areas of anthropic exploitation of mountain resources were identified. Thus, it has been noted that the artillery emplacements, which by their very nature are located at fundamental junctions for the passage of men and vehicles and therefore in particular positions of dominance along the valley floor, largely reflect the same position as the fortifications of the medieval age. The reconnaissance on the ground identified areas of high potential linked to the presence of anthropic structures from different eras at certain obligatory passage points. The discriminating variable for the type of study carried out was visibility, in this sense it was noted how unlike artillery emplacements tending to be "hidden" from the enemy's eyes; so, in order not to be hit, territory observation medieval structures were built to cover a wide spectrum of view so as to control the entire area. In any case, at least for the test area and validation of the results, a great correspondence can be noted between the artillery positions and the areas used for the defence of the Trentino valleys in the mediaeval age, a symptom of the fact that the mountainous territory, due to its impervious characteristics, makes it necessary to massively re-use certain areas used in more ancient times for defence.

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117. Valmaron Valley: A First World War logistics centre above the Venetian Prealps, Italy

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The First World War (1915-1918 on the Italian Front) represents the major historical event that most changed the landscape conformation of the Plateau of the Seven Municipality territory. Indeed, the militarisation of the landscape occurred in a relatively short period of time and with a impact degree on the morphology and appearance of the environment never encountered before.

The remains of the war, structures such as trenches, dugouts, tunnels, artillery emplacements, barracks, field hospitals, graveyards, but also war-related infrastructures as roads, walkways, cableways and, lastly, shelling and its destructive effect on the natural environments (deforestation) and on the human settlements (most often razed to the ground), constitute the specific features of the First World War landscape. Today, this conflict landscape appears as a fossil landscape, which often finds it difficult to fit into the concept of collective heritage, because it is often discarded and undervalued by the community, if not completely unknown. In addition, these material ruins of the conflict are under continuous threat of transformation and obliteration, due to human activities or natural calamities.

Furthermore, in the last decades, Conflict Archaeology represented - and still represents – a prolific field of research aiming at developing new and scientific insights about our knowledge and understanding of the past conflicts. One of its most specialized domains (spatially, temporally, functionally) is the Archaeology of the First World War, a laboratory of potential new lines of research, based on several methodological approaches and techniques related to the context of investigation: in addition to classical archaeological methods, such as excavations or studies of the material culture (Saunders 2003), the First World War heritage is investigated also by using remote sensing applications (Mlekuž et al. 2016; Magnini et al. 2022).

The aim of this research is documenting, monitoring and studying a war-related logistic and health centre located in the eastern part of the Plateau of the Seven Municipality, specifically at Località Valmaron (Vicenza, Italy). The site is located along a valley, at 1352m above sea level, surrounded to the west by Monte della Forcellona (1487m), to the east by Colle del Lupo (1512m) and to the south by Cima Chempele (1547m). A main road crosses the valley, linking Enego to Marcesina Plain. A further way go up the valley to the north, also linking up with the northernmost part of the Plain.

In order to reconstruct the warscape, a few historical aerial images belonging to "Archivio Piatti" were taken into account: the place has been photographed by squadron Sal22 of the French Aviation on 14 July 1918. At the moment of the aerial image acquisition, the whole area represented the rearguard zone of the Imperial Army. The images provide an unique source of information regarding military features: open-air deposits of materials, barracks, healthcare facilities and trenches are visible. Moreover, a graveyard is viewable: there are no bibliographical references to this structure, nor does it appear on the map of cemeteries located on the Plateau of the Seven Municipalities drawn up in 1923. Therefore, the aerial photographs were uploaded into a GIS software (ArcGIS PRO) and subsequently georeferenced, using the regional technical map (carta tecnica regionale – CTR) available online by the Veneto Region as basis. The visible and recognizable military features were vectorized. Afterwards, the digitized warscape was compared with today's landscape: surprisingly, a very large number of structures are still present in the area, in particular the terraces built for the construction of the barracks, the cemetery and the related paths. Finally, it was also possible to record the level of forestation of the area under investigation, as certaining the absence of forest on the slopes to the west of Valmaron.

To better understand the spatial distribution and the relationship between the war-related features and the landscape, the whole area (187ha) has been investigated through UAV mapping to obtain a high-resolution Digital Terrain Model (DTM), supplementing ALS-derived data available by the Regione Veneto (resolution: 3x3m). Then, remote and near sensing analysis have been integrated by ground truthing.

Field work confirmed the presence of military facilities. Furthermore, it was possible to document obliteration processes with regard to the trenches and the graveyard. The former, being on the top of the hills covered by the forest to the west of the valley, were intentionally filled by timber salvage operators following the Vaia storm in October 2018. As regards the cemetery, also in this case the site has been partially obliterated due to the timber transporting machines. Finally, a new forest road has been built thus affecting some war-related barrack areas.

In the end, the study of archival data, complemented by remote sensing and ground survey, can lead us to new insights into the employment and exploitation of mountains, thus broadening the knowledge of places otherwise lost to memory.

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151. Rescuing Rosalila: 3D scanning of complex archaeological tunnels for conservation efforts in Honduras

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Rosalila often referred to as the "mountain of Yax K'uk Mo" is nestled in the mountainous Copan Valley of Honduras. Rosalila, commissioned near the beginning of the 6th century CE, possibly by Copan's fourth ruler, is a uniquely preserved ancient Maya temple in the ancient city of Copan. Today, Copan is an UNESCO World Heritage site located in northwestern Honduras; however, from the 5th to 9th centuries Copan was a powerful polity in the Maya world. Rosalila, one of the most important ancient Maya temples for scientific inquiry, is in grave danger due to environmental stresses and complex loading factors. Located within Temple 16 (Figure 18), a multi-layered construction encompassing several royal temples including the tomb of the founder of Copan's dynasty, Yax K'uk Mo, dating to 437 CE, represents a sacred mountain. Copan's final dynastic ruler, Yax Pasaj Chan Yopaat (Ruler 16), commissioned the final construction phase of Temple 16 in the late 8th century. While the Maya destroyed the vast majority of buildings to create solid foundations for new buildings that went up over them, Rosalila was not only preserved but also carefully encased with a thick layer of white plaster before the Maya sealed it by a fill of mud and cobbles. Rosalila has three levels reaching a total height of 12.9 meters. It is within the sacred spaces created by these high vaulted rooms (with an average height of 4.80 meters) that the Maya carried out elaborate ceremonies documented by the plaster walls covered in soot from the burning of incense and torches. Importantly, it is a rare case where we have brilliantly coloured stucco masks that provide data on color pigments and iconography that are foundational to our understanding of temple design and the cosmological significance of ancient Maya architecture (Agurcia Fasquelle 2016).

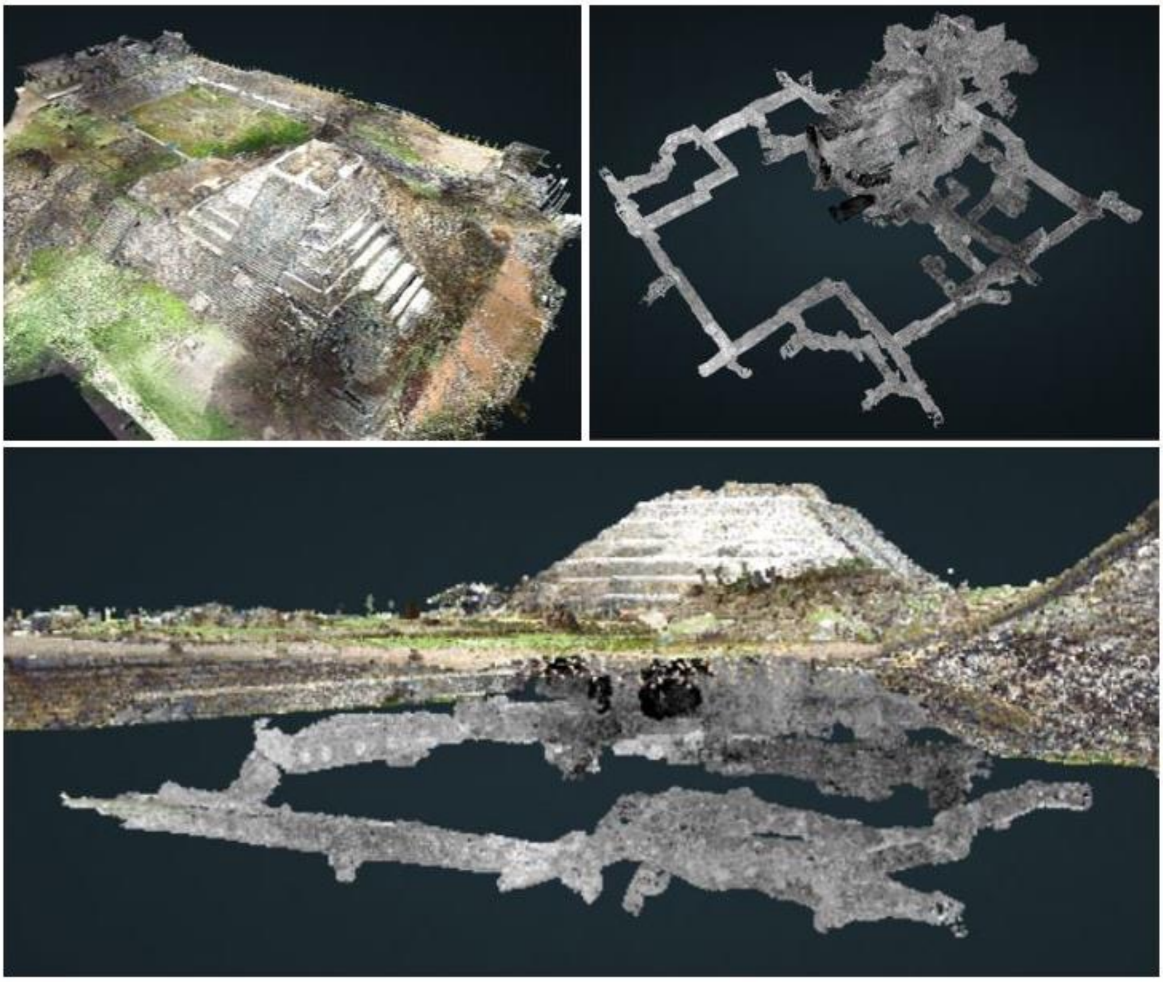

Figure 18. Exterior NE Facing View of Temple 16 (top left); Interior View of Rosalila Excavation Tunnels of Temple 16 (top right); SW Facing View of Temple 16 with Excavation Tunnels below surface (bottom). Visualized in Potree, (Rescuing Rosalila 3D Scanning Project)

Given the importance of Rosalila to our understanding of ancient Maya society, the Rescuing Rosalila Project, directed by Honduran archaeologist Ricardo Agurcia Fasquelle, is spearheading international conservation efforts for Rosalila. As part of conservation efforts, we have acquired low and high-resolution laser scans of the excavation tunnels within Temple 16, specifically focusing on those tunnels that likely impact the stability and preservation of Rosalila. Additionally, we have acquired low-resolution laser scans and UAV photogrammetric imagery of Temple 16's exterior to georeference the tunnels and assess vegetation impacts such as the large trees whose roots now infiltrate the temple. While 3D scanning has been employed at Copan and other archaeological sites (Remondino et al. 2009; Wood et al. 2017), the complexity and large datasets (encompassing over 1000 scans), with the majority from winding excavation tunnels at multiple depths and orientations, has resulted in a complex dataset. This dataset has led to unique challenges for developing a structural model to evaluate the primary causes of structural deterioration of Rosalila and make recommendations for preservation efforts. These efforts are critical due to human-induced climate changes resulting in larger and more frequent hurricanes that have led to more rapid deterioration of Rosalila and Temple 16.

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164. Non-invasive approach to Ancestral Pueblo settlement studies: Results of archaeological investigations in the Canyons of the Ancients National Monument, Colorado, USA

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Non-invasive approach to Ancestral Pueblo settlement studies: Archaeological investigations in the Canyons of the Ancients National Monument, Colorado, USA

The paper is focusing on non-invasive methods of documenting and subsequent analysis in various software of archaeological sites located in three canyons of southwestern Colorado in the North American Southwest. There are around forty Ancestral Pueblo culture habitation sites with sandstone architecture and rock art located mainly in canyon alcoves or very close to them (cliff dwellings) and on open spaces, including towers functioned possible as defensive and communication features as well as farming fields and possible water reservoirs. All sites are dated roughly to the thirteenth century AD. This area is within the Canyons of the Ancients National Monument, the legally protected area managed by the US Bureau of Land Management. The project focuses on the reconstruction of social and cultural changes in the area in the thirteenth century AD and is conducted by the Jagiellonian University in Kraków.

Native American populations had inhabited this region since the pre-Columbian period and left an enormous amount of archaeological traces, mainly sandstone architecture and rock art (Cordell 1997; Palonka 2022). Ancestral Pueblo culture created a micro-regional community of allied sites located in the Lower Sand Canyon area that was changing through time. Using non-invasive methods of survey and documentation we would like to trace and line up the history of the inhabitants of this micro-region as well as demographic fluctuations and migrations. A significant part of digital documentation was conducted using 3D terrestrial laser scanning and photogrammetry methods (and other advanced methods of digital photography-e.g., Opitz and Cowley 2013; Palonka et al. 2021) at the alcoves with architecture and rock art. It was supplemented by UAV photogrammetry at the few sites and the surrounding terrain and recently by using LiDAR. Part of the project is also devoted to geophysical research (mainly electrical resistivity and magnetometry with some addition of GPR); from 2011 to 2019 geophysical research was conducted in around twenty sites. It gave us satisfying results revealing many buildings buried underground and changed our views about the demography of this settlement complex. Also, we are trying to approach the research of this unique micro-region on a macro scale:

Examining sites using methods of tele-detection. We are integrating processed LiDAR DEMs in different visualizations as separate layers with satellite photos (also as different layers). That kind of view is helping us to mark new archaeological sites, and fill blank pages in settlement history of the area, as well as relations between sites, environment, and the landscape by applying spatial analyses methods. For example, we are studying location of settlements in relation to water sources and intervisibility between the sites. We would like to present some of the results of our work, to show how much new information and analysis (including integration of data in GIS database) can be done with the application of different digital techniques in this specific area. Also, we would like to show the strengths and weaknesses of using particular methods in this specific landscape and archaeological sites.

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Session 12. Formal modelling and models of social complexity – in concepts, numbers, equations and agents (Part 1)

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Claudio Cioffi-Revilla, George Mason University, USA

Room 14

Introduction	13:30 - 13:45
105. Simulating the networks of cities in the Eastern Mediterranean *Crawford*, Artopoulos and Romanowska*	13:45 - 14:10
99. Conceptual and computational modelling of social complexity and urban networks in Anatolia *Daems**	14:10 - 14:35
174. Theoretical analysis of the Auerbach-Zipf law of social complexity *Cioffi-Revilla**	14:35 - 15:00

Introduction

CAA has a historically long tradition fostering formal theory and research on social complexity, building on earlier foundations by social scientists (including archaeologists), mathematicians, and computer scientists. These approaches proliferated in archaeology as they helped researchers to understand past societies, their evolution, transformations and strategies in new and exciting ways. This stands in contrast to the rapid empirical shift whereby researchers increasingly invest in data-intensive approaches and digital means of analysing them. As a result, we are seeing a significant rise in robust and more mature scientific practices in archaeology for examining past peoples and their polities in a systematic, formal, testable, and reproducible way.

Modelling links data and, in particular, trends in data to causal processes (whether social, natural, cultural, etc) that gave rise to them. While data analysis answers such questions as "what?", "where?", "when?" or "how many?", modelling focuses on "why?" and "how?" making the two approaches complementary and in many cases necessary if the goal is to understand long-term trajectories of human groups.

This session is dedicated to archaeological models of all types: conceptual, mathematical, or computational. To stimulate a discussion on the role of models and modelling in archaeology we hope to encourage wider use of formal methodologies, in particular, computational models. The goals of this session are:

- To showcase the best applications of different forms of formal modelling to archaeological questions concerned with social complexity. This can include but is not limited to agent-based models, mathematical models, spatial and statistical models, formal ontologies etc.

- To exchange new and exciting avenues of research such as new modelling methods, surprising applications of models from other disciplines, or new techniques and tools that other modellers should be aware of.
- To discuss the "academic outreach" of the modelling community and explore innovative ways of teaching, presenting, and using formal models in and outside of the world of academia.

While the format of the session calls for standard 20-minute presentations we will happily consider alternative formats, such as software demos, coordinated discussions over pilot studies or even interpretative dance. We will encourage participants to share publications, drafts, data, and code prior to the event so that participants can engage in a more informed and meaningful exchange at the conference venue.

Papers addressing the following themes and other investigations of social complexity origins and pre-modern phases are sought for this session:

1. Formal models of social complexity, whether computational or mathematical
    a) Agent-based models of the emergence of social complexity (With or without geospatial landscapes)
    b) Mathematical models of social complexity formative phases
2. Computational or mathematical tools for analysis of long-term patterns of social complexity
    a) Braudelian long-durée
    b) Cycling patterns of social complexity
    c) Long-range geospatial analysis of social complexity
    d) Spatiotemporal hyperspatial models of social complexity
3. Formal conceptual analysis of social complexity
    a) Use of computational tools such as UML, SysML, and other formalism for conceptual analysis
    b) Network-theoretic models of social complexity
    c) Comparative conceptual analysis of social complexity using formal methods
4. Formative phases of social complexity
5. Social complexity in comparative perspective: cross-polity analysis
6. Data sonification for social complexity

105. Simulating the networks of cities in the Eastern Mediterranean

Katherine Crawford, The Cyprus Institute

Georgios Artopoulos, The Cyprus Institute

Iza Romanowska, Aarhus University

The Eastern Mediterranean is a politically dynamic and environmentally sensitive region, hosting some of the world's longest records of urban evolution. Despite the importance of cities, our understanding of the mechanics that contribute to their collapse or continuity over broad timespans remains narrowly studied, locked in disciplinary silos. While archaeological and historical research has a long tradition of studying the development of past cities, focus has been broadly given to studying the rise and collapse of civilizations rather than considering urbanisation phenomena and the evolution of cities within regional networks.

The use of ABM is especially well suited for studying the topic of regional urban systems' collapse and consequently of some cities' resilience. Despite its potential, only a few ABM models have been developed that specially consider ancient urban dynamics (Wilkinson et al. 2007). A major issue that has limited previous studies on large reginal scales is the lack of accessible regional datasets.

The project, 'EIDOS of a City: simulating the collapse and resilience of ancient Eastern Mediterranean urban environment via agent-based modelling', is a first attempt towards addressing the question of why some cities lasted millennia while others collapsed at the first sign of instability within the Eastern Mediterranean. Big data, consisting of over 30,000 settlements from the Levant, Orontes Watershed, and Cyprus, coupled with agent-based modelling is being used to identify some of the mechanisms that contributed to urban collapse or resilience within the region.

The model presented in this paper, which forms a component of the EIDOS project, aims to simulate the rise and fall of city populations based on different variables within a larger regional network of cities across Cyprus and the Levant. Drawing upon the large dataset already compiled for the project, the model will focus will attempt simulating settlement networks during the bronze age, as an initial case study. One of the objectives is exploring scenarios about the rise and fall of city populations based on measures of economic exchange, drawing upon the Mercury model (Brughmans and Poblome 2016). The base economic standing of each city is influenced by one or more of the following: access to raw metallurgical deposits, metallurgical workshops, and pottery production workshops. Economic exchange can occur between settlements, connected via roads and waterways, within a specified geographic radius or between harbours. The model aims to track if increased economic income results in increased population and vice versa. The ABM results will then be compared to the settlement persistence patterns studied from the larger settlement dataset.

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99. Conceptual and computational modelling of social complexity and urban networks in Anatolia

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Human societies have changed dramatically over the last 12,000 years, from small hunter-gatherer bands to highly urbanized, industrialized, and globally connected societies. These changes are often interpreted as increasing social complexity. Yet, what exactly constitutes social complexity and how it changes over time is not always specified. It is all too easy to perceive this change as an almost teleological sequence of progress and advancement towards a better society. No doubt modern societies have produced many benefits worthy of being characterized as progress. However, by recasting all of history in this light, we run the risk of discarding the past as an inherently inferior and altogether different world. In doing so, we lose out on the benefits of understanding long-term patterns of change (and stability) to inform our present and future. The study of the emergence of social complexity in human communities is considered one of the "grand challenges" for archaeology in the 21st century (Kintigh et al. 2014). Even though social complexity is a topical subject in current archaeological debate, (implicit) teleological and Eurocentric discourses of social evolutionary complexity remain prevalent (Pluciennik 2005).

In this paper, I present a novel framework of social complexity formation centred on three causal mechanisms of decision-making: connectivity, diversification and intensification. These mechanisms drive pushing and pulling forces that shape flows of energy, resources and information in the aggregation and dispersal of social complexity. This framework draws from complex systems thinking as a suitable ontological framework to provide a bottom-up approach to social complexity as an emergent property in human societies. In this sense, human societies can be conceptualized as complex systems aggregating and/or dispersing flows of energy, resources and information to sustain their population and maintain/expand their organisational structures (Daems 2021).

I will show how this conceptual model can be translated into a computational model, using agent-based modelling as the main methodological tool. I will use this computational framework to explore the interplay between causal mechanisms in driving social complexity trajectories. I then outline how this model exploration can be used to shed new lights on archaeological data and case studies. I particularly draw comparisons with a case study of southern Anatolia (modern-day Turkey) from Iron Age to Hellenistic times (1200-100 BCE). In this case study, I use archaeological data such as settlement hierarchies, artisanal production and distribution, as proxies for the capture, processing and usage of flows of energy, resources and information to study resilience and change in long-term trajectories of social complexity.

This study shows that shifts and trade-offs in decision-making can have long-lasting consequences in social complexity trajectories expressed in human-environment interactions. It also raises an important point of reflection for the long-term consequences of decision-making in the present and the initiation of future pathways of development. The framework proposed here provides a suitable approach to use the past to inform such decision-making processes through the lens of complex systems thinking. This work will therefore not only provide the outlines for a novel approach to improving our knowledge of the past sui generis, but also elucidates how understanding long-term trajectories of social complexity can inform trade-offs in decision-making and pathways of complexity formation in the present.

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174. Theoretical analysis of the Auerbach-Zipf law of social complexity

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The mathematical model known to archaeologists as the rank-size rule (Adams 1965; Renfrew and Bahn 2019; Guidi 2000, 2005; Wurzer et al. 2015)—and to most other scientists as Zipf's law—was independently discovered by German physicist Felix Auerbach (1913), and decades later rediscovered and made famous by American linguist Georg Kingsley Zipf (1932, 1935, 1941, 1949). The Auerbach-Zipf law states that in the population settlement system of a polity composed of n settlements, the size of a given population settlement, P, is governed by a harmonic rank-ordered series:

$$P\langle_1, P_2, \cdots, P_n\rangle = P_1 + \frac{1}{2} P_1 + \frac{1}{3} P_1 + \cdots \frac{1}{n} P_{1,} (1)$$

where any given population Pi is proportional to the largest settlement, P1, and inversely proportional to the rank Ri of the settlement. Formally, the Auerbach-Zipf law is a scaling law or power-law given by the well-known hyperbolic equation:

$$P = k \frac{S_1}{R^{\propto}}, (2)$$

where k is a continuous proportionality or scale parameter, R is a discrete variable denoting the settlement's population rank, and ↵ is a continuous shape parameter generally with a value around 2 (with empirically estimated values in the range $1 \gtrsim \hat{\propto} \gtrsim 3$). Thesignificance of the Auerbach-Zipf law cannot be overstated in the interdisciplinary theory of social complexity, mainly because this theoretical model provides an unambiguous and universal (i.e., cross-culturally valid) standard for determining and reliably measuring the emergence of social complexity of a given population settlement pattern (meaning, in decreasing order of population size, the interdependent sizes of all the cities, towns, villages, and hamlets of a regional polity at some point in time τ). All of the above (and obviously much more) is current knowledge in archaeological and social complexity theory.

This paper addresses the following problem: while numerous empirical or statistical analyses of the Auerbach-Zipf law already exist in archaeology (and, more generally, in human geography), surprisingly little attention has been paid to the much broader formal theory of social complexity that is based on this elegant, relatively simple, and universal mathematical law. In this paper we develop social complexity theory by deriving a novel set of results on the Auerbach-Zipf law, based on the observation that this mathematical structure is a hybrid function defined by both continuous (k and ↵) and discrete (R) variables or parameters; as opposed to being a simpler, homogeneous function consisting of solely continuous variables (Cio_ 2021). Moreover, in addition to being hybrid, the Auerbach-Zipf law is also a scalar function; as opposed to being a vector function involving both magnitudes and directions. Being a hybrid scalar function, we shall apply the newly developed nabladot calculus (Cio_ 2014, 2022), which is an appropriate type of calculus for analysing change in hybrid functions (in scalar or vector forms, as the case may be). The paper will begin by providing motivation and initial research questions, in §1, based on the above observations, namely: (1) the well known Auerbach-Zipf law is a hybrid scalar function (a fact not so well known in archaeological theory); and (2) as a hybrid function, the Auerbach-Zipf law contains significant potential for developing the theory of social complexity in new and interesting directions. This motivation also includes a view of the Auerbach-Zipf law as a fundamental mathematical structure that contributes to deeper understanding of the regional origins and subsequent evolution of social complexity. The formal approach is both mathematical and computational.

In §2 we shall introduce and formally define concepts and analytical methods used in the hybrid analysis of the Auerbach-Zipf law. This section also includes a synopsis of nabladot calculus to familiarize readers with the main ideas and analytical methods.

In §3 we shall present a set of results obtained from application of the nabladot calculus to the Auerbach-Zipf law. This section will address results from analysis of the law as a scalar model, some of which are, in turn, scalar results (such as norms, elasticities, and other magnitudes) while others are vector functions and fields (such as the gradient, for analysing change, the divergence, the curl, and the Laplacian, Jacobian, and Hessian fields). In general, these results will demonstrate exactly how population settlement size P depends on each of the independent variables, as defined in equation 2. All results will be presented in three closely related formats: formally, intuitively, and visually, the latter based on various types of graphs of the Auerbach-Zipf law, such as 3D surfaces, contour plots, and vector fields. Computational verification of mathematical results using the Wolfram Mathematica system also deepens and promotes our theoretical understanding. The fourth and final section will discuss the main theoretical findings from this first application of nabladot calculus to social complexity theory, methodological issues encountered in this investigation, and future directions for theoretical and empirical research.

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Session 13. Machine and deep learning methods in archaeological research: beyond site detection (Part 1)

Arnau Garcia-Molsosa, Catalan Institute of Classical Archaeology

Hector A Orengo, Catalan Institute of Classical Archaeology

Iban Berganzo-Besga, Catalan Institute of Classical Archaeology

East Writing School

Introduction	09:00 - 09:15
13. Beyond the Greater Angkor region: Automatic large-scale mapping of Khmer Empire reservoirs in satellite imagery using deep learning *Landauer*, Klassen, van der Kroon and Verschoof-van der Vaart*	09:15 - 09:40
16. An integrated approach for the classification of incompatible, high dimensional data *Vos**	09:40 - 10:05
18. How to deal with an insufficient amount of training data and other insights from hands-on image recognition use with ancient coin data *Gampe* and Tolle*	10:05 - 10:30
Tea/Coffee	
19. Deep convolutional neural networks for remote sensing investigation of looting of the archaeological site of Al-Lisht, Egypt *Woolf**	11:00 - 11:25
135. A new hybrid machine learning algorithm combining lidar and multispectral data for the location of mounds *Berganzo-Besga, Orengo*, Lumbreras, Carrero-Pazos and Fonte*	11:25 - 11:50
33. Applying machine and deep learning to the analysis of stone tool production *Johnson*, Eberl*	11:50 - 12:15
Lunch	
36. Supporting the analysis of a large coin hoard with AI-based methods *Deligio* and Tolle*	13:30 - 13:55
137. Automated identification of complex multi-cell phytoliths: First results, potential and possibilities *Berganzo-Besga, Lumbreras, Ramsey and Orengo**	13:55 - 14:20
59. Structuring data: exploring ways of transforming natural language into database attributes *Hinojosa Baliño**	14:20 - 14:45

Discussion 14:45 - 15:00

Introduction

Although machine learning (ML) and deep learning (DL) related methods have been in use for several decades, they have only been applied to archaeological problems recently. Some early implementations focussed on the classification, seriation and analysis of material culture such as artistic representations (Barceló 1995a and 1995b, Di Ludovico and Ramazzotti 2005), use-wear of prehistoric tools (Van den Dries 1998), historical glass artifacts and ancient coins (Van der Maaten et al. 2007). The application of ML and DL in archaeology has experienced a strong turn towards the detection of archaeological sites during the last years (but see Wright and Gattiglia 2018 and Orengo and Garcia-Molsosa 2019 for the identification of ceramic fragments and Oonk and Spijker 2015 for geochemical analysis) making heavy use of multispectral satellite and lidar data. Since the pioneering work of Menze and Ur 2012, the wider availability of data (in particular high-resolution lidar), cloud computing platforms and AI processes and code has boosted ML and DL site-based detection (e.g. Lisset al. 2017, Trier et al. 2018, Berganzo-Besga et al. 2021).

Despite the importance of site location for the discipline, it is obvious that ML and DL enclose enormous potential to boost many areas of archaeological research, particularly within but not restricted to the field of computer vision. ML and DL are able to build inference models from sample data that can organise information without the need to explicitly program the process. Archaeologists are gaining skills and access to computational resources while, at the same time, new interfaces facilitate the use of these techniques to researchers not specialised in computer methods (see, e.g. Altaweel et al. 2022). The increased availability of models and examples opens the possibility to extend the debate towards how specific historical and archaeological debates can benefit from these new analytical instruments and the knowledge they generate.

This session aims to bring together archaeological ML and DL applications, discuss the problems related to their application and offer insight on to best practices. We welcome contributions about the application of ML and DL to different aspects of archaeological research and practice. With that perspective, we expect to provide a platform where the participants can observe and discuss the ensemble of opportunities that ML and DL can provide, with special interest on the possibility to create synergies between different fields of application, that are being developed in isolation.

Some of the suggested topics for the session are:

- Case studies on the application of AI to different sources of archaeological information. That can include the analysis of texts, artistic representations, bioarchaeological remains, material culture or archaeological sites. Combinations of such will be particularly welcome.
- Best practices and procedures, which can include comparative analysis. We are interest on examples on how to approach sensible datasets and how to facilitate reproducibility and Open Science principles in general.
- Big-data, data cleaning, data augmentation and data ingestion, as transversal challenges in many fields. Contributions addressing how researchers are developing, working with and taking advantage of large datasets, problems arising and potential solutions.

- The continuously increasing availability of detectors and methods makes sometimes difficult to select the best processes and algorithms for specific tasks. In this regard we welcome talks on algorithm selection, modification and performance evaluation.
- Talks addressing the development of computationally cost-effective workflows, in particular for the use or analysis of large datasets and the application of intensive computing processes will constitute a welcome addition to the session's discussion.

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13. Beyond the Greater Angkor region: Automatic large-scale mapping of Khmer Empire reservoirs in satellite imagery using deep learning

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Sarah Klassen, Leiden University

Josine van der Kroon, Leiden University

Wouter Verschoof-van der Vaart, Leiden University

The Khmer Empire controlled much of mainland Southeast Asia from 800–1300 CE. During this time, the medieval Khmer built several urban centres, including the massive low-density urban complex of Angkor. Recent research suggests that as many as 900,000 people lived in the Greater Angkor Region at its height (Klassen et al. 2021). The Greater Angkor Region includes over 1000 temple communities with over 3000 associated reservoirs and 1000 km2 of rice fields. These temple communities were primarily engaged with rice agriculture and provided the economic basis needed for the rise of urbanism at Angkor. Researchers have now mapped over 25,000 features in the Greater Angkor Region and used this spatial data to estimate the amount of harnessed water on the landscape, its im-pact on the adaptive capacity of the site, and to evaluate the process of agricultural intensification that enabled urbanization (Klassen et al. 2021). While much work has been done at Angkor, little work has been done to determine the extent of medieval Khmer agricultural systems beyond the boundaries that delineate the Greater Angkor Region. Previous opportunistic surveys have identified over 4000 temples in Cambodia. If each temple has approximately three associated reservoirs, we can expect to find over 10,000 reservoirs across Cambodia. Based on these numbers, it is clear that the objective of mapping all reservoirs would require some degree of computational automation to map these overwhelming numbers of features in the landscape. Subsequently, this data can reveal regional systems of agricultural production and new insights in the Khmer landscape outside the Greater Angkor Region.

Data source acquisition and Neural Network training

As a remote sensing data source to detect reservoirs, this project uses Microsoft Bing satellite imagery. The main reason is that other data sources are either only available for minor parts of our research area (such as LiDAR), have a substantially lower resolution (such as multichannel satellites), or are too costly (Bing is free of charge within some limits). First, we used shapefiles containing some 200 recently (and very precisely) mapped reservoirs from different regions of Cambodia to determine rectangular areas. Subsequently, these were cut into tiles of approximately 150x150 m2, including some surrounding landscape. For every tile a so-called binary mask tile was computed, containing zero pixel values outside reservoirs and non-zero values inside.

Both tiles and masks served as input for the training of a Deep Learning Semantic Segmentation model, based on a Convolutional Neural Network. This technique has become state-of-the-art for automatically delineating objects from background in images. The segmentation model consisted of an DeepLabV3+ architecture and was implemented in PyTorch (Chen et al. 2017).

Method refinement

Initial tests of the trained approach already showed some promising results. However, due to two factors it was not yet suitable for large-scale application:

- Occlusion: a well-known problem of satellite images in the visual spectrum is clouds occluding the earth's surface. These images could be removed manually from the limited dataset of 200 reservoirs, but some automation would become inevitable if larger datasets or large test areas were to be addressed;
- Changing landscape: Although the original training dataset came from different regions in Cambodia, it soon became apparent that the geological and landscape patterns or "image backgrounds" vary greatly across southeast Asia. These differences had a (severe) impact on the detection quality.

We addressed both problems by "going big": Fortunately, approximately 3,000 reservoirs had been mapped over the past 100 years across Cambodia and could serve as additional input, thus mitigating the regional differences and promising to boost the detection quality. However, they could only be used with some caution: As a large portion was mapped in the more distant past, there were numerous cases where reservoirs were no longer visible or had changed their shapes substantially due to drought or changes in land use. Using these in training of the Neural Network would lead to an un-wanted increase in false detections. Nevertheless, reviewing all of them manually would have been impractical due to their large number.

Figure 19. Actual (yellow) and predicted (grey) reservoir shapes in a test region near Angkor Wat.

We, therefore, utilised techniques derived from the field of Semi-Supervised Learning (Sohn et al. 2020) and Pseudo-Labelling: Simply said, all 3,000 manually mapped reservoirs were turned into tiles and subsequently fed into the segmentation model trained on the smaller (200 samples) dataset. If the model's prediction was somewhat similar to the manually mapped reservoir shape (or, more precisely, their Jaccard similarity coefficient exceeded a certain threshold obtained empirically) we were confident that their visual features were sufficiently similar to the samples in the original precisely mapped sample set. Therefore, these tiles were added to the larger dataset and we subsequently used them to re-train the model, thus obtaining a new model that can detect reservoirs in a more generalised set of landscape types.

Preliminary results and outlook

Figure 19 provides an example of current results: Yellow shapes marked with ID numbers represent reservoirs mapped by experienced archaeologists (i.e., ground truth). Grey patterns show reservoir predictions obtained from the developed segmentation model. As can be observed, some reservoirs are currently not detected at all (e.g., top left of image), but on average, about 50 to 60 percent are successfully detected, somewhat depending on the underlying landscape. Note that the objective of also detecting the exact boundaries of reservoirs leaves challenges. Besides, the detection quality drops to almost zero in forested regions —a result that was been expected as even human observers face major difficulties identifying reservoirs partly hidden by tree canopy. Apart from adding even more samples to the training dataset with the method outline above, we currently aim at utilising recent progress in Deep Learning research by including advanced model backbone architectures such as Swin Transformers. The ultimate goal is to provide a tool for archaeologists to automatically map reservoirs on a broad spatial scale (e.g., a region or even an entire country), which involves minimal involvement of the archaeologists (e.g., to remove false positives and add missing detections manually).

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16. An integrated approach for the classification of incompatible, high dimensional data

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Classification systems in archaeology have traditionally been applied to artefacts or for site prospection. However, a wealth of evidence beyond that found in objects and site locations could benefit from the application of machine learning algorithms to aid the interpretation of ancient behaviour. The incorporation of various scientific methods is increasingly used in archaeological investigations, the information derived from these provides a good example of the type of data that can benefit from classification. However, the results achieved by such methods can be ambiguous or vague, and their combined use is often complicated by the incompatibility of different datasets.

This paper discusses the value of a model integrating decision tree algorithms and Bayesian confirmation to archaeological research by: (a) increasing the identification potential of different proxies of ancient behaviour; (b) allowing for the combination of incompatible data types, for example continuous and discrete data; and (c) aiding the analysis of high dimensional data. A case study presented will focus on the use of paleoenvironmental indicators of activities, geochemistry and phytolith analysis, to characterise activity areas in the Neolithic sites of Wadi el-Jilat, Jordan. In this case study, integrating Bayesian confirmation with a decision tree algorithm was used to tackle issues of vagueness and equifinality inherent to the data, providing a means to associate the existing identification of activity areas with probabilities and alternative context categories (Vos et al. 2021).

The combination of the two datasets as part of a single model enabled us to refine the initial interpretation of the use of space at the archaeological sites by providing an alternative identification for certain activity areas. The model used in this study has wider applications than its use on paleoenvironmental data within a spatial research setting, as any field seeking to incorporate expert opinion with additional sources of information could benefit from its application. The main advantage of such an approach is that it allows for the combination of various sources of information and interpretations, a useful quality in relation to the endless possible manifestations of human behaviour in the past, analysed and recorded with different data formats.

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18. How to deal with an insufficient amount of training data and other insights from hands-on image recognition use with ancient coin data

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The practical application of machine learning (ML) methods like image recognition with the help of convolutional neural networks (CNNs) to archaeological material like coins brings a lot of different challenges. We aim to present a wider view on these challenges, our achieved results and the insights we learned in dealing with the challenges of training a machine learning model with numismatic data.

In our current project "Data Quality for Numismatics based on Natural language processing and Neural Networks" (D4N4) we want to implement a coin type recognition which covers as many coin types as possible from the "Corpus Nummorum" (CN) dataset. The associated database includes more than 40,000 coins from four different ancient landscapes (Thrace, Moesia Inferior, Troas and Mysia). In the last years a typology was elaborated with approx. 19,000 different types broken down mainly by the cities' mints. Due to the large number of coin types, the amount of coins per type leads to an insufficient image recognition training set (in average only about two coins per type). In previous approaches we accomplished good results with a twenty coins per type threshold (Gampe 2021; Gampe and Tolle 2019). However, if we apply this threshold on our current task only 88 types are covered. This big discrepancy to the total number of types forced us to think of new ways to deal with this issue.

We are currently pursuing two approaches at the same time:

1. We include additional coins and coin images from a digital photo archive (Lübke und Wiedemann) and other sources. We could already improve the number of coin types with more than twenty images to 122. This way approx. 4,600 images are available for training and testing the CNN model on these 122 classes.
2. We combine coin types from the same mint in order to have more images per training-class. So, we are training on CN mints instead of types. As a result we cover 92 classes (76% of all

121 mint classes) with a minimum of twenty coin images associated. This allows us to use about 33,000 coin images from our database for our training and testing procedure. Only about 200 images are distributed among the remaining 29 classes which are sorted out due to the threshold.

We are currently working on more sophisticated ways to combine our coin types:

- By similarities in the design based on natural language processing (NLP).
- By a regional-CNN based object detection applied directly on the images.
- By unsupervised approaches like the Deep Clustering method (Caron et al. 2019).

This way we hope to increase the number of training classes to prevent overfitting on classes with much more coin images than others and at the same time improve the performance while we keep the current coverage.

For comparison: Both approaches currently achieve 77 – 80% Top-1 accuracy on the ML specific metrics. This corresponds to our expectations for a result that could help numismatists in their daily work. Of course, we hope to increase the accuracy in future.

Beside the training data challenge, we encountered several other issues which are not really treated in ML specific papers and guides:

- One of them is a deviation of the Top-1 accuracy test set metric in the last epoch of the training with "TensorFlow Keras" from a manual measurement on the same set. The magnitude of this discrepancy (up to 5%) varies from model to model, but it is a constant problem. There is a risk of overestimating the performance of a model.
- Another thing was the training duration when using a dataset (more than 30,000 images) for learning the mint classification. Using the original image sizes, a training lasts almost five hours on our system. Most of this time was spent with transferring the image data to the graphic cards' memory and downscaling to the input size of our CNN. We discovered that we can shorten this procedure if we do the image scaling beforehand. This way, we could execute a training in approx. one hour instead of five.

But we discovered that this can cause another issue. We use a class activation mapping (CAM) approach to identify regions on the images which have contributed the most to the identification made by our model. We hope to improve the explainability of our results with the generated heatmaps of the salient regions on our images. But we found out that the outcome of these heatmaps depends on the deployed compressing algorithm and the size of the image. This behaviour can cause confusion when the same input image in varying sizes produces different looking heatmaps. However, an influence on the metric numbers could not be determined.

- The last thing we want to highlight is the conversion of the coin image to the input format of our CNN. The data structure is called an "array" and it contains various numeric values representing the image. Depending on the algorithm one can convert an image to an array filled with integers or floating point numbers (float). Our CNN models were trained with arrays of floats. When we used arrays of integers we got inaccurate results for the classes' percentages which makes an assessment of the models' performance almost impossible.

Our technical lessons learned are:

1. A blind trust in the metric numbers issued by the TensorFlow Keras ML library is not appropriate.
2. There are several dependencies between different steps of the training and evaluation process which can influence the output of a model.
3. The use of the same technical settings for training and testing a ML model is needed for a correct evaluation of its performance.

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19. Deep convolutional neural networks for remote sensing investigation of looting of the archaeological site of Al-Lisht, Egypt

Timberlynn Woolf, USC

High-resolution satellite imagery has become a powerful tool and resource for monitoring archaeological site looting and site destruction remotely. The monitoring of damage and looting over time has been largely dependent upon direct human interpretation of images. The manual image comparison method is laborious, time consuming, and prone to human-induced error. Recent advancements in AI are transforming the way we approach scientific questions or problems. AI is leading to transformations across society. The potential of AI in assisting the scientific process is potentially, or even likely revolutionary. To examine the applicability of AI methods to problems in digital archaeology, this study selected the well-known problem of looting pit detection. This allows for a straightforward means of translating the archaeological problem into a deep learning problem and having a meaningful comparison of results. Recently, deep convolutional neural networks (CNNs) have shown astounding performance in object recognition and detection. This study seeks to demonstrate the viability of using CNNs within the field of digital archaeology for the purpose of augmenting or replacing the manual detection of looting. It brings recent advancements from AI to an applied digital archaeology challenge showing the potential AI brings to the field.

For this study, satellite Imagery of the al-Lisht region in Egypt was obtained via grant from the DigitalGlobe Foundation and from publicly available imagery from Google Earth Pro. The Sites selected for this study were; al-Lisht, Dahshur, and Saqqara of the pyramid field regions of Egypt. Site selection of these regions were based on and compared with previously obtained and analysed images of the selected archaeological site of these regions for algorithmic identification of looting in these same areas. These regions were selected by this study and by previous studies based on their multiple instances of looted burial sites, substantial expanses of open desert, and for multiple distractors such as farmland, non-archaeological structures, and modern graveyards. Factors of variation that were considered through this process included viewpoint variation, scale, variation, deformation, illumination, background clutter and intra-class variation.

The first dataset was built from satellite imagery granted by the DigitalGlobe Foundation consisting of WorldView-3 panchromatic imagery from 2017 obtained of the archaeological site of al-Lisht in the pyramid field region of Egypt with a spatial resolution or ground sample distance (GSD) of 0.30m. The second dataset was built using Google Earth Pro with a spatial resolution or ground sample distance (GSD) of 2.5 meters. Sets of publicly-available satellite imagery from Google Earth Pro spanning from 2008 to 2018 were obtained of the site of al-Lisht, Egypt. Dataset building consisted of gathering and labelling, two primary datasets with uniform numbers of images in each category. 300 Individual looting pit images were labelled with site grid location (letter), site location name, location within that grid (upper left etc.), data point count number and data point longitude and latitude. 300 non-looting pit images consisting of the same landscape and resolution absent of looting pits were selected from the same regions. Both pit and non-pit images were then loaded and cropped to 500 x 500 pixels in the online photo editor Pixlr and filed in an image data tracker.

Architecture selection for this study was done on deep convolutional neural network VGG16. By using a CNN previously trained on a large scale image recognition dataset, it is possible to bootstrap the training of a new CNN classifier using layers of the previously trained network architecture and weights and with a new classifier and smaller dataset. This process is called transfer learning. In transfer learning the general features for image recognition (edges, etc.) are transferred to the new network which is then optimized against the specific image data that this study attempts to classify (looting pits). For the looting pit image classification task, feature extraction was used. VGG16 CNN was chosen as the starting point for transfer learning. Publicly available weights from training against ImageNet dataset of 1.4 million images were used. The VGG16 architecture convolutional base of the network which is trained on ImageNet was used to extract interesting features from this study's own pits versus non-pit images, and then trained a pits versus non-pit densely-connected classifier (with only two classes) on top of these features. The VGG16 architecture was modified by removing the final fully-connected classification layers and applying the ImageNet trained weights to the remaining lower layers. This studies own fully-connected classifier was added to fit the recognition task (number and size of inputs, two classes in the classification problem). The weights in this network are optimized by the gradient descent training process. During training, images pass through the VGG16 ImageNet weighted base network which finds general image features. The outputs of the VGG16 network feed into the fully-connected layers (created specifically for classifying the looting pits) which become optimized for looting pit image specific features over the course of training.

Results for this applied methodology in expediting image recognition of looting pits obtained an overall accuracy of 96% with the GEP dataset and 90% accuracy with the DGF dataset. I was able to yield positive results with GEP training accuracy reaching 92%, and validation accuracy reaching 96%, and test accuracy reaching 96%. For DGF training accuracy reaches 93%, validation accuracy reaches 92%, and test accuracy reaches 90%. The running time for performing the classification of 300 images was achieved in 2 to 3 minutes versus the reported human performance on the task. These results show that CNNs can be highly efficient with a high performance in object recognition and detection and proves to be a valuable tool in augmenting or replacing the manual detection of looting. As a preliminary study, these results speak to the promise of using AI for archaeological problems in the future. Though not available at this time, the CNN architecture will be exported and made available to the scientific community as an open tool. I am currently exploring future plans for development of the network and its possible application to other geographical contexts and environments.

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135. A new hybrid machine learning algorithm combining lidar and multispectral data for the location of mounds

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Mounds, are one of the most common archaeological features. These can correspond to funerary tumuli or barrows but also to larger archaeological sites. Therefore, many attempts have been made to automatedly detect mounds, usually applying deep learning detectors to filtered lidar data. Several of these attempts have succeeded in detecting a high percentage of the validation dataset. However, these have usually also incorporated a high number of false positives, which significantly reduce the possibility to use these results for archaeological analysis or for systematic field verification.

In this paper we present a recently published hybrid algorithm (Berganzo et al. 2021) that combines deep learning using a lidar-derived Multi-Scale Relief Model (MSRM) and Sentinel 2 multispectral imagery (level-1C, bands 2-8, 8A, 11 and 12) using a pixel-based machine learning approach for the detection of tumuli in the autonomous region of Galicia (Spain), which extends over a 5% of the country (almost 30000 km^2).

Methods and materials

We employed the lidar-derived digital terrain model (DTM) at 1 m/px freely available from the Galician Regional Government Geographical Portal. After testing several methods for micro-relief visualisation, the DTM was subject to MSRM (fmn = 1, fmx = 19, x = 2) analysis (Orengo and Petrie 2018), which produced the best model for the detection of features. This is perhaps due to the multiscale nature of the MSRM, which assures that the size variability of the mounds will not affect the representation of their shape.

The next step was the training of a pixel-based random forest binary classification algorithm using multitemporal Sentinel 2 multispectral data (Orengo et al. 2020). The algorithm classified the Galician area in pixels that could contain tumuli with a value of 1 and pixels that could not with a value of 0 (e.g. pixels corresponding to urban areas, rocks, roofs, etc.). The classification result was multiplied for the MSRM providing a MSRM in which the only data was in areas conductive to the presence of tumuli (agricultural areas, pastures, forests, etc.). This model was then used to extract and train a Region-based Convolutional Neural Network (R-CNN)-based YOLOv3 detector. An Nvidia Titan XP GPU with 12 GB of RAM hosted at the Computer Vision Centre of the Autonomous University of Barcelona was used to train the DL algorithms. The chosen work environment was the parallel computing platform CUDA 11.2, the ML library Tensorflow 2.1.0, the DL library cuDNN 8.1.1, the software development tool CMake 3.20.2 and the CV library OpenCV 4.5.2.

The training/validation of the YOLO algorithm employed a database with 306 tumuli field validated tumuli. From these, 200 were employed for training and 106 for validation. Data augmentation was also employed adding 400 new images to the training.

Results

The YOLOv3 algorithm has validated the known burial mounds with an AP@0.50 of 66.75% and a loss value of 0.0592. Furthermore, 10,527 burial mounds were detected all over Galicia with a minimum similarity of 25%, a minimum size of 7 m, a maximum size of 74 m, a mean size of 29 m and a mode of 25 m. Likewise, the locations of these detected tumuli were indicated in order to facilitate their identification in the field.

Using the data reserved for validation of the model provided values of 0.64 for Recall and 0.97 for Precision, which indicates a very low presence of false positives. Manual validation using three high-resolution aerial imagery sources indicated that 10.5% of the detected features were FPs, resulting in a detection rate of 89.5%. This suggests that, of the 10,527 tumuli detected approximately 9422 correspond to TPs.

Discussion

Our approach provides a way forward for the detection of tumuli avoiding the inclusion of most false positives. Combining multispectral data, which is able to understand the physicochemical characteristics of the feature with lidar data that can represent its form we obtain a much nuanced 'description' of the feature that can be used to detect it with much higher confidence levels.

The algorithm has been designed for its use with free computational resources and can be applied in areas of the world where topographic data of enough resolution are available. Providing specific training data, this hybrid approach can also be used to detect other types of features where a large number of false positives pose an issue.

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33. Applying machine and deep learning to the analysis of stone tool production

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Because stone tools were used by nearly everyone in all times and places, understanding how stone tools were made and used is essential for interpreting the social, economic, and political processes of ancient societies. Further, stone is also the most durable of all materials used by Pre-Columbian societies in North America and is therefore one of the most common artifact types recovered from archaeological sites. Because the tools themselves are often transported from the places they were made, archaeologists must analyse the debitage, or leftover stone pieces, that are knocked off when making a stone tool. The smallest of these artifacts, micro-debitage measuring < 6mm, tend to be less vulnerable to post-depositional movement from human activities, such as cleaning and sweeping, and natural processes, such as bioturbation and erosion. Because of this, archaeologists can study the spatial organization of micro-debitage to best understand where stone tools were being made at archaeological sites.

Materials and methods

Traditional methods for analysing micro-debitage are tedious and time-consuming, however. Soil samples must be taken from archaeological excavations in order to capture the micro-debitage. Artifacts within these samples are usually separated from the soil matrix through water-screening or flotation, and then archaeologists typically use a microscope to manually differentiate micro-debitage and other artifacts from soil and natural particles. For an experienced analyst, this method can take up to 10 hours per sample. To alleviate these issues, we collaborated with the Data Science Institute at Vanderbilt to develop a novel method for micro-debitage analysis that combines dynamic image analysis and machine learning. Using the same methods employed by prehistoric people, we knapped experimental tools and collected the debitage and micro-debitage after each stage in the production process, including core reduction, thinning, and resharpening, for example. We then ran these assemblages through a 3D soil analyser which took 2D and 3D photos of each individual particle. From these photos, 40 measurements of each particle were taken. We used these measurements to test whether micro-debitage could be automatically detected within soil samples.

Results

Our results indicate that machine learning can accurately classify micro-debitage within soil samples in up to 99 percent of cases. Further, we used the photos from the 3D particle analyser to test whether different material types (in this case, chert and obsidian) could be classified and differentiated using deep learning neural networks. The neural networks maintained a minimum accuracy rate of 96 percent.

Discussion

When applied to archaeological soil samples, these methods have the power to reduce the time needed for micro-debitage analysis by up to 98 percent while simultaneously increasing the transparency, reproducibility, and accuracy of micro-debitage analysis. Thousands of soil samples are taken from archaeological excavations all over the world and are often stored in museums and repositories where few archaeologists ever look at them again. This method has the potential to revolutionize the way that we analyse stone tool production and the way that we use legacy soil samples.

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36. Supporting the analysis of a large coin hoard with AI-based methods

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Karsten Tolle, Goethe-University

The coin Hoard of Le Câtillon II was found in Jersey in 2012, and consists of nearly 70,000 Celtic coins generally attributed to the Coriosolitae, a tribe from Brittany. Identifying and photographing each coin took a great deal of time and manpower. Classification and the die studies are ongoing, and have not yet been completed. Philip de Jersey, who is doing the studies, assumes that this will take at least several more years.

In our current project Classifications and Representations for Networks: From types and characteristics to linked open data for Celtic coinages (ClaReNet), funded by the German Federal Ministry of Education and Research (BMBF), we are applying and evaluating AI-based methods to Le Câtillon II.

We are currently trying to assist in the assignment of coins to types and the die study, including:

- Object detection: Dividing the different denominations based on size.
- Unsupervised image classification:
- Separating coins in bad condition.
- Forming groups using unsupervised methods, the goal being to identify the classes defined by the domain expert.

Data

As input we used images of nearly 60,000 coins, each with an obverse and reverse image. Typically each image shows the coin and a scale represented by a 1cm black bar (Figure 20). It is known that the dataset contains coins of different denominations, more precisely staters, quarter staters and petits billions. The staters of the Coriosolitae are normally separated into six different classes by the domain experts.

Figure 20. Typically the image shows the coin, the scale and the ID given by the expert. Image: Jersey Heritage, CoinID: CATII-C-00001.

Object detection: We used Tensorflow's Object Detection API to detect both the coin and the scale. We applied a model from Tensorflow 2 Detection Model Zoo, more precisely a CenterNet Hourglass104 512x512 model, which has a good time-performance ratio. Using the bounding box for the coin and scale, the size of the coin could be approximated. We calculated the height and width of obverse and reverse, providing four measurements for each coin. With this approach it was also possible to filter fragmentary coins.

Based on a clustering of the calculated size, we could identify two clusters that were in line with the expectation of our domain experts. Coins in a cluster with a centroid at about 2.2 cm correspond to the average size of the staters. The second cluster is around 1.3 cm, which should include quarter staters or petits billions.

There are some problems due to the non-uniformity of the images. Firstly, on some pictures the scale is not shown and therefore a calculation is not possible. For some pictures with very dark areas, the scale was not detected correctly. Lastly, on some pictures either the scale or the coin bounding box was not above the threshold of 90% that we had defined for certainty. As a result, for 2.9% of the coins the size was not calculated.

Unsupervised image classification: Subsequently, methods for unsupervised image classification were used to analyse the dataset. We received a preliminary classification list from the domain experts, but the goal was to avoid using it. The research question here was Whether the classes assigned by the domain experts are also formed by the algorithm, and thus the results verify the list. We focused on the staters, since they represent the majority of the dataset and these are the coins the domain experts so far concentrated on. We decided to use the method presented in the paper “Deep Clustering for Unsupervised Learning of Visual Features” (Caron et al. 2018). This combines a convolutional neural network (CNN) with unsupervised clustering algorithms, such as k-Means, to create pseudo-labels for the CNN. Therefore, no ground truth and no domain knowledge is required to apply the method. For the first run, both the obverse and reverse of the coins were used as input. The algorithm used expects a cluster number k as input, and the paper recommends a higher k than the number of expected classes. After some experiments, we used k = 100 and analysed the resulting clusters manually. The results we observed were:

- Coins in poor condition had been clustered together (corroded, broken, ...).
- Images of the obverse and reverse had been consistently separated.
- Some clusters showed similarity to the classes defined by the experts.
- Some mixed clusters showed nothing in common.

While the first three points show that the algorithm is useful, the last point indicates that it is not a solution for everything.

Our approach then was to use a divide and conquer methodology. Our idea was to iteratively use the chosen algorithm to exclude clusters with coins in extreme conditions and clusters that showed no similarity. Clusters that showed a strong similarity were taken for the next iteration. To evaluate how well this approach performed, we used the classification list provided by the domain experts. The list had not been fully approved by the experts, and may contain errors. But since we are checking the clusters and not individual coins, we think this is acceptable. This way, we were able to calculate the percentage of each class within each cluster. For five of the six classes, we could identify clusters with more than 70% of coins of these classes. Only for one class, which in general has only a very small number of instances, was this not the case.

Our ongoing work is to use these results and to focus on the five classes that the algorithm was able to identify. The idea is to create a ground truth for each class that is based on two systems: the domain experts’ list and the cluster results. Using this new dataset we wish to apply supervised image classification to create a model that can be used to retrace our methodology and predict the class in clusters that we excluded. Following this approach, we expect to improve the incorrect assignments in both the experts’ table and the clusters, and strengthen the model. The remaining class we intend to treat separately, but with a similar approach. Even if with our approach we aim to reproduce the six classes of the staters of the Coriosolitae, we also wish to understand in which cases the AI methods tend to result in a different separation. This is in fact one of the major research questions in our project ClaReNet.

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137. Automated identification of complex multi-cell phytoliths: First results, potential and possibilities

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Phytoliths are opaline microscopic structures made of silica, they are formed in the cellular and intercellular spaces in plants from the uptake of soluble silica (SiO2-nH2O) in the ground water. Formed as individual cells (single-cells) or as conjoined cells (multi-cells), phytoliths vary according to their anatomical origin (leaves, culm, husks, etc.), with specific forms having varying diagnostic potential. Phytoliths are extremely robust and are a major component of many archaeological and paleoenvironmental deposits. However, phytolith analysis is prohibitively time consuming, leaving specialists to work with very small datasets over long spans of time. An automated detection and classification process could radically reduce work time while increasing the quantity of processed data, the quality of information retrieved and assuring consistent identification across all datasets. The aim of this paper is to demonstrate that it is possible to automate phytolith identification using Deep Learning (DL)-based algorithms.

Methods

For both phytolith classification and detection we have a single dataset of 378 microscope images (dataset 1). The comparative plant material comes from M.N. Ramsey's comparative collections, including the Mount Scopus Collection, collected over four seasons by trained botanists in Israel, and the Hillman Collection, sampled from UCL's comparative material originally collected by Prof. Gordon Hillman in Turkey. The comparative material was prepared by first cleaning with distilled water to remove dust. Once dry, the samples the different plant parts (leaf, culm, husk, awn) were separated. Organic material was burned off in a muffle furnace for 3 hours at 500 degrees Celsius, the remaining ash was then directly mounted on slides in Entellan. Images for Avena, Hordeum and Triticum were taken from multiple accessions (multiple slides of different plants from the same taxa), ensuring that our results are not biased by the unique characteristics of one plant or slide preparation. The images were taken on a Leica DM500 and a GXCAM-U3-5 digital camera with ToupeLite software.

The resulting 2560 x 1922-pixel images dataset is composed of 121 images of Avena sativa (32.01% of the total), 90 of Hordeum spontaneum (23.81% of the total), 142 of Triticum boeoticum (37.57% of the total) and 25 of Triticum dicoccoides (6.61% of the total). We have divided this dataset into 188 images for training (49.74% of the total), 95 for validation (25.13% of the total) and 95 for testing (25.13% of the total). This paper will use this dataset to try to classify the phytoliths visible in the images in these 3 genera.

From this dataset (dataset 1) two new datasets have been created: one with 1,470 phytoliths with no background extracted from the original images (dataset 1A), as many of these images included several instances of phytoliths, and other with 975 images of 256 x 256 pixels divided from the original images (dataset 1B).

Four different approaches have been tested to investigate their detection capacity: 1. automatic classification of phytolith genera without background; 2. automatic classification of phytolith genera with background; 3. automatic classification of phytolith microscope images; and 4. automatic detection and classification of phytoliths in microscope images, which would constitute the most practical application as it can be directly implemented in digitised microscope images. An Nvidia GeForce RTX 3090 graphics processing unit (GPU) with 24 GB of RAM was used to run the DL algorithms. The chosen work environment was the parallel computing platform CUDA 11.2, the ML library Tensorflow 2.1.0, the DL library cuDNN 8.1.1, the software development tool CMake 3.20.2 and the CV library OpenCV 4.5.2 as recommended for DL.

Results

Although the algorithm is still under development, initial results range from 85 to 89% overall accuracy for the selected multi-cell phytolith types. Further development during the following weeks is expected to improve these results and produce a working algorithm that can be used for the automated identification of phytoliths.

Discussion

All approaches tested here have been able to produce results that are above 85% overall accuracy in the correct identification of phytolith classes. In particular, the automatic detection and classification of phytoliths in microscope images, with a current overall accuracy of 88.42% shows enormous potential to be implemented as an automated stand-alone tool within digital microscope workflows.

This can be particularly useful when combined with the use of complex digital microscopes able to produce focussed images by combining multiple digital images at different focus. These can significantly improve the workflow by producing crisp images that can significantly reduce the misidentifications related to unfocussed parts of phytoliths. Also, given the fact that some of these microscopes can incorporate DL algorithms it should be possible for these to produce phytolith type counts automatedly near instantaneously, a radical improvement on the current manual analysis speeds (manual methods produce speeds of between 1-10 slides a day, contingent on analyst experience and slide composition). The continuous improvement and incorporation of new training datasets for phytoliths and the most common phytolith morphotypes types could result in a viable automatization of phytolith identification. This would produce a revolution in phytolith studies, which would be able to exponentially increase the data available in a fraction of the time and reach much more significant conclusions at larger scales of analysis.

Additionally, the capacity of the algorithm to automatedly provide complementary data such as the level of phytolith fragmentation, area and shape can offer important insights during the interpretation phase. Another important advantage would be the improvement of the statistical significance of the of the data as it will allow the analysis of the entire slide instead of the small portion (minimum counts of 300 single-cell and 50 multi-cells per slide), which constitutes current practice.

59. Structuring data: exploring ways of transforming natural language into database attributes

Israel Hinojosa Baliño, Durham University

The nature of the Endangered Archaeology in the Middle East & North Africa (EAMENA) Database, its complexity and scope, requires to assess archaeological heritage, threats or damages to it, but also to familiarise with the terminology used by the project. This database, however, relies on information recorded in Excel spreadsheets by volunteers who may not be trained in GIS and/or databases, or whose work is only for short periods. At the beginning of this year, being myself a temporary worker, I developed a simple spreadsheet in Excel to retrieve specific information of an archaeological site from unstructured data and transform it into structured data in the form of tags, categories or codes used by the EAMENA project. This spreadsheet was inspired by sentiment analysis and uses natural language processing and text analysis. The spreadsheet works by copying and pasting unstructured text (e.g., a text from a news article, an archaeological report, or a Wikipedia page) into a spreadsheet cell. The program will analyse the text to produce structured data automatically, or the volunteers can use their specific text chain either to train or transform data. Eventually, the results are used to fill in the standard forms used by EAMENA staff to upload information to the online EAMENA database.

The original spreadsheet was created in the context of the EAMENA project to aid the work of the volunteers when filling the standard forms, which require the use of codes, tags, or specific categories that can be difficult to memorise or consult. But this spreadsheet can benefit from a high-level, general-purpose programming language and be adapted to any other project necessities. The information retrieved is based on a simple data dictionary that can be fed manually in a potentially limitless array that can have characters in different languages, facilitating recording specific terminology and avoiding data duplicates.

This presentation will show the original Excel spreadsheet, the proof of concept in a real archaeological scenario, however, the spreadsheet works with arrays, and the main flaw of this approach is the way Excel works and the array limits. Because of this, I adapted the methodology to a high-level programming language and I will show you how, with few lines of code in R, a similar outcome can be achieved. This is a work in progress, but it clearly shows the adaptability and scalability of the original approach by recursively and progressively analysing the rows of a data frame, identifying keywords or phrases, and "tag" the findings with specific codes that are stored also as arrays.

Session 16. Reaching across the digital divide: Towards equitable practice in digital archaeology and heritage management

Rebecca Roberts, University of Cambridge

Faye Lander, University of the Witwatersrand

Stefania Merlo, University of Cambridge

Azadeh Vafadari, University of Cambridge

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Abdul Samad, Directorate of Archaeology & Museums Government of Khyber Pakhtunkhwa

Rajesh Vasantha, University of Kerala

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Ezekia Mtetwa, University of Uppsala

Kundishora Tungamirai Chipunza, National Museums and Monuments of Zimbabwe

Muhammed Waqar Mushtaq, The Islamia University of Bahawalpur

Ravindra Nath Singh, Banaras Hindu University

Becca Peixotto, American University

Anton Coetzee, University of the Witwatersrand

Room 9

Roundtable	13:00 - 15:00

Introduction

The digital divide is far from a new phenomenon. In the last three decades global intergovernmental bodies with large-scale initiatives including the International Telecommunications Union (ITU), the United Nations World Summit on the Information Society (WSIS 2021), as well as UNESCO's Fostering Innovation and Inclusive Digital Transformation for Sustainable Development Programme (Anon 2021) (2021), to name a few, have raised the alarm about the disparities in digital access, digital affordability, digital knowledge production, and fundamental digital human rights. There is perhaps little doubt that the Digital Revolution, as coined in the 1980s, has been a revolution of unequal proportion.

Archaeology is by no means immune to digital inequality, especially as this divide affects both the research design and public dissemination stages of research. This session will explore the following questions:

- Inequity can be seen in the access that researchers in both private and public institutions have to digital research resources. While the backdrop for this has often been heavily pitted between the Global North with fiscal means, capacity, and technical know-how, and the least developed nations representing the Global South, where many nations are in the process of rebuilding economies, healthcare, and education, within relatively new postcolonial contexts, it is important to acknowledge that that digital exclusion is evident for marginalized groups around the world (UN Habitat 2020). What are the practical implications of such resource limitations in digital research? And what are some of the practical solutions for researchers from areas with limited technological infrastructure?
- Digital inequality can also result from systemic societal barriers, such as access to education or social pressure, resulting in the exclusion of a large percentage of researchers, heritage practitioners, and members of the public. For example, in the United Kingdom only 19% of university undergraduates in Computer Science are women (Yates and Plagnol 2021). What are the barriers that might keep researchers from participating in the digital revolution? And how does the exclusion of these marginalized populations affect data collection and research project designs in archaeology
- Finally, we will explore barriers to the dissemination of information, both among researchers and to members of descent or invested communities. This applies particularly to works involving digital heritage and the ownership or copyrights of data produced from the study of objects of cultural patrimony (Sayre 2016, Stobiecka 2020). Are the current open-source coding platforms and free digital data storage sites, such as Github or R-Markdown, enough to ensure equitable information access? And how do these open access forums change the peer review process in archaeological research?

Contributions to the session are expected to do one or more of the following:

- Highlight the history of the digital revolution within archaeological sciences, the inequalities that have developed, and their current impact on data collection, research project creation, and information dissemination.
- Explore current digital-based archaeological work, particularly in the context of postcolonial thought, from the perspectives of those practitioners who are actively involved at the local level in lower-resource environments.
- Confront and challenge disparities in archaeological research participation, opening space for greater dialogue within many disciplines of archaeology and heritage management that are applying new and existing technologies.
- Examine the potential solutions to digital inequity that researchers have applied in their own research and collaboration.

Our hope is that by the strength of the archaeological research community, we will be able to examine the impacts of digital inequity in archaeology and work towards actionable solutions that participants can implement in their own work.

This session will be run in the form of a modified roundtable, with a mix of invited discussants and discussants who submit their proposal in the open call. As digital exclusion implicates global practices and policies, the session takes the opportunity to include two to three members involved in not-for-profit, international regulatory bodies expert in heritage and data policies. The session will also include a series of invited flash talks from those working from the 'other side' of the divide in order to give as wide a range of voices a platform. These will include heritage professionals from sub-Saharan Africa and South Asia who are currently partners as part of the Mapping Africa's Endangered Archaeological Sites and Monuments (MAEASaM) and Mapping Archaeological Heritage in South Asia (MAHSA) projects - both of which are funded by the Arcadia Fund.

The session format will be as follows:

- A position paper will be circulated in advance of the roundtable, which participants are expected to have read in advance of the session
- Responses will include a small number of discussants (5) (both invited, and the call for discussants will be open), who give longer responses of 10-15 minutes, and 5 short 3-minute lightning talks that will highlight a range of specific examples from invited speakers. These will then form the core material for the discussion.
- The resulting discussion will be chaired by the organisers, with the discussants given the floor.
- Following this, the floor will be opened up to those attending the session for comment and questions.
- Summary to be given by chairs to close out the session.

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Session 18. Exploring further the possibilities of 3D Spatial Analysis

Gary Nobles, Oxford Archaeology

Alexander Jansen, Durham University

James Taylor, University of York

Marina Gavrushkina, Leiden University

Markos Katsianis, University of Patras

#CAASIG3DSA

Room 7

Introduction	09:00 - 09:15
5. Historicizing and contextualizing past and future cultural landscapes: Some opportunities and challenges with 3D photorealism, analysis, and immersion *Whitley**	09:15 - 09:40
146. From shape to grow conditions: A workflow combining micro-3D scanning, geometric morphometrics and machine learning for the analysis of past agricultural strategies *Orengo*, Livarda, Kriti, Mylonas and Ninou*	09:40 - 10:05
48. Estimating energy costs with pithouse reconstructions and photogrammetry *Noxon**	10:05 - 10:30
Tea/Coffee	
93. Reassessment of old excavation documentation with the help of 3D-GIS using the example of the early medieval settlement of "Elisenhof" *Göbel**	11:00 - 11:25
139. The audibility of speech and the visibility of the speaker in the ancient Forum Romanum *Kopij*, Pilch, Popławski and Drab*	11:25 - 11:50
76. Modelling ancient bronze craft techniques: From 3D objects models to ore provenances *Huet*, Cicolani and Artioli*	11:50 - 12:15
Lunch	
75. A workflow for reproducible use-wear analysis with open-source software, from 3D data process to 3D data sharing *Huet*, Ibáñez, Zupancich and Estebaranz-Sánchez*	13:30 - 13:55
37. 3D modelling of vegetation around archaeological sites: How we try to bridge the gap between field archaeology and archaeobotanical specialists	13:55 - 14:20

Maguet, Leroyer, Mazier and Barreau*

Discussion	14:20 - 14:35
53. A new geomatic approach to detect verity and classify half-nomad mobility in the South-Eastern Arabia *Antinori* and Ramazzotti*	Poster

Introduction

With the broadly attended virtual meeting in 2021, the CAA's 3D Spatial Analysis Special Interest Group again welcomes papers which are oriented towards the analysis in 3D space or analysis of 3D space, both theoretically and methodologically.

In this session we want to tackle themes such as:

- What do 3D and 2.5D approaches afford us beyond traditional 2D perspectives, with innovations in 3D spatial analysis continuing?
- Why do we, as archaeologists, want to apply 3D spatial analysis, how would we apply it and what questions would it help answer?
- What added complexities does working in three dimensions bring, how do we make the most of them, and how do we resolve or theorise around such complexities?

Papers are invited which cover any form of 3D spatial data: artefact/object based, recorded geospatial data (GIS/CAD), interpretive 3D modelled data (including procedural/(H)BIM), semantic analysis, and even imagined spaces, this could include their physical manifestations (e.g. Archaeogaming, 3D printing). Crucially, papers should go beyond the presentation of purely 3D recording/modelling methods and processes. What insights can we achieve which are not possible from visual inspection alone? While we would like presentations which push the boundaries (theoretically/technologically), we also welcome position papers. Presenters may want to consider how their research fits within archaeological workflows (established or burgeoning) and broader Spatial Data Infrastructures: what does the integration of associated data bring and what analytical capabilities does or could this create? How do we use these 3D digital objects, datasets and results once they are created? What purpose do they serve, what will their legacy be? Presenters are urged to discuss how the results of 3D spatial analysis are communicated: What are the merits of staying in 3D space against reducing or simplifying it to 2.5D and 2D presentation formats, and vice versa?

Submissions from young researchers/early career researchers are particularly welcome. We want to enable researchers to discuss ideas, whether or not you have access to the best data, funding for big computer systems, or underlying technical knowledge. Such positional papers should focus on what we want to get out of 3D spatial analysis. In this aspect we encourage 'blue-sky thinking' particularly if the tools and capabilities are not yet in existence.

Presenters can select one of two formats for their paper: papers which are more exploratory and 'blue-sky' in nature may prefer a 10-minute lightning talk format, while those with a more traditional structure may be better suited for a 20-minute standard format. The author(s) should specify their preference when submitting their proposal. If in doubt, contact one of the session organisers well before the paper deadline. The session will conclude with a discussion bringing together the principal themes which emerge from the presented papers, incorporating elements from last year's discussion. Facilitated through the 3D Spatial Analysis CAA SIG, we endeavour to keep these discussions continuing beyond the meetings at CAA International.

5. Historicizing and contextualizing past and future cultural landscapes: Some opportunities and challenges with 3D photorealism, analysis, and immersion

Thomas Whitley, Sonoma State University

Heritage management across the globe has become more aware of, and more fully engaged with, the concept of "cultural landscapes" in the last few decades. This is the idea that a broad swath of the physical and conceptual environments in a region comprises the framework within which past and present people are culturally entangled, and for which future communities will be. This goes beyond the identification of archaeological sites, artifact densities, and calculated viewsheds, to defining and understanding past environments, geophysical processes, traditional forms of knowledge and practice, and the most appropriate methods and techniques for education and heritage management. However, we are essentially limited to reductionist approaches that can never truly convey an immersive experience of any given past, present, or future cultural environment, only momentary glimpses or fragmentary views. Yet, our digital techniques should attempt to incorporate an insider, or descendent community's, perspective in a way which best represents their understanding of "significance" with the objective of creating heritage management plans that interpret or protect cultural landscapes appropriately.

In this paper, I will use several examples of work currently being carried out in Sonoma and Marin Counties, California, USA, to identify, illustrate, and analyse the past, present, and future cultural landscapes of descendent tribal communities; specifically, the Federated Indians of Graton Rancheria (FIGR); the recognized representative body of descendent Coast Miwok and Southern Pomo peoples, who are the traditional owners of this portion of California. The methods used incorporate GIS and 3D situated and immersive photorealism to create both visitor experiences, educational interpretations, and preservation objectives in federal, state, and regional parks. Specifically, this involves the use of ArcGIS, county-wide seamless 2m-LiDAR topography/bathymetry, experimentation with several different erosion and climate scenarios, and application of animations and 3D viewpoints in Terragen rendering software. It also entails synthesizing and contextualizing ~20,000 years of ecological and climatic data, and integrating numerous projections for what future conditions are likely to be.

The projects addressed in this paper began in 2017, with a long sequence overview of past and predicted climatic changes in Point Reyes National Seashore (Whitley et al. 2018), and continues with four on-going projects that involve consultation with FIGR. Each project entails a different level of engagement and different perspectives on the cultural landscapes of the past; including oral history interviews with elders, formal review/oversight by the tribal council and Tribal Historic Preservation Office (THPO), and active incorporation of data/interpretations developed by tribal archaeologists. California legislation makes it unambiguous that tribal consultation is mandated under any project which seeks permitting through the California Environmental Quality Act (CEQA), but how consultation is implemented can vary quite dramatically and produce outcomes never imagined when CEQA was passed in 1970.

The opportunities that arise are to re-engage tribal members more fully with the landscapes that have been systematically denied to them, to develop techniques that allow a more complex understanding of how heritage is situated within both physical and conceptual environments, and to provide land managers with evaluative tools to deal with the on-coming effects of climate change on significant resources. The challenges come with finding a common ground between the four audiences for these outcomes – i.e., tribal communities, regulatory and land management agencies, the general public, and the archaeologists/heritage management practitioners. Although this is very much a series of works-in-progress, they do provide some insight into creative directions for engagement and interpretation for many similar projects and other descendant communities round the world.

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146. From shape to grow conditions: A workflow combining micro-3D scanning, geometric morphometrics and machine learning for the analysis of past agricultural strategies

Hector A Orengo, Landscape Archaeology Research Group, Catalan Institute of Classical Archaeology

Alexandra Livarda, Landscape Archaeology Research Group, Catalan Institute of Classical Archaeology

Alexandra Kriti, Landscape Archaeology Research Group, Catalan Institute of Classical Archaeology

Ioannis Mylonas, Institute of Plant Breeding and Genetic Resources, Hellenic Agricultural Organization

Elizabeth Ninou, Department of Agriculture, International Hellenic University

The shape of objects usually encloses information about their function. Geometric morphometrics (GM) in combination with statistical approaches have been employed to obtain quantifiable data about objects' shapes and use these data to define typologies and functionalities. Equally, animal bones (including human) and archaeobotanical remains have been analysed using similar approaches to obtain information, compare specimens and classify items.

During the last years the increased availability of 3D scanners and more efficient photogrammetry algorithms and software have facilitated the generation of 3D models of archaeological items. However, despite the multiplication of 3D models, little has been done to develop new workflows that can take advantage of the volumetric nature of these models and simple GM measures continue to be employed to define complex objects. Similarly, the questions under investigation have not evolved to take advantage of the detailed information that 3D models offer. This is even more evident in the case of archaeobotanical data, the small size (typically sub-centimetric) of which restricts their accurate 3D scanning.

In this paper we will present current ongoing work to develop a workflow based on a combination of micro-3D scanning, 3D GM and machine learning using archaeobotanical material. The objective is to go beyond the simple identification of seeds, to try identify the growing conditions of archaeological grains, which likely include the agricultural regimes employed by past societies.

Methods and materials

During the last two years a series of experimental cultivations of 23 varieties of barley under controlled agricultural regimes (including different degrees of irrigation and manuring) has been developed in collaboration with the Institute of Plant Breeding and Genetic Resources and the Hellenic University in Greece.

We have employed a metrology-grade 3D scanner to obtain digital twins of a selection of barley grains from different varieties experimentally grown under different agricultural regimes. Initial metrological comparison and quality analysis of a selection of these, has indicated the potential of full 3D shape analysis for the identification of past agricultural regimes as clear differences in shape have been identified between individual grains grown under different agricultural regimes. The next step in the workflow was the automated orientation and scaling of the grains which allowed the collection of 35 automatedly extracted measurements. These measurements were used to train a machine learning algorithm and apply it for the identification of different varieties of barley but also the agricultural regimes under which barley varieties were cultivated.

Results

Initial analysis and quality assessment (including Distance from Reference Mesh and Hausdorff Distance) show the scanning method faithfully represent grain shapes. Differences between scans of the same grains provided a maximum mean Distance from Reference Mesh of 5.527 µm to a minimum mean Distance from Reference Mesh of 0. 405 µm. Also marked differences between different varieties but also between the same varieties with difference cultivation regimes. For the few examples scanned up to now we have noticed mean differences of around 90 µm in seeds from the same varieties with similar cultivation regimes while those with different regimes showed mean differences of about 145 µm (0.145 mm).

Initial training of the machine learning algorithm showed mixed results with only a 62% accuracy. We believe this is due to the metrics selected (still not fully 3D aware) and the few training data still available.

Discussion

Although more scanning is necessary to obtain reliable data for the training and verification of the machine learning algorithm, the preliminary results of this workflow show excellent potential to differentiate between different varieties of the same species and also between different growth regimes. During the next few months the availability of training data will grow significantly allowing us to improve the algorithms. Also new 3D measures are being tested to improve the algorithm discriminatory capacity. This presentation will provide the last results and will discuss the methodological approaches and ways forward to extract important information enclosed in the shape of seeds. Given enough training data, this method could become a unique new tool for archaeobotanists as 3D scanning methods improve, become cheaper and more common.

48. Estimating energy costs with pithouse reconstructions and photogrammetry

Corey Noxon, Ritsumeikan University

What can archaeological reconstructions teach us about the original objects they aim to emulate, and how we can best collect and analyse that available knowledge? These questions have been central in my attempt to quantify differences in energy costs involved in the construction of different types of pithouse dwellings from the Jomon period in Japan through the analysis of pithouse reconstructions. While caution is certainly advised in this undertaking, there is also useful information contained within these structures that should not be put to waste.

The Jomon period spanned over 10,000 years and although there were a variety of dwelling types present during that span, the most prominent dwelling type archaeologically was the pithouse.

Although often seen as a singular dwelling type, in actuality pithouses exhibited a high degree of variation. Pithouses were more circular in some instances and more elongated and oblong in others. The number of interior support structures varied significantly, and the size of pithouses changed over time as well. The reasoning for these changes is still unclear however. One possibility is that the changes in pithouse construction reflect changes in the degree of sedentism at the time.

Prior studies have shown an association between the energy costs of dwelling construction with sedentism as it relates to intended uselife (Kelly, Poyer, and Tucker 2006; McGuire and Schiffer 1983). Lighter built, more ephemeral structures can be built in a relatively quick period of time using readily available materials with less initial energy expenditure, but can require significant maintenance if used for long periods of time. The use of more robust and more standardized materials can help to create a longer-lasting structure that requires less maintenance, but requires a greater initial energy expenditure. In addition to changes in size, the variation of architectural components Jomon pithouses also show some key variations in architectural components, such as central supporting pillars, exterior wall posts, and stone-lined floors, and while assumptions can be made regarding whether some forms might be more energy-intensive than others, a clear quantitative comparison is yet to be made. Unfortunately archaeological traces beyond postholes are rare, and there is very little evidence of what the structure of pithouses were like above ground. To explore possible energy costs I turned to a number of pithouse "reconstructions" across Japan with the hope of gaining some useful insights.

Pithouse reconstruction designs and materials vary, and no completely accurate reconstruction exists because there are no fully preserved pithouses to compare them to. Prior studies have also shown that reconstructions often serve as a better reflection of conditions and society at the time they were built better than the time they are intended to present, so this line of inquiry has been followed with a significant degree of caution and scepticism (Ertl 2021). Pithouse reconstructions do, however, often follow original floor plans recorded from archaeological excavations, and in their variety display a range of associated energy costs which can provide a conservative base for energy estimates.

There are a number of practical challenges present in gathering data from pithouse reconstructions. While the general concept of a pithouse is fairly simple, recording the intricacies of their construction can be a significant challenge. In order to determine the amount of energy used to create the structure, the materials that make up the structure need to be recorded and measured. Keeping track of the size and positioning of dozens or hundreds of individual components in 3D space can be difficult to accomplish within the relatively tight confines of the pithouse reconstructions. Additionally, as the reconstructions are generally open and available to the public, the time available to document them can be limited as well.

With these difficulties and limitations in mind, I decided to approach this project using photogrammetry to create 3D models of the pithouse reconstructions which could then be measured off site. The number of measurements wouldn't be dictated by the amount of time available on site and the locations where measures were made could be recorded on the model itself. The use of 3D models also allows for the manipulation of pithouse features in order to explore material costs for different configurations, such as adjusting roof or wall heights.

While the recording and analysis work is ongoing, initial results seem promising. Early test models have displayed a very high level of detail and look to be able to serve as accurate digital replicas to use in further energy cost analyses. While energy cost analyses are ongoing, the "digital replication" process itself is providing an additional benefit by creating detailed records of these pithouse reconstructions not as representations of objects from the past, but as structures in the present. The lifespan of these structures, even when well made and maintained, is relatively short. By the end of this project, hopefully we will not only have a better understanding of possible drivers behind changes in pithouse types and sizes, but will also have a detailed snapshot of how present day researchers viewed and interpreted the past in the form of these pithouse reconstructions.

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93. Reassessment of old excavation documentation with the help of 3D-GIS using the example of the early medieval settlement of "Elisenhof"

Karin Göbel, ZBSA

The Centre for Baltic and Scandinavian Archaeology (ZBSA) in Schleswig has established its own GIS-department and within the last 14 years several excavation documentations have been entered into GIS and have contributed to a great deal of practical experience. Especially in the case of old excavation documentations, it can be observed that the state of preservation of the plans is in reciprocal correlation to their importance. It is therefore a great step forward that the plans can be downloaded digitally from a data portal and the original plans no longer have to be touched. A digital transfer to GIS make them available for new analyses in combination to each other and with new research results. In our department we are working primarily with ESRI software in combination with SQL databases and I developed a special workflow to visualize profiles in 3D. Evaluation in 3D has become increasingly important in recent years. Nevertheless, editing in 3D is currently only possible to a limited extent, so that this still has to be done mostly in 2D. In addition, each project has its own challenges and obstacles and depending on the base data the GIS utilisation has to be adapted. The following example provide an insight into the amazing possibilities of 3D-GIS even with old excavation documentation: In the years 1957-1964 systematic excavations led by Dr. A. Bantelmann discovered the remains of a rural settlement on the Elisenhof mound on the north bank of the river Eider near Tönning in the district of North Friesland/Germany. These mostly date from the second half of the 8th century to the 10th century AD. The state of preservation of the timber was remarkable due to the constant overbuilding and the associated covering of sod and dung and gave a good insight into the history.

This predominantly rural settlement, with its large stable houses and the well-developed paths towards the river Eider, may also have supplied transport ships in the 9th and 10th centuries and thus have been part of the infrastructure of trade between the North Sea and the Baltic Sea via the Eider, Treene, Haithabu and the Schlei. Although numerous books have been published on the early historical mound "Elisenhof and its finds our picture of life at that time is still incomplete. This report is intended to bring Elisenhof to life and perhaps to ensure that its former residents have not been forgotten.

For this reason the excavation documentation was scanned and transferred to a GIS, which includes 141 area, 212 profile, 42 detail and 4 elevation plans, as well as numerous photos and slides, 312 of which have already been digitized. Since excavation documentation can now be visualized not only in 2D, but also in 3D using a GIS, and the data no longer have to be evaluated separately according to the two local measurement systems, there are new opportunities for analysis and explanatory research. Because only the lower parts of the houses have been preserved, it is particularly interesting to visualize and discuss different reconstructions within the documented objects in 3D. However, it must be remembered that the accuracy of these old excavation data cannot be compared with today's standards, as much of the wood could not be measured exactly. Many of these timbers could only be given the height level of the different layer drawings. Since there was no ID for the majority of the objects on the various excavation plans, a clear assignment could not always be made. However, these details are noted in the attributes of the features, such as source, elevation, multiple drawing, type etc., and can be called up in 3D as attributes via an info button. The importance of documentation what kind of data and what has happened with it has become an increased significance.

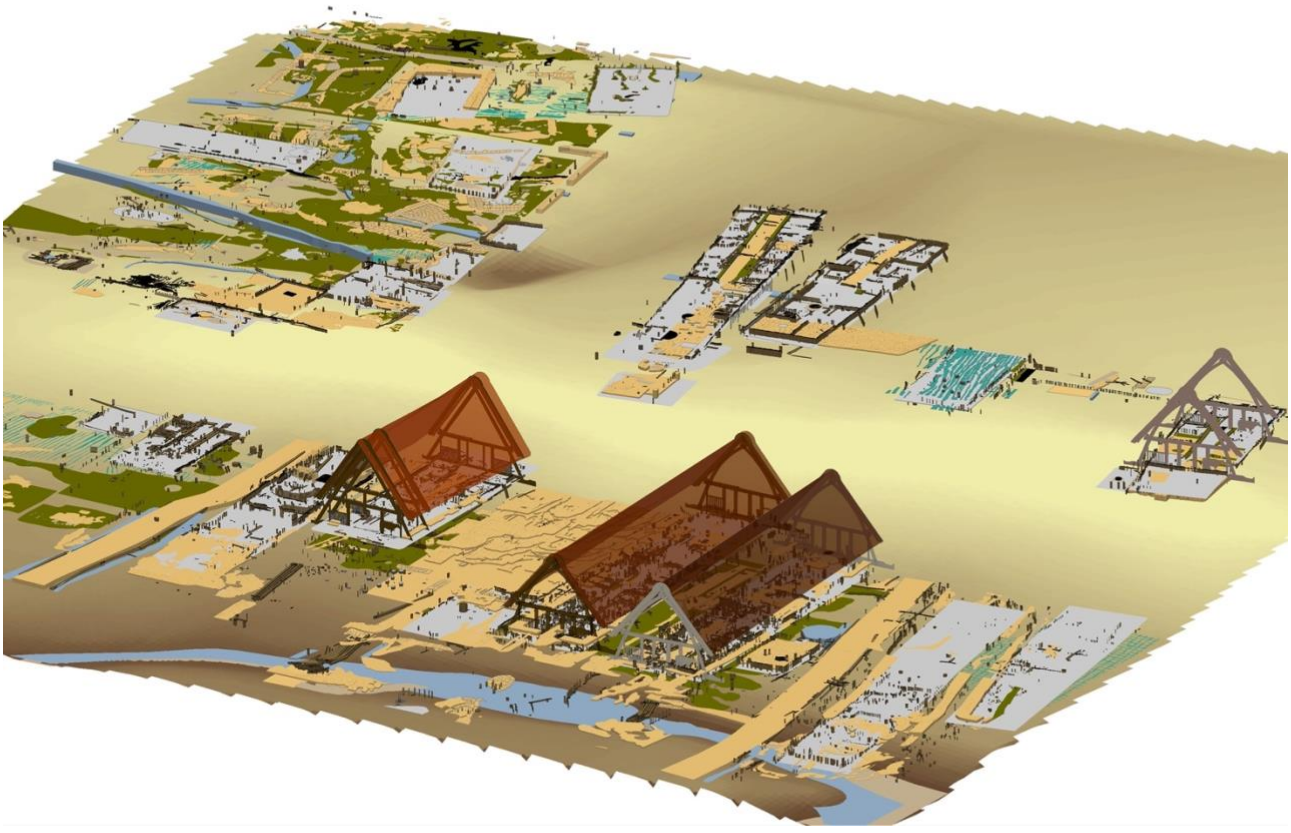

Figure 21. The early medieval settlement of "Elisenhof".

While the older houses in the 8th century were built on the raised banks orientated East-West, the following houses are perpendicular to them in a North-South direction. This had the advantage that the natural incline of the river bank could be used to build the living quarters of the farmsteads with an incline to the stable part without major earth movements and protected them from flows of slurry. In terms of flood protection, this type of construction was much more risky for the southern farmsteads. At the same time, the roof surfaces were now exposed to the prevailing westerly winds in this area much more intensively to the wind pressure or the dangerous wind suction and thus to an increased wind load. A storm surge simulation in the GIS with a water level raise of only 1.2 m above current sea level shows clearly the dangerous proximity of the southern residential and stable buildings to the river. It is striking that the building walls of these southern farmsteads were reinforced with sods from the outside and partly also from the inside. This intensive reinforcement of the walls by sods is not documented in the buildings north of the river bank wall. Perhaps these are not new house types but only modified ones.

There might be very good reasons not to share data, but if we gather all the information together we will all gain knowledge and improve our understanding of history. Therefore the excavation documentation from Elisenhof with scanned excavation plans, numerous photos, as well as the vector data in shape format from the edited objects are available to the general public: https://open-data.schleswig-holstein.de/organization/zbsa. In addition, a WebGIS can be used on request, which is currently only available in a 2D version.

139. The audibility of speech and the visibility of the speaker in the ancient Forum Romanum

Kamil Kopij, Jagiellonian University, Institute of Archaeology

Adam Pilch, AGH

Szymon Popławski, Wrocław University of Science and Technology

Monika Drab, Wrocław University of Science and Technology

For several centuries, the Forum Romanum was the site of public events that shaped the policies of Rome, which echoed throughout the Mediterranean world. Not only were elections of Roman officials held there, but also popular assemblies where new laws were passed and provincial governors appointed. Moreover, it was a place for discussion of proposals for new laws and negotiations between the elite and the Roman people. Therefore, a spatial and acoustic analysis of this space seems to be important. It allows us to estimate how many people might have gathered in the Roman Forum and, moreover, how many people might have heard a speaker or perceived the gestures he was making.

In our paper, we would like to present the results of our gesture visibility and acoustic analyses of the rostrums located in the Roman Forum during the Late Roman Republic and Early Imperial periods. As there were always at least two speaking platforms in these periods, we also checked whether it was possible to hold two meetings at the same time, i.e. whether or not the speakers would disturb each other.

Simulations, that used custom-made 3d virtual reconstructions of the Forum Romanum, were carried out in Catt-acoustic software. When carrying out the simulations we took into account not only the geometry of the space, but also the acoustic properties of the materials used in the built environment. In the virtual recreations we considered three different levels of background noise 36dBA (low-level ambient noise), 49dBA (typical audience noise) and 55dBA (raised audience voice. The result of the simulations are maps showing the level of the Speech Transmission Index (STI) at each point of the analysed spaces. This in turn will allow us to calculate the number of people who could hear the speaker intelligibility using two methods of estimating crowd size based on modern observations of behaviour of crowds: mean density and moderated density.

Furthermore, with the results of our experiment on the visibility of rhetorical gestures (divided into three classes based on the level of detail in the gesture), we conducted a virtual visibility analysis to determine how many people could see the speaker's gestures.

Through these virtual procedures, we are able to expand our knowledge of social events, the analysis of which was previously limited to determining the maximum available space, and thus to estimating only the maximum number of people that a space could accommodate.

76. Modelling ancient bronze craft techniques: From 3D objects models to ore provenances

Thomas Huet, University of Oxford, School of Archaeology

Veronica Cicolani, CNRS AOrOc-UMR 8546 CNRS-PSL ENS

Gilberto Artioli, Università degli Studi di Padova, Dipartimento di Geoscienze

The characterisation of Italic bronze craftsmanship is a key to re-reading and modelling cultural interactions in Europe during the Early Iron Age. The copper alloy chaîne opératoire is one of the most complexes in Protohistory, involving: the mining activities, the supra-regional trade and the production of highly distinctive artifacts.

The ANRJCJc Itineris (https://anr.fr/Projet-ANR-21-CE27-0010), started in 2021, combines 3D modelling by lasergrammetry or photogrammetry, archaeology and archaeometry to point out the definition of northern italic metalwork traditions and the cultural transfers, emphasizing the role of artisans and their involvement in the process of cultural identity formation.

Starting from the object, our work covers the archaeological and archaeometric identification with the 3D modelling of the objects and the 3D location of one to several isotopic and elemental samplings on these 3D models. Typology of these objects and chemical analysis of the samplings will be compared with reference collections: published catalogs for the morphology of the object, and the AAcP database (Padua University, http://geo.geoscienze.unipd.it/aacp/welcome.html) which registered elemental and isotopic tracers for sourcing ancient copper metals and smelting slags (Artioli et al. 2016). The multi-factorial analysis will permit cluster objects depending on their typology, compositions and archaeological context. Along with these comparisons, scripted routines (with R) and 3D objects libraries will be set hosted and shared through GitHub's URLs (https://github.com/ANR-Itineris), TGIR Huma Num's Nakala DOIs, displayed through open-source formats (plain text HMTL, CSS and JavaScript) and frameworks (3DHOP), respecting the FAIR policies (Wilkinson et al. 2016).

This multi-scalar and comprehensive approach points out the geographical and cultural provenance of the metal alloys and artifacts. This short paper (10-min) will present this workflow - from the object to the mine - using archaeological and archaeometric analysis.

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75. A workflow for reproducible use-wear analysis with open-source software, from 3D data process to 3D data sharing

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Use-wear analysis's purpose is to identify tools' functions. (Vaughan, 1985). These last years, significant developments in microscopy, with the possibility of obtaining 3D measurements (using white light and laser scanning, photogrammetry, confocal microscopy, etc.), make use-wear analysis one of the current most challenging fields of technical analysis (Ibáñez and Mazzucco, 2021). Experimental reference collections are necessary for the analysis of archaeological tools. In these reference collections, Prehistoric tools are replicated and used in different activities, so the experimental use traces can be used to interpret the traces observed in archaeological tools. The sharing of reference collections, normalizing statistical indexes and reproducing analysis are important elements for improving our research.

This is even more bolded today in the context of open science and Web3D (Scopigno et al. 2017). Our aim is to document experimental tools with 3D technology at different scales of analysis in order to put the information in open access. Besides the acquisition process, which needs commercial hardware (Confocal microscope, camera, etc.), this short presentation will present an entire workflow (data process, storage, annotation, analysis, visualisation, sharing) based on 3D measurements and open-source software (Blender/Meshlab, R, JavaScript, GitHub, 3DHOP and Web3D), to fit the goals of FAIR data (Wilkinson et al. 2016) for use-wear analysis.

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37. 3D modelling of vegetation around archaeological sites: How we try to bridge the gap between field archaeology and archaeobotanical specialists

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Modern archaeological process tends to consistently include sites within their environmental context and, in particular, within the vegetal environment. However, archaeobotanical studies remain difficult to read and to understand, especially for non-specialists, as their results are still disseminated using complex diagram which – because of the non-linear relationship between raw assemblages and composition of past vegetation – do not deliver a mere image of the environmental context. Fortunately, several decades of research have led to the development of quantitative pollen-based models that provide estimates of vegetation composition, on a regional scale and within a smaller radius around a target site (respectively REVEALS and LOVE algorithms). Therefore, quantitative reconstructions on large spatial scales tend to develop (e.g. TerraNova and Landclim projects, see Githumbi et. al 2021) and we now have a few works which synthesized regional landscape evolutions: these results have provided important insights into past environments, but - due to the visual complexity of the results? - are not yet integrated into the interpretations of field archaeologists. Indeed, we assume that it is necessary, at the local scale, to have the vertical structure of the vegetation to understand the interrelations between human societies and nature. Meanwhile, 3D technologies have extensively spread in various research fields, forming now an essential key for restitution, exploration and conservation of archaeological data. It seems to be particularly suitable for the representation of complex information such as palaeoenvironmental data and specifically adapted to the cross-disciplinary approach. A few encouraging trials of archaeological landscape 3D modelling were conducted in Europe, but none of them used the same methods. We therefore intend to propose a methodological approach of archaeobotanical data that will allow multiscalar 3D rendering and virtual exploration of ancient landscapes.

Material and methods

We selected two distinct areas of work, mainly because of the availability of various data sources and the existence of previous quantitative reconstruction studies (R. David, 2014):

- The Paimpont forest (Morbihan, Brittany), for the palynological and anthracological work carried out in a restricted area during a PhD thesis in 2011, which also provides a synthesis of existing historical and archaeological sources. The corpus represents 4 pollen cores and 10 charcoal assemblages, to which we added 9 other small sites (small lakes and peat bogs) located in a 40km radius.
- The downstream part of the Marne river (Seine-et-Marne, Ile-de-France), with two interesting concentrations of palynological data: the Neuilly site (5 cores) and the flood plain near Jablines, within the Marne meanders (7 cores). These sites were incorporated to a regional vegetation quantitative estimation based on the REVEALS-model use that enables us to work on local vegetation estimates. Moreover, the proximity between the cores and the richness of the archaeological remains located in this space, are major assets for the spatialization and the 3D restitution at the semi-local scale (10 000 - 100 000 ha).

From these two datasets, the project aims to develop a method for a) spatialize palynological and anthracological data within a more or less extended radius around archaeological known settlements and b) implement the vegetation (herbs, mosses and trees), in a realistic 3D virtual environment.

A long preliminary phase of calculating the estimate assemblage is necessary: we rely here on the Landscape Reconstruction Algorithm to obtain regional (REVEALS) and local (LOVE) estimates. Once we have an assemblage that is identical in all points within a given radius, we can proceed to the spatialization step: now the aim is to get a distribution of the input percentages varying in space according to various geomorphological (geography and topography), edaphic (geology and pedology) and anthropic (archaeology and anthracology) parameters.

More precisely, using a GIS system, we are working on the development of a method to compute the interpolated results from the different sites, creating iso-pollen maps for different taxa (or groups of taxa) that consider the previously cited parameters, and then to synthesize this multi-layer information into a single estimate of the number of plants of each species for each map division (georeferenced polygons).

Once we have this, we will have to place the specimens in a realistic virtual word. The ground reconstruction is based on a digital terrain model (DTM), that we converted into a 3D mesh by using a Poisson Surface Reconstruction plugin (qPoissonRecon). A test of some of the most popular 3D software led us to consider working in preference with Unreal Engine 5 (free under creators license, real time engine) to create the ground and background aspects. Regarding the implantation of vegetation, existing attempts (e.g.. Griffon et. al 2010) at 3D landscape simulation - past or present day - often make different choices among which we will also have to choose: working with plant libraries or with plant factories? using scripted or manual implementation methods, that are made considerably easier by the foliage brush tools in UE5? dealing with continuous or discrete values (different types of plant ecosystems)?

Results

So far, we conducted preliminary work of data completion and harmonization, its goal being to allow us the use of the Landcape Reconstruction Algorithm (Sugita and Tallinn team's work). In particular, it was necessary to reinforce both sets of data by establishing a robust age-depth reference curve for each core. Until now, quantitative reconstruction methodology recommended that palynological cores with less than 3 radiocarbon dates and/or with a sedimentary hiatus should be set aside. However, the use of a Bayesian statistical software, Chronomodel v.3 - developed among the OSUR team (University of Rennes 1) - allowed us dating cores that were not taken into account in R. David's reconstruction: indeed, this tool is able to compute an age-depth reference curve by taking into account dating elements such as direct 14C dates, but also delimitation of pollen assemblage zones, known historical events (death of a king, fires...) as well as archaeological information such as radiocarbon dates and chrono-cultural attribution realized on stratigraphically correlated remains.

Discussion

Visualization of archaeobotanical data is an expected improvement for the archaeobotanical community. Indeed, the use of 3D virtual environments forms a thrilling innovation in exploring scientific hypotheses, and should stand as a solution to integrate the huge archaeobotanical datasets that are systematically collected on preventive archaeology fields, analysed but not really used for the moment. It is also an effective way to communicate the results to various audiences (museums, land developers...), and maybe to make our own scientific contribution to the debate on climate change, biodiversity and human resilience.

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53. A new geomatic approach to detect verity and classify half-nomad mobility in the South-Eastern Arabia

Guido Antinori, Sapienza University of Roma

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This poster presents the preliminary results of the first survey conducted in February 2022 by the Missione Archeologica della Sapienza nella Penisola Arabica e nel Golfo (MASPAG), with the support of the Ministry of Heritage and Turism of Oman. The surveyed area falls within the al Batinah South Governorate of Oman, in the provinces of Nakhal, al Awabi and Wadi al Ma'awil, still untouched by archaeological research and thus an ideal place to start a new landscape archaeological project. The primary aim of our survey was to test a geomatic predictive model integrating morphological anomalies detected from satellite images, high resolutions photos from drone and archaeological features traced through ground verifications (Casana 2020). In order to achieve our objectives, the work was divided in two main stages. First, we conducted the satellite survey via freely available Google Earth images identifying unusual morphologies in the landscape that might be consistent with archaeological features documented in surroundings areas (most prominently burial mounds). Based on the results, we organized targeted ground verifications activities centred on the main clusters of these anomalies, mainly around Khatum – near wadi Far – and Muslimat – near wadi al Ma'awil. In order to manage the documentation in a uniform and centralized manner even during fieldwork, the geo-database built on QGIS was synchronized with a portable device thanks to QField plug-in, with which we were able to feed the dataset directly from the field, surveying around 300 unpublished burial mounds within their previously unrecorded landscape. Based on the data collected during this first season, we are currently preparing analyses of human mobility in the identified landscape to develop a predictive model. Starting with DEMs downloaded from the NASA EarthData platform, we have compiled friction cost surface to map least cost paths between the main clusters of confirmed archaeological features. We have already observed how the mobility patterns branch off strongly in the direction of several anomalies, which have therefore been identified as the starting point for survey activities of the 2022-2023 season. These preliminary results are quite interesting, the new planned geomatic model works as an artificial adaptive system (Ramazzotti 2014) and allow us to verify the possible archaeological consistency of the aerial macroscopic anomalies as well to refine our perception of South-Eastern Arabia ecotopes simulating and merging top down and bottom up approaches (Knappett 2013; Ramazzotti, Buscema, and Massini 2018). cted in February 2022 by the Missione Archeologica della Sapienza nella Penisola Arabica e nel Golfo (MASPAG), with the support of the Ministry of Heritage and Turism of Oman. The surveyed area falls within the al Batinah South Governorate of Oman, in the provinces of Nakhal, al Awabi and Wadi al Ma'awil, still untouched by archaeological research and thus an ideal place to start a new landscape archaeological project. The primary aim of our survey was to test a geomatic predictive model integrating morphological anomalies detected from satellite images, high resolutions photos from drone and archaeological features traced through ground verifications (Casana 2020). The results of such integration are quite interesting, the new planned geomatic model works as an artificial adaptive system (Ramazzotti 2014) and allow us to verify the possible archaeological consistency of the aerial macroscopic anomalies as well to refine our perception of South-Eastern Arabia ecotopes simulating and merging top down and bottom up approaches (Knappett 2013; Ramazzotti, Buscema, and Massini 2018).

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Session 20. Investigating and/or modelling ancient paths: Discussing theories and methodologies to achieve best practices and common standards

Francesca Fulminante, UCL & Bristol University, UK; University Roma Tre, Italy

Ulla Rajala, Stockholm University

Joseph Lewis, Cambridge University

Room 6

Introduction	09:00 - 09:15
11. Towards a coherent framework for explaining known historical routes *Lewis**	09:15 - 09:40
104. The Rudston Monolith: Its origins and transportation *Wilcox**	09:40 - 10:05
114. Transcontinental, multi-factor convolutional probabilistic corridors: Elements for cloud-computing enhanced mobility studies *Wilkinson*, Orengo, Petrie and Jürcke*	10:05 - 10:30
Tea/Coffee	
126. All roads lead to Rome: Using least cost path to explore cultural transmission during Roman Empire *Carrignon*, Coto-Sarmiento*	11:00 - 11:25
130. When the "easiest" path is not the most effective: About preference for steep slopes when moving on a mountain environment in a diachronic perspective *Forgia**	11:25 - 11:50
156. Iterating over The Old Straight Track: An exercise in model-building *Pafort**	11:50 - 12:15
Lunch	
167. Least cost modelling in the Oberhalbstein Alps: Beyond the single optimal path *Geitlinger**	13:30 - 13:55
2. On track: The Chalcolithic pathways of west Portugal *Sánchez de Oro**	13:55 - 14:20
Discussion	14:20 - 14:35

Introduction

Least-cost past analysis, including network least-cost path analysis have developed immensely in the last few decades, also thanks to scholars such as Irmela Herzog and Philip Verhagen. In particular, the least-cost path has become common practice in the reconstruction of paths and routes especially in Pre and Proto-historic times, and the Middle Ages. According to Irmela Herzog, the least cost path is an especially valid instrument for reconstructing paths in those periods.

Recently Farina and Oubina and Joseph Lewis have demonstrated the utility of least-cost path also for predicting without "re-constructing", roman roads, respectively in northern Spain and highlands and lowlands zones of England. In addition, Oliver Nakoinz and Franziska Paupel have proposed and interesting model, which uses funerary tumuli as landmark to reconstruct paths , but can also be used with different landmarks such as secondary settlements etc.. Similarly, Iza Romanowska and other scholars have recently combined GIS and least-cost path with agent-based modelling. This testifies how least-cost path is still an evolving and dynamic field.

However, we believe that this field is still severely unexplored from a philosophical and methodological perspective: we would like to see papers exploring different premises and interpretations. Can we see the development of more theoretically informed least-cost path analysis? Furthermore, the use of different elevation data sources, algorithms and software packages affects the results and these issues need to be underlined. We should not forget the different cost sources either: does it matter if we use time or energy? And how detailed breakdown we want of our thought moving community: separation according to gender and age?

Least-cost paths are also used in other computerised analyses as an initial step of enquiry: should these applications be problematised? In addition, there is lack of commonly accepted and/or standardised procedures. Therefore, we call for contributions of both theoretical and practical case studies from different regions and timeframe to favour debate and discussion and finally reach hopefully a consensus of best practices and common standard procedures.

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11. Towards a coherent framework for explaining known historical routes

Joseph Lewis, University of Cambridge

The modelling of historical routes using least-cost path analysis is now commonplace within archaeology. More recently, a shift has occurred from predicting unknown routes based on assumptions of optimality to the fitting of movement models for explaining known routes (hereafter postdiction). Although these postdictive models have been used to understand routes in different regions and time periods, with notable examples being Roman roads (e.g. Lewis 2021; Fonte, Parcero-Oubiña, and Costa-García 2017; Güimil-Fariña and Parcero-Oubiña 2015), its application is inconsistent between studies, resulting in limited comparability. This is made more difficult by the presence of alternate cost functions, the lack of a systematic approach on how to incorporate and parameterise multiple cost factors, and the often subjective nature of how goodness-of-fit is evaluated.

This paper addresses the above issues by introducing a coherent philosophical and methodological framework that can be used when aiming to explain historical routes. Within this framework, I propose that (1) cost functions that represent a single process, e.g. fitted models of time taken to traverse a gradient, are consistent in their causal model structure and instead represent fitted models based on different data realisations of the same process. From this, modelled routes based on different cost functions representing the same causal model structure can be tested for invariance using sensitivity analysis. If the outputs using different cost functions corroborate, the cost functions and their values are validated; (2) cost factor weights can be computationally inferred from known routes; (3) the necessary goodness-of-fit of a model can be stated a priori to form the foundation for model assessment.

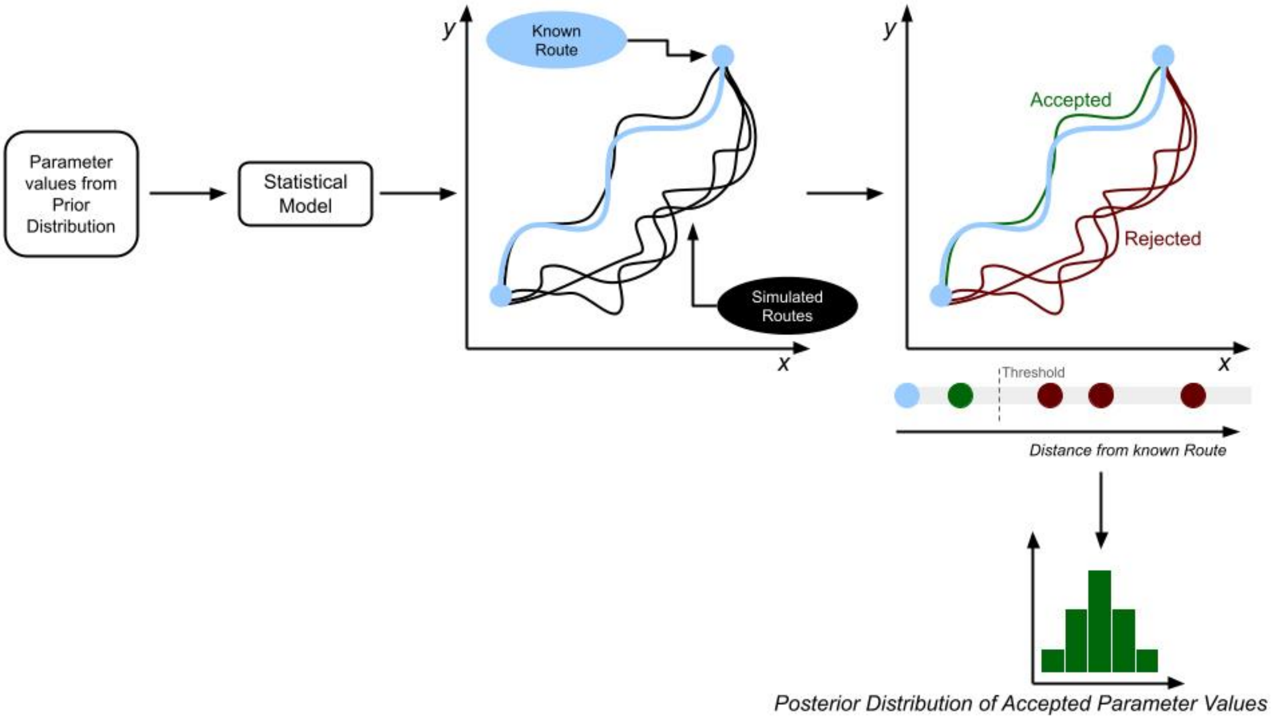

Figure 22. ABC Framework.

Using Approximate Bayesian Computation (ABC) as the core method, the framework will be illustrated through its application on simulated datasets as well as for explaining the routes of Roman roads in Roman Britain. Roman roads will be limited to those appearing in the Antonine Itinerary (a collection of documents compiled from publicly displayed lists accumulated over time until around A.D 300). The initial contribution of this case study will be to assess the variability of Roman roads in Roman Britain and to identify whether the route of the roads followed a single, shared decision-making rule.

Through this framework, the postdiction of known historical routes in different regions and time periods will become directly comparable: for example, the parameter estimates for cost factor weights for one route can be spatially and temporally compared to another route; a model based on one region can be assessed for its ability to predict routes in another region, i.e. its transferability; whilst routes with unique explanations can start to be differentiated from the general.

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104. The Rudston Monolith: Its origins and transportation

Wyatt Wilcox, University of Oxford

The Rudston monolith lies within the graveyard of All Saints Church, Rudston, East Yorkshire and forms part of a Neolithic and Bronze Age monument complex at the eastern end of the Great Wold Valley. It is the largest monolith in Britain, standing at a height of approximately 7.62 metres and is estimated to weigh circa 40 tonnes. Late eighteenth century excavations suggested that the monolith extended as far below ground as it extends above ground. The gritstone used for the monolith is not native to the Yorkshire Wolds. Two possible origins have been proposed: 1) long-distance transport from the North York Moors; 2) local transport of a glacial erratic deposited by the ice sheets that once extended onto the Wolds from the North Sea. This paper explores the first of these origins, using families of optimal pathways that take into account both former areas of wetland and uncertainty due to error in the digital elevation model used in the analysis.

Geologic background

Three potential gritstone sources can be identified from the British Geological Survey 1:50,000 mapping:

1. Moor Grit – outcrops of the Middle Jurassic Ravenscar group at Hundale Point on the coastline of the North York Moors;
2. Lower Calcareous Grit – later Jurassic outcrops at Red Cliff on the North Yorkshire Coast, and outcrops at Langton and Grimston on the Howardian Hills;
3. Upper Calcareous Grit – later Jurassic outcrops at Cayton, near Filey on the North Yorkshire coast.

Drawing upon recent work describing movement of the Pukao colossal hats on Easter Island (Hixon et al 2018), possible routes from these sources to the site of the Rudston Monolith are explored through the use of optimal pathways analysis.

Methods

A family of optimal pathways was generated for each of the possible sources using the Distance Accumulation and Optimal Path as Line tools in ArcGIS PRO, prioritizing routes directly up or down slopes to reflect controlled movement of the monolith using the parbuckle technique. Vertical costs of movement were modelled using standard equations for movement of objects on inclined planes. Variable friction costs were modelled to reflect movement across different types of terrain with wetlands modelled in ArcHydro's Wetland Identification Model. Costs of movement were calculated using a surface approximation approach based on the Eikonal Equation (Setian 1999). A Monte Carlo simulation was used to model uncertainty due to errors in the digital elevation model (c.f. Fisher 1993), with the counts of overlapping features from the simulated optimal pathways reflecting the probability that line segments were used in the optimal pathway.

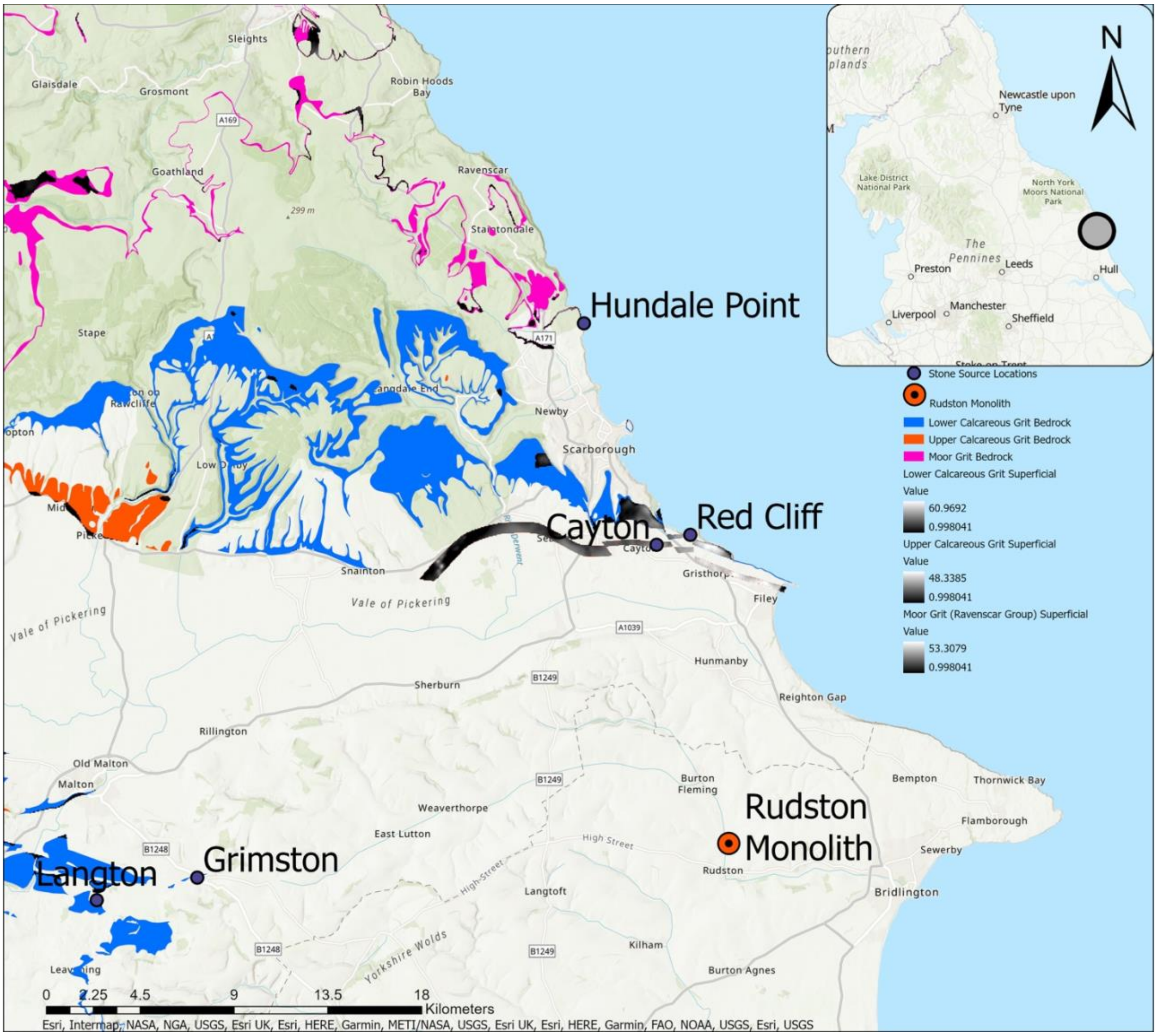

Figure 23. Possible sources of gritsone.

Results and discussion

Two possible routes were identified on the basis of modelling – a coastal route from the outcrops of gritstone at Cayton, Red Cliff, and Hundale passing through the Barondale valley to the north of Rudston and an inland route from the outcrops of gritstone at Grimston and Langton following the Great Wold Valley. The latter route, though longer, forms the eastern section of a long-distance network of connections between the Lake District and the Holderness Coast. Both ends of this route correspond to the only two documented examples where stone was used in the construction of burial mounds in Eastern Yorkshire. The first of these is the Whitegrounds Barrow on the Howardian Hills, which was excavated in the 1960s. The second of these is the long barrow at Rudston, which was excavated in the mid-to-late eighteenth century. Of the two possible routes identified, the inland route is considered most probable due to its correspondence with the use of stone in Eastern Yorkshire barrows. However, this suggestion of probability is made with the caveat that the debate can only be definitively resolved through the geological provenancing of the monolith itself.

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114. Transcontinental, multi-factor convolutional probabilistic corridors: Elements for cloud-computing enhanced mobility studies

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Cameron Petrie, University of Cambridge

Friederike Jürcke, University of Cambridge

Mobility has been essential for the development of communications and relationships between different human groups. Transcontinental routes, formed by the continuous adjoining of intra-cultural roads, played an essential role in the development of common or synchronous social and economic changes as early as the Bronze Age, with evidence for cultural interchange, direct or indirect, between very distant parts of Eurasia. These routes were shaped by regionally interlinked settlements When approached at a large-scale, routes represent the pathways and highways by which human space and time became increasingly compressed over the longue durée.

Despite the importance of movement to comprehend the origins and development of human economies, our understanding of human mobility in the past remains unsystematised. How did environmental conditions affect movement? How did the domestication of animals and the evolving technologies of transport extend human connectivity to different ecological zones? These questions are particularly pressing when considering long-distance and transcontinental routes, such as those which formed part of the historical "Silk Routes", where factors affecting movement can greatly vary along the route, where the mobility network tend to reflect seasonal variations and socio-economic factors and where we are talking about the cumulative outcomes of large numbers of journeys, rather than single itineraries.

In this paper we present a methodological toolkit by which we can model a network of route corridors using a multi-factor probabilistic approach, leveraging high performance cloud computing that can be related to multitemporal settlement data and ultimately queried using common statistical approaches.

The method presented represents an enhancement of traditional cost or friction modelling, combining multiple factors and not simply slope costs. The preparation of the cost surface, which measures the cost of traversing each raster cell, presented the first step in the workflow. This was developed combining a series of satellite-based sources modified to adapt to different cost values. The first of those was the slope cost for humans, which was derived using the sixth-degree polynomial developed by Herzog (2013) from ethnographic data from Minetti et al. (2002) using an

ALOS DEM (30 m/px). This raster forms the basis of the cost surface to which all other factors are multipliers (except for the sea mask, which is summed).

The Global Water Mask (250 m/px), a global map of surface water was used to identify large water bodies with a cost value of 50 to discourage transit over water. However, these not include temporary or even perennial water bodies such as rivers that can hinder movement. For this we used the JRC Monthly Water Recurrence dataset, cost values were set to range between 1 and 4 depending on the quantity of water documented in each 30 m pixel for the specific month. Snow costs were derived from the MODIS MOD10A1 V6 Snow Cover Daily Global 500m product were also included.

Another important factor to take into account when modelling movement at a transcontinental scale is the water, or rather lack of water. However, this is a very complex cost to factor as how the lack of water affect movement is dependent upon a multiplicity of factors. The most important of these factors is temperature, which was derived from TerraClimate. Temperature data was limited to user-selected values distributed in a 0-2 range and used as an exponent where the base was the value of dryness. Dryness values were extracted from a multiyear monthly series of Landsat 5-derived EVI values truncated to a minimum threshold of 0.05, which is a common value to define desertic conditions, and scaled from 1 to 2.

We also created a layer factoring the attraction to areas with higher presence of water. However, the attraction of this factor needs to be weighted by the local environmental conditions. Therefore this attractor (i.e. reduced cost) layer is only implemented in areas with high aridity and temperature. Taking this into account and, given the capacity of humans to carry water we created a focal mean convolution of the previous 'lack of water' cost layer with a 7 km radius to provide a more relevant representation of the locations where desert and temperature are high and, therefore, the presence of water can be considered an attracting factor. The convolution was included as an exponent in a where the base was the same Landsat 5-derived EVI multi-year monthly values clipped to a minimum threshold of 0.2 (minimum EVI healthy vegetation value).

Lastly, a layer aiming to model the cost of traversing high mountain areas was derived using a purposely developed function, which produces a curve intersecting the two values for which we have data on how altitude affects walking performance (Minetti et al. 2006).

All cost derivates were spatially cropped to the user-defined area of interest (AoI) and averaged by user-selected periods, which allowed us to extract cost surfaces for different seasons or months. All these cost layers were multiplied between them and the sea mask was added.

The next step in the production of corridors was the generation of cost distance rasters per specific point of interest. For this the knight move algorithm was employed. Despite being more computationally costly, the 16-way knight's move doubles possibilities for radial movement from any given raster cell compared with traditional 8-way algorithms. This provided much more natural movement cost outputs. Different cost distance rasters were then combined to create corridors between two or more points of interest using cell stats.

We have employed the workflow described above to generate probabilistic corridors modelling routes at different scales, including a series of sites/artefact networks from Eurasia. The generated corridors represent heuristic platforms by which connectivity of intervening places can be assessed in quantitative terms.

The corridors presented here provide a unique tool for the analysis of long-distance movement. They are multi-factor, which allows them to take into account environmental factors affecting movement over large distances that are usually not significant (or not considered) during the calculation of local or regional routes. They also introduce convolutional costs, which allow changes in costs according to local conditions. They incorporate time-aware datasets that allow users to consider the variability of routes according to seasonal variations. The nature of the corridors (including a range or values rather that a single best route) together with the possibility to join several corridors from multiple start-destination points allows probabilistic modelling of distributions along the route and exploratory analysis, which adapt much better to the nature of hypothesis-based archaeological enquiry and the fact that cost values and coefficients are based on modern data and require future verification by ethnographic or other means.

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126. All roads lead to Rome: Using least cost path to explore cultural transmission during Roman Empire

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Maria Coto-Sarmiento, University Tübingen

The huge variability found in pottery production allows us to detect different patterns that can explain how technical skills were transmitted and shared over time. Despite having an enormous knowledge of pottery production, it can be difficult to identify the precise social interactions and learning strategies that shaped large-scale pottery production and defined the modes in which technical skills were transmitted through time and space on a large scale.

The aim of this study is to analyse the impact of the Least Cost Path on the exploration of cultural variation in amphora production. To do so we analyse a dataset of amphorae from a group of workshops specialised in pottery production located in Baetica province (currently Andalusia) from 1st to 3rd century AD. This type of amphorae was commonly used for the massive transportation of olive oil from Baetica province to different places during the Roman Empire.

The study of cultural variation in pottery production has been a key method to understand different patterns detected in the production. According to some studies (Li et al., 2014; Shennan et al., 2015; Coto-Sarmiento et al., 2018), one of the main aspects that influence how production techniques change from one workshop to another, and therefore that could explain the differences measured in the amphorae found at these different workshops, is the geographical distance between them. It is assumed that workers from workshops closer in space will be more likely to interact and share knowledge about pottery production; or that the same workers may be able to work in different production sites if those sites are close enough. Thus, the amphorae produced by close workshops are more likely to share physical similarities than amphora produced by distant workshops.

The increasing use of computational and quantitative tools in archaeology has made it possible to combine alternative methods to answer different hypotheses about geographical distance and morphometric variation. Among such tools, Least Cost Path (LCP) is a convenient one for calculating such distances. Nonetheless, accurately measuring these distances and defining what they represent exactly is far from trivial. In the context of cultural transmission, these distances often reflect the probability of social interaction between individuals that use different routes to communicate, trade and transport amphora production. Thus, Least Cost Path can help us to formalise different hypotheses about the social organization of groups of workers, workshops, etc.

In this study, we propose to compare and measure different ways of computing Least-Cost paths to illustrate how they can be used to represent different meaningful historical hypotheses about the interactions between a group of workshops specialised in amphora production located in Baetica Province. To do so, we use the R-package Least-Cost Path (https://cran.r-project.org/web/packages/leastcostpath/index.html), combined with a python model of cultural transmission already used in previous study (available here: https://github.com/simoncarrignon/apemcc), to analyse how different social and economic interactions impact amphora production.

We believe that the combination of different tools presented here can provide a strong baseline for the exploration of transmission processes in the large-scale production of different artefacts, but such tools must be carefully used and precisely understood, as what may seem to be trivial choices in method parameters may hide critical underlying assumptions that can drastically change the output of the analysis.

130. When the "easiest" path is not the most effective: About preference for steep slopes when moving on a mountain environment in a diachronic perspective

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Over the last 10 millennia, the Madonie mountain range has been exploited by hunter-gatherers during the Early Holocene, and pastoral groups since the Middle Neolithic. This is evidenced by the results of archaeological and palaeo-environmental research that has been carried out on the same mountain range over the last fifteen years.

The Madonie mountains are located in the northern part of Sicily, spanning an altitude from approximately 200 m a.s.l., at the bottom of the Imera River Valley, to 1,979 m a.s.l., at Pizzo Carbonara. The peopling of the Madonie since the Early Holocene is evidenced by the conventional radiocarbon age of 9450±50 years BP from the archaeological deposit of the Vallone Inferno rock shelter (Scillato, Palermo), which my team and I have been excavating since 2008. Surface lithics scattered on the highlands suggest an even earlier - late Upper Palaeolithic - human presence during the late Pleistocene. Following a gap of a few millennia, a Middle Neolithic layer (5460 – 5220 cal BC) at Vallone Inferno documents the seasonal exploitation of the area by pastoral groups. The rock shelter is situated at an altitude of 800 m a.s.l., at an inevitable passage point for people and herds interested in exploiting the high altitudes of the mountain range. The results of surface surveys of sample areas and test pits, in middle and high elevation ranges, have documented the exploitation of the mountainous territory by successive prehistoric and historic communities, revealing the presence of persistent places.

The archaeological data set above has been compared with the results of a Least Cost Analysis in a diachronic perspective, and with the modern network of hiking paths.

The selection of the variable "slope" for the weighted-cost surface, the alternative elaboration of cost surface giving preference to lower or higher degrees of slope, with different geo-topographic targets, and the relative results have been compared with the archaeological background, suggesting the existence of diverse mobility strategies.

In computing the least cost paths (cost surface and cost distance computed with ArcMap), I have selected two approaches: One which gives preference to the flat routes, and another which gives preference to the steep slopes. In the latter case, the surface cost has been weighted giving preference to the higher degrees of slope, avoiding exclusively "vertical" movements.

In order to analyse the mobility strategies adopted locally, I have selected two targets coinciding with the peaks where the main persistent archaeological places are located on. As concerns more specific case studies involving the mountainous territory at a regional scale, I have selected specific archaeological targets.

Having computed the paths adopting the abovementioned approaches, I have compared the results with the archaeological background, evidencing different mobility patterns.

These differences have been tentatively associated with diverse types of strategies and economic frameworks in a diachronic perspective.

The least cost paths which appear to be "coherent" with the hunter-gatherer archaeological background (open air sites, lithic scatters) seem to coincide with a "stronger" mobility strategy, with a preference for higher slopes and ridges. The same holds for the seasonal pastoral mobility exploiting the vertical shift between lowlands and uplands. On the other hand, a slow mobility with a preference for a lower degree of slopes has been tentatively associated with the seasonal mobility of small groups within the mixed agro-pastoral system of the colonial period, linked to the Greek colony of Himera, as detailed below.

Upper Palaeolithic / Mesolithic

Hunter-gatherer "fast" mobility: Preference for steep slopes in the connection between lowlands and uplands. Paths cross the relevant open-air sites and rock-shelters. Interpretation: Seasonal "fast" mobility of groups of hunters-gatherers from the lowlands to the uplands.

Middle Neolithic (end 6th millennium cal BCE)

(Local scale) Pastoral groups exploiting the mountain environment: Preference for steep slopes in the connection between lowlands and uplands. Paths cross the relevant open-air sites and rock-shelters. Interpretation: seasonal "fast" mobility of pastoral groups from the lowlands to the uplands.

(Regional scale) Pastoral groups exploiting the mountain environment: Preference for steep slopes in the connection between lowlands and uplands and across the mountainous environment. A long path connecting a production site with a reception site of a specific raw material (obsidian) crosses the Neolithic pastoral shelter of Vallone Inferno, on the Madonie mountain range. Interpretation: Seasonal mobility of pastoral groups involved in the obsidian exchange network.

Greek colonial period (6th-5th century BCE)

- From the Greek colony of Himera to the uplands. Preference for flat routes in the connection between lowlands and uplands (part of the community exploiting the mountain environment). Paths cross the relevant rural sites. Interpretation: Mixed agropastoral system with a short-, to mid-mobility range to the high pastures and rural sites distributed along the paths to the uplands, without defensive concerns.
- From the settlements of the natives to the uplands. Preference for steep slopes. Paths cross the relevant rural sites, in strategic position with a visual control of the territory (results of viewshed has been compared with the results of the LCA). Interpretation: specialised pastoral system with a mid to long-mobility range to the high pastures and defensive concerns.

156. Iterating over The Old Straight Track: An exercise in model-building

Catja Pafort, Realm of the Green Knight

In Britain, the theory of site-to-site navigation proposed by Alfred Watkins in The Old Straight Track (1948 [1925]) is well-enough known. It springs from an age of dubious etymology and strange theories to explain natural and historical phenomena. While it has been thoroughly rejected (see, e.g. articles collected on Behrend (n.d.)), its nature nonetheless makes it suitable for an exploratory modelling study.

Watkins proposes that prehistoric sites – mounds, hillforts, barrows, standing stones and more – form 'trackways' in the shape of straight lines that were used for navigation by pre-Roman travellers.

The Old Straight Track can be modelled with a deceptively simple conceptual model: all is needed is a list of sites and the ability to connect them with straight lines. Here, one might expect a relatively straightforward answer (it is an example of 'alignment of random points in a plane', a well-researched problem in mathematics) which immediately illustrates some of the pitfalls of modelling: Without engaging with the concept of 'list of sites' from an archaeological point of view, without defining 'straight line' in archaeological context (the basis here should be human perception rather than mathematics) and, last but not least, without creating tools for evaluating results and comparing them to random distribution of sites, modelling The Old Straight Track is meaningless. At its heart this is an archaeological problem that should not be reduced to a mathematical one.

The study uses sites on the Isle of Anglesey to explore the use of game technology (Apple's SpriteKite and GameplayKit frameworks) to iteratively develop a series of models related to the theory of The Old Straight Track. Beginning with the simplest model, each modelling step was embedded in a desktop application (to allow easy data entry, model- and parameter changes, as well as collection of relevant statistics) and interrogated from a conceptual/methodological point of view which in turn gave rise to modified or reimagined models. The platform and technologies were chosen for their accessibility and ease of use since they are designed for use by relatively inexperienced programmers and offer solution for many of the technical challenges faced by modellers, from connecting items to pathfinding algorithms.

The goal of this study was to develop and evaluate a lightweight iterative modelling process where not only the results of models, but the process of designing them yielded insights into the archaeological topic at hand.

Problem clusters

1) Site Selection

This is not a modelling problem as such – the computer does not care about the identity of sites – but an archaeological one. Which sites qualify for inclusion in the model, which sources can be used, how are uncertainties handled – all of these questions influence the design of the data model. It is not enough to simply have 'a site': to get meaningful results, models need to contain specific information to make it easy to reconstruct what the sources for the site list were and to potentially allow resulting routes to be verified through fieldwork.

A possible development direction for future work is the reconstruction of historic landscapes as not all site categories are equally well preserved or equally well represented in the sources consulted.

2) 'Straight Lines'

'Connecting sites with straight lines' is relatively trivial if one works with a ruler on a paper map, even though the questions of scale and accuracy still arise. Computers need more detailed instructions, and here multiple approaches were applied and compared for accuracy.

At which point does allowing a loose interpretation of 'straight line' create too many choices for a traveller, and does this lead to them ultimately not reaching their destination? This and related questions could be answered by building an agent-based model (ABM) based on a network of sites where independent entities ('agents') attempt to navigate a map of sites according to rules of how the 'next' site in a journey should be identified (distance, angle).

3) Evaluation

Watkins' theory of tracks formed by a linear alignment of sites can only be fully disproven by a model based on a suitable database of sites, the creation of which is beyond the scope of this study, though the shortcomings of easily accessible information were clarified by the model construction process.

In order to evaluate models, suitable measurements need to be built into them, such as the number of routes found in the study area, the average number of sites on routes, or the overall length of routes so they can be compared not only to random distributions of sites (multiple randomisations were evaluated), but also to a more accurate database of sites as the assumption is that more accurate input should lead to better model performance.

Further models

At its heart, the Old Straight Track is a theory about navigating landscapes by sighting objects. It is easy to forget that 'drawing lines on a map' is itself a model and quite likely an inadequate one. To fully answer the question whether navigation as described by Watkins was even possible, a 3D model based on DEM would need to be developed which allows connections only between sites that – according to viewshed analysis – are connected by a line of sight.

A further development here would be an interactive model to create an immersive experience that allows navigating the 3D model at will.

Conclusion

The process of creating a model, interrogating it from both modelling and archaeological points of view, and using the insights to feed into the next model iteration has led to in-depth understanding of the methodological and technical challenges associated with modelling The Old Straight Track. The resulting model cluster application invites a playful approach appropriate to the technology used and opens the door to comparisons with different datasets and further developments. The iterative approach allowed for a gradual development of programming skills alongside conceptual understanding.

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167. Least cost modelling in the Oberhalbstein Alps: Beyond the single optimal path

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Many archaeological applications of least cost analysis aim to yield a single optimal route between two specific locations. However, the assumption that there is a single accurate least cost path is not only implausible with regard to the nature of human movement, but also ignores the many methodological uncertainties and presuppositions underlying least cost path modelling; as already explored by earlier contributions (i.e. Gietl et al. 2008), the outcome of least cost path analyses is highly dependent on the used algorithms, software, cost functions, digital elevation models, and further model parameters. This paper explores methodological flaws of common slope-dependent least cost path procedures by considering different ways to construct least cost models in the Swiss Oberhalbstein Alps. Since 2020, the Swiss Oberhalbstein Alps are objective of the survey project cvmbat, addressing the Roman conquest of the Alps in 15 and 16 BCE. The modelling of the routeways therefore also fulfilled the purpose of providing the project with potential targets for the field work and of giving an impression of the axes of communication within the area of research. Furthermore, the Oberhalbstein Alps have already been investigated by historical route research and several archaeological projects, providing the analysis with valuable contextual material for the evaluation of the constructed models.

In order to explore the methodological biases of standard operating procedures for the construction of least cost paths, single least cost paths were constructed between the two Late Iron Age and Roman settlements Riom-Parsonz and Tiefencastel Kirchhügel. The paths were calculated on the basis of three different anisotropic software algorithms, digital elevation models, and cost functions; the ArcGIS Cost Distance tool (Dijkstra algorithm, movement restricted to 8 direction), the QGIS r.walk and r.drain tool (Dijkstra algorithm, movement restricted to 16 directions), and the ArcGIS Distance Accumulation tool (Eikonal equations, no direction restriction) were applied as anisotropic software algorithms. The DHM25 map with a resolution of 25 meters, the SwissALTI3D Lidar map with a resolution of 0.5 meters, and a coarsened version of the SwissALTI3D map with a resolution of 8 meters were used as digital elevation models. Tobler's hiking function, Minetti's sixth degree energy expenditure function, and Llobera's and Sluckin's slope-dependent cost function with a critical slope of seven degrees were implemented as cost functions. The area of the unshippable river Julia, flowing through the centre of the area of research, was additionally multiplied with an extra cost-factor of 5.5. The following conclusions were drawn from the comparison of the different least cost paths and known archaeological sites and historical routes:

- In contrast to paths derived from the DHM25 model, the resolutions of the Lidar map and its coarsened derivative were high enough so that modern features such as roads were clearly visible. Since the modelled least cost paths tended to closely follow these modern routes, at least in the area of research high-resolution DEM data does not appear to be suitable for the calculation of least cost paths.
- Though the ArcGIS Distance Accumulation tool is from a technological point of view most advanced, all algorithms seem to correlate to a similar degree with the known historic routes and archaeological sites.
- There was a high variety within the courses of the least cost paths derived from different cost functions. Although the slope-dependent cost function was as expected the only function, which was able to reproduce the typical alpine serpentine course of routes, with regard to the correlation with historic routes and archaeological sites no single function seems to clearly outperform the others. Nevertheless, through the comparison and superposition of these different paths, there seem to appear distinct areas, where pathways perceivably converge, potentially representing strategic corridors within the landscape (Figure 24).
- Finally, cost surface models comprise abundant of interesting contextual information about the landscape and the surrounding of least cost paths. However, by exclusively focusing on single paths this contextual information is totally ignored.

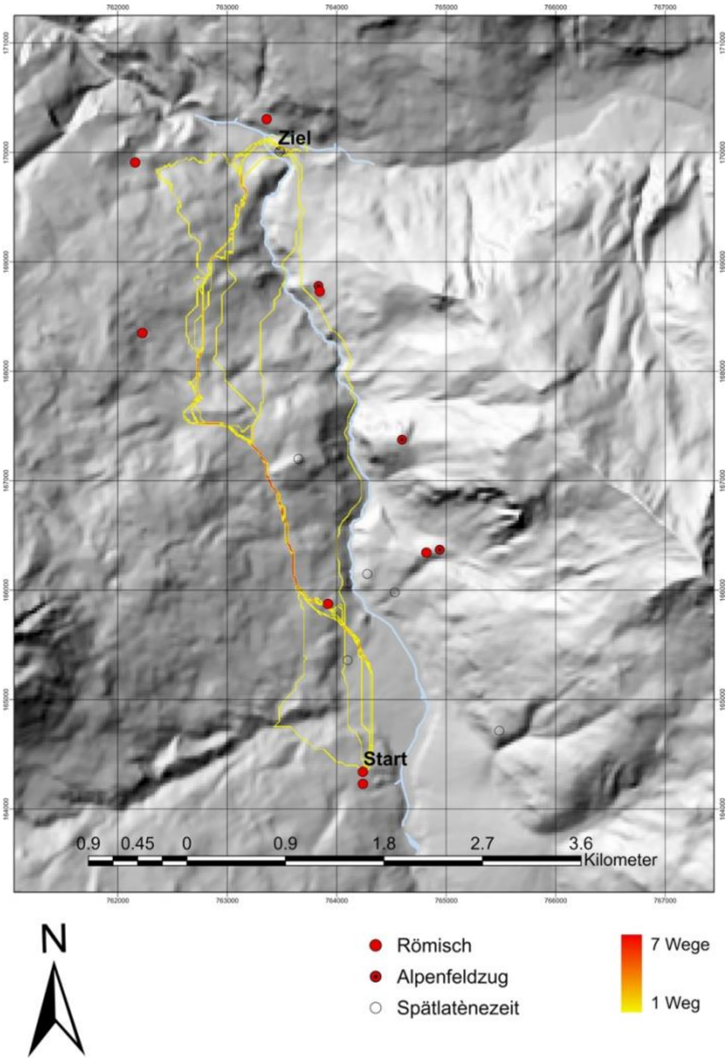

Figure 24. Least cost paths between Riom-Parsonz and Tiefencastel Kirchhügel.

In order to further explore these strategic areas and to overcome single least cost paths, two additional least cost models were constructed on the basis of the DHM25 elevation model, the ArcGIS Distance Accumulation tool, and the various cost functions; on the one hand a probabilistic model, which similar to a recent approach by J. Lewis (2021) was simulated by the iteration of the standard vertical error (5.5 m) of the used DEM, on the other hand a total cost raster, derived from the mean accumulated cost needed to access each raster cell from every raster cell within a certain surrounding (cf. Mlekuž 2014).

From a methodological point of view, the inclusion of the vertical error in the probabilistic model seems particularly significant, as especially in mountainous regions even high-resolution DEM can have considerable deviations, which potentially distort the outcomes of slope-derived path models. Nevertheless, a similar incorporation of probability in the construction of the total cost raster did not appear feasible; without access to graphics processing units or high performance computers such a model would be beyond the computational power of personal computers. Apart from reproducing the already observed strategic corridors, the probabilistic least cost path model suggested additional strategic places, potentially representing additional targets for future fieldwork. These strategic areas were also clearly visible on the total cost model, however, by providing a more holistic impression of accessibility within the whole area of research, the total cost raster furthermore put the strategic corridors into their greater landscape context.

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2. On track: The Chalcolithic pathways of west Portugal

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The West region of Portugal in the 3rd millennium B.C. is undoubtedly an area with a singular landscape multiplicity. This is due to the influences of the Atlantic Ocean and the Tagus river and the diverse geological structures, which allow us to detect and define micro-regionalisms. Recognising that these natural divisions influenced the structuring of prehistoric settlement, we have tried, through Geographic Information Systems (GIS), to understand and evaluate possible patterns of mobility and spatial relations between archaeological sites and the identified micro-regions. Thus, and resorting to Least Cost Path (LCP), a total of 182 routes between chalcolithic sites were identified, suggesting mobility flows possibly determining the existence of archaeological realities, such as surface remains, or even contemporary funerary monuments.

Sessions (Thursday)

Session 03. Quantitative approaches applied to lithic studies

João Carlos Moreno de Sousa, Universidade de São Paulo

Mercedes Okumura, Universidade de São Paulo

Judith Charlin, CONICET-Universidad de Buenos Aires

Room 10

Introduction	09:00 - 09:15
7. Diachronic changes in distribution patterns of core reduction intensity and the origins of Early Middle Palaeolithic behaviours at the unit TD10 of Gran Dolina, Sierra de Atapuerca, Burgos *Lombao*, Morales and Mosquera*	09:15 - 09:40
23. After the revolution: How 3D modelling is changing lithic analysis *Wyatt-Spratt**	09:40 - 10:05
67. Integrating 2D and 3D shape analysis in lithic technology: A discussion around a case study and future research perspectives *Falcucci**	10:05 - 10:30
Tea/Coffee	
50. Using both a mobile GIS application and a webmapping application for collaborative networking: The return of experience of PCRs "Réseau de lithothèques" and GDR SILEX with multidisciplinary research groups for prehistoric studies *Fernandes, Tuffery* and Delvigne*	11:00 - 11:25
83. Standardization on the technological analysis and statistic processing of lithic artifacts: Application of a proposed protocol on the points from meridional Brazil *Moreno de Sousa**	11:25 - 11:50
153. A particular texture? Quantitative surface analysis of an Australian grindstone quarry assemblage *McGee**	11:50 - 12:15
Lunch	
159. Evaluating the occupation patterns of the Palaeolithic archaeological sites of Galicia through the application of predictive modelling *Díaz-Rodríguez*, Pérez-Alberti and Fábregas-Valcarce*	13:30 - 13:55

169. For lack of a better flake: Simulating formational emergence and re-use in lithic aggregates 13:55 - 14:20

Davies, Douglass and Reeves*

Discussion 14:20 - 14:35

Introduction

Since Albert Spaulding's (1953) classic paper that introduced modern statistical thinking to Archaeology, many theoretical and methodological developments have been used in order to further understand questions related to diversity, function, style, as well as identity and cultural boundaries among past human groups. No doubt that lithic materials are the most well preserved and conspicuous remains observed in precolonial archaeological sites all over the world. Quantitative methods are those that manipulate numbers and use measurement in the research process (Aldenderfer 1998:93), such methods can be applied to either quantitative or qualitative variables. The union between quantitative methods and lithic analyses have been important to allow archaeologists to handle the vast amount of data that can be generated through the several different approaches applied to describe, summarize, and interpret such materials, including hypothesis testing. Important topics for lithic research, like raw material procurement, tool manufacture, assemblage variability, as well as tool use and behavioural questions (Odell 2004) can be properly addressed using a myriad of quantitative methods from descriptive to inferential statistics, including multivariate models. Technological analyses of lithic assemblages and the subsequent use of statistical approaches are usually applied to assemblages excavated from archaeological sites (including extensive surface sampling), although it can also be applied to assemblages generated by experimental archaeological studies (Moreno de Sousa 2019). In the last decades, new techniques focusing on image acquisition, visualization, modelling, and measurement of lithic materials, including laser scanning (Shott and Trail 2020) and photogrammetric approaches (Magnani et al. 2020), have allowed the creation of 3D datasets of artifacts. Besides the importance of such digital collections in terms of preservation and online access to these materials, shape analyses including traditional or geometric morphometrics (in 2 or 3D), as well as Fourier analyses can be applied to such datasets (Buchanan et al. 2014, Charlin and González-José 2012, Iovită 2010). Other quantitative approaches like Bayesian statistics have become more popular in the last two decades (Otárola-Castillo and Torquato 2018) and machine learning techniques have been recently incorporated in some projects (Elliot et al. 2021). Beyond the most popular questions regarding lithic diversity and site function, some quantitative methods have also been recently applied to address questions regarding taxonomic classification and stone tool evolution, including phylogenies of stone tools (Lycett 2011, O'Brien et al. 2001) and a combination of cladistics and shape analysis (Cardillo and Charlin 2018, Lycett et al. 2010). Quantitative methods have also been important for the study of artifact spatial variation at different scales (from intra-site to regional and latitudinal patterns), and the modelling of cultural processes across landscapes, using a combination of geostatistics and GIS tools (Clarkson and Bellas 2014, Hodder and Orton 1976, Kintigh and Ammerman 1982). In common, many new analytical approaches need to be properly adapted to the specificities of the nature of Archaeology as a discipline, including theoretical and methodological issues (Okumura and Araujo 2019). In this session, we seek to further discussions on these important topics pertaining to quantitative methods applied to lithic analyses (ranging from traditional approaches to innovative applications, as well as a combination of both). Critical review papers, original research highlighting case studies, and other short discussion pieces are welcome. These can range from systematic reviews of specific or general topics to case studies demonstrating ways by which scholars have addressed such topics in their specific research context. Exploratory studies presenting new and innovative uses of quantitative methods applied to the analysis of lithic materials are also welcome. We hope to stimulate further discussions concerning quantitative methods applied to lithic studies and compile a resource for researchers moving forward in this area. Exploratory studies presenting new and innovative uses of quantitative methods applied to the analysis of lithic materials are also welcome. We hope to stimulate further discussions concerning quantitative methods applied to lithic studies and compile a resource for researchers moving forward in this area.

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7. Diachronic changes in distribution patterns of core reduction intensity and the origins of Early Middle Palaeolithic behaviours at the unit TD10 of Gran Dolina, Sierra de Atapuerca, Burgos

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Juan Ignacio Morales, IPHES-CERCA, URV

Marina Mosquera, URV, IPHES-CERCA

Between 600-300ka, a process of "Neanderthalization" took place in Europe, characterized from a paleoanthropological point of view by the appearance of the first anatomical features of early Neanderthals throughout western Europe. This process is accompanied by a series of behavioural changes documented in the archaeological record, both at technological level (fire use, the appearance and generalization of bone technology or the first evidence of Levallois cores), and at subsistence level and social dynamics, with the emergence of organized communal hunting strategies (Rodríguez-Hidalgo et al. 2017).These behavioural changes are characteristic of the transitional period between the Lower and Middle Palaeolithic.

Although these behavioural changes may reflect a different form of territorial, economic and technological organization, to date no study has been conducted on assemblages of these chronologies (600-300ka) with the aim of documenting the diachronic evolution in human stone tool economy through the quantification of core reduction intensity. In this way, it has been suggested that core and tool management patterns reflect aspects of territorial organization and structure of human technical processes. One way to measure this aspect is through the estimation of the reduction intensity or use-life. This concept is expressed at a theoretical level as the extraction of the utility or working potential of each piece regarding its volume. At a practical level there are many ways to express this ratio depending on the category (core or tool) or type of tool, although one of the most frequent is as a percentage of extracted volume.

In this paper we applied two methodologies oriented to the quantification of reduction intensity in cores, the Scar Density Index (Clarkson 2013) and the Volumetric Reconstruction Method (Lombao et al. 2020) on cores from the four subunits of TD10 unit from Gran Dolina (Sierra de Atapuerca, Burgos, Spain). From these data we have calculated Weibull distributions for each of the studied assemblages. In addition, we have combined these reduction approaches with technological analyses.

Gran Dolina's Unit TD10 represents an ideal scenario to delve into the diachronic evolution of raw material management strategies during this period, since the four subunits (TD10.4 to TD10.1, from bottom to top) present a chronological range spanning between 500 and 220 ka, and previous studies have documented technological characteristics of transitional assemblages between Modes 2 and 3 in the uppermost subunit TD10.1 (de Lombera-Hermida et al. 2020).

The results obtained through the SDI and VRM suggest changes in the intensity of reduction along the Gran Dolina TD10 sequence. Thus, in the oldest subunits (TD10.4-TD10.3) the Weibull distributions are characterized by a discard ratio that grows rapidly at early times and slows down as reduction progresses, generating a general trend of low reduction. In TD10.2 this pattern changes, producing Weibull distributions with higher shape values, indicating an increase in the degree of core reduction. This increase in reduction intensity is maintained in the TD10.1 subunit.

These diachronic changes in reduction intensity occur in parallel with technological changes. In the TD10.4 and TD10.3 assemblages, the exploitation dynamics can be ascribed to Mode 2 and are characterized by a clear relationship between morphologies and knapping strategies. Thus, the aim is to optimize the knapping sequences through the selection of blanks with specific shapes, instead of conditioning and configuring them morphologically prior to obtaining products. This, together with the high remaining volumes of the cores (especially when compared to the subunits from TD10.2 and TD10.1), and the abovementioned reduction patterns, seem to indicate that there is no attempt to maximize raw material utilization.

On the other hand, from TD10.2 onwards, there appear elements allowing to define the TD10.2 and TD10.1 assemblages as transitional between Mode 2 and Mode 3, or as Early Middle Palaeolithic, such as the generalization of centripetal strategies, including the presence of Levallois-like Simple Prepared Cores. In addition, the greater volumetric exhaustion of the cores, together with an increase in orthogonal multipolar knapping strategies and the use of flakes and small-sized fragments as blanks to obtain products, seem to indicate that the technological behaviour in these two subunits is more oriented to a more efficient and intense management of the lithological resources.

This new technological behaviour could represent an innovative element during the transition between Mode 2 and Mode 3, reflecting a different way of managing abiotic resources, which would be in line with the changes identified in the subsistence strategies and the emergence of new technological behaviours.

These results demonstrate the potential of combining technological analyses with quantitative studies of reduction intensity to characterize dynamics of technological behaviour and occupation patterns. However, it is necessary to extend the study sample to other sites with long archaeo-stratigraphic sequences to confirm the obtained results.

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23. After the revolution: How 3D modelling is changing lithic analysis

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With over 200 peer-reviewed papers published over the last 20 years, 3D modelling is no longer a gimmick but an established and increasingly common analytical tool for stone artefact analysis. Laser scanning, photogrammetry, and CT scanning have all be used to create 3D models of stone artefacts, and a variety of different analytical approaches - from geometric morphometrics to custom reduction indices to digital elevation maps - have been utilised. 3D lithic analysis studies are increasingly global in scope and studies aim to answer questions ranging from the spread of hominid populations, assessing functional efficiency, and re-assessing cultural taxonomies. While there have been several key reviews that have looked at the impact of the computational revolution on lithic analysis (Grosman 2016; Magnani et al. 2020; Shott 2014), there have been no published systematic reviews specifically focusing on how 3D modelling has been applied to lithics.

This paper will combine a quantitative bibliometric analysis with a qualitative review to assess just how "revolutionary" 3D modelling has been for lithic analysis. It will explore trends in the use of 3D modelling in stone artefact analysis, the impact it is having on the wider lithic analysis literature, and methodological, regional and theoretical gaps which future research projects could explore.

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67. Integrating 2D and 3D shape analysis in lithic technology: A discussion around a case study and future research perspectives

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Shape analysis in lithic technology is considered a powerful tool to better frame past human behaviour in relation to stone tool manufacture, modification, and use. Despite that, geometric morphometrics is a routinary methodological approach only in a few academic institutions and several well-known Palaeolithic technocomplexes lack of such promising studies. The rarity of shape quantitative approaches is remarkable in the case of European Early Upper Palaeolithic assemblages, which are characterized by a sharp increase in the production of projectile tools, compared to the Middle Palaeolithic. The raising affordability of 3D structured light and laser scanners, coupled with the increased number of researchers willing to share open access repositories, scripts for multivariate statistical analysis, and software packages might in turn represent a turning point. In this framework, 3D applications are usually regarded as more powerful than 2D outline studies because allow to capture the complete, three-dimensional shape of a lithic artifact. Nevertheless, few studies have tried to combine the two approaches to answer specific questions or designed workflows that take into account precise aspects of stone tool variability.

In order to address these interrelated problems, I recently developed a 3D scanning protocol relying on micro-computed tomography in collaboration with two colleagues from the University of Tübingen that allowed us to scan several hundreds of small-sized stone tools from a well-known Protoaurignacian site in southern Europe. These scans are available in an open access repository on Zenodo (https://doi.org/10.5281/zenodo.6362150). Taking advantage of this new 3D scanning protocol and open-source software (e.g., Wishkerman and Hamilton 2018; Herzlinger and Grosman 2018), I explored the variability of a large sample of Protoaurignacian tools to assess the selection and modification of bladelets, which had previously been studied using discreet attributes and linear measurements only (Falcucci et al. 2018). In this upcoming study, the 3D geometric morphometric approach was complemented by the 2D analysis of tools' cross-section outlines using Elliptic Fourier Analysis after the 3D artifacts' segmentation. Furthermore, I explored the relation between the identified 2D and 3D shape features and other quantitative measurements digitally computed (e.g., 3D volume and mean retouch angles) using multiple regression models and discriminant functional analysis. The identification of multidimensional features characteristic of specific tool types enabled to define the most effective strategy for the ongoing use-wear and experimental analysis of this assemblage.

In this paper, I will critically assess the applicability of the different methods employed and I will thus propose a strategy to effectively integrate the amount of data that can be collected from 3D models in relation to specific research-driven questions. I hope that this contribution will emphasize the merits of conducting more integrated studies in lithic technology and stimulate future collaborative research to address some of the existing limitations.

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50. Using both a mobile GIS application and a webmapping application for collaborative networking: The return of experience of PCRs "Réseau de lithothèques" and GDR SILEX with multidisciplinary research groups for prehistoric studies

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Christophe Tuffery, Inrap

Vincent Delvigne, CNRS

Siliceous materials were probably the most commonly used materials by prehistoric people to produce various types of tools. They are also the most common materials found among the archaeological remains of this period because these materials evolve slowly over the prehistoric time scale. The knowledge of the evolution of these materials before their use by the populations and since their burial in the ground and the archaeological sites where they are found, mobilizes many researchers since the beginnings of prehistory in the middle of the 19th century. In France, four collective regional research projects have started since 2006 to bring together nearly a hundred researchers from various disciplines (geologists, archaeologists, prehistorians, petroarchaeologists, geochemists, mineralogists, geographers, etc.). They collaborate on this research topic and their work is regularly published (Delvigne et al. 2018). These collaborative research projects have been complemented since 2019 by a Groupe De Recherche national sur le silex (GDR SILEX), co-funded by the CNRS, the Ministry of Culture, the Inrap and Paléotime.

Figure 25. Groupe De Recherche.

Methods and materials

In order for the researchers involved in these projects to work in a consensual manner, a harmonised method for the characterisation of geological siliceous materials was first established. Based on an innovative concept of an evolutionary chain of siliceous materials (Fernandes 2012), this method required a period of several years of exchange between different researchers who were not used to working together. Until then, each researcher had a list of terms, definitions and methods of observation and description of siliceous materials, which were not very compatible. Thanks to this method, a convergence of their work could be initiated and is currently underway. A glossary of more than 600 terms has been drawn up and will soon be published in French and

English. It will be integrated into the multilingual Pactols thesaurus, which is widely used for archaeology in France.

Results

An Excel form and an MS Access database were developed between 2014 and 2017. They were used to characterise several dozen samples of siliceous materials. They made it possible to take into account the taphonomic, geological and petrological characteristics of the samples. The database has been used for several archaeological sites of the Recent Palaeolithic. It is used for training researchers, who thus adopt the proposed characterisation method (Figure 25).

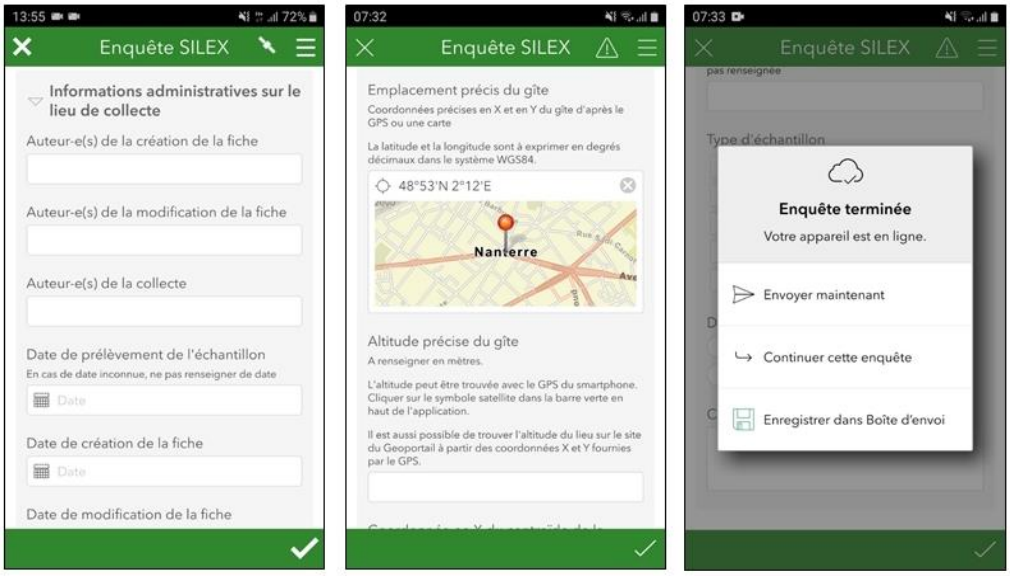

Figure 26. GDR SILEX.

Based on these initial results, a form describing the field collection points and rock librairies inventory of siliceous material samples was defined. A first version has been proposed in Excel. Then in 2021, a mobile application on smartphones and tablets was developed using the ESRI ArcGIS Survey123 application (Figure 26). A survey form has been developed. A version is available in French and another in English. These tools have been adapted according to user feedback. This application, which runs on many smartphones and tablets under Android, Windows and iOS, is gradually being used by researchers, either in the field during surveys or in the laboratory during the inventory of rock libraries. In parallel, a web-based mapping application has been developed since 2017 on the ArcGIS Online platform, to facilitate data sharing and reuse. Researchers' prospecting data and data on siliceous formations, adapted from those produced by the French geology institute, BRGM, are published in the form of WFS. These data webservices are published under the Etalab 2.0 open license and are accessible from GIS software such as QGIS, and allow the use of spatial analysis functionalities that extend the functionalities already offered by the online mapping application (Figure 27). The Nakala platform was used made for sharing photos (flint formations identification, samples collect). Nakala is a platform of the Huma-Num research infrastructure (CNRS, Aix-Marseille University, Campus Condorcet). It allows the publication and sharing of documentary resources, including photographs. For our purposes, we used Nakala to share the photos taken in the field during the identification of flint formations and the sample photos.

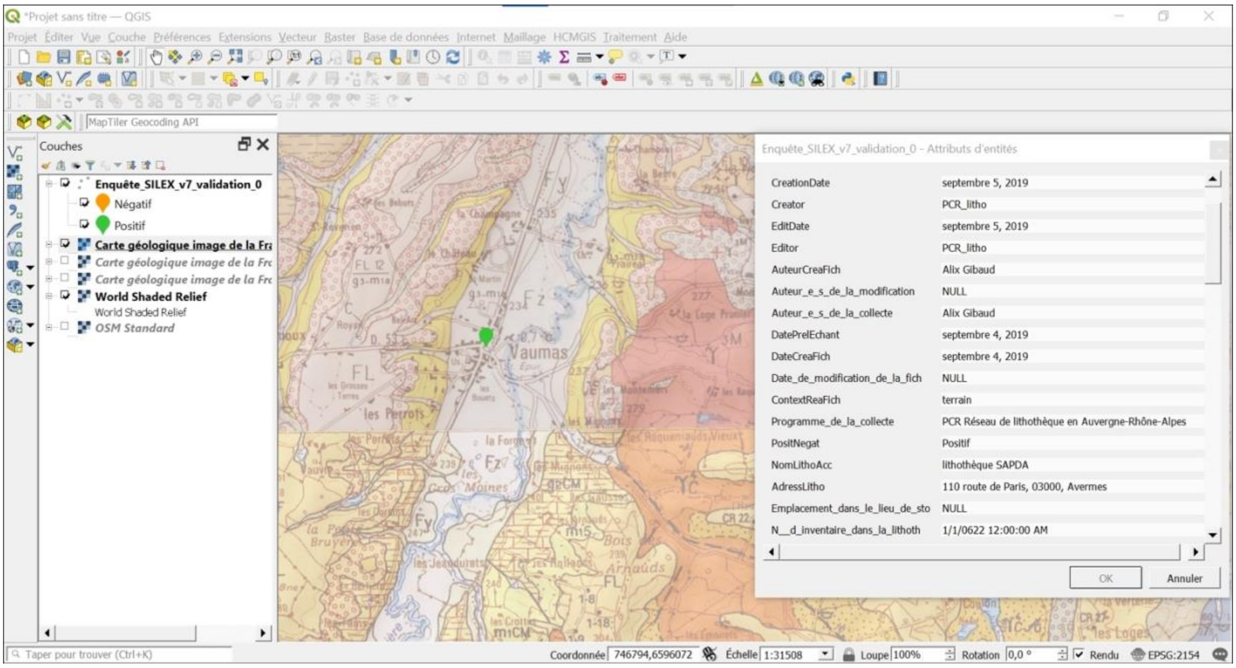

Figure 27. Web services accessed via QGIS.

Discussion

The workflows for the use of these various digital tools are now well established, but they continue to evolve at the margins according to the feedback from users, their needs and the new possibilities offered by the evolution of the technical solutions used. Training courses in France and, recently, in Germany and Belgium, are offered to enable more and more users to learn how to use them and thus have them collaborate on the same project thanks to the digital tools developed for them and with them. The collaborations initiated by the multidisciplinary community of researchers involved in these projects demonstrate that digital tools can be used to support the necessary consensus between researchers who were not used to working in the same way before. But before technical interoperability between digital tools can be achieved, a first and indispensable step is to obtain semantic and methodological interoperability between the researchers involved. Without these two forms of interoperability, digital tools, however technically powerful, cannot achieve relevant and convincing results. Achieving these different forms of interoperability takes a long time. Researchers' practices, which are individually and collectively established social practices, can only evolve if researchers are willing to do so and not under duress. Faced with these major challenges, which are also the conditions for open science, some researchers are more willing than others to adopt digital tools and develop their digital skills. All of them need to be accompanied, to follow training courses and to be able to rely on some of them who act as gatekeepers between traditional research practices, without digital tools, and research practices based on digital tools and methods (Tufféry et al. 2021). The interest of this work and the first results achieved is to show that the need for collaborative work between researchers from different disciplines requires finding the conditions for sharing knowledge and pooling know-how. It is around digital technology that these needs can be met. But this possibility requires all the more reflection on the methodological and epistemological consequences of the evolution of scientific practices under the effect of an increasing use of digital devices.

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83. Standardization on the technological analysis and statistic processing of lithic artifacts: Application of a proposed protocol on the points from meridional Brazil

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Although many lithic researchers base their analysis protocols in consecrated papers and books, the specific protocols used by most scholars are either crafted individually or created in collaboration with their research team. Most of the times, this leads to a multiplicity of protocols created by different researchers for the same class of artifacts. As a result, these different researchers tend to observe different attributes or even to use different classificatory schemes. For example, while 'Researcher A' observes the stem of lithics points (attribute) and classify them as convex or concave (features), 'Researcher B', can classify them as convex, concave or bifurcate. When trying to statistically compare these assemblages, the results might point to significant differences. If this happens to many observed attributes (e.g., negatives organization, flaking technique, etc.) researchers will be led to wrongly conclude that these are two different cultural groups (or at least two different lithic industries) when they might be actually very similar assemblages analysed using different protocols. The issue gets even worse when researchers do not even observe the same attributes (e.g., 'Researcher A' only observes shape, while 'Researcher B' focus on technological attributes), making the data incomparable. To get around this problem, most researchers interested in comparing assemblages in order to better understand technological and cultural diversity chooses to reassess all assemblages using their own protocol and thus creating new comparable data. This solution, however, implies in spending time and funding reanalysing these assemblages. In this sense, the lack of a standard protocol for analysing and comparing multiple assemblages of lithic artifacts has hindered, or at least delayed, the advance of a better understanding of the cultural diversity associated to prehistoric hunter-gatherer groups.

Given that lithic points are used as one of the main classes of artifacts to describe cultural patterns of hunter-gatherer groups in the Americas, our paper presents a proposal of a new protocol of analysis, as well as the results of the application of such protocol in assemblages that were previously associated to the same 'archaeological tradition' in South-eastern South America.

Methods and materials

In the last few years, we have been discussing, developing, and testing a new protocol for analysis of lithic points from Brazilian assemblages. Although we call it a 'new' protocol, most of the suggested observations and classifications of attributes and features are based on previous ideas given by other authors, considering that most of these attributes and features are widely observed by distinct researchers. The innovation, in this case, consists in the list of attributes, their features and the possibility of including new classification (variables for each attribute), as well as the way that assemblages are statistically compared using bivariate or multivariate statistics. The complete protocol has been detailed described and successfully applied in our previous publication about lithic points from meridional Brazil (Moreno de Sousa & Okumura 2020). In that occasion, the protocol was applied to lithic assemblages from three archaeological sites: Alice Boer, located in central São Paulo state, dating between 8500 and 7000 BP; Tunas site, located in north-eastern Paraná state and dating between 11.000 and 8000 BP; and the Garivaldino site, located in mid-eastern Rio Grande do Sul state and dating between 11.000 and 5000 BP. After this publication, the protocol was applied to new samples by us and it is now been applied by colleagues from other research teams in Brazil. Some preliminary results on many assemblages are now providing a new understanding on cultural and technological diversity of hunter-gatherers.

The protocol was elaborated considering thirty metric, morphological and technological features of points, as well as raw material identification, and the diachronic sequence of the negative removals. These features are analysed by descriptive statistics (including frequencies for qualitative attributes), Shapiro-Wilk normality tests for quantitative attributes, and bivariate or multivariate tests. The protocol proposes the use of Chi Square (X^2) and Fisher for bivariate qualitative analysis, Student T Test (normal distribution) and Mann-Whitney (non-normal) for bivariate quantitative analysis, and ANOVA (normal distribution) and Kruskal-Wallis or Dunn-Bonferroni (non-normal) for multivariate quantitative analysis.

Results

The protocol has showed to be successful in achieving our goals and provide new data on the past hunter-gatherer cultural diversity. Data is also successfully comparable, allowing researchers to track technological changes through time and space. Our main results have defined at least ten distinct lithic industries in which distinct types of lithic points are associated.

Discussion

In meridional Brazil – here considered as including the Paraná and Uruguay basins, as well as the Southeastern and Southern Brazilian coast – all hunter-gatherer sites and assemblages presenting stemmed lithic points were associated in the past to a single archaeological tradition (the 'Umbu Tradition'), regardless of any other features. The main issue of this problematic association is related to the lack of standard protocols for the technological study of different types of artifacts (Moreno de Sousa & Okumura 2018, 2020). The application of our protocol has allowed us to describe a much greater diversity in terms of lithic industries associated to ancient hunter-gatherer groups, contributing towards a better understanding of the cultural diversity of the past human groups that inhabited meridional Brazil.

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153. A particular texture? Quantitative surface analysis of an Australian grindstone quarry assemblage

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Indigenous Australians produced massive numbers of grindstones over thousands of years. Much has been proposed about their economic and social significance with little in the way of supporting evidence. Similarly, little is known about their production and the quarrying process. Currently, research methods focus primarily on use-wear and residue analyses to qualitatively assess artefact functionality. These methods ignore the whole artefact, are difficult to replicate, and cannot be reasonably applied over large assemblages.

There has been a significant and ongoing trend towards the quantitative study of grinding and pounding tools (Zupancich and Cristiani 2020; Cristiani and Zupancich 2020; Chondrou et al. 2021). This paper will present initial applications of surface roughness quantification methods as applied to a grindstone quarrying assemblage in Mithaka Country, located in the Channel Country region of Queensland, Australia. These methods are replicable, flexible, low-cost, non-contact and informative. Utilizing in-field photogrammetric data collection and free, open-source mesh analysis software, multiple surface roughness parameters will be utilized to produce multi-scale grindstone surface profiles. This data will allow for the comparative study of surfaces on artefacts, between artefacts and between assemblages, developing beyond the current standard of basic qualitative description.

Surface analyses from completed grindstones and quarried refuse will be presented, demonstrating the efficacy of the methods and providing new insights into how Indigenous quarries were utilized, and grindstones produced. Specifically, this ongoing research seeks to investigate questions surrounding material selection, surface and texture modification, weathering processes and artefact standardization. It is currently not possible to discuss these questions in a quantitative fashion, this research seeks to remedy this problem and invite future developments.

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159. Evaluating the occupation patterns of the Palaeolithic archaeological sites of Galicia through the application of predictive modelling

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The main objective of this work is to analyse the occupation pattern of the Palaeolithic sites in the Galician territory, in the Northwest of the Iberian Peninsula. We wanted to know if there was an occupation pattern or various patterns. In addition, we tried to check if the theoretical model previously proposed by some researchers was fulfilled.

The distribution of sites known to date can be clustered and divided into six large areas. These areas are the Baixo Miño, the Middle Miño, the Eastern Mountain Ranges, the Monforte de Lemos basin, the Central Mountain Ranges and the Northern Mountain Ranges.

In this case, we decided to study three of these areas, which had the most up-to-date data and were linked to systematic research projects.

Methods and materials

The methodology followed in this work focused on creating a documentary corpus with updated information on the sites based on the different research projects and the specific literature. At the same time, the covariates to be analysed were obtained from the specific literature and the theoretical model proposed by different researchers, both for Galicia and for other similar areas of the Iberian Peninsula. The archaeological sites were incorporated into a database and the covariates were modelled with GIS. We tried to use free software such as GRASS GIS, QGIS, SAGA GIS and also ArcGIS.

The modelled covariates were analysed in the R software. First, each variable was studied with descriptive statistics for each area and later we created a predictive model for each area. In the Monforte de Lemos basin, we have decided to study their occupation pattern diachronically to see if there was a common occupation pattern. To carry out its analysis we used those sites whose data were more precise. The sites of the Central Mountain Ranges were framed to the Final Upper Palaeolithic and the Epipalaeolithic from the recovered material culture since we do not have chronological dates in this area. Finally, for the Northern Mountain Ranges area, we have some dating and lithic industry remains that have allowed these archaeological sites to be framed in the Final Upper Palaeolithic and the Epipalaeolithic.

For the creation of the predictive model, we have used the Generalized Linear Model (GLM) (Conolly and Lake 2006). The results of this model depend, to a great extent, on the combination of the covariates used. For this reason, the choice of these covariates is important, since introducing variables that are correlated can cause errors or result in an unreliable model (Baddeley, Rubak, and Turner 2015). To avoid the existence of a correlation between the covariates, we resorted to the Pearson correlation test, which allowed us to identify those similar to each other. In total there are 19 covariates, although taking into account the Pearson correlation's test, this number was reduced to 12 in the case of Monforte and the Northern Mountain ranges and 11 in the central mountain ranges.

To validate the reliability of the model, the sample of sites was divided into a control sample and a training sample. The result indicates that in those cells whose values are closer to 1 there is a greater probability that archaeological sites will be located.

Results

Attending to the predictive model of each area, 5 covariates have a high predictive value for the Monforte de Lemos basin: absolute altitude, the cost to potential wetland areas, cost to potential hydrology areas, absolute slope and visual prominence index.

In the case of the Central Mountain Ranges, there are 3 covariates: absolute altitude, the cost to potential hydrology areas and aspect.

Finally, in the Northern Mountain Ranges, we identified 4 covariates: absolute altitude, the cost to potential wetland areas, cost to potential geology areas and diffuse insolation index.

Discussion

In summary, when we analyse the predictive covariates for the set of archaeological sites, we can obtain more precise information. In general, there are similarities, especially between the two mountain ranges, while in the Monforte de Lemos basin there are more significant differences. Attending to the altitude, the proximity to potential hydrology, the visibility, the prevailing winds and the hunting areas.

However, in the mountain ranges, we can see differences in the altitude, the aspect and the accessibility in the middle environment.

In general conclusions, we can say that there no exists a single settlement pattern for the Galician region. Rather there are three different occupation patterns. Each area has its peculiarities and this leads us to affirm that there exists a strong regionalization.

We have checked that the altitude is important in all three zones. Followed by wetland areas and hydrology (in two of them). And we have been able to verify the importance of some of the variables defended in the theoretical model. Therefore, to a large extent, previous theoretical ideas are corroborated.

A predictive model is an important tool, but it must be accompanied by a more descriptive analysis. Furthermore, there are variables that we cannot model and that therefore cannot be incorporated into a predictive model. Also, the results obtained depend on the combination of covariates used. For this reason, it is essential to check, from statistical methods, each covariate previously. It is the first time that a predictive model has been used in this study area to analyse Palaeolithic sites. It is a positive point because it allows us to have a starting point for the future. We believe that in the future, it would be necessary to redefine the variables related to biotic factors. It would also be interesting to be able to model other types of variables that have not been included so far.

Another interesting point would be the analysis at the chronological level, although the scarcity of data prevents us from refining further in this regard. Hopefully, in the future, we can continue in this way.

Finally, it would be interesting to expand the scope of the study. Using the methodology of this work and applying it to other areas of Galicia or northern Portugal and comparing the results.

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169. For lack of a better flake: Simulating formational emergence and re-use in lithic aggregates

Ben Davies, University of Utah

Matthew Douglass, University of Nebraska-Lincoln

Jonathan Reeves, Max Planck Institute for Evolutionary Anthropology

Lithic artefacts are the most enduring and ubiquitous part of the global archaeological record. As such, lithics have conceivably been both passive and active parts of cultural systems from their initial creation onward. Lithic re-use is well documented in ethnographic contexts but is poorly understood in archaeological terms. We believe that this is due in part to a longstanding treatment of artefacts in the archaeological record as end products, rather than elements of an ongoing process of formation. Here, we discuss a general approach to the analysis of lithics that emphasises their patterning as emergent outcomes of formational processes observed at a given point by archaeologists. We focus on geometric properties of flaked stone aggregations (e.g., volume, surface area) that are sensitive to the separation of constituent parts (e.g., flakes, cores). We formulate agent-based models to assess how processes of manufacture, selection, transport, and discard contribute to patterning that emerges in these properties over time. We build on previous studies by assessing how this patterning may be affected by subsequent selection of material for reuse, illustrating conditions where the residues of re-use activities may be more or less apparent. We then discuss these results in terms of archaeological and ethnographic studies conducted by the authors and others in Australia and Africa, highlighting the value of agent-based simulation as theoretical scaffolding to connect models of human behaviour to the archaeological record.

Session 06. Towards an open platform for computer simulations of past socio-ecological systems

Philip Verhagen, Vrije Universiteit Amsterdam

Iza Romanowska, Aarhus Institute of Advanced Studies, Aarhus University

Dries Daems, Middle East Technical University

Clemens Schmid, Max Planck Institute for the Science of Human History (MPI-SHH), Max Planck Institute for Evolutionary Anthropology (MPI-EVA)

North Writing School

Roundtable	09:00 - 10:30

Introduction

Archaeologists are increasingly relying on computer simulations to reconstruct and understand past societies. They are successfully building and running simulations of agrarian production, trade, settlement development and movement, to name a few. The current state of the field, however, is characterised by idiosyncrasy and limited communication and integration of the community, hampering the ability of modellers to cumulatively build on each other's work. This is predominantly due to the lack of appropriate tools and platforms enabling closer integration.

To remedy this situation, the NAS2A project (Network for Agent-based modelling of Socio-ecological Systems in Archaeology; https://archaeology-abm.github.io/NASA/) is developing an open library of model algorithms and code for modelling of socio-ecological systems in archaeology. It aims to redefine current practices in collaboration and synergy in modelling communities by developing an openly available and functional models library, offering a host of elements (modules, techniques, algorithms, how-to's/wikis etc.) as modular building blocks for elaborate and case-driven models and research questions.

In this roundtable we will present the results of the project's first results towards developing the necessary infrastructure and standards, and invite feedback from the roundtable audience. In particular, we want to address the following questions:

- how can we ensure that model elements can be used for a wide range of research questions?
- how can we facilitate interaction, comparison and testing of models across platforms and programming languages?
- how can we achieve a sustainable infrastructure for this?
- and what more is needed to make simulation modelling accessible to a wider community of archaeologists?

Session 09. Archaeology and digital humanities: The road already travelled and the road ahead

Christophe Tuffery, INRAP

Leticia Tobalina-Pulido, Casa de Velázquez-EHEHI

César González-Pérez, Incipit (Institute of Heritage Sciences) of the CSIC (Spanish National Research Council)

Patricia Murrieta, Lancaster University

Laurent Costa, Maison de l'Archéologie et de l'Ethnologie

Marta Lorenzon, University of Helsinki

Raquel Liceras Garrido, Universidad Complutense de Madrid

Room 15

Roundtable	09:00 - 10:30

Introduction

It is admitted that archaeology and archaeologists are very often absent from debates, conferences, papers about digital humanities. Most of archaeologists do not know exactly what digital humanities are consisting in and a few of them identify themselves as digital humanists. Their research projects are rarely funded from the agencies and programs concerning digital humanities. Ethan Watrall proposed to see digital humanities as a metaphor of a tent (Watrall 2016). As this author wrote, "most archaeologists (...) are so far away from the tent that they cannot even see it". This session proposes to give an opportunity for archaeologists to make the point on this lack and to identify ways of reinforce the place of archaeologists in digital humanities debates and practices.

With the development and a large use of ITC, archaeologists reached a new step in the evolution of their tools and methods available for producing archaeological observations and documentation as well. Archaeology is "moving to an age of data-centric, data-driven analysis or data-led thinking, in which data takes pre-eminence over theory" (Huggett 2020). Astonishing, these new conditions of production of archaeological knowledge are rarely put in questions from an epistemological point of view. This lack shed lights on the fact that it becomes necessary to develop a more reflexive about building digital archaeological knowledge and their impacts to archaeological reasoning.

For less than a decade, some archaeologists, involved is use of several digital tools and methods, began to enlarge their own communities and discussions to those of other disciplines such as geography, history, philology, epigraphy, archive studies, etc.. Archaeologists began to use digital technologies and tools such as DBMS in 1980s, then mapping software and GIS in 1990s, and GPS and digital photo and satellite imageries in 2000s. In the last decade, new data such as Lidar or high-resolution photos from drones or other sensors, were included in the toolbox of tools and methods used by archaeologists, such as photogrammetry, geophysics, and computed tomography were widely developed to address needs of data acquisition and treatment. Some experiments were also engaged in the use artificial intelligence to explore massive archaeological sets of big data (Djindjian 2020) as well as virtual or immersive reality (Quinio and al. 2020) to present archaeological remains and sites, mainly for public exhibits : Pompei (http://pompeii.refutur.com/en/), Syria (http://syrianheritagerevival.org/), etc., more rarely for research projects such as SCHOPPER project (http://schopper-anr.org/). The importance and potential contributions of research in the field. They could identify researchers from other disciplines of digital humanities so that they could engage collaborations with crossed benefits.

Archaeologists have probably to better identify and address challenges and problems in using some of digital technologies without reinventing the wheel, so that they could reach a new step in their digital practices according to scientific problems and requirements of scientificity.

One major issue is to improve capacities of archaeologists to know how to be involved in transdisciplinary projects and not only in multidisciplinary ones. Research activities to be engaged in this domain would have as objective for archaeologists not to become computer specialists but to know where to find digital skills they could need and to be able to collaborate with them. Another objective for archaeologists could be to identify trends and capacities of digital technologies already used in other disciplines that could be adapted in their own.

Officials form archaeology organisations (EAA, etc.) could define prospective reflexions for next decades in the aim to give orientations and major issues to be achieved in the context of main research and funding programs at a European (H2020, etc.) and worldwide levels.

Themes covered by papers include:

- What kind of scientific and/or technical "revolution" does digital tools and methods are representing for archaeology
- What are the conditions for archaeologists to use tools and methods of digital humanities according to scientific needs?
- How archaeologists may compare their methods and results to other disciplines and domains of expertise, which are using the same tools and methods?
- How archaeologists may better be involved in transdisciplinary projects in digital humanities?
- Are archaeologists enough trained and well informed to know all digital technologies available in their domains of research?
- What could be the modifications in teaching programs that digital humanities could invite academic institutions in the archaeology domain?
- What about the role of computer scientists in the projects of digital humanities involving archaeologists?
- How could it be possible to promote theoretical discussions about the use of new technologies in archaeology?

All these technologies are used by archaeologists within the various stages of the research data life cycle, that may be ordered in three main steps: preparation (prospect: desk research and exploratory field research), data collection (excavation) and data analysis (descriptive and analytic research).

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Session 12. Formal modelling and models of social complexity – in concepts, numbers, equations and agents (Part 2)

Iza Romanowska, Aarhus Insitute of Advanced Studies, Aarhus University, Denmark

Claudio Cioffi-Revilla, George Mason University, USA

North Writing School

92. Foraging communities: How to model social complexity *Reschke*, Hertler, Hoelzchen, Puspaningrum, Anwar and Ngetich*	11:00 - 11:25
20. Hunter-gatherer role in vegetation change during the last and current interglacials in Europe: agent-based modelling *Nikulina*, Scherjon, MacDonald, Zapolska, Serge, Davoli, Pearce, van Wees and Roebroeks*	11:25 - 11:50
89. Agent-based model to simulate desert kite complex reality: An incremental method to reconstruct mechanisms and dynamics of past hunting strategies *Castiello*, Rey-Coyrehourcq, Banos, Mathian, Barge, Crassard, Chahoud and Vila*	11:50 - 12:15
42. Applying fractal analysis on settlement plans for assessing degrees of village planning and household autonomy *Bruvoll**	Poster
51. An Agent-based model of pre-Columbian land-use in the Monumental Mound region of Amazonian Bolivia *Hirst*, Mayle, Singarayer and Lombardo*	Poster
Lunch	
95. Foodways, nutrition, and demography in the Indus Village model *Angourakis*, Bates, Suryanarayan and Petrie*	13:30 - 13:55
165. Testing the extent to which the circumscription theory can explain the emergence of social complexity in the Valley of Oaxaca using an agent-based modelling approach *Williams* and Mesoudi*	13:55 - 14:20
68. Modelling the spatial diffusion of past populations: A cellular automata approach *Hewitt**	14:20 - 14:45
86. MINERVA: Modelling the Roman economy *Pažout* and Brughmans*	14:45 - 15:10
Tea/Coffee	
131. Archaeo-riddle: A collaborative project to test the accuracy of archaeological inference *Cortell-Nicolau*, Carrignon, Brainerd, Simmons, Lewis and Crema*	15:30 - 15:55

15. Empirical evaluation of a methodology for argumentative and ontological analysis of archaeological remains *Calderón-Cerrato*, González-Pérez and Pereira-Fariña*		15:55 - 16:20
132. The Model City: The many dimensions of modelling an urban system *Romanowska**		16:20 - 16:45
Discussion		16:45 - 17:00

92. Foraging communities: How to model social complexity

Jan-Olaf Reschke, ROCEEH Senckenberg, Senckenberg Research Institute; Goethe University, Dept. Of Biosciences, Paleobiology and Environment

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Many events of dispersal can be directly linked to changes in the environment. An exception seems to be the spread of Homo erectus out of Africa before 1.8 million years ago. A study by Jan van der Made (2011) illustrates the absence of major climatic or faunal events during this period. The dispersal of H. erectus out of Africa should therefore have been caused by other factors. Technological advancements can also be excluded, as those hominins used Oldowan tools since 2.6 million years ago. Instead, the first evidence for caretaking over several generations may indicate how increased social complexity allowed H. erectus to disperse into Eurasia (van der Made, 2011).

The development of social complexity is explained by theories like the grandmother hypothesis, highlighting the role of mothers and grandmothers foraging together with their grandchildren, or the theory of male provisioning (Alvarez, 2000). Moreover, many proposed strategies require complex interactions of several individuals, possibly without a direct biological relationship. This joint foraging and food sharing among individuals is also observable in recent hunter-gatherer societies (Dyble et al., 2016).

Research question

We intend to identify the effects of various forms of social interactions on foraging behavior and the resulting success in different environments. The results should demonstrate how certain environments promote complex social interactions to ensure hominin subsistence.

Methods

To study the role of social interactions in foraging behaviour, we apply Agent-based modelling (ABM). Several models have already been suggested to study the behaviour of early hominins. These models represent two different approaches. The first approach focusses on agents as individual foragers. They allow to study the foraging success and the resources consumed under changing conditions but lack interactions between the agents. The results only show the behaviour of solitary foragers without heterogeneous features. Agents represent standardized hominin foragers. The second approach includes models, in which the agent represents a group of foragers. They can be used to test the performances of various strategies. The group may have the option to choose between several types of resources, but all activities are performed as a single unit. In such models, decisions and interests of group members are neglected, because the group agent decides in all processes. The needs of individual members only are accounted for as a cumulative step in the interest of the group agent. In both approaches, individual features, like sex and age, and/or needs are neglected.

As we intend to model several steps of increasing social complexity and its effect on subsistence behaviour, we need to design an ABM with a system of different types of agents in a steplike arrangement.

Application

In our subsistence model individual agents act as the basic unit with the task of acquiring resources to cover demands. They reside at a main camp, represented by an additional agent coordinating all types of group-specific behaviour. Individual agents should be heterogeneous in resource demands, abilities, and/or preferences, representing individuals of different age and sex. Most individual agents represent adults, but a special subgroup of inexperienced foragers occurs, the members of which are not able to participate in foraging activities. Non-foraging agents need to be fed and trained by experienced agents. Non-foragers impose additional demand of food upon a forager agent. It moreover involves resource sharing.

As a result of different characteristics, foraging agents prefer to target specific resources by choosing among different foraging strategies. While some target plant resources in smaller groups ('gatherers'), others may target resources with a low chance of success, but high yield ('hunters'). To start a foraging trip, a foraging agent needs to join a group with similar intentions. As a result, a group agent is created, who will organize joint activities. After meeting certain conditions, the group agent and all individual group members start to perform the planned activity by leaving the main camp and establishing a logistical camp in the surrounding. These activities need to be coordinated. This is the point, where social scenarios are required to mediate between the interests of the individual agents and overarching goals.

Experimental setup

Various social scenarios can be designed addressing feeding, training, and sharing of resources ('caring') with non-foraging agents and how the group resolves conflicting interests:

The most basic form of a caring unit consists of a single foraging agent taking care of a single non-foraging agent, but numbers as well as features may vary on both sides. To study the effect of various combinations of foragers participating in a caring unit are monitored by observing the condition of the non-foraging agents and record the portion (of calories and/or time) the different foraging agents contribute.

We propose three major strategies covering the coordinating of activities, which can be used in diverse combinations and with changing influence:

1. Social activities themselves are designed as incentives for individual desires; and/or
2. An individual agent decides on behalf of the others on shared interests; and/or

3. The camp agent as an overarching agent may identify and eventually enforce group interests, thus overriding individual interests.

Further scenarios are conceivable.

To test how foraging success is influenced by different forms of social interactions, we also need to create appropriate experimental setups. The environment allocates a variety of resource types, some of them stationary, others mobile. Resources differ in return. Environmental scenarios we intend to test are either uniformly distributed or clumped distributions of resources, and seasonality in resource availability. Depending on the social scenario under study, the group can thrive while failing to support their non-foraging members in others.

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20. Hunter-gatherer role in vegetation change during the last and current interglacials in Europe: agent-based modelling

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Humans started transforming their environment long before the emergence of agriculture and industrialization. Foraging societies conduct niche construction activities including vegetation burning which significantly modifies the occupation area of hunter-gatherers. Currently available evidence suggests that both Neanderthals and Mesolithic humans practiced vegetation burning during the Last Interglacial (~ 130,000–116,000 BP) and Early-Middle Holocene (~ 11,700–6,000 BP) (Nikulina et al. 2022). Due to the scarcity of evidence and the absence of a common research protocol to study the anthropogenic impact on landscapes, there are gaps in research about the dynamics of interglacial environments and the role of hominins in landscape changes. Particularly, the extent of vegetation burning organized by hunter-gatherers is still a focal point of research.

Landscape dynamics are complex and include variable components such as climatic fluctuations, the impact of megafauna, and anthropogenic activities. Therefore, there is a need for further research which can allow us to assess different possible scenarios for anthropogenic impact as a part of a complex system. Agent-based modelling (ABM) is used in the current research, because ABM is a common tool to explore complex phenomena and examine different scenarios (Romanowska et al. 2021).

The underlying research consists of several phases. First, the natural environment (i.e., before anthropogenic impact) is reconstructed based on a combination of different spatial datasets including new results obtained within the Terranova project. GTOPO30 data (www.usgs.gov) is used as a digital elevation model (DEM). Areas with elevation above 1,800m are classified as high mountains which represent natural barriers impacting fire spread. WISE data (www.eea.europa.eu) for distribution of large rivers and lakes is used, since they are also natural barriers in our model. To define natural vegetation openness, net primary productivity (NPP) and the distribution of dominant plant functional types (PFT), we applied climate-forced vegetation modelling, using a dynamic vegetation model (CARAIB) forced by the dynamically downscaled and bias-corrected version of the iLOVECLIM climate model. Estimates of megafauna vegetation consumption (i.e., metabolization of gross primary production) are included to define megafauna contribution to vegetation openness.

Secondly, pollen-based estimates of plant cover are added to the model to validate outputs. These results are obtained through the first Landscape Reconstruction Algorithm (LRA) model called REVEALS (Regional Estimates of VEgetation Abundance from Large Sites). This model corrects biases caused by inter-taxonomic differences in pollen production and dispersal in pollen records. Results of this model more accurately reflect the actual vegetation openness and distribution of PFT in Europe in the past. Data Management and Spatial Analyst tools of ArcMap 10.6.1 are applied to all spatial datasets to ensure that they have similar features (coverage, resolution, projection, etc.).

The model is implemented in Netlogo 6.2.0. There are four groups of agents which determine vegetation change in the model: hominins, megafauna, lightning, and climate. Hominins burn vegetation around their campsites, and there are two key parameters which are explored: number of groups (population size) and foraging area (area within which hominins act). Lightning intensity is characterized via the number of patches per step that could be potentially burned, but the occurrence of actual natural fire events depends on probability of ignition. The latter also defines further fire spread after anthropogenic burning and lightning. This probability depends on the time passed since the last disturbance event and natural fire return intervals (FRI). These are calculated for each dominant PFT via 2002-2020 MODIS (MODerate resolution Imaging Spectroradiometer) burned area data from the MCD64A1 C6 product in conjunction with "space-for-time" substitution. Such an approach allows us to extend FRI estimations beyond the period recorded for MODIS. After fire events, megafauna transform vegetation via consumption. Following all disturbance events, vegetation recovers, and the speed and results of this process are defined via CARAIB.

During simulation runs, validation occurs via constant comparison of modified vegetation cover with REVEALS estimations in terms of vegetation openness and vegetation composition (proportions of PFT) to adjust parameter values for experiments. Besides, the input of each agent to vegetation change is tracked. To define the most probable scenarios of past vegetation change due to anthropogenic impact, statistical analysis is conducted in R. The final output will be presented as maps showing suggested vegetation changes after hunter-gatherer activities.

Currently, preliminary results from the first simulations have been obtained. The expected final results of this study will allow us to clarify the role of interglacial hominins on vegetation in Europe. This research represents a case study where ABM in conjunction with geographic information systems (GIS) are used to incorporate and compare a wide spectrum of spatial data related to landscape changes. The wider implications of the current research contribute to the current discussion about interglacial dynamics and the role of humans in it.

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89. Agent-based model to simulate desert kite complex reality: An incremental method to reconstruct mechanisms and dynamics of past hunting strategies

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Desert kites are very large traps designed to capture wild animals in large numbers, and which were in use from the Neolithic to recent periods. More than 6300 kites distributed between the Aralo-Caspian zone and western Arabia have been identified on high-resolution satellite images, which have resumed a general interest for researchers. Although their role as hunting mega structures for trapping game has been recently confirmed by Crassard et al. (2022), the specific way these complex traps worked and contributed to change local ecological landscapes remains an enigma. The kites' particular layout, with driving lines, enclosure, and pit-traps, suggests an original, elaborate and perhaps even standardized hunting technique. However, the partially preserved paleoenvironmental contexts, the scarcity of artefacts and faunal remains, and the lack of information concerning animal species and population size, make it extremely difficult to clarify the functioning dynamics of traps, hunting procedures and possible related activities.

In this study we present a modular and incremental Agent Based Model (ABM) strategy (Cottineau et al. 2020) to address the questions raised by the complex reality of the desert kites, e.g. the temporality of the hunting activity, the number of hunters and their hunting strategies, the number and possible species of animals trapped according to their ethology and their movement. The method, set up in NetLogo, compares several hypotheses/scenarios with different agents, parameters and levels of complexity, such as the morphology of the archaeological structures and the topography, in order to simulate the human and animal behaviours during the hunting in a realistic way. We also use procedural generation method (PCG) to generate coherent and morphological-similar kites and compare the results with existing kites, to better understand the importance of morphology in human and animal behaviours. Specifically, the ABM scalability aims at measuring and evaluating the impact of each single hypothesis on the system behaviour and to compare their specific outputs with the limited archaeological evidence and expert knowledge. The model assessment is based on empirical data, parameters calibration and sensitivity analyses. A complete exploration of the full set of parameters is finally performed in OpenMole platform (Romain et al. 2013) which provides a convenient way of automated calibration and large-scale code executions using HPC (High Performance Computing) environment, as well as a reusable design of simulation experiments.

The model results, by revealing both successful and unsuccessful mechanisms and their associated parameters, as well as realistic or unrealistic animal/human behaviours, help in understanding the "kites system" and in strengthening archaeological theory and interpretations of these mega-traps and their impact on past environments and subsistence strategies.

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42. Applying fractal analysis on settlement plans for assessing degrees of village planning and household autonomy

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Regularly structured settlement plans result from conscious planning, and can indicate the presence of a hierarchical leadership, a central administrative institution, or a system of generally accepted cosmological rules dictating the relative placement and orientation of buildings. Unplanned settlements on the other hand, where each household decides autonomously where and how a new house should be placed, emerge as fractal-like irregular patterns.

The level of irregularity in settlement plans is difficult to quantify by traditional measures. Fractal analysis techniques have just barely been attempted in archaeology for this purpose (Brown, Witschey, and Liebovitch 2005; Farías-Pelayo 2017), but the advent of open source programming in recent years makes it now possible to formalise the approach and adapt it to the needs of archaeologists.

Fractal dimension and lacunarity are good indicators of irregularity in spatial patterns, and can potentially reveal underlying processes that generate them. Values are estimated through the box-counting and gliding box algorithms, and empirical results can be compared against values from theoretically generated settlement models. Even though a variety of social mechanisms can potentially lead to fractal patterning through processes like diffusion-limited aggregation or Lévy flights, the identification and measurement of fractals serve to exclude other processes, like central planning.

This poster presents a pilot study in the use of fractal analysis for quantitative characterisation of settlement plans from European Prehistory, and with measures as proxies for intra-site settlement hierarchy vs. household autonomy. The methods have only recently been implemented in R, and have wide potential for use in quantitative study and image recognition of any 2D spatial patterns, such as rock art, pottery styles, and remote sensing imagery.

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51. An Agent-based model of pre-Columbian land-use in the Monumental Mound region of Amazonian Bolivia

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For decades, the extent to which pre-Columbian (pre-1492 AD) societies were able to modify and "domesticate" Amazonian environments has been heavily debated. Some of the strongest evidence of pre-Columbian landscape domestication comes from the Monumental Mound Region of the Llanos de Moxos, a rainforest-savanna mosaic landscape in Amazonian Bolivia. Between 400-1400 AD, members of a Monumental Mound Culture (MMC) undertook landscape engineering in this environment to produce >120 large habitation mounds, interconnected by a complex network of causeways, canals, and lakes (Lombardo and Prümers 2010). Unlike contemporary indigenous groups living within Amazonia, members of the MMC are thought to have sustained themselves on a primarily maize-based diet (Prümers 2015). This implies that large-scale maize cultivation may have taken place within the Llanos de Moxos, an environment that is currently only considered suitable for cattle ranching. However, little is known about how the MMC may have utilised and modified the surrounding rainforest and savanna ecosystems, as well as the population size that such an environment could support. Whilst traditional palaeoecological and palaeobotanical techniques can provide an insight into past human activity, a modelling approach is better suited to quantify the scale of human land-use (e.g. deforestation, arboriculture, maize cultivation), estimates of population sizes, and the processes that underlie human-environment interactions on the landscape.

Here, we attempt to address these questions by examining the outputs of an Agent-based model developed to generate hypotheses around the nature and extent of pre-Columbian land-use within the Monumental Mound Region. This primarily focuses on the extent and spatial distribution of anthropogenically altered land under multiple population and land-use scenarios, such as restricting cultivation solely to areas of forest or open savanna. The model is designed to generate a representation of the MMC within a virtual landscape of gridded land patches, which are informed by ecological, environmental, and topographic data published by international organisations (e.g., WHO, FAO) and in academic literature. This patchwork landscape is inhabited and can be modified by pre-Columbian household agents, whose behaviour is driven by ethnographic data sourced from contemporary indigenous groups living within the Llanos de Moxos. An Agent-based simulation approach is novel here because no such study has considered the Monumental Mound Region and few similar models have been developed to understand the environmental impacts of pre-Columbian Amazonian communities more generally (e.g. Riris 2018). Such simulation techniques are also ideal for exploring these human-environment interactions because system characteristics (e.g., population, patterns of landscape alteration) are treated as the products of human behaviour operating at the individual level. As such, the model outputs we present can be compared to empirical observations as they become available to improve our understanding of processes which underlie the system. These outputs will also act as a foundation to guide future archaeological and palaeoecological research within the Monumental Mound Region.

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95. Foodways, nutrition, and demography in the Indus Village model

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Cameron Petrie, University of Cambridge

We present the latest advances in the continued development of the Indus Village model. As part of the TwoRains ERC project (2015-2021, University of Cambridge), the model aims to explore the sustainability of food-producing regimes during the urban phase of the Indus Civilisation (c. 2500 to 1900 BC) under the highly variable and diverse landscapes of the Indus River Basin.

Material and Methods

The Indus Village is designed as an agent-based modular system, prioritising intelligibility, reproducibility, and extensibility (Angourakis et al. 2020). Each module or sub-model has been progressively developed, documented, explored, and combined into higher-level models, all publicly available (Angourakis 2021). Each model often touches different disciplines and fields and relies on different reasoned assumptions and referenced datasets.

Having recently consolidated the models involved directly in crop dynamics as the Land Crop model (Angourakis et al., in review), we move on to integrating the Household Food Economy model, containing the Food Strategy, Food Storage, Food Exchange, Nutrition, and Household Demography models. This model represents the part of the food economy cycle defined as a sequence of processes happening on a household scale, spanning from the obtention of foodstuffs to the disposition of labour and dietary preferences towards food production. Households obtain a series of foodstuff amounts in different moments of the annual calendar through crop cultivation, animal husbandry, fishing, gathering, hunting and exchange (activities evidenced in the context of the Indus Civilisation). These amounts are accounted for as stocks of foodstuff that are stored, exchanged, and consumed. Food consumption is calculated daily, assuming that households pursue the satisfaction of a diet, i.e. a composition of foodstuff amounts, which is treated as a cultural trait specific to households. The food effectively consumed is translated into nutrient amounts, and distributed among household members. Nutrient amounts are compared to the members' specific sex-age requirements, producing a household-level nutrition score. Next, the nutrition score modulates an equation-based mortality sub-model inside the Household Demography model, which also encompasses equivalent sub-models for fertility and nuptiality. Each household holds an ever-changing population, from which an amount of labour is made available for investment back into food production activities. To close the food economy cycle, the Food Strategy model determines how households apply a learning algorithm to steer their food production strategy, specifically regarding which activities to invest labour in, considering diet satisfaction as the fundamental target.

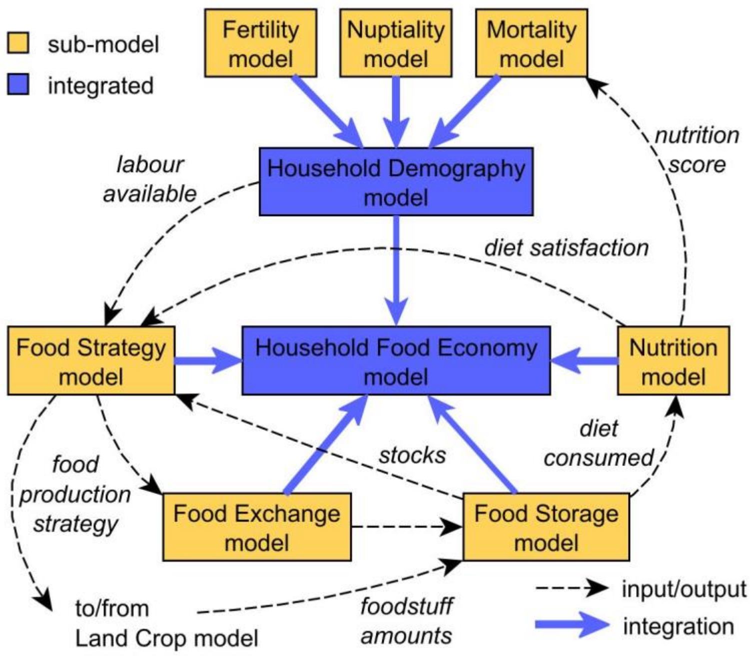

Figure 28. Road Map: Household food economy.

Results

This paper summarises the behaviour and parameter sensitivity of each sub-model included in the Household Food Economy model. We highlight how the Food Storage model brings the importance of storage technology and food sharing norms for a sustainable collective food economy, while non-local food sharing or trade are exposed by the Food Exchange model as impactful factors of resilience. We further comment on the dynamics of the Nutrition model, which reveals in explicit terms how diet composition and volume reflect in the satisfaction of nutrient requirements of a sex-age structured population, beyond a simple account of calories per capita. The significantly more variable behaviour of the Household Demography model is classified into qualitatively distinct groups (e.g., failure or collapse, pseudo-exponential growth, growth cycles), which are characterised parametrically and compared to patterns observed in real population dynamics. We further summarise the implications of alternative algorithms in the Food Strategy model, particularly on how these can impact the balance between diversification and specialisation in the population. Last, we introduce preliminary results of a set of experiments done on the Household Food Economy, focused on testing specific scenarios of interest and exposing the main implications and caveats of the integrated model.

Discussion

We do not expect to answer our overall questions with anything but the complete Indus Village model. However, the process of model development and the results obtained so far have been valued contributions to advancing the research agenda associated with TwoRains. We believe that the model presented here complements the study of the Indus Civilisation and its food economies, while its role in the Indus Village will help to test and improve the hypotheses about the de-urbanisation of the region after this period, among which is climate change. Furthermore, by creating a modular model of prehistoric agriculture and food economy (that remains public and documented), we hope to have a longer and broader impact on the community of modellers of socio-ecological systems in archaeology.

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165. Testing the extent to which the circumscription theory can explain the emergence of social complexity in the Valley of Oaxaca using an agent-based modelling approach

Alice Williams, University of Exeter

Alex Mesoudi, University of Exeter

The large, complex societies humans live in today are a relatively recent development. Complex societies appeared in different locations around the world, with many different explanations having been proposed for the timing and location of their initial appearances. One idea suggests that underlying each example is a restriction in population movement by barriers in the landscape. These barriers create a metaphorical 'pressure-cooker' for warfare, potentially accelerating the formation of social complexity (Carneiro 2012). Barriers can take the form of environmental borders (such as mountains or desert); concentration of resources; or infringement on the territories of neighbouring groups. A classic example used to support this theory is the emergence of the Zapotec state in the Valley of Oaxaca - a highly environmentally circumscribed location in highland Mexico. In this paper, I use an agent-based model to test whether the assumptions of the circumscription theory could indeed explain the formation of social complexity in the Valley of Oaxaca, between 1400 BCE and 200 CE.

Firstly, I test whether the circumscribing effect of the mountains surrounding the Valley of Oaxaca could have amplified the emergence of social complexity. If the assumptions of the circumscription theory are supported, I predict that the formation of settlement hierarchy in the model will correspond with the patterns of settlement hierarchy formation seen in the archaeological record from the Valley of Oaxaca.

Secondly, I test whether the level of resource circumscription seen in the valley could predict the initial location that social complexity emerged. I predict that higher levels of settlement hierarchy are more likely to emerge in the sub-valley richest in resources.

Methods

I built an agent-based model based on the assumptions of Carneiro's circumscription theory using NetLogo. Agents in the model are villages which can form groups called polities. Hierarchy forms within polities through conquest warfare. The landscape of the model is based on environmental survey data from the Valley of Oaxaca (Nicholas 1989). There are five environmental zones based on level of potential maize productivity, ranging from highest by the riverbanks to lowest in the surrounding mountains.

The rate of population growth from an initial 21 villages is based on archaeological settlement survey data from 1400 BCE to 200 CE (Kowalewski et al. 1989). Population size is based on the number of settlements, not the estimated number of individuals, due to the scale of the model and difficulties in accurately estimating past population size. The rate of population growth is kept as consistent as possible between experiments to control for the effect of population pressure. Each time step in the model approximately equates to ten years in the archaeological record.

All other parameters which are not being tested in this paper are parameterised using archaeological and environmental data where possible. The parameters for the frequency of attempted conflict between polities and the distance that villages can move within the valley are tested in each experiment.

In the first experiment, I test the effect of environmental circumscription in the Valley of Oaxaca. The model is run for 160 time steps (roughly equating to 1600 years). Each test is repeated 100 times. The average maximum level of settlement hierarchy of polities in the model are recorded for each time step and summarised between iterations by standard error bars. The pattern of settlement hierarchy formation in the model is compared with archaeological information on the levels of settlement hierarchy in the Valley of Oaxaca from 1400 BCE to 200 CE.

In the second experiment, I test the effect of resource distribution within the valley. I compare the rate of hierarchy formation between the three sub-valleys over 200 time steps with 50 iterations. Initial villages are located: (1) where the initial archaeological villages were located; (2) anywhere on the most fertile land; (3) with equal likelihood in any sub-valley. The average level of settlement hierarchy of polities and the total number of villages within each valley was recorded for each time step and summarised between iterations using standard error bars.

Results

In the first experiment, comparable levels of settlement hierarchy formed in the circumscription model compared to the archaeological record, but only if two conditions are met: (1) villages are allowed a wide range of movement; and (2) the frequency of warfare between polities is high (each polity will initiate conflict every decade).

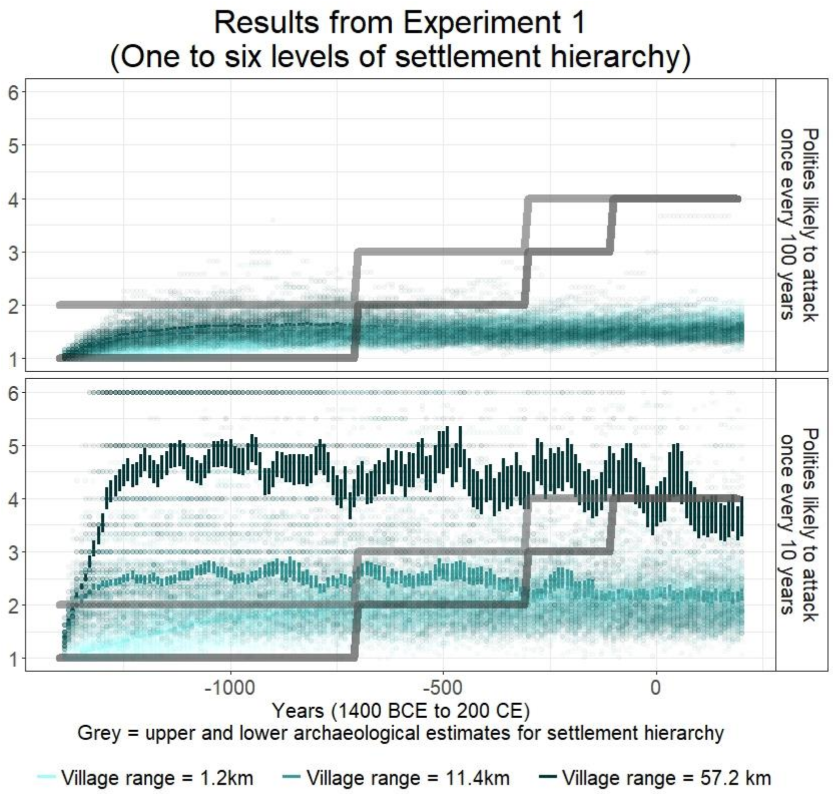

Figure 29. Experiment 1.

The results from the second experiment suggest that the concentration of resources could also have had an influence on the initial location of the emergence of social complexity within the valley, assuming that people chose to initially occupy the most fertile areas of land.

Discussion

These results suggest that environmental and resource circumscription may have had an effect on the timing and location of the emergence of social complexity in the Valley of Oaxaca, but also highlight important areas of archaeological investigation to confirm these conclusions. Evidence for the frequency of warfare is key. Assumptions on the choice of settlement location and distances that people would have been willing to move also require further explicit testing to support or refute the circumscription theory. This paper shows the use of agent-based modelling to test ideas about the past and guide further work.

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68. Modelling the spatial diffusion of past populations: A cellular automata approach

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Archaeological researchers often seek to understand the spatial diffusion of past populations and cultures. This can be accomplished by simulating agents' movements across a cost or friction surface in response to specific drivers or constraints. Past populations can be understood as any past living organism with the potential to diffuse through some medium, i.e. air, land, or water. The friction surface can be understood as a suitability map of terrain roughness, an ocean surface perturbed by currents, a political map of friendly or hostile territories, or simply any three-dimensional mathematical space in which some quantity varies from one point of the surface to another. In this communication, I explore the idea of past population diffusion through a simple cellular automata model programmed in the R environment.

Methods

For exploratory purposes, a single Moore neighbourhood of 8 cells surrounding a central candidate is proposed. The starting point for a particular agent (individual, body or group) is determined randomly, its neighbourhood is defined, and thereafter a walk is commenced to the lowest cost cell of the neighbourhood, around which a new neighbourhood is defined. The process is repeated for n iterations or until some constraint is reached. Previously visited locations are excluded from each neighbourhood. When the simulation ends, the points visited by the agent, and the path taken from the beginning to end of the trajectory can be plotted on screen or exported to file.

The model exists as a working prototype programmed in the R environment. The prototype takes two inputs, 1) a grid of equal cells of 200m x 200m resolution which can either be imported from a vector format file (e.g. GeoPackage, GeoJSON or ESRI Shape) or generated on the fly in R; 2) a raster layer, measuring 20 km east-west and 10km north-south, representing a friction surface. In the case of the prototype, the friction surface is simply a slope map (in degrees) obtained from a digital terrain model. The simulation model is initiated by randomly seeding a point, defining a cell neighbourhood, and then extracting, using any relevant function (sum, mean, min) the values of all raster cells falling within the grid. After eliminating the candidate cell and any previously visited cell, the minimum (i.e. least cost) cell is determined, a new point is located at its centre and the previous and new locations are connected by a line (Figure 30). The model has been tested at 10 and 100 iterations, giving run times of xx and 68.06 seconds respectively.

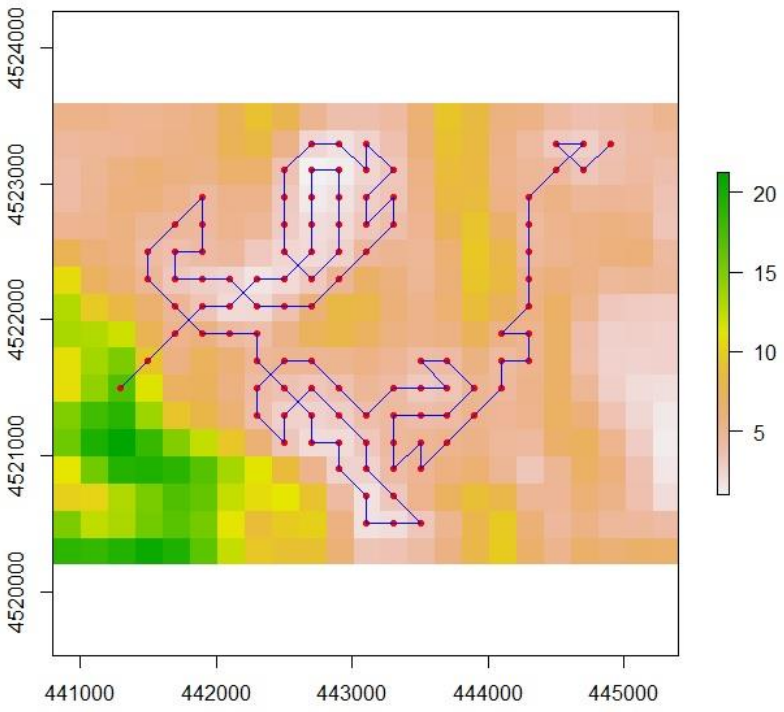

Figure 30. Model run showing an agent starting from a random point on steep ground (in green, bottom left) negotiating several areas of low cost terrain before discovering a least cost route out (top right).

For the purposes of simplicity, the vector grid and the raster cell resolution are the same (200x200m) in the prototype. Normally this would not be the case, and the dimensions of the vector grid, the neighbourhood size – i.e. number of grid cells around the candidate cell – and the raster resolution would be determined by the needs to the application case, as is discussed in the next section.

Discussion of practical applications of the model

At this level of abstraction, there are many potential applications. One realistic application could involve a group of human agents, e.g. hominin groups, whose dispersion across the landscape can be hypothesized to follow the path of least cost, typically associated with the complexity of the terrain (Winder et al 2015). In such a case the cell neighbourhood would typically be small, perhaps 1km or less, reflecting the limited ability of a small group to thoroughly scan complex terrain before deciding to move on, depending of course on the time available. The effect of incomplete information (i.e. invisible or poorly understood impedances) can be simulated by introducing stochastic perturbations in the least cost algorithm. Conceivably, the degree of stochastic perturbation could be linked to the time spent scanning the neighbourhood (where time is a function of neighbourhood size) i.e. more stochastic disturbance for larger neighbourhoods, reflecting the greater chance of sub-optimal decision making by the group.

Extending the model, the movement of interdependent species, e.g. large ungulates, can be simulated simultaneously, with the aim of understanding how predator species dispersion across the landscape might influence the movement of hunter-gather groups. The example is hypothetical, and likely to be most useful given specific data points, e.g. to simulate movement of hunter gatherers and their typical prey species around known occupation sites in specific localities. In such a case the constraint on visiting previously visited locations would be relaxed, and the cost surface could be additionally weighted with a probability surface reflecting the range of prey species, or even their specific simulated location.

A second practical case example could relate to the dispersal of simulated agents across a body of water. Recent agent-based modelling approaches (e.g. Hölzchen et al 2022) have addressed this question at high spatial resolution using high resolution data on temperatures and ocean currents, suggesting the need for rafting technology in some instances and the possibility of crossing by passive drifting in others. The present model could contribute to these kinds of studies, in particular, by running and analysing multiple simulations (a Monte Carlo approach) to determine whether some trajectories are more likely than others. At present, the model is computationally intensive, but efficiency could be increased by improvements to the code or by implementing parallel processing on multiple cores.

The model could be applied at any spatial or temporal scale, from migrations out of an occupation site over a number of days, to an ocean voyage measured in weeks or months, to a species dispersion event measured in millennia (e.g. Mithen and Reed 2002). The model could also be applied to practically any dispersion case for which data are available, e.g. viruses, vegetation or airborne particles.

The main objective of this communication is to demonstrate the simplicity and power of cellular automata for modelling spatial diffusion processes, to show its implementation in the R environment, and to stimulate discussion around archaeological applications for future research.

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86. MINERVA: Modelling the Roman economy

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Tom Brughmans, Aarhus University

The study of the Roman economy is in need of methodological innovations: the use of formal models to test complex theories and hypotheses about its performance, functioning and organization through a centuries-long perspective (Brughmans 2020; Brughmans et al. 2019). While many conflicting theories exist (e.g., market principles vs. their absence due to information uncertainty), it is incredibly rare to see published examples of formal tests that demonstrate these theories can explain centuries-long data trends in the archaeological record. This means the plausibility of complex theories is rarely demonstrated in cases where it is possible to do so, and that the behaviours of conflicting theories cannot be formally compared.

The goal of the MINERVA project (funded by the Independent Research Fund Denmark as a Sapere Aude research leadership grant) is to analyse and explain centuries-long data patterns to enhance our understanding of the Roman economy's long-term functioning. In doing so, it aims to support the growth of computational modelling in Roman Studies.

This presentation will introduce project MINERVA and its three lines of research, focusing in particular on preliminary results of the road data collection:

1) Aggregation and analysis of large open ceramics datasets, including tableware in the Eastern Mediterranean, and amphorae in the German provinces and in central Italy. Ceramics are copiously available, and well-studied and described in traditional scholarship. Ceramic tableware and amphorae offer comparable data throughout centuries and the entire Empire, allowing for the study of changes in the intensity and direction of inter-regional trade. The statistical analysis of ceramic dataset focuses on changes through time in the geographical distribution and in the volume and proportions of ceramic types at sites, and trends in correlation between distance from place of production with ceramic volume and diversity.
2) Developing a highly detailed open model of the Roman transport network system. Existing digital models of the entire Roman imperial transport system exist at a coarse level of detail that is not representative of our current knowledge of Roman roads or of geographical structuring. We aim to draw on all available historical and archaeological data to develop a model of the Roman road system in high detail across the entire Empire. The digital data will be made openly available on the online gazetteer Itiner-e. It aims to become an online platform for a community of scholars to explore, query, download and edit historical road data, leading to a continually improving resource. This dataset is developed in close cooperation with the project Viator-e (https://viatore.icac.cat).
3) Perform computational simulation experiments to explore whether current theories about the distribution and transportation of foodstuffs and tableware can explain the observed ceramic data patterns. Particular attention is paid to the explanation of centuries-long patterns, with the aim of identifying macroeconomic trends and cycles of inter-regional trade in the Roman economy that only reveal traces over long time periods. Agent-based models informed by transport variables and the highly detailed transport network model will be created to perform these simulation experiments.

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131. Archaeo-riddle: A collaborative project to test the accuracy of archaeological inference

Alfredo Cortell-Nicolau, University of Cambridge

Simon Carrignon, University of Cambridge

Leah Brainerd, University of Cambridge

Charles Simmons, University of Cambridge

Joseph Lewis, University of Cambridge

Enrico Crema, University of Cambridge

In the past years, awareness of how different forms of data can impact Archaeology is growing. Because of its very nature, archaeological data span large geographical and temporal scales; but it is fragmentary, cannot be randomly sampled, and presents uncertainty, gaps and biases. This makes the representativeness of the available sample an open question and has consequences in how inferences are made. Recent advances in computational and quantitative archaeology have promoted the development of new ways to tackle specific issues and challenges associated with the archaeological record, often with increasing levels of sophistication.

Assessing the robustness of these methods is not trivial, as we cannot directly and formally estimate their ability in reconstructing past processes. A growing number of studies has employed so-called 'tactical simulations' to determine whether proposed methods are able to recover key parameters of interest from simulated datasets. However, these solutions are limited by the fact that assessments are usually carried out by the very same researchers conducting the studies, and the simulated processes are designed for narrow sets of applications that embed the biases of those researchers, from the way they model the phenomena to how they approach the question and how they select the specific methods they use to answer it.

Here we make a call for a collaborative approach to further explore these issues. We will generate and supply an artificial archaeological dataset, with the underlying generative process not revealed until after the experiment. Following Axelrod (1980) and Rendell et al. (2010), we propose a tournament, or a collaborative endeavour, where participants will have access to this dataset and will be asked to analyse a specific question relating to prehistoric demography using their own inferential technique. Data, specific rules, reward, archaeological ('virtual') background information, research questions and other practicalities will be presented at the conference session. Because everything will be developed in silico, there is no archaeological information to which the participants will be able to refer to, except the one that will be provided by the project, where the main concerns will be based on demography and social complexity. This is done in this way to focus strictly on the methodology and eliminate possible research bias and previous opinions on real archaeological outputs.

During the CAA presentation, we will describe the project, its data, rules, etc. but the participants will not have to register for the competition yet. Following this presentation, a website will be open for any researcher to explore and join the project where the specific rules, Terms and Conditions for participation will be made available. A time period will be provided to develop the different proposals, after which a new meeting will be held where all these will be analysed and discussed. In any case, proposals can be anonymous if the participant so desires. For the participants who wish to share their methodological approach, informed consent procedures will be issued in due time.

Participants will be able to share their analysis in any format, but it is particularly recommended that they use standalone scripts relying on open-source tools, easily portable and reproducible on any platform. Comparison between quantitative analyses should be made as straightforward as possible and, in order to do that, the use of tools and concepts from open science and reproducible research is strongly encouraged.

The idea of this project is to offer a space for debate, where different theoretical and methodological options can be discussed and shared. By testing different methodological approaches under a controlled environment, the archaeological community will be able to test (1) its dependency on good data quality (2) the strengths and weaknesses of common and not-so-common archaeological methods and (3) ways to consistently share and compare the results given by these different methods. In addition, providing the same data and same research question to all the participants ensures that they will not be conditioned by the research biases affecting the real archaeological record or that the affecting biases will be the same for everyone. Ultimately, this can be seen as a further step for promoting the collaboration among archaeologists concerned with the robustness and accuracy of potential inference.

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15. Empirical evaluation of a methodology for argumentative and ontological analysis of archaeological remains

Beatriz Calderón-Cerrato, Incipit CSIC

César González-Pérez , Incipit CSIC

Martín Pereira-Fariña, Faculty of Philosophy

We often detect opposing opinions on the same issue in social debates, something that generates divisions between the agents involved. Mansilla de la Sierra is an example of this. It was a village located in La Rioja (Spain) that was surrounded by the Najerilla, Gatón and Cambrones rivers and was inundated due to the construction of a swamp. In this case, we observe two different discursive approaches: on the one hand, that of an evicted people, forced to abandon their home and their heritage that strives to keep it alive; on the other, an institutional discourse that justifies its actions by putting economic benefit first. Our main goal with this pilot study, part of our PhD degree project, is to test our new analysis methodology made to represent, analyse, and interpret complex discourses. To achieve this goal, we use the ontological analysis, to collect the most relevant entities of the case study, and the argument analysis, which will allow us to objectively verify how the arguments are constructed.

In relation to the case studied, it is contextualized at the beginning of the 20th century, when the Spanish hydraulic policy found in the swamps a satisfactory solution for the country's agrarian problem. During the Franco era, their construction were executed and hundreds of villages were flooded. However, Mansilla has a peculiarity, and that is that, during the dry season, the old village emerges, revealing what remains left. This has made possible to maintain the economy of the new village, constructed after the inundation, also called Mansilla de la Sierra, which benefits from the rural tourism that such a scenario generates. In addition, the neighbourhood and the people close to the village are an example of community involved in the defence and maintenance of the archaeological heritage, as evidenced by the various restorations paid for by the City Council of the only heritage building that was saved from the flood: the hermitage of Santa Catalina.

Methods and materials

We have analysed five texts in total: one journalistic article, one post from a personal blog, two administrative texts and one scientific dissemination article. The election of these discursive genres obeys to the attempt to bring us closer to the arguments of the most relevant agents in the history of Mansilla: the Franco government, the tourists who revive the village's economy, the opinion of an expert in the area's heritage and the local press.

Regarding analysis, we employed two perspectives. First, an ontological analysis was used to obtain agents, actions, places, etc., referred to in the texts. To do this, we used CHARM (Cultural Heritage Reference Abstract Model, www.charminfo.org) (César González-Pérez et al., 2018), an abstract ontological model of cultural heritage expressed in the ConML (www.conml.org) (César González-Pérez, 2018) modelling language. The Bundt software toolset was employed to create, store, and manage associated ontological models. Secondly, discourse analysis was used to describe the inference and dialogical structures (Budzynska & Reed, 2011) present in the texts. To do this we used IAT/ML, a recent methodology developed by Incipit CSIC and University of Santiago de Compostela researchers. The LogosLink toolset was employed to store and process the associated discourse models. Finally, we combined the models obtained from these two types of analysis to gain deep information about Mansilla de la Sierra.

Results and discussion

The main result of this pilot study has been the development of the above-described analysis methodology as well as the empirical experimentation with it based on the digital tool LogosLink. We have linked the ontological and the argumentative analysis about the case of Mansilla de la Sierra. Using denotations, we have been able to link the relevant objects that ontologically define the village with the different forms of allusion to them found in the texts. We also have found that these differences could be based on the agents and their position about the Mansilla de la Sierra flooding. In addition, the argumentative relations show information about the relationship between the objects and how these are defended in positions both related to and contrary to the construction of the swamp and the consequential flood.

From this study, we can expand the use of our methodology to other heritage issues, but also to other social issues currently under discussion related to racism and feminism.

Moreover, in a later discourse analysis based on critical discourse analysis, it will be possible to obtain a general view about the discursive strategies used to value and connote certain ideas on the subject studied. In addition, we have the advantage of minimizing the possible subjectivity of the researcher in the analysis of social issues with political implications, one of the greatest criticisms made to this discipline. Finally, we think that out methodology can be useful to identify the common and irreconcilable points of opposing positions in current social debates about archaeological elements to advance them.

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132. The Model City: The many dimensions of modelling an urban system

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Cities are highly complex, dynamic and multidimensional. They are not a simple aggregation of individuals, houses or businesses but social, cultural, economic, demographic and environmental powerhouses that drive change at a regional, national and global scale. The level of complexity involved in urban processes calls for robust formal methods, such as simulation. Simulation is a computational method used across all branches of science to study complex dynamic processes, determine causality, and ask questions too complex for data analysis methods. Why do some cities thrive while others struggle? How is the type of city governance influencing its social structure? What would happen if all bakers left the city? Simulation is also a theoretical tool. It defines the studied system in unequivocal terms: what is meant by "resilience"? How is craft production defined? Is economic stratification equivalent to social division? In this way, formal modelling radically exposes theories to critique and testing.

Despite the ample use of simulation in social sciences, a full model of the evolution of an urban centre over centuries has never been developed. Cities exist as entities in models, but despite the discipline repeated calls for a model of interlocking urban dynamics, such framework does not exist. As a result, it is difficult to address some of the phenomena emerging from the social complexity of urban centres, to formalise the language and frameworks used to describe them and to push forward the entrenched debates on urban ecology, evolution and resilience.

The Model City is a formal, abstract and modular model of a city that will enable the community of researchers studying past and present urban systems to test a wide range of theories about the long-term urban dynamics, factors that encourage urban growth and sources of urban resilience. At its core lies the question: "What processes drive urban evolution over the long term?" The Model City uses agent-based modelling (ABM), a well-established simulation technique developed to handle systems comprised of individual autonomous units that interact with each other and can adapt to changing circumstances.

In this paper, I will focus on the theoretical underpinnings of The Model City - the ontology of the model, including such dimensions as scales, entities, rules of behaviour, algorithms, etc. I will present alternative implementations and their repercussions as well as contrasting theoretical frameworks in hope of opening the discussion on how would archaeologists like to see the ancient cities modelled and working towards a consensus as to what elements should a baseline simulation model of a city consist of.

Session 13. Machine and deep learning methods in archaeological research: beyond site detection (Part 2)

Arnau Garcia-Molsosa, Catalan Institute of Classical Archaeology

Hector A Orengo, Catalan Institute of Classical Archaeology

Iban Berganzo-Besga, Catalan Institute of Classical Archaeology

East Writing School

Introduction	09:00 - 09:15
66. Improving Grad-CAM and model trust: notes from experience *Sipilä* and Dickens*	09:15 - 09:40
100. A Computationally cost effective deep learning work flow for national digitisation of land use from historic maps *Kramer*, Painter and Dommett*	09:40 - 10:05
116. Does deep learning dream about complex data sets? Tackling uncertainty on multiple levels in magnetometer data sets *Schneider* and Lambers*	10:05 - 10:30
Tea/Coffee	
122. Artificial interpretation? Utilising deep learning classification in the archaeological interpretation of submerged landscapes *Fraser* and Landauer*	11:00 - 11:25
141. A workflow for the large-scale automated extraction of archaeological mounds from historical map series *Berganzo-Besga, Lumbreras, Garcia-Molsosa, Alam, Gerrits, Green, Khan, Campbell, Suárez-Moreno, Tomaney, Roberts, Orengo* and Petrie*	11:25 - 11:50
129. Asking a bot about the ancient Romans *Mitsopoulou, Koukouli*, Petousi, Katifori, Lougiakis and Ioannidis*	11:50 - 12:15
Lunch	
134. Socio-technical approaches for system sustainability: Using qualitative methods to investigate use cases for archaeological machine learning *Killoran**	13:30 - 13:55
Discussion	13:55 - 14:20
27. Automatic morphological analysis of ancient charred olive stones from images *Lucena, Fuertes*, Navarro, Rodríguez, Muriel, Montes and Belaj*	Poster

79. An overview of the utilization of machine learning (ML) in archaeological research: Earth observation data and analysis of endangered monuments and sites using machine learning techniques — Poster

Argyrou and Agapiou*

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66. Improving Grad-CAM and model trust: notes from experience

Ikka Sipilä, UCL Institute of Archaeology

Luke Dickens, University College London

Deep learning models are often considered to be 'black-boxes' in that the factors influencing the final predictions and the relative importance of these factors are not immediately clear. We see this as a barrier to a wider adoption of deep learning within disciplines where it is essential to independently verify the predictions. The usual expectation is that a visual explanation or interpretation of the model's decisions can be provided and model explainability and interpretability is an on-going topic within the deep learning community. One way to address this issue is to apply secondary models and approaches to the primary predictors, which provide some form of interpretation or explanation of the predictions, although this is a developing field within deep learning and questions remain about the validity of various approaches. A number of methods for explaining or interpreting image based deep learning models exist, including, but not limited to: LRP, Deep Taylor Decomposition, Gradient Backpropagation, Occlusion Sensitivity, Integrated Gradients, DeepLift, Input*Gradients, LIME, Meaningful Perturbation, as well as a variety of concept-based methods and Class Activation Mapping (CAM) methods. One widely employed method for explaining a model's decision making is Grad-CAM, which belongs to the family of CAM methods and this includes its use in archaeological image recognition tasks (e.g. Cifuentes-Alcobendas and Domínguez-Rodrigo 2019). The widespread use of Grad-CAM may be partly explained by its ease of implementation, low computational cost, and the intuitive interpretation of the heatmap. However, Grad-CAM, like other saliency methods reliant on gradients, is affected by issues like vanishing gradients, gradients' failure to retain spatial information, and the possibility that the same regions of the input image are highlighted by different classes (Desai and Ramaswamy 2020; Rudin 2019). The aim of this research is to improve Grad-CAM to counter some of these problems. It is expected that by removing some of the problematic aspects of Grad-CAM's heatmaps, we can enhance the overall trust in deep learning models.

Methods and materials

Grad-CAM is formally defined as $L^c = ReLU(\sum_k \alpha_k^c A^k)$, where α_k^c are the neuron importance weights that capture the importance of feature map k for class c, and A^k are the forward feature map activations of a convolutional layer k. ReLU is a function that limits the values in the final heatmap to be non-negative. The neuron importance weights α_k^c are computed by:

$$a_k^c = \overbrace{\frac{1}{Z}\sum_i \sum_j}^{\frac{1}{Z}\sum_i \sum_j} GAP \, \frac{\partial y^c}{\partial A_{i,j}^k},$$

where GAP refers to Global Average Pooling operation and is the gradient of the score for class c with respect to feature map activations Ak. The chosen class on which the gradients are computed can be any class, but it makes the most sense to use the predicted class. In practice Grad-CAM works by first recording the tensor of forward activations in some convolutional layer for a given input image after which the gradient from the class score to the activation maps is computed. The neuron importance weights α_k^c are formed by computing the average value of the gradients of a given activation map Ak. The Ak activation map is subsequently multiplied by the corresponding neuron importance weight to create a tensor of neuron importance weighted Ak activation maps. These maps are summed together and passed through ReLU to create a heatmap, which tends to be much smaller in width and height dimensions than the original input image, so the heatmap is upsampled using bilinear interpolation.

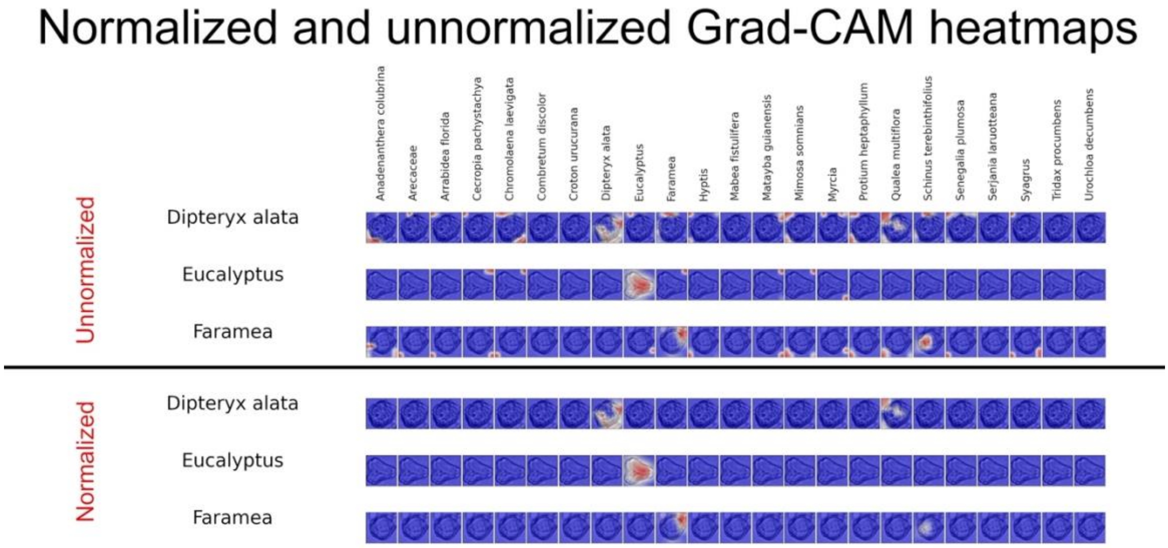

Figure 1. Normalized and unnormalized Grad-CAM heatmaps for three different test images of the POLEN23E dataset. Note the amount of noise in the true negative classes when using unnormalized Grad-CAMs. The true positives are shown on the left and the label at the top reflects Grad-CAM targe class.

Figure 31. Grad-CAM heatmaps.

This method does not take into account the magnitude of the activations and the gradients, which are important since the Grad-CAM heatmaps based on two different classes have the potential to highlight the same area of an image as different objects may share similar features. The magnitude of the activations and gradients, however, is directly related to the class prediction and normalizing the heatmaps across all classes is likely to increase trust in the method. To achieve this, Grad-CAM heatmaps are created for all classes, each of which is then normalized by dividing it with the maximum value found across the Grad-CAMs of all classes, which is likely to come from the Grad-CAM of the predicted class. Formally, given a set of classes C = {c1, ... cn}, we have a set of Grad-CAMs H = {Lc1, ..., Lcn} and a set of maximum values: Hmax = {max(Lc1), ... max(Lcn)}. We then find the highest scalar across all Grad-CAMs by simply taking g = max(Hmax), which we use as the normalizing factor, giving us a normalized Grad-CAM:

$$\sim L^c = \frac{L^c}{g} * 255$$

Here, 255 scales the resulting normalized heatmap to range [0, 255], giving a maximum pixel value of 255 in the Grad-CAM heatmap of the class with the most relevance to the model.

This research additionally demonstrates that using Grad-CAM on ensemble (i.e. many models that together provide a shared prediction) and multi-input (e.g. many input images to one model) models is also viable, mainly through a similar heatmap normalization process. The methodologies involving ensembles and multi-view models are not detailed here due to lack of space. These normalization techniques are discussed with the help of POLEN23E pollen grain dataset consisting of 23 different classes.

Results and discussion

This research shows that Grad-CAM may lead to noisy and imperfect explanations of the image recognition model's decision making. It is demonstrated that Grad-CAM can be improved by a simple normalization, which in turn supports the use of Grad-CAM with ensemble and multi-input models. The functioning of the normalization method is demonstrated in Figure 31.

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100. A Computationally cost effective deep learning work flow for national digitisation of land use from historic maps

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Matthew Painter, ArchAI

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Historic maps hold unique insight into our past, a snapshot of landscapes and features, much of which may now be lost in the modern day terrain. By comparing historic maps to their modern counterparts we can gain insight on how land use over the country has changed, and this can inform current day decisions on land management at a national scale. A recent example, highlighted by our joint case study between ArchAI and the National Trust determined that more than half of orchards in England and Wales have been lost since 1900. The area of traditional style orchards has declined by over 80% in the same period. Our analysis required digitisation of historic maps on a country wide scale, a process that would be extremely expensive if performed solely by human interpreters.

Data sources

The Historic Mapping data was provided by the National Library of Scotland (NLS) through a Web Map Tiling Service for each county. The images were downloaded at the highest available zoom level and georeferenced after download. The map series has a lot of missing data and the map layers of different counties have some overlap. As part of the comparative analysis, the locations of modern-day orchards were derived from the Traditional Orchard HAP mapping through Natural England and Natural Resources Wales. Additional orchard data (including more intensively managed 'modern' orchards) was sourced through the OS Data Hub. The UK Centre for Ecology and Hydrology (UKCEH) Land Cover 2020 vector data was used to assess the subsequent land use in instances of loss of orchards.

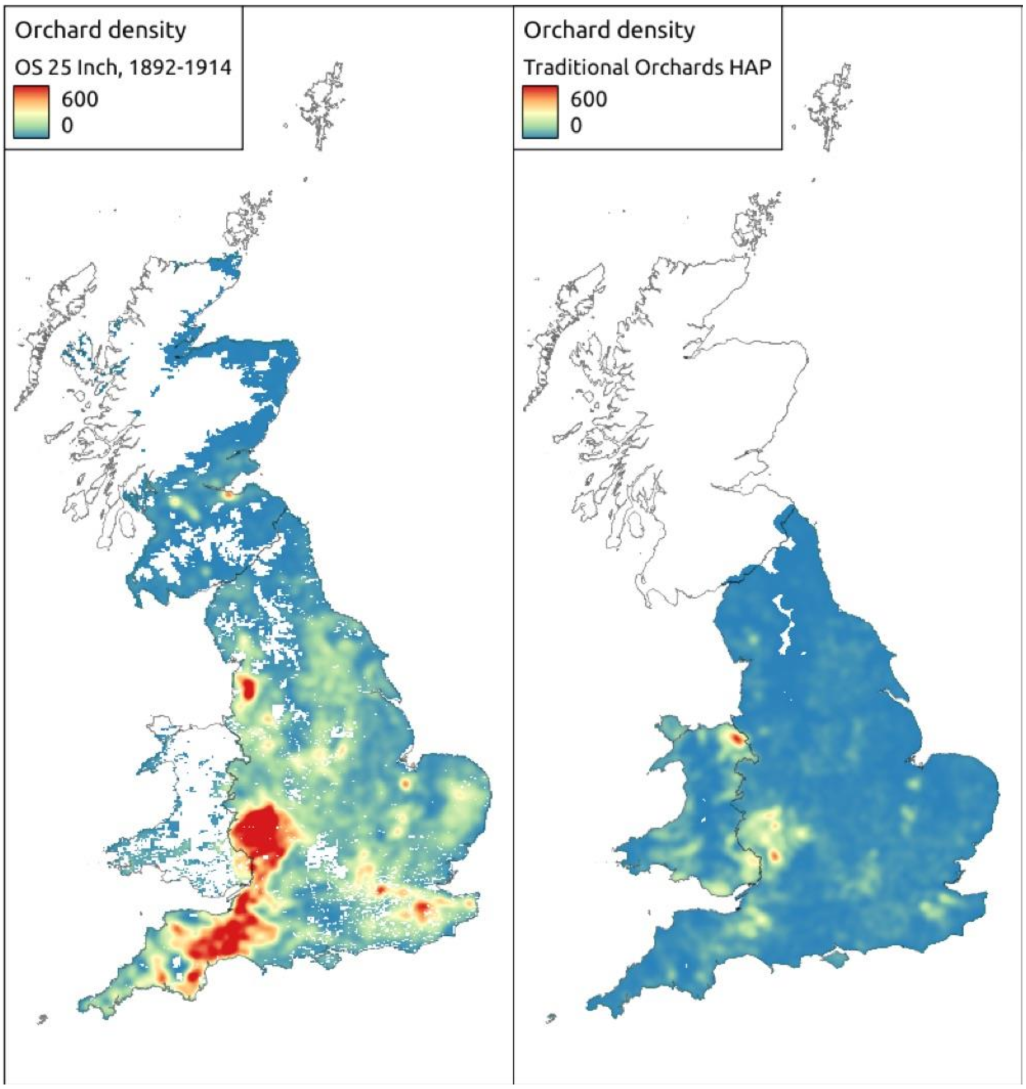

Figure 32. Orchard density.

Methods

In this paper we detail our solution for digitisation of historic maps on a UK wide scale. Our approach focused on applying modern deep learning methods in a computationally cost effective manner. Using the maps detailed in the previous paragraph, we created a training set (and independent validation set) of manually digitised map 1km square tiles, chosen at random from a uniform grid over the whole of the UK. We then trained a segmentation model on this data using the Adam optimiser. We also used common deep learning data augmentation techniques such as random rotations and translations of the input, alongside the addition of Gaussian noise. For our segmentation model, we used a deep neural network. Often, deep learning architectures are designed for maximum performance, generally at the expense of computational complexity. We instead utilised growing research on efficient deep learning, using the MobileNet family of models (Howard et al. 2019) to form the basis of our approach. Specifically, we used a MobileNet as the backbone of a DeepLabV3+ segmentation model (Chen et al. 2018). Segmentation models allow us to find orchard fields of any shape and size, outputting binary masks which can be easily converted to polygons to be visualised in standard GIS software. Using efficient and (comparatively) low-capacity models offer many advantages. Firstly, they ensure we can scale up to the whole country without requiring prohibitive compute capacity. Secondly, the lower capacity allows us to rely on far less (expensive) human digitised data for the training process when compared to more standard larger models. Finally, fast training and evaluation allows us to rapidly iterate and determine which aspects were lacking in our approach. An illustrative example from our development was our finding that the models were performing poorly on urban areas. This was caused by under-representation in our randomly created grids across the country and solved by manually selecting and labelling grids in cities. By quickly evaluating on country-wide scales, we could address this issue early on and save on computational requirements.

Results and discussion

Using our lightweight approach to site detection, we were able to quickly digitise all available maps covering the UK (Figure 32). We were able to establish 0.738 ± 0.044 precision with 0.791 ± 0.076 recall on average over our validation set. The major sources of confusion were other highly gridded symbols in the maps, such as tree nurseries. Using our predictions, we were able to establish a national comparison of orchards loss and creation since 1900. In terms of counties, we found that Devon and Worcestershire have seen the biggest losses of hectares, losing 7,082ha and 8,240ha respectively. The greatest losses in orchard area have been seen in cities, including Greater London (94%), Merseyside (92%) and Bristol (90%). The loss of orchards in England and Wales since 1900 is largely because land use has changed to account for more developments in urban and suburban areas, the creation of deciduous woodland and for improved grassland. We were able to shown this through comparison with the UK's Centre for Ecology and Hydrology's Land Cover 2020 mapping. These results highlight the importance of using Deep Learning for assessing land use patterns at a national scale. The outcomes of this project can be used to inform schemes designed for sustainable land management. We were able to establish this result using a computationally cost effective deep learning work flow which saved time and is better for the environment.

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116. Does deep learning dream about complex data sets? Tackling uncertainty on multiple levels in magnetometer data sets

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Karsten Lambers, Leiden University

This presentation discusses the (so far mainly theoretical) framework of a PhD project on the subject of automated analysis of magnetometer data, started recently at the Digital Archaeology Group at Leiden University. The aim of this presentation is to focus on the rationale behind the modus operandi of the PhD project and to advance the main points to be investigated and discussed in future research papers. The PhD is part of an international collaborative DFG funded project "The Late Antique and Early Islamic Hira – Urbanistic Transformation Processes of a Trans-regional Contact Zone" (grant no. SCHU 1562/10-1), a cooperation between the Museum for Islamic Art Berlin, the German Archaeological Institute (DAI) – Oriental Department, the Technical University Berlin, Eastern Atlas GmbH, and Leiden University, as well as the SBAH (Iraqi State Board of Antiquities and Heritage) as local partner.

Large-scale data collection is an established practice in Archaeological Remote Sensing by now. Air- and space-borne sensors deliver big data in archaeological terms and in the last decade geophysical prospection started to collect data at largescale as well. The evaluation of the increasing amount of data requires analytical methods which can handle this situation, namely (semi-)automated analysis methods. These are already established for air- and space-borne data (e.g., Orengo et al. 2020), but cannot be transferred directly to geophysical data, given the specific character of the latter.

So far, the main data types to which (semi-)automated analysis methods are usually applied are satellite imagery, LiDAR data, aerial imagery and lately drone imagery (e.g., Orengo and Garcia-Molsosa 2019). All of these data types are usually treated as 2D images. The (semi-)automated methods applied to them predominantly work on pixel-level (pixel-based image analysis (PBIA), geometric knowledge-based analysis (GKBA), machine learning (ML)) or object-level (object-based image analysis, OBIA). In the last decade Computer Vision (CV) applications have become more and more common in Archaeological Remote Sensing (e.g., Berganzo-Besga et al. 2021. These deep learning (DL) approaches, in contrast to the pixel- or object-level treatment, address images on scene-level and mainly use neural networks (mainly different versions of convolutional neural networks, CNNs) to classify images.

Geophysical datasets and especially magnetometer data have already been in the focus of automated analysis, but until recently, they have been mainly investigated on pixel-level (GKBA: GPR data and Magnetometry; ML: GPR, Magnetometry and Magnetic Susceptibility) or object-level (OBIA: Magnetometry and GPR). Although an artificial neural network (ANN) was used to classify magnetometer data as early as 2004, the complexity of geophysical datasets and especially of magnetometer data shifted the focus initially to data types which can be handled easier, such as LiDAR data and satellite imagery. Recently U-nets (CNNs, Wolf et al. 2020) were applied to magnetometer data with the aim to perform binary classification, i.e., to classify archaeological objects against a non-archaeological background. The specific characteristics of magnetometer data and the uncertainty involved in its interpretation and classification are the main driving forces behind the PhD topic.

Main argument

The present PhD research focusses on the (semi-)automated analysis of two magnetometer surveys conducted in 2016 and 2021 at the late-Antique and early-Islamic site of al-Ḥīra, situated in south-central Iraq.

Magnetometers record anomalies which emerge due to the contrast in the magnetic properties between the (archaeological) objects or features in the ground and the surrounding medium. These observed anomalies can be very complex because various sources of magnetic anomalies such as soil particles, naturally occurring rocks, archaeological and recent objects might be in superposition, meaning they will be registered additively as a single signal of mixed origin. This leads to a situation in which objects that are deeper and display higher amplitudes appear similar to objects that are nearer to the surface but emit lower amplitudes. This complexity creates ambiguity and uncertainty and affects magnetometer data sets on data, interpretation, and analysis level. The PhD aims to touch upon these different levels in form of separate research papers.

To address the uncertainty of magnetometer data sets on data level, a better understanding is required how anomalies recorded in magnetometer survey results correlate with the actual archaeological objects buried in the ground. The magnetic properties of these objects can be more clearly assessed through measuring their magnetic susceptibility once they are excavated. Magnetic susceptibility measurements were collected by an SM 30 Magnetic Susceptibility Meter at topsoil and Plana level in a specifically chosen trench during the 2022 spring excavation season in order to shed light on the relationship between archaeological objects in the ground and the anomalies registered during the magnetometer survey.

To address the uncertainty of magnetometer data sets on analysis level, first state-of-the-art supervised object segmentation approaches will be compared (e.g., semantic vs. instance segmentation) with a focus on the binary vs. multi-class classification problem. On a more general data analysis level unsupervised learning approaches will be investigated to tackle the uncertainty caused by the nature of magnetometer data and also by human analysts. Contrary to the supervised approaches, unsupervised learning is independent from the input information, i.e., from human intervention. The two earning approaches and the used respective DL architectures will be compared.

Applications or implications

It is expected that the uncertain character of magnetometer data can be successfully addressed on the data, interpretation, and analysis levels in the PhD project. It is also expected that transparent, reproducible, and replicable workflows for the classification of magnetometer data sets will be created using supervised (for binary and multi-class problems) and unsupervised learning approaches and that these will be reused and developed further by future research. Also, the dataset used for both learning approaches will be published as a benchmark dataset to be reused in further research.

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122. Artificial interpretation? Utilising deep learning classification in the archaeological interpretation of submerged landscapes

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Digital archaeology is expanding in line with the exponential rise in the quantity and detail of data now available to researchers (Venditti and Mele 2020). Artificial intelligence has proved key in enabling many scientific disciplines to reappraise their digital toolkit. Archaeological use, however, while ground-breaking (e.g. Orengo et al 2020), remains underdeveloped. In the field of submerged landscape archaeology where datasets are being produced covering vast areas in every greater detail, the use of AI could prove revolutionary in the interpretation and investigation of these large, inaccessible environments.

Our current understanding of prehistoric submerged landscapes is predicated on GIS spatial analysis and geophysical interpretation (e.g. Flores-Aqueveque et al., 2021). Such methodologies require specialised manual interpretation and time resource to discover, what are, at the basic level, repeating identifiable patterns - a task to which neural networks have proven adept.

This twelve-month early research fellowship project undertook a proof-of-concept investigation into the building of an AI model that could examine and pick out undersea features from seismic profiles. To our knowledge, this would be the first application of AI technology to interpret seismic data for archaeological investigation.

Utilising part of a large data repository gathered by the University of Bradford, high resolution 2D seismic profiles from over 50 lines of parametric echosounder and sparker surveys were taken over an area of the southern North Sea known as the Brown Bank (Missaen et al 2020). A number of methods were tried for data input for the machine learning model. These included vector shape classification, trace waveform prominence and image classification and met with varying degrees of success and inherent problems which will be covered in this paper.

Finally, a neural network using image segmentation input was chosen and a catalogue of training and testing images created. Images were taken at the same resolution across multiple seismic survey lines. These included manually interpreted geomorphological features to act as a positive learning catalogue, as well as non-interpreted seismic profile images as a negative learning catalogue. For greater efficiency, a pre-process tiling script was employed to enable multiple detailed ‘snippets’ of the original to be created at an appropriate pixel size for the model. This allowed us to transform a few hundred images into thousands of test inputs.

The underlying architecture of the AI model comprised a DeeplabV3+ Convolutional Neural Network with a ResNet-34 backbone with state-of-the-art features such as a self-attention layer and various recent data augmentation techniques. Although the visual features of the seismic data were rather specialised (greyscale linear features), applying Transfer Learning techniques with the model pre-trained on ImageNet proved helpful.

Investigating the change from terrestrial to marine landscapes and their associated inundation events in the southern North Sea, the neural network was able to identify transgressive palaeofeatures within seismic datasets. The application of this, even in its present form, could reduce manual processing of data significantly. In addition to this, the model is currently a proof-of-concept design to demonstrate the utility of computer vision in the archaeological interpretation of seismic data, achievable within twelve-months. Further complexity can be implemented within this model which could allow the identification of ancient, terrestrial water-courses and the picking of specific materials within the seismic profile, such as peat beds – a potent archaeological proxy for submerged landscape investigation.

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141. A workflow for the large-scale automated extraction of archaeological mounds from historical map series

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Arnau Garcia-Molsosa, Landscape Archaeology Research Group, Catalan Institute of Classical Archaeology

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Cameron Petrie, University of Cambridge

Historical maps document important information about past landscapes, particularly those produced before the expansion of large-scale mechanized agriculture. They thus reflect a landscape that is lost today. Of particular interest to us is the great quantity of archaeologically relevant information that these maps recorded, both deliberately and incidentally. Despite the importance of the information they contain, researchers have only recently begun to automatically digitize and extract data from such maps as coherent information, rather than manually examine a raster image. However, these new approaches have focused on specific types of information that cannot be used directly for archaeological or heritage purposes.

This paper provides an implementation of deep learning techniques to extract archaeological information from historical maps in an automated manner. Early twentieth century colonial Survey of India 1" to 1-mile map series has been chosen, as they provide enough resolution to identify archaeological sites in the form of mounds (Green et al. 2019) and time depth to avoid many recent large-scale landscape modifications and cover very large areas (comprising India and Pakistan). Initial exploration of CNN-based segmentation approaches provided excellent results (Garcia et al. 2021). This presentation will deal with the development of open source algorithms that can be applied using standard computational resources.

Methods

The first step in the implementation of the workflow was the digitalisation of hundreds of Survey of India maps at 300dpi. Then these were georeferenced using a minimum of 12 well-selected ground control points (usually around 20) and a Adjust transformation, which is an algorithm implemented in ArcMap that combines a polynomial transformation and triangulated irregular network interpolation approaches for the raster transformation. Typical georeferencing produced RMS values of around 10.3 m with a maximum of around 30 m (Petrie et al. 2019).

A selection of mounds was used for the training of three different deep learning segmentation methods using Mask R-CNN. The first one focused on mounds represented as discontinuous form-lines, the second on mounds represented as hachures and the third one shaded relief. Besides standard data augmentation methods such as rotation and skewing, synthetic data was also incorporated created from the modification of repetitive types of false positives.

Results

The results show deep learning to be an efficient tool for the recovery of the georeferenced shape of mounds. Initial results of the detectors developed for form-line and hachure-based mound depictions show detection capabilities of over 80% with a low rate of false positives. During the following months the incorporation of more training data and the development of more sophisticated methods of data augmentation is expected to improve these initial results.

Discussion

Deep learning-based segmentation, detection and extraction of features from historical map series can provide excellent results when an adequate training dataset has been gathered and is therefore at its best when applied to the large map series that can supply such information. Taking into account the early date and coherence in the use of mapping conventions and common symbology of large multi-national series such as those within the British and French colonial empires, the deep learning approaches described here opens up the possibility to map sites and features much more quickly and coherently than other available methods, opening up the potential to reconstruct archaeological landscapes at continental scales.

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129. Asking a bot about the ancient Romans

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Part of making Cultural Heritage accessible to and appreciated by the public is the ability to answer questions as quickly and accurately as possible. Traditionally this task was performed by either trained professional guides or by Cultural Heritage experts. However, since the number of automated guides and other software applications for Cultural Heritage is rapidly increasing, there is an equally increasing number of visitors, either remote or on-site, that choose to access Cultural Heritage sites without the assistance of an expert. The search for automated solutions for answering those visitors' queries or engaging in a conversation with them is therefore becoming more and more relevant.

Question-Answering (Mishra et al. 2016) and chatbot (Tzouganatou 2018) systems have been researched extensively over the years. Multiple approaches have been introduced that vary from employing simple NLP and Machine Learning techniques to using Neural Networks for tasks such as language and image recognition and text generation. Several of these approaches have been applied in the Cultural Heritage domain in an attempt to either answer questions of or engage in conversations with visitors of museums and monuments. Each method has its own strengths and limitations and up to date no single best practice is recognised that can offer optimal results for this greatly complex problem.

In this work we briefly review these existing approaches and attempt to examine their strengths and weaknesses. We then further consolidate these findings by presenting more in depth two use cases, one rule-based and one AI-based.

The rule-based chatbot we examine has been developed and tested in the context of an EU-funded research project to function as an info-bot for an archaeological site. The content offered by the infobot was designed based on key themes and topics underlying the cultural site of interest. The initial content selection and curation served as the basis for the development of the conversational aspects of the bot. The content was then further augmented, refined and tested through a series of live chat sessions with the public. These formative evaluation sessions provided feedback not only for the improvement of the content, but also for the interaction aspects of the bot, including its personality and conversational intelligence.

For our AI-based use case, we test the abilities of GPT-3, OpenAI's recently presented language generation tool (Brown et al. 2020). GPT-3 relies on a massive amount of internet data and is showing a remarkable ability to understand and generate text. OpenAI has released an API for accessing the GPT-3 with numerous functionalities and configuration options. They also provided a user interface where users can test the API directly, without developing their own software. As our test case for the assessment we used the question answering content created for a museum collection of Roman antiquities. The question answering content was developed to complement a digital storytelling experience created in the context of a EU funded project that we were working on at the time. It featured the character of a Roman centurion and through a first-person narration presented to the visitor historical facts about the area and the archaeological site that the collection is dedicated to. The story weaved in the objects on display, encouraging users to engage with them in new ways, beyond seeing them only as museum objects. Two versions of the storytelling experience have been developed, an on-site one, for mobile devices, and a virtual one, coupled with a 360° panoramic photo-based representation of the museum gallery. For the latter, a question answering extension of the application has been created, based on common questions by visitors when experiencing the story and implemented using a simple bag-of-words technique. The question answering pool contained 155 questions. The answers to these questions have been edited by history experts.

This question answering material has been used as the content for the assessment of the GPT-3 API. These questions are about: historical facts mentioned in the narration, the narration plot itself, the museum exhibits, the historical period in general and other, sometimes completely unrelated, topics. We selected a small sample from all the categories, except for those about museum exhibits, and experimented with various prompts and configuration options available by the API. We were particularly curious to see how GPT-3 could handle questions about the story, for which it only knew a few information about the plot that were added to the prompt. In this presentation we will describe the experiments we ran and their results as well as our overall experience with GPT-3.

We will conclude our presentation with a discussion about the future of artificial agents, AI or rule-based ones, as heritage experts to support knowledge retrieval for the visitors. We reflect on the difficulties and limitations, as well as proposed solutions towards realizing the vision of such agents become an integral part of a successful and engaging experience design.

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134. Socio-technical approaches for system sustainability: Using qualitative methods to investigate use cases for archaeological machine learning

Lucy Killoran, University of Glasgow

Understanding archaeological survey as a sociotechnical process is necessary for the successful integration of ML into survey workflows. Using ML in an integrated way requires decisions to be made about various workflow elements, which goes beyond thinking of ML simply as a tool for site detection. This paper will present research which uses qualitative methods to investigate sociotechnical aspects of using ML for archaeological survey, in the context of large-area survey for heritage management in the UK.

Heritage agencies are interested in using ML to automate or expedite survey tasks, however these organisations are likely to have existing digital and data infrastructure with rigid structures and numerous dependencies, meaning that technology-led integration of new tools into workflows is not straightforward, and informal workarounds rather than sustainable integration may be the norm. This paper proposes an alternative starting point for the integration of ML tools in archaeology which is user-led rather than technology-led (Yang et al., 2020). Qualitative, user-led processes which examine the sociotechnical factors surrounding archaeology's use cases for ML tools are more likely to result in the development of ML integrations which are sustainable, interoperable, and can be built into reproducible workflows: the cornerstones of open science. This approach follows well-established standards of human-centred design (British Standards Institution, 2019) together with the human-centred paradigm emerging in wider AI discourse (Ramos et al., 2019).

This paper will report on two experiments: (1) the design of a lo-fi prototype GIS plugin for ML-enhanced survey which was tested with stakeholders in an online workshop; and (2) participant-observation fieldwork on Arran, Scotland exploring the process of field-checking automated detections as part of a collaborative project with Historic Environment Scotland and ArchAI. Ongoing work applying ethnographic methods to the observation of workflow processes will also be mentioned. The results of experiment (1) will provide insights into the process and challenges of designing interactions with ML tools. The results of experiment (2) consider how fieldwork will be affected by the use of ML tools, including how interpretation happens in the field, and how these insights can inform ML system design.

This paper will offer suggestions for qualitative approaches that can be used to better understand archaeological use cases for ML, as a step in the process towards producing open and sustainable ML integrations. While the approaches presented address the context of survey, they have wider applications and would be useful to anyone considering integration of new technologies into workflows.

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27. Automatic morphological analysis of ancient charred olive stones from images

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Eva Montes, University of Jaén

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In the context of the research project: ArqueoGen-Olea we have formed an important collection of more than 1,200 archaeological charred olive stones of different chronologies and contexts (50 sites) from the south and east of Spain, which we are analysing both at the DNA level, and morphologically, which will allow us to define the period and routes of entry of the olive tree in the Iberian Peninsula.

Geometric Morphometrics provides a set of techniques that allow to quantitatively analyse the size, shape and variation between objects (Bourgeon et al., 2018; Mitteroecker and Gunz, 2009; Cintas et al. 2020). In archaeology these techniques have been used for the analysis of rock representations, study of projectile tips, and ceramic vessels.

The approach presented in this work shows the typification in an unsupervised way using automated computer methods, based on concepts of Geometric Morphometrics and Principal Component Analysis. In addition, a Clustering study is carried out to determine the geometric space made up by a set of images of charred olive stones.

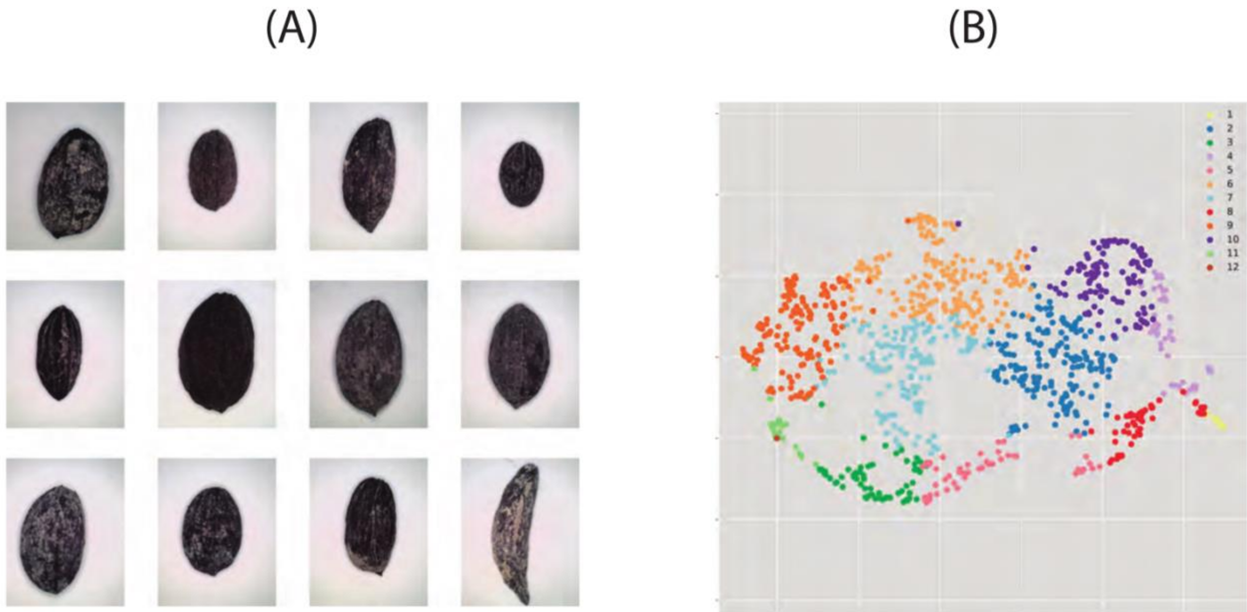

Figure 33. Olive stones: (A) example images and (B) UMAP visualisation.

Subject

From the recovered global archaeobotanical collection, our technique extract contours from a set of 994 olive stone images, taken from 36 archaeological sites, ranging from prehistoric to medieval periods, whose base and apex have been marked by an expert. The contours are subsampled in two landmarks (base and apex) and 10 semi-landmarks distributed along the contour. We apply Principal Component Analysis (PCA) to the 24-dimensional resulting space, and finally a K-means clustering with different number of clusters.

Figure 33 first shows an example of the set of images in the dataset used in the experiments, then shows a UMAP visualization with the shape spaces generated from PCA divided into 12 clusters.

Discussion

The clustering experiments carried out from the morphometric information of the contour detected in the olive stones used, show how they are grouped around the 12 established classes. Although these are not perfectly isolated, the defined groupings allow us to establish classes that can subsequently be linked to groups of contemporary varieties that have a similar morphology and that have been selected for the current reference collection.

We are currently completing the reference collection of olive stones of current species that will allow us to analyse and compare the morphometry with archaeological samples, while also allowing us to obtain important data on the origin and evolution of olive cultivation in the Iberian Peninsula.

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79. An overview of the utilization of machine learning (ML) in archaeological research: Earth observation data and analysis of endangered monuments and sites using machine learning techniques

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Athos Agapiou, Cyprus University of Technology

One of the most common techniques applied for detecting and characterization of is the pedestrian survey, with fieldwalking being the most common type of survey (Orengo H.A., Garcia-Molsosa A. 2019). It is a fact that many archaeological sites have been discovered with the contribution of historical maps and texts, while others have been discovered almost by accident during other construction projects. Nevertheless, traditional pattern recognition methods (i.e., through photointerpretation) may have limited applicability for archaeological research for covering large areas or looking into an extensive archival dataset.

During the last decade, progress in the approach to uncovering archaeological sites or features through Machine Learning (ML) techniques has been reported in the literature. This progress allowed archaeologists to advance the traditional methods and support the detection of archaeological proxies (Jamil et al., 2020). This advancement is demonstrated through numerous articles highlighting decision-making and the analysis of scientific models using ML techniques with minimal human interaction. Preliminary through several articles related to our study, it appears that few archaeological studies are based on the use of historical maps. A series of historical maps may provide important information not only for archaeological but also for historical research. Archaeological sites, historical monuments, and other archaeological areas of interest are recorded through landscape features, including toponyms, specific symbolism, or topographic expressions (Petrie et al., 2019). Further important findings, together with those published by Agapiou et al. (2021), followed the work of Orengo and Garcia-Molsosa (2019), show that low-altitude remote sensing sensors can give us significant outcomes.

The research goals are focused on two areas: (a) to evaluate, study and extract information from historical maps that present a large amount of archaeologically relevant information (Garcia-Molsosa et al., 2021) such as those of Kitchener's maps in Cyprus (Figure 34), while on the other hand, (b) to adopt low-altitude multispectral cameras, covering images beyond the visible part of the spectrum, and apply machine learning detection methods for the detection of surface ceramics.

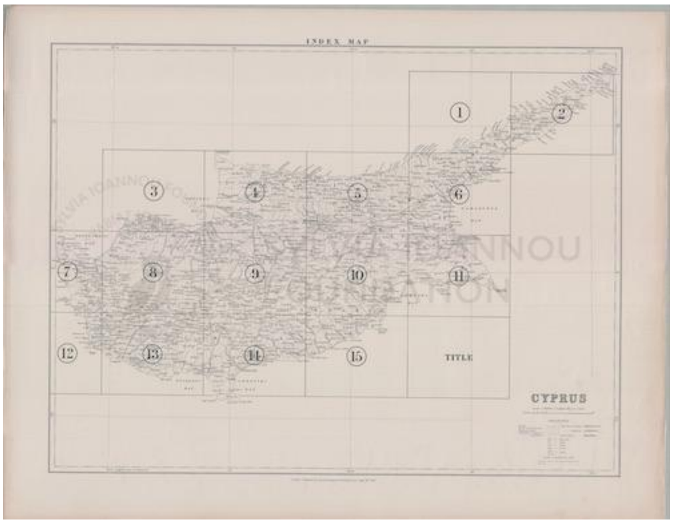

Figure 34. The survey of Cyprus by Horatio Herbert Kitchener during 1878 – 1883. The first topographic survey of the island (index map) (source: Sylvia Ioannou Foundation.

To extract information from historical maps, certain amount of processing will be necessary, like digitization and georeferencing, while features will be extracted manually. As for the workflow that integrates images of low-altitude multispectral cameras, comprises photogrammetry to join all these photographs in a single orthomosaic, machine learning (random forest) and other geospatial analyses using a Geographical Information System (GIS) software to identify and isolate ceramic fragments (Figure 35). Finally, a comparison of both processes and valuation of their results is expected to give us significant results as for the accuracy of the framework and the techniques for detection of surface and sub-surface archaeological remains in Cyprus.

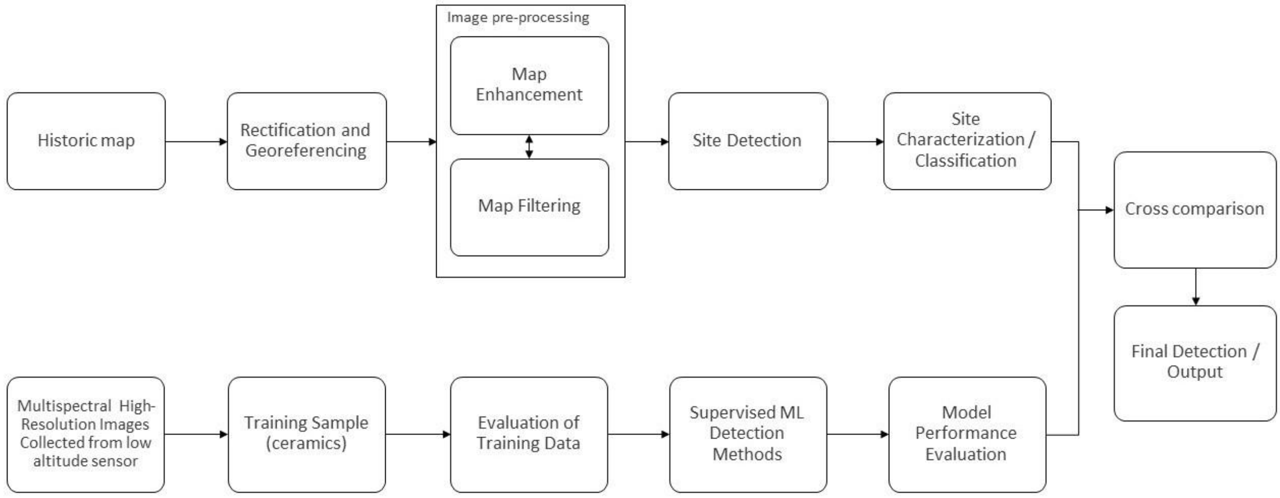

Figure 35. Framework using historical maps that present a large amount of archaeologically relevant information and processing steps using images beyond the visible part of the spectrum.

Acknowledgments

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Session 15. Workflows and experiences on collaborative working and community building using digital tools

Martin Hinz, University of Bern

Florian Thiery, Römisch-Germanisches Zentralmuseum, Mainz, Germany

Sophie C Schmidt, Free University Berlin, Germany

Room 11

Introduction	15:30 - 15:40
24. FAIR Phytoliths Project: Working open-source for community benefit *Karoune*, Lancelotti, Ruiz-Pérez, García-Granero, Kerfant and Madella*	15:40 - 15:50
58. Preserving Syrian heritage sites via technology *Delany**	15:50 - 16:00
118. Poseidon: Practical challenges in establishing an aDNA data management system *Schmid* and Schiffels*	16:00 - 16:10
119. Practically virtual: Experiences from the organisation of the CAA SIG Scientific Scripting Languages in Archaeology *Hinz**	16:10 - 16:20
133. Collaborative writing: Using GitHub as a tool for collaborative writing and community building? *Thiery* and Schmidt*	16:20 - 16:30
154. Hundreds of lost villages! Use of mobile applications in detection and inventory of abandoned settlements from the former East Prussia *Majewska**	16:30 - 16:40
47. Digital tools and methods for sharing knowledge and know-how about flint formations and collect samples between multidisciplinary researchers for prehistoric studies : the return of experience of PCRs "Réseau de lithothèques" and GDR SILEX *Delvigne, Tuffery* and Fernandes*	16:40 - 16:50
Discussion	16:50 - 17:15
158. XRONOS: An open repository and curation platform for chronometric data *Roe* and Hinz*	Poster

Introduction

For a long time now, archaeological research has not been conducted by individual researchers who come up with brilliant theories in their study rooms and investigate them by themselves and on their own terms. It is a fact that no serious scientific research can be conducted without substantial and extensive collaboration.

The internet facilitated a significant change in work processes, something we have been able to experience vividly in the last two years. Since it was intended from the start as a tool to enable scientific exchange, it is all the more astonishing that collaborative work via the internet did not develop further from back-and-forth emailing of text manuscripts for such a long time. By now there are a variety of different systems and solutions: communication via Slack or Signal, co-writing via Google Docs or Overleaf, data co-creation in online database systems, Open Science Framework or Wikidata, as well as code co-development via GitHub or GitLab.

Streamlined and meaningful collaborative work on research questions is possible nowadays, not just with textual products. Especially in the case of analytical archaeology, where data analysis is a focal point, scientific scripting languages shine. There are several research tools and little minions that combine textuality with machine executability to facilitate a collaborative process of thought and analysis.

In recent years, we think, version-controlled workflows, e.g. GIT-based, have become established in this field. But that is certainly not all, as there are a multitude of different solutions to this challenge! Quite often the difficulty lies in finding the best work-flow for certain people or groups. For this reason, in this session we would like to bring together those who work on collective projects, shared software development, reproducible research as well as collaborative writing and data acquisition based on different platforms, and let us and a broad community of researchers in on their workflows.

We invite you to address, but not be limited to, the following questions in a short lightning talk (max. 7 mins):

- Which technologies and workflows have proven effective, which are dead ends?
- How did you generate the Community? And did you keep the ball rolling to create a sustainable structure of collaboration?
- How can you make the best use of the possibilities of collaborative writing and analysis with the help of interlinked workplaces?
- Which tools and approaches are suitable for keeping a scattered team together and motivating it?
- What limits and problems arise in connection with the joint development of reproducible script-based analyses?
- How did you overcome challenges you faced when switching to a digital workflow?

After the presentations an open discussion led by the session chairs is intended to stimulate a further exchange of workflows. Both, this session and a workshop on scientific co-creation using Git and Github are organised by the CAA Special Interest Group for Scientific Scripting Languages in Archaeology in cooperation with the CAA SIG on Semantics and LOUD in Archaeology (Data-Dragon).

24. FAIR Phytoliths Project: Working open-source for community benefit

Emma Karoune, Historic England

Carla Lancelotti, Universitat Pompeu Fabra

Javier Ruiz-Pérez, Texas A&M University

Juan José García-Granero, Spanish National Research Council

Celine Kerfant, Universitat Pompeu Fabra

Marco Madella, Universitat Pompeu Fabra

The FAIR Phytoliths Project is an open-source community-led project that aims to improve data sharing in phytolith research. We have purposely taken an open-source approach using Github, so that we are building a transparent and reproducible record of our project as it progresses. This new open approach is needed due to current issues in phytolith research regarding data quality stemming from a lack of open data sharing and openness of publishing metadata (paradata) such as methodologies (Karoune 2022, Zurro et al. 2016). Our project is the first of its kind in phytolith research.

We mean open-source in terms of accessibility to our project materials, rather than the use of solely open-source software. This means our project has used open Github repositories from its initiation and we constantly update these with our work throughout the project, such as initial funding applications, project planning documentation, meeting notes, training materials, data and metadata. This open manner of working enables our wider community to see the progress of our project at every stage and therefore builds trust in the results and conclusions.

We are a distributed team working from the UK, Spain and USA, so we had to work out how to work synchronously and asynchronously on our various research tasks. All our team meetings are conducted over zoom and we use a Slack workspace for everyday conversations to progress tasks. We have used open-source and/or free software, where possible, to enable us all to perform data collection and access documentation.

All our data collection was completed using google forms, for which we collaboratively developed the method to standardise data collection to reduce the subjectivity and typo errors in data collection. This initial careful planning has reduced the need for data cleaning.

We also documented our work thoroughly to enable multiple data collectors - this created a transparent record of data collection. The data analysis was performed on R Studio linked to a GitHub repository. We are archiving all our research outputs by linking Github repositories to Zenodo.

Community building is a large part of our project so we have utilised various communication channels to enable this to happen. We have a community slack workspace, twitter and facebook accounts to create awareness, allow communication between members and share outputs. We are also using existing mailing lists and a virtual forum established by the International Phytolith Society. We have set up a new committee within the International Phytolith Society to work on Open Science. This has expanded our initial working group and we now have members from all world regions.

Switching to digital workflows has been challenging for our team and is even more of a challenge for the rest of our community. Barriers to this approach are skills in tools and software such as Github, the use of repositories, coding languages such as R and the need for translation of resources and training into languages other than English. We have accessed training through open science programmes like Open Life Science and also spent time teaching each other skills. It takes time to learn these and so you need to give time for this to happen during projects. We are currently offering training to our wider community so that we can start to disseminate what we have learnt to other researchers and we are starting to provide resources and training in other languages (Spanish and French) to be more inclusive of our whole community.

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58. Preserving Syrian heritage sites via technology

Brittany Delany, Arc/k Project

Our Cultural Heritage initiative builds capacity for local Syrians to digitally document, preserve, and monitor heritage sites in Syria through documentation methods and innovative technology.

The Arc/k Project provides educational tools and resources to heritage stakeholders around the world in order to help them document and archive at-risk heritage. Photography, photogrammetry and other documentation techniques are part of this toolkit. Tutorials are available online and coaching sessions take place on video conference.

Partners include: ARTIVE, a non-profit dedicated to heritage preservation through technology, The Day After Heritage Protection Initiative, ATHAR Project and Smithsonian Cultural Rescue Initiative. These advisors guide Arc/k Project on how to best combat illicit trafficking of movable artifacts and to monitor data through safe databases.

Learn more: https://arck-project.org/arc-k-wins-heritage-award/

118. Poseidon: Practical challenges in establishing an aDNA data management system

Clemens Schmid, Max Planck Institute for the Science of Human History (MPI-SHH), Max Planck Institute for Evolutionary Anthropology (MPI-EVA)

Stephan Schiffels, Max Planck Institute for Evolutionary Anthropology (MPI-EVA)

The increase in openly available ancient human DNA samples demands new software solutions to store, distribute and analyse both genomic and archaeological context data. Already at CAA2021 we (representing a larger team) introduced Poseidon, a computational framework including an open data format, software, and a public online repository to enable convenient, reliable, and FAIR access to genotype data from all around the world.

Poseidon was designed as a community project: Code and data are open, all documentation for the data format as well as the software tools are available online, and we rely heavily on version control with Git/GitHub for software and data management. Such a fully transparent mode of operation is well established in open-source (research) software engineering, but not yet common practice in archaeology. After working with this setup for more than two years, we accumulated a number of insights to share and discuss.

In this lightning talk we would like to position Poseidon in the landscape of genetic and archaeological data storage projects, summarise its tech stack both for software development and collaborative working and finally highlight some of our successes and failures in and around community building:

- Clear format definition and versioning is the indispensable foundation of any larger scientific software framework. However, well-specified machine-validatable file formats are scarce in archaeology and few are widely distributed. We found it extremely helpful both for internal and external communication to define context and meta-data files, and assign every change in their structure a unique, semantic version number. It allows for independent, decentralised data keeping, which sets Poseidon apart from projects with a monolithic database.
- The technical challenges of collaborative working with code and data can be very well addressed with the tools available. Git/GitHub is an excellent environment for version control, remote collaboration, issue communication and automated continuous testing. Unlike other frameworks with custom web interfaces, Poseidon requires its users to familiarise themselves with this environment to participate in the collaborative process. This raises problems for training and documentation, but also improves quality, consistency and accountability of contributions.
- The data storage in Poseidon's public data repository is open, well structured and versioned. This ensures the reproducibility of analyses, as users can roll back to past package versions. However, managing and sharing large (tens of gigabytes) genotype datasets is still costly and unsatisfactory, especially if one wants to allow users to edit and maintain them. This is a specific, not fully resolved challenge for Poseidon, that many other archaeological data keeping projects (e.g. for isotopic or radiocarbon data) do not have to face.

As of now, Poseidon is slowly growing and improving to accumulate a critical mass of community engagement and become fully self-sustaining. The big goals of the project and the heterogeneous requirements of the archaeogenetic community manifest in various technical and social challenges for the future, which we are happy to disclose and explain in the roundtable discussion.

119. Practically virtual: Experiences from the organisation of the CAA SIG Scientific Scripting Languages in Archaeology

Martin Hinz, University of Bern

From our experience, to keep a working group going that has set an overarching goal but is not primarily working on a specific project, this requires specific arrangements. On the one hand, communication must be kept flowing so that those involved receive continuous feedback and a continuous sense of the relevance of their efforts. In addition, a reliability and regularity of exchange (more precisely, meetings) must be achieved so that participation becomes habitual, making participation a decision which is not a case by case issue any more. Finally, a basic condition for the active participation of all those involved is that they also know what their concrete tasks are. For this, a division of labour is very helpful, but also to break down the big overarching goal into smaller, practical and tangible responsibilities. This framework is already a challenge in a local research project, where one can always reinforce the commitment by going to the office of the individual participants or chatting over lunch. The challenge is even greater, however, when it is a distributed endeavour that has the vague goal of strengthening and better establishing the use of script languages and reproducible research in archaeology.

On 26 August 2020, the CAA's special interest group for Scientific Scripting Languages in Archaeology was officially confirmed. This was a very exciting step for all those who have worked to make this working group a reality. However, the date itself illustrates that throughout its life to date the SIG has been condemned to work virtually exclusively under the conditions of the COVID situation and without being able to meet in person. However, due to the very wide geographical spread of the group's members, this was certainly the only practical modus operandi anyway.

Since our inaugural meeting on 6 October 2020, we have now held a regular monthly meeting to exchange ideas through various video communication platforms. We have experimented with different structures for the monthly meeting, starting with a casual exchange with each other, to a more structured and organised form of the meeting, to a mixed form where a lecture part and a general exchange part coexist. At the same time, we started to work on various joint projects, such as building a collection of teaching materials or working together on existing projects.

Our main working tools were different video conferencing platforms, GitHub and for quick exchange Slack. In this talk, I would like to share my experience of how the possibilities of digital online collaboration made such a project possible in the first place. At the same time, I will discuss the challenges that arise when trying to work together in this distributed way. The activities of this working group can be contrasted with the experiences we have had in the smaller, local working group ISAAK. Ultimately, I look forward to receiving ideas for our further work within the SIG in the subsequent discussion.

133. Collaborative writing: Using GitHub as a tool for collaborative writing and community building?

Florian Thiery, RGZM

Sophie C Schmidt, FU Berlin

We all know the challenge: writing a scientific paper together with several friends and colleagues related to the CAA family from different backgrounds and distributed all over Europe. A system is required that 1) allows working collaboratively, 2) can store more than one datafile, 3) can track changes, 4) enables branches for testing and single paragraphs and 5) supports markdown. This talk uses the example of writing a paper for the “Archäologische Informationen” edited by the DGUF (Deutsche Gesellschaft für Ur- und Frühgeschichte) on “Recommendations for the review of archaeological research software [1]”. For this special topic a well-known solution that is usually applied to software and source code has been chosen: GitHub [2]. After a process to find and consolidate an interdisciplinary group of researchers interested in the reviewing of software the group began to write in a single markdown file (Draft_EN.md). Changes were organised using pull requests (PR) with commits which could be commented or modified. An HTML rendering to visualise the text was set up. In this use case, after submitting and publishing the paper the real challenge began: keep the ball rolling and create a sustainable structure of collaboration to further develop the thoughts in the paper. For this the DGUF has set up a “Forum” to discuss the recommendations with other papers as answers or comments. Two such papers have already been published: “Contribution to the discussion: Handreichung zur Rezension von Forschungssoftware in der Archäologie und den Altertumswissenschaften” by Nicole High-Steskal and “Einige

Anmerkungen zur „Handreichung zur Rezension von Forschungssoftware" by Massimiliano Carloni. With these, new challenges arise: who will include the critiques and new perspectives on the paper in the recommendations? Should this be done by the authors of the original paper or by the reviewers themselves by using PRs in GitHub? How do you manage this post-publication process? Who is responsible? It remains an open challenge in finding the best workflow for this task, as well as finding and keeping individual researchers and groups motivated. This paper is intended to provide ideas and impulses for discussion.

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[2] https://github.com/Research-Squirrel-Engineers/Impuls_SoftwareRezensionen_DGUF.

154. Hundreds of lost villages! Use of mobile applications in detection and inventory of abandoned settlements from the former East Prussia

Anna Majewska, University of Lodz, Faculty of Geographical Sciences

Abandoned settlement units are a research topic long explored by representatives of many disciplines. Archaeologists, historians and historical geographers have the most experience in this area (e.g. Beresford 1954; Vařeka 2006; Wolski 2007; Funk 2013). There is no denying that the development of GIS, and LiDAR technology in particular, has elevated the study of declining settlements to a previously unavailable level, both in terms of the detail of diagnoses and their spatial scale. It is thanks to the possibilities offered by the remote analysis of detailed terrain data, especially for large areas, that it has been possible to identify many lost localities, that have been previously unsuccessfully searched for.

The use of LiDAR has crucially changed the very path of cultural landscape resource recognition. Field prospecting, although still crucial, is no longer the initial stage of the research diagnosis, but rather the next one – the verification one, for the findings made remotely.

Another milestone in streamlining the work of archaeologists undoubtedly comes from mobile applications, which provide great opportunities for, among other things, rapid synchronisation, updating and verification of various types of data in real time, while conducting field research, which is a real facilitation and improvement of the research process. This was the case of the author's research project on the identification of depopulated villages in the Polish part of former East Prussia and the diagnosis of their material structures. One of the main objectives of the research was to identify all settlement units from the area where settlement discontinuity occurred between 1945 and 2020. The methodology adopted was to conduct an interdisciplinary study combining historical geography with archaeology of the contemporary past. The studies was carried out between 2018 and 2020. These formed the basis for a doctoral thesis on the memory of the landscape of depopulated villages located in the Polish part of former East Prussia and the material dimension of the interruption of settlement in the area, defended in October 2021.

As a result of the study, nearly 800 depopulated villages were identified. In my presentation, I would like to focus on this particular issue, as the process of identifying depopulated localities in light of the use of mobile applications is particularly interesting. The aim of the paper is to indicate the possibilities offered by mobile applications in the field of recognition of former settlement units on the basis of the results of the conducted research project.

The first stage of the research was a digital comparative analysis of historical cartographic materials with current ones, in order to preliminarily single out villages that were depopulated after 1945. At that stage, the contents of 240 sheets of the Topographische Karte Messtischblatt map at the scale of 1 : 25,000 from 1920–1940 were compared with the contents of orthophoto maps and satellite imagery from 2016–2020 using the ArcMap software. As a result of the analysis, 788 completely depopulated villages were identified in the research area. In this way, a database of settlement units was created, forming the basis for further research, especially research concerning identification of settlement remnants on site. The subsequent stages of the research process strongly relied on the flow of information using mobile devices and applications.

For the purposes of the research, the mobile application called Geoportal Mobile was used, which provides remote access to numerous cartographic data from the resources of the state-run Head Office of Geodesy and Cartography (GUGiK) made available through the Spatial Information Infrastructure Geoportal, including an up-to-date orthophoto map and detailed elevation data from airborne laser scanning. The Geoportal shares results of airborne laser scanning that covered the whole of Poland as part of a governmental project (scans carried out in the years 2017–2020). Those data are not homogeneous. Their quality varies across the country and is the highest in urban areas. In the research area, i.e., north-eastern Poland, the quality of the data is similar – scan density ranged from 4 points per square meter (pts/sq m) for rural areas to 12 pts/sq m for urban areas. The data were published in processed form – a shaded terrain relief (DTM) on Geoportal. Use of the application linked to data from said portal allowed the results of LiDAR data modelling to be confronted, in real time, with the lay of the land being viewed during on-site prospection. The application makes it possible to, among other things, track one's current location based on GPS, which was crucial in the process of identifying relics of depopulated villages. One by one, the locations of objects preliminarily identified thanks to the application were being marked on an ongoing basis on a map created in the Google Maps application also containing a database of all the several hundred depopulated villages. One of the main assumptions of the research process was to work on a database that would be accessible on Android phones so that each research participant could fill in missing information and add data on an ongoing basis during on-site work. The adopted model was based on synchronous use of the database created in Google Maps with LiDAR data being read using the Geoportal Mobile application. The action model that was selected produced very good results – hundreds of identified objects.

The results of the project, including hundreds of identified depopulated settlement units and their relics and a number of completed spatial analyses, show how the research process itself can be accelerated and how incredibly detailed data can be obtained from LiDAR data through their active use during field surveys. The ongoing completion of the database through mobile applications was of the greatest importance. The use of the Geoportal Mobile application also allowed us to determine very precisely the morphology of individual objects located in abandoned homesteads, their physical and morphometric features, state of preservation, and their location within degraded settlements. Lessons from this research can also be used to design similar mobile applications for cultural landscape research and spatial analysis, including for archaeology.

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47. Digital tools and methods for sharing knowledge and know-how about flint formations and collect samples between multidisciplinary researchers for prehistoric studies : the return of experience of PCRs "Réseau de lithothèques" and GDR SILEX

Vincent Delvigne, CNRS

Christophe Tuffery, Inrap

Paul Fernandes, Paléotime

Siliceous materials were probably the most commonly used materials by prehistoric people to produce various types of tools. They are also the most common materials found among the archaeological remains of this period because these materials evolve slowly over the prehistoric time scale. The knowledge of the evolution of these materials before their use by the populations and since their burial in the ground and the archaeological sites where they are found, mobilizes many researchers since the beginnings of prehistory in the middle of the 19th century. In France, four collective regional research projects have started since 2006 to bring together nearly a hundred researchers from various disciplines (geologists, archaeologists, prehistorians, petroarchaeologists, geochemists, mineralogists, geographers, etc.). They collaborate on this research topic and their work is regularly published (Delvigne et al. 2018). These collaborative research projects have been complemented since 2019 by a Groupe De Recherche national sur le silex (GDR SILEX), co-funded by the CNRS, the Ministry of Culture, the Inrap and Paléotime.

In order for the researchers involved in these projects to work in a consensual manner, a harmonised method for the characterisation of geological siliceous materials was first established. Based on an innovative concept of an evolutionary chain of siliceous materials (Fernandes 2012), this method required a period of several years of exchange between different researchers who were not used to working together. Until then, each researcher had a list of terms, definitions and methods of observation and description of siliceous materials, which were not very compatible. Thanks to this method, a convergence of their work could be initiated and is currently underway. A glossary of more than 600 terms has been drawn up and will soon be published in French and English. It will be integrated into the multilingual Pactols thesaurus, which is widely used for archaeology in France.

Figure 36. Groupe De Recherche.

An Excel form and an MS Access database were developed between 2014 and 2017. They were used to characterise several dozen samples of siliceous materials. They made it possible to take into account the taphonomic, geological and petrological characteristics of the samples. The database has been used for several archaeological sites of the Recent Palaeolithic. It is used for training researchers, who thus adopt the proposed characterisation method.

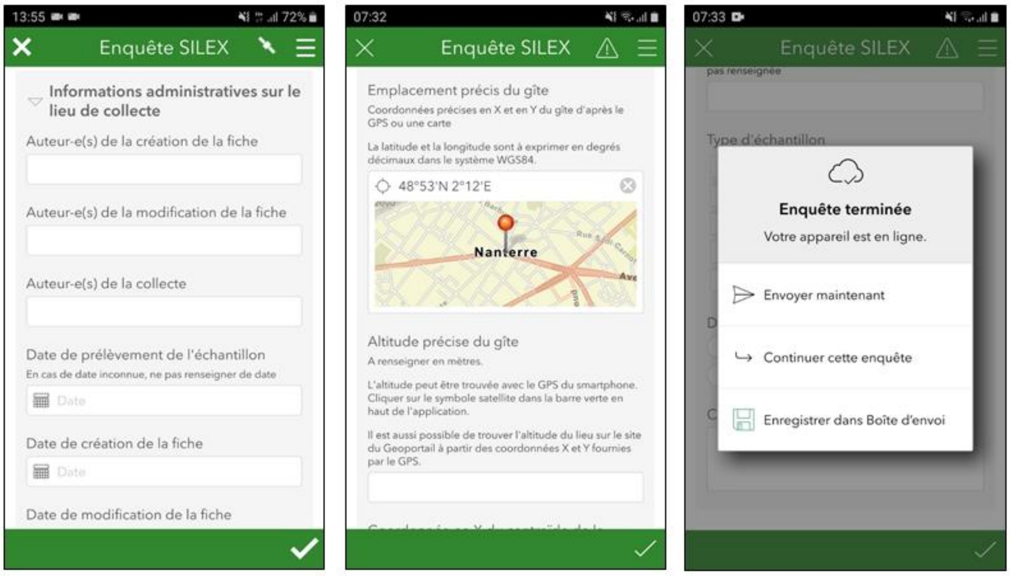

Figure 37. GDR SILEX.

Based on these initial results, a form describing the field collection points and rock libraries inventory of siliceous material samples was defined. A first version has been proposed in Excel. Then in 2021, a mobile application on smartphones and tablets was developed using the ESRI ArcGIS Survey123 application. A survey form has been developed. A version is available in French and another in English. These tools have been adapted according to user feedback. This application, which runs on many smartphones and tablets under Android, Windows and iOS, is gradually being used by researchers, either in the field during surveys or in the laboratory during the inventory of rock libraries. In parallel, a web-based mapping application has been developed since 2017 on the ArcGIS Online platform, to facilitate data sharing and reuse. Researchers' prospecting data and data on siliceous formations, adapted from those produced by the French geology institute, BRGM, are published in the form of WFS streams. These data streams are published under the Etalab 2.0 open license and are accessible from GIS software such as QGIS, and allow the use of spatial analysis functionalities that extend the functionalities already offered by the online mapping application. The latter is currently being migrated to an opensource solution based on QGIS Server. A QW2C client for QGIS Server, developed with ReactJS and OpenLayers, has been used. This opensource solution has advantages but also some limitations compared to the solution on ArcGIS Online. The ongoing migration should help to overcome these limitations and demonstrate the performance of open source solutions and meet the growing requirements of the open science movement. Finally, metadata are associated with the data. They will soon be used on the ArcaDIIS (Archaeological Data Infrastructure for Interoperability and Sharing) platform, which will make it possible to publish data in the form of data papers.

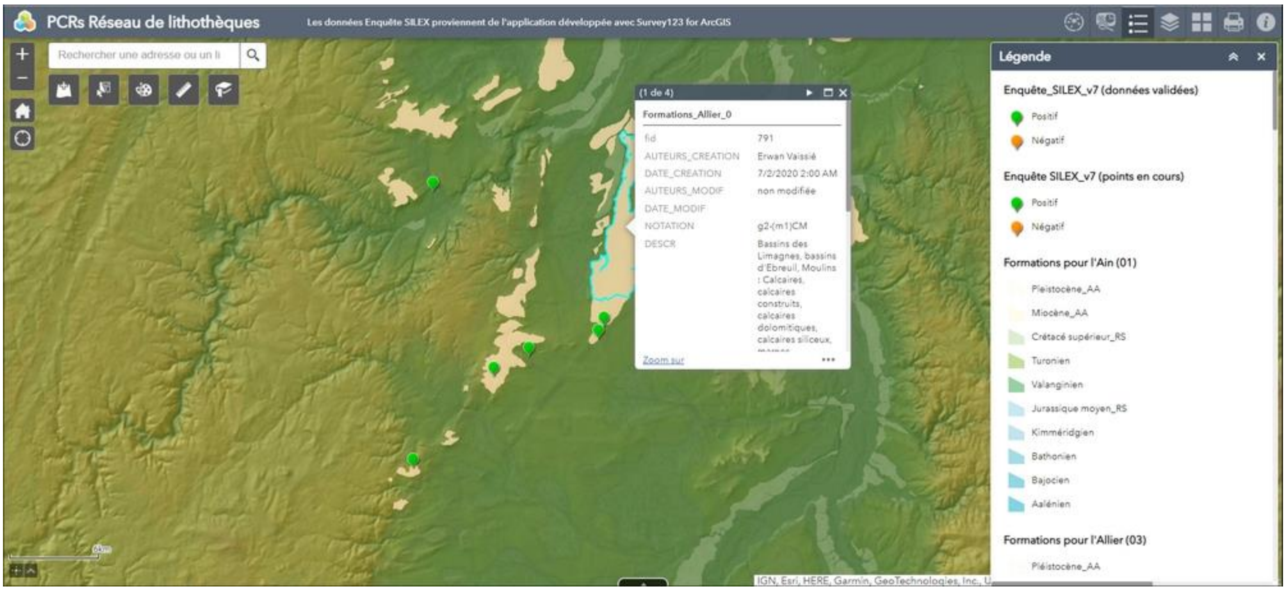

Figure 38. ArcGIS web mapping application.

The workflows for the use of these various digital tools are now well established, but they continue to evolve at the margins according to the feedback from users, their needs and the new possibilities offered by the evolution of the technical solutions used. Training courses in France and, recently, in Germany and Belgium, are offered to enable more and more users to learn how to use them and thus have them collaborate on the same project thanks to the digital tools developed for them and with them. The collaborations initiated by the multidisciplinary community of researchers involved in these projects demonstrate that digital tools can be used to support the necessary consensus between researchers who were not used to working in the same way before. But before technical interoperability between digital tools can be achieved, a first and indispensable step is to obtain semantic and methodological interoperability between the researchers involved. Without these two forms of interoperability, digital tools, however technically powerful, cannot achieve relevant and convincing results. Achieving these different forms of interoperability takes a long time. Researchers' practices, which are individually and collectively established social practices, can only evolve if researchers are willing to do so and not under duress. Faced with these major challenges, which are also the conditions for open science, some researchers are more willing than others to adopt digital tools and develop their digital skills. All of them need to be accompanied, to follow training courses and to be able to rely on some of them who act as gatekeepers between traditional research practices, without digital tools, and research practices based on digital tools and methods (Tufféry et al., 2021). The interest of this work and the first results achieved is to show that the need for collaborative work between researchers from different disciplines requires finding the conditions for sharing knowledge and pooling know-how. It is around digital technology that these needs can be met. But this possibility requires all the more reflection on the methodological and epistemological consequences of the evolution of scientific practices under the effect of an increasing use of digital devices.

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158. XRONOS: An open repository and curation platform for chronometric data

Joe Roe, University of Copenhagen

Martin Hinz, University of Bern

Computational archaeologists have benefited immensely from our field's recent embrace of open data and open science approaches, and one of the principle domains in which this has been applied in recent years is chronometric data. Comprehensive compilations of radiocarbon dates have become available for many parts of the world in the last decade and, as natural next step, there are now several initiatives to collate this data globally, including the retrieval tool c14bazAAR (Schmid, Seidensticker, and Hinz 2019), the IntChron exchange format (Bronk Ramsey et al. 2019), and the synthetic database p3kc14 (Bird et al. 2022). But this effort is far from complete. Radiocarbon datasets are still sorely lacking for many parts of the world and, even in those regions with good coverage, the quality of data is highly uneven and largely undocumented. There exists no central repository ensuring the long-term sustainability and completeness of these datasets, and the potential of placing other sources of chronometric information (e.g. dendrochronology, typological dating) in an open data framework has hardly been realised at all.

Here, building on and complementing these initiatives, we present XRONOS <https://xronos.ch>: a new web-based platform for chronometric data from archaeological contexts worldwide, combining an open data repository with tools for importing, curating and analysing chronometric information from diverse sources. The principal design goals of the software are to:

1. Combine all available sources of radiocarbon and other chronometric data in single database;
2. Develop robust tools for the continuous ingestion and refinement of this data;
3. Disseminate this data within an open and FAIR framework, embedding it in the wider world of Linked Open Data in archaeology and beyond.

This poster describes the conceptual and technical infrastructure developed to realise these goals in XRONOS' initial phases (2019 and 2021–2022), including a generalised data model for site and radiocarbon information, extendable to other chronometric data; an R- and Ruby-based pipeline for continuous ingestion of data from a variety of sources; continuous, semi-automated data cleaning protocols; a Ruby-on-Rails application providing a web-based frontend to the data and a REST API for programmatic access; and an R package for interfacing with the API. The XRONOS framework provides more open, more reliable, and more comprehensive access to chronometric data than previously available, as well as a foundation for its continuous expansion and refinement. It is hoped that this will already further the application of quantitative and computational methods to archaeological chronologies and, as an open science and open source project, we warmly encourage colleagues to participate in shaping the future direction of XRONOS.

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Session 21. Interdisciplinarity in Digital Archaeology

Lorna-Jane Richardson, University of East Anglia, School of Art, Media and American Studies

Catriona Cooper, Canterbury Christ Church University

Room 11

Introduction	09:00 - 09:15
26. What comparative architectural analyses can do *Wutte**	09:15 - 09:40
30. Remote fieldwork: The impact of COVID-19 on a study of ancient Roman wall paintings *McClinton**	09:40 - 10:05
31. The role of interdisciplinarity and interculturalism in being and doing digital archaeology *Cook**	10:05 - 10:30
Tea/Coffee	
44. Building a digital chain in archaeology. ICTs in the TRANSFER project: Towards an experience in ancient artisanal practises *Xavier de Silva* and D'Alessio*	11:00 - 11:25
121. What is a digital archaeologist? *Hageneuer**	11:25 - 11:50
142. Digital archaeology at the Museum of Cultural History, University of Oslo *Pantos, Bonelli*, Kimball, Kristensen, Samdal and Uleberg*	11:50 - 12:15
166. Integrative archaeological and archaeogenomic database for studying population history *Vyazov*, Flegontov, Isildak, Sagmanova and Flegontova*	Poster
Lunch	
173. Community-centred digital archaeology in a historic black American community: Submitting authority and collecting expertise *Woehlke*, Mohammadi and Meoni*	13:30 - 13:55
Discussion	13:55 - 14:10

Introduction

The complex cultural and social concept of authority and expertise is, within the context of archaeology as much as anywhere else, central to the assignment of intellectual authority through expertise to an entity or person. The literature regarding the definition of what constitutes expertise is vast and varied, and encompasses skills, processes, decision-making or knowledge. There has been much work in recent years exploring the interdisciplinarity of digital archaeology (See Huggett (2021) and Morgan (2019)). This session will build on this work, to explore the creation and maintenance of a professional digital archaeological workforce. We will ask, is digital archaeology a distinct discipline, or a smorgasbord of skills, technologies and values; and who defines the expert or the amateur. Why do some people identify as digital archaeologists, and others do not? What skills are needed to be a 'digital archaeologist'? What is the impact of the ubiquity of computing in the wider archaeological field? Where are the blurred edges of digital archaeology and other disciplines, such as computer science, history, UX, sociology, art, biological sciences etc?

This session will explore the inherent interdisciplinary nature of the field, and aims to invite papers that explore what makes us digital archaeologists:

- who is included or excluded from this identity,
- how can we overcome embedded euro-centric and colonial undertones to those involved in the work,
- how this work can be future-proofed in the face of sectorial challenges and economic pressures.

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26. What comparative architectural analyses can do

Anja Wutte, TU Wien

The presented project concentrates on the comparison of architectural aspects and formal design principles of ancient Egyptian architecture. Results and methods of previous studies are based on qualitative studies of plans and interpretation (traditional archaeology). The presented research explores the application of quantitative and comparative spatial analysis methods to gain new insights into Egyptian architecture and the use of shape grammars as a typology defining tool. Furthermore, related work shows that there is a need of a systematic approach such as a development study of Egyptian architecture only interdisciplinarity can offer to evaluate evolutional aspects.

The premise of this paper is that an interdisciplinary approach between Egyptology, architecture and computer science can offer novel insights into a corpus of studied monuments. The procedure to adapt and combine methods from different scientific disciplines will be discussed on the basis of the presented example. As example ancient Egyptian Late Period funerary monuments at Thebes are presented.

Methods and materials

This research is possible because of interdisciplinary research and an overarching strategy which incorporates architecture, computer science and Egyptology. For that reason, methods as well as considered approaches are multifarious.

The chosen methods support and lead to novel results about Late Period funerary monuments. The analysed monuments date to the Twenty-fifth (appr. 746-655 BC) and Twenty-sixth Egyptian dynasty (appr. 746-655 BC) and were built by high officials on the west bank of Thebes. Those funerary monuments emerge to be complex and partially heterogeneous, yet share similarities and a formal canon. The primary purpose is to evolve and present information and theories about the development of those monuments' design and building concepts, combining archaeological sources, architectural science, and computational reconstructions. The analysed structures will be examined through methodologies such as analysing their spatial structure (Wutte, Ferschin, and Suter 2015), accessibility, decoration, building utilization as well as formal structure (Wutte and Duarte 2021). This enables a more adaptive and easier to manage way to compare and study several monuments and can in further consequence be suitable for other studies of ancient architecture.

In focus is the procedure to extract homogenous data from a group of monuments to be able to conduct quantitative, qualitative, and comparative studies (Tilly 1984). While homogenous data includes uniform data gathering, uniform data processing, and uniform data presentation.

Results

To collect metric and uniform data of ancient Egyptian architecture, analysis methods from contemporary architectural science were adapted and modified to be suitable for ancient architecture studies. This includes several approaches, such as spatial characteristics, accessibility, lighting features, occurrence and distribution of decoration of the studied funerary monuments. Adaptions and modifications of contemporary architectural methods, as well as its benefits include, but are not limited to:

- refining: redefinition of terms
- tweaking: statistical data combined with spatial analysis results - e.g., identification of spatial location of decoration to define relations between location and decoration quantity
- skipping elements: skipping of analysis results not suitable for the study
- adapting: specific characterization of elements

Benefits of the analyses are increased availability of data, uniform data to enable immediate comparison, and change of perspective from two-dimensional plans to three-dimensional models. Quantitative analyses enable to understand relationships between different components. Components include accessibility, lighting features, decoration and formal structure (shape definition).

Digital models are enriched with semantic data to analyse, visualize, and compare the buildings in an adaptive, standardized, and reproducible way:

- Adaptive because the presented approach is not limited to funerary monuments in Egypt but can be applied to other types of architecture as well as in other cultural settings. A corpus of several monuments can be studied to gain metric results.
- Every complex of the corpus is analysed the same way, which defines the methods as standardized. Furthermore, results are based on metric data, rather than individual interpretations.
- Methods are reproducible and objective. Results are not a question of interpretation but of data. Barely procedures are applied to compare Egyptian architecture in a systematic manner to build typologies or to determine design parameters.
- Ideally, analysis methods are as much effective as possible. This means that a maximum of data is gained from a minimum of available source material. In case of the studied monuments two-dimensional floorplans functioned as source data, while visualization supports enriched space models.
- Enriched space models also function as data collection for the studied monuments. Collecting data from stand alone publications and excavation reports is time consuming and complex. Gathered data collections can easily be extended, changed, and interactive comparisons are facilitated.

Discussion

Research of the presented paper attempts to improve methodological strategies to analyse ancient architecture. Methods from modern architectural science are adapted and modified to accomplish this aim.

Already in 1985 traditional archaeological research was critically questioned, inter alia by A. Snodgrass when he states: "Where such books go beyond pure description and become interpretive, the interpretations that they offer are not testable by any objective criterion." (Snodgrass, 1985, 32). Although, archaeological research of the Twenty-first century is regarded as of processual and scientific nature, Snodgrass' critique is still – to some extend - appropriate. In this paper again traditional archaeological research and interpretation methods as well as limits and edges of disciplines are critically questioned through spatial modelling, and objective and comprehensible data interpretation. Interdisciplinary research should mean to overcome edges and limits, which is present in the proposed paper. The presented research intents to show how easy and natural interdisciplinarity can work - in the sense of "integrative archaeological research".

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30. Remote fieldwork: The impact of COVID-19 on a study of ancient Roman wall paintings

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Remote fieldwork is becoming an increasingly common phenomenon in the era of COVID-19 (Fuller & France 2014; Favilla & Pita 2020). While many research projects were paused or cancelled owing to COVID, others have transitioned to being entirely digital. Simultaneously, scholars are increasingly using digital data in their research (Deslandes & Coutinho 2020; Ogundiran 2020). Such observations were true before the outbreak of COVID-19, but the increased need for remote work during the pandemic has arguably expedited the so-called "digital transition".

Meanwhile, when studying specific sets of material, particular challenges are posed by the use of 3D models for analysis and interpretation (McClinton 2019; Bergmann 2016). For example, is it acceptable to solely use photographs and 3D scans when conducting visual analysis on a set of Roman wall paintings? What affordances does this approach offer us, and what are the potential methodological pitfalls?

These questions sit at an intersection between fields: art history, archaeology, and digital humanities. For example, scholars in art history have questioned if on-site work is crucial when studying Roman wall paintings (Drucker 2013). Meanwhile, archaeologists remain sceptical of research on any site which is conducted remotely (Maschek 2010). Questions surrounding efficacy and interpretation abound: is it possible to form accurate conclusions about a set of Roman wall paintings without seeing them "in-person"?

Presently, I am researching a set of materials from a Roman house in central Italy. I received a permit to work in January 2020, and following the outbreak of COVID-19, it became clear that it would be difficult to travel to Italy. Consequently, I shifted the goals for the project to be partly focused on digital data acquisition to enable "remote study". Now that this digital data is available, the question remains: how did this adaptation impact my interpretation and results, and how does the digital data complement "in-person" observations, and vice-versa? Moreover, will this project be accepted by scholars in the field? I propose to present this paper at CAA in order to meet potential collaborators, collect crucial feedback for future research, and further discussion surrounding this topic.

31. The role of interdisciplinarity and interculturalism in being and doing digital archaeology

Katherine Cook, University of Montréal

Despite the critical contributions of diverse voices and visions in imagining innovative applications of digital technologies to transform access, representation, ethics and transparency in archaeology, the politics of who identifies as a "digital archaeologist" and who is identified as such remains exclusive, inequitable, and often embedded in complicated relationships to expertise, privilege, and authority. The intersections of archaeology as a discipline, with its own fundamentally colonial roots, with technology-based industries and disciplines that are also known for their inequities, abuse, and trauma (Martin 2017), often render the sphere of digital archaeology politically charged, difficult to navigate and a minefield of oppressive structures and attitudes. Moreover, the ways in which these same technologies, which have been celebrated for their abilities to democratize, open, and transform the study of the past, have in turn been commandeered as a vehicle for abuse, intimidation, and violence towards diverse voices (Deruiter 2018). To be a digital archaeologist, therefore, has been increasingly recognized as accentuating existing oppression and exclusion.

Why does the prefix of "digital" seem to render this identity for archaeologists more uncomfortable, political or exclusive? How do we transform digital work to recognize and value diverse perspectives, voices, and approaches during times of increasing precarity and disparity within and beyond the discipline? What is the relationship between interdisciplinarity and interculturalism, and why are inclusive and decolonizing practices central to concepts of interdisciplinarity in digital archaeology?

Attempts to address the lack of inclusivity or diversity of the identity of "digital archaeologist" is currently extremely limited by the colonial, euro-centric foundations of archaeology, technology, and the Academy more broadly. Increasingly, the sense and value of interdisciplinarity is coming to recognize the contributions of different ways of knowing, ontologies, and epistemologies, including diverse indigenous knowledge systems, but also black, queer, trans, and feminist epistemological contributions and scientific heritage.

This paper argues that this is not only valuable to reshaping our understandings of digital work in archaeology, but also is essential to redefining our connections to other disciplines, approaches and communities of practice. It also recognizes the complex relationship between self-identity and experience, and collective identities and practice, which in turn shape research and the communities of people who contribute to this work. Bringing together theoretical discussions of what digital archaeology is and does, alongside documented testimonies (publicly accessible through blogs, social media, etc.) and personal reflections on the experience of doing digital archaeology, this paper will sketch the complexity of being and working in the interdisciplinary ecosystem that is woven together with digital archaeology. It will also review case studies of transformations to disciplinary structures, career and education models, and funding and ethics frameworks for research to discuss potential avenues for remodelling digital archaeology as an interdisciplinary and inclusive community of practice.

As interdisciplinary, collaborative, and applied research transforms the problematic history of who is considered expert or amateur (anchored to racism, sexism, homophobia, eurocentrism, etc.) in archaeology (Richardson 2014) and research spheres in general, we have the opportunity to unsettle and disrupt digital archaeology in connection with decolonizing, inclusive practices to build more dynamic, diverse communities of practice, which in turn reshapes the work being done. Without transforming who is valued, recognized, and included at the digital archaeology table, it is impossible to address the ever-more-complicated ethical dilemmas of digitization, sustainability, access, and representation.

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44. Building a digital chain in archaeology. ICTs in the TRANSFER project: Towards an experience in ancient artisanal practises

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Mirco D'Alessio, Marche Polytechnic University

The increasingly effective collaboration between new technologies and archaeology has been recently supported by fundamental and internationally recognised guidelines such as the London Charter and the Seville Charter (Brusaporci and Trizio 2013). The use of digital is an essential tool to help archaeologists in the study of the archaeological sites and records, and it provides new methods of use, able to fascinate new audiences and therefore promote the heritage of a territory.

Through this paper we aim to sherd a light on the importance of promoting a digital chain in archaeology more than defining the professional figure of a so-called digital archaeologist. Considering the essential principles of Public Archaeology, it is nowadays clear that the possibilities of ICTs in archaeology go beyond their applications to research and documentation reaching their acme in the communication of the cultural heritage to the public (Volpe 2020). If archaeologists can, and today must, come to master some digital tools especially related to documentation, it is also true that innovative applications, such as those leading to the development of AR and VR experiences, need more specific and advanced skills, those, for instance, of computer engineering. In today's hyper-specialised context what may be more difficult in the creation and development of an accurate content is the communication between the different expertise of each professional involved in the digital chain we want to build. It is clearly undeniable that a good valorisation project related to the CH must not fail to be archaeologically accurate, but it also has to identify the right target, the appropriate language, develop engagement in the public, and be able to promote education through entertainment. All these aims fall in one or more specific fields that need to be properly linked together.

In order to analyse the characteristics of an effective digital chain in archaeology, we will show the work phases of the pilot action we developed in the frame of the European TRANSFER project. The latter focuses on the management and valorisation of a network of archaeological parks in the Adriatic area, promoting sustainable planning methods and standards for cultural heritage as an asset of research through the elaboration of a common management model. TRANFER also aims to define a professional figure that could be a link between the different skills and expertise needed in the management and valorisation of archaeological parks. This professional ideally has an archaeological education but also the soft skills necessary to interact with ICTs experts and other professionals in connected fields. This networking and coordination skills are essential in the creation and operation of a digital chain which can produce and develop innovative projects of valorisation and management in the field of archaeology.

Going into details, we chose to focus on a complex of republican kilns in the Roman colony of Pollentia-Urbs Salvia as the pilot action of the TRANFER PROJECT for the archaeological park of Urbisaglia (Marche, Italy). As the structures are now completely obliterated under the following republican building, it seemed even more interesting to investigate the possibilities offered by a virtual visit of this artisanal complex. The development of the final product of this project needed many steps all characterised by the interaction of multiple expertise and professionals coordinated by archaeologists. The latter may not be defined as digital archaeologists, but they served as coordinators of the entire process, being entirely in charge in the phase concerning the study of the archaeological context and later promoting the connections between the other professionals and providing the coherence of the entire project.

Therefore, what we want to investigate showing the different phases of the TRANSFER Project pilot action is the hidden potential of a digital chain in the archaeological field, not only for scientific purposes, but also from a communicative point of view. Numerous studies reveal a close correlation between the emotional appreciation of a given VR experience, the level of learning, and the willingness of the user to repeat the experience and suggest it to third parties, to achieve this goal, essential for an excellent dissemination of the CH, four fundamental themes must be emphasized: education, entertainment, escape, and aesthetics (Leopardi et al. 2021). To achieve these four goals, it is necessary to involve, in this digital chain, close collaboration between many different and heterogeneous fields, linking in specific archaeology, engineering, and the world of entertainment. We started from the archaeological study of the structures, integrated also with an experimental archaeology approach in order to supply for that information we struggle to find in the archaeological records regarding the kilns and their functioning. The actual realisation of the experience went through two distinct but strongly connected phases: the first is about the study and realisation of the virtual environment, the second concerns the specific development of the VR application. About the first we followed a specific workflow characterized by the realization of 2 models at different level of detail (LOD). First, we realized a proxy model, a schematic and low detailed model used to achieve the archaeological validation through an iterative methodology, so using the digital reconstruction as a scientific tool. Secondly, we used this first model as the base for the realization of a high detailed and realistic 3D environment, this is important to achieve the emotional involvement of the final user. All the manual reconstructions were performed within the open-source software Blender. Moreover, we proceeded with the design of the experience, using tools typical of the world of video making and entertainment such as scripts, storytelling, storyboards and animatics. Then, we focused on the realization of the app, performing live shoots in greenscreen, renderings, and animations, realized in collaboration with experts in visual effects and film footage. Finally, the app was built and mounted inside the multi-platform game engine Unity. The final result obtained is a virtual movie for Oculus Quest 2, that is an immersive virtual experience in which the user can observe and experience the digital reconstruction of the Roman kilns of Urbisaglia, discover the functionality of the structures and the stacking of the vases, accompanied by an expert Roman craftsman, and thanks to the implementation of the hands tracking, touch with their own hands the virtual objects made.

The analysis of these many phases from the point of view of the interactions between different fields will help us going deeper in the definition of digital archaeology and hopefully make a step forward in the definition of its blurred edges.

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121. What is a digital archaeologist?

Sebastian Hageneuer, DE

The respective curricula of any archaeological discipline, whether Classical Archaeology, Prehistory, Egyptology, or Archaeology of West Asia are filled with numerous interdisciplinary topics. As an archaeologist of West Asia, I took Akkadian and Sumerian philology courses, introductory courses to museum studies, and a class on Cultural Heritage conservation. Still, I would not call myself an “expert” in any of those fields. Even in my major, I possess expertise not in the entire field, but only in those few areas that I have put my focus on – in my case the study of mud-brick architecture and Digital Archaeology. So, what exactly is an “expert” in Digital Archaeology? Is there a difference between an archaeologist using digital methods and a digital archaeologist using archaeological data? In my opinion, there is, and the difference lies in their specific research focus.

At the University of Cologne, we offer two master programmes in Digital and Computational Archaeology. One of them is closely intertwined with the master programme for traditional archaeological disciplines and is suitable for comparison. At the end of their studies, digital and non-digital archaeologists know a little bit of the other’s field, but what they will become experts in, depends on what they will put their research focus on. Therefore, to me expertise is not defined by the university degree, but rather by the individual’s emphasis on certain research areas more exemplified by their CV than their master’s degree.

As this distinction seems obvious, the day-to-day experience for digital archaeologists is quite different. Following my argument, research in Digital Archaeology focusses more and more on the development of methods and technology and lesser on central issues of archaeology itself. Most funding programmes still expect digital archaeologists to focus on archaeological research questions. They offer funds to archaeological projects that also involve digital methods, in other words defining Digital Archaeology as a subdiscipline to archaeology. The research questions of digital archaeologists are rarely considered and are therefore often not compensated in terms of elevated costs in soft- or hardware.

Archaeology itself is a highly interdisciplinary field, with lots of experts from different areas working together. As an archaeologist of West Asia needs to collaborate with an Assyriologist on an excavation to decipher the unearthed cuneiform texts, so do archaeologists of all disciplines need the expertise of Digital Archaeology in the research and application of new digital methods. I therefore deem it necessary to define Digital and Computational Archaeology not as a subdiscipline to archaeology, but as an equal field of study with individual requirements.

Archaeology needs to work interdisciplinary with Digital Archaeology to be prepared for future endeavours.

142. Digital archaeology at the Museum of Cultural History, University of Oslo

George Alexis Pantos, Museum of Cultural History

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Espen Uleberg, Museum of Cultural History

Steinar Kristensen, Museum of Cultural History

Magne Samdal, Museum of Cultural History

The Museum of Cultural History (MCH) at the University of Oslo plays a leading role in archaeological infrastructure at both the regional and national level in Norway. In collaboration with other Norwegian university museums, MCH is working toward an improved version of the national artefact database, Unimus (unimus.no), leads the national e-Infrastructure project ADED (Archaeological Digital Excavation Documentation), and is developing the recent BItFROST project (a 3D archive and dissemination infrastructure project).

The digital support unit (DigDok) within MCH plays a key part in the above projects as well as the day-to-day digitisation needs including museum artefact documentation and site documentation for archaeological excavations throughout southern and eastern Norway. This combination of both museum, excavation documentation, and national level infrastructure is less common among museums in other countries both within Scandinavia and Europe. The current digital support unit at MCH combines previously separate groups within the museum and, together with its close collaborators, forms a diverse mixture of data specialists, photographers, 3D documentation specialists, and ‘digital archaeologists’ that is not always common within more segregated museum/archaeology settings.

This paper draws on recent initiatives that use technology to facilitate communication and collaboration across diverse archaeological and heritage specialisms. Through these case studies, it will deliberate on the role of digital archaeology and how these relatively recent specialisms relate to other more-established craft and specialist areas. Reflective thought is given to the success and shortcomings experienced from communicating the benefits and limitations of technological approaches in archaeology—both within DigDok itself, but also with its target audience. By drawing on other studies, such as the recently published ICCROM report into sustainable heritage practice (Van Malssen et al. 2021), we hope to contextualise the museum’s own experiences within the wider setting of challenges faced by digital archaeologists and other heritage professionals in the face of ongoing democratization of technology and changing expectations within society.

These techno-societal developments have more than just practical implications. In a recent paper delineating archaeological ‘data-imaginaries’, Huggett (2022) emphasizes the distancing effect technology can have between the archaeologist and their subject, and the need for a critical approach to the adoption of technology. Similar concerns are also highlighted by Morgan et al (2021) in their exploration of drawing practices in archaeology. These discussions reflect a recent growth in awareness of the relevance of ‘craft’ within archaeological practice—a term more commonly associated with other more technical disciples, e.g., photography, and that have experienced many years of disruption and transformation through technological progress. We hope to contribute to these debates by drawing on the diversity of experience and specialisms within the DigDok group.

Crucially, we ask what place is there for the 'digital archaeologist', as the practical skills that once set this group apart become common, unnecessary, or, conversely, ultra-specialized. It will argue that as technology brings its latest challenges, there is much that can be learned from the experiences of others and a diverse approach with digital archaeologists less as early adopters but as moderating role between technological needs and the more human aspects of the discipline.

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166. Integrative archaeological and archaeogenomic database for studying population history

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The Migration Period in the Eurasian steppe and forest-steppe is a bizarre pattern of population processes. Hunnic invasion to the East European steppes in the 3rd c. CE precipitated dramatic and wide-scale relocations of local groups of different origins, leading to intensive population admixture and formation of heterogeneous societies which were the main actors during the whole period. The sophisticated nature of the migration process caused by the Huns and associated groups requires a multi-proxi study based on integrated archaeogenomic and archaeological records.

We developed a Web-based and GIS-driven database, integrating archaeogenomic and archaeological data. It is based on a graph database engine (Neo4j) that allows us to store, analyse and manage complex relationships between the archaeological evidence, its context, and interpretations. The functionality of our multi-user system includes data mapping, visualization, selection, and processing.

In addition to archaeological data, our database also includes published genome-wide archaeogenetic data from the Allen Ancient DNA Resource which are linked to respective burials.

The web-GIS toolkit enables users to select certain groups of burials and archaeological sites and perform simple analyses of genetic data: hierarchical clustering of genetic distances, PCA (both basic and with projection on user-defined axes), ADMIXTURE, f-statistics, and qpWave/qpAdm. The database also enables users to store connections between ancient individuals revealed by the identity-by-descent (IBD) methodology, a high-resolution method of genetic analysis.

Overall, our database deals with both complex archaeological data and genome-wide archaeogenetic data retrieved from published studies and linked to related archaeological objects. From the archaeological side, our database offers users a flexible way to select, filter, and visualize archaeological data and their relationships. Moreover, our interface allows users to easily search and select archaeogenetic data and perform basic genetic analyses to study human history. We hope that this database and the simple toolkit will help to cross the divide between research in archaeology and archaeogenetics.

173. Community-centred digital archaeology in a historic black American community: Submitting authority and collecting expertise

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The Digital North Brentwood Heritage Project is multifaceted and interdisciplinary. It began as a simple idea for a course activity featuring the 3-D digital documentation of some historic structures in a 19th and 20th century Black community in Maryland, USA. Over time, the scope of the project began to grow into a long-term commitment to support the North Brentwood community as they worked to address challenges connected to environmental racism embedded in the community's founding, or modern challenges connected to the forces of gentrification.

The expansion and diversification of the project is connected to the transfer of authority from university faculty to the Town and descendants connected to its historic community. Initially, members of the Town Council were happy that someone from the University was doing work that raised awareness about their underrepresented history. As additional conversations were had, we realized that there was more potential for the spatial data we were collecting, than our original, limited scope. Currently, the spatial data will be adapted to produce specific results that support the community in a variety of ways, all of which have a connection to archaeology and heritage preservation, but often secondary. This additional community support largely fell into disciplines outside archaeology. Currently, we are developing work around stormwater management infrastructure, VR heritage interpretation, and community archaeology.

North Brentwood's first residents purchased land in an undeveloped suburban area within the floodplain of the North Branch of the Anacostia River, in Prince George's County, Maryland. Policies that enabled segregated housing developments prevented people of color from purchasing land in many parts of the county. In general, areas opened up to Black property ownership were not in ideal locations. This community was in an area that faced a high risk of flooding. Mitigation measures have been taken, but they are not resilient, and are likely to fail more often as climate change increase overall precipitation and precipitation rates in this portion of North America. Flooding is still the number one challenge faced as a community living in North Brentwood. This is a risk to the community. It is a risk to their historic built environment. It is a risk to their archaeological heritage.

A new challenge facing the North Brentwood community is gentrification. These forces are increasing the rate at which multigenerational and long-term residents are leaving. Developers and new residents usually know very little about the community, which may result in a loss of identity over time. Gentrification also leads to an increase in the rate of change to the built environment, which will obscure e the historic landscape over time.

These challenges facing the community have shifted the direction of the project in ways that confront their needs more directly. Addressing these challenges has forced us, as archaeologists, to collect experts and their expertise from other disciplines, then integrate them into a project seeking to address a multitude of increasingly messy problems.

The 3-D data collected by our project is being used in a collaboration with the Stormwater Infrastructure Resilience and Justice Lab to model historic flood events and to model mitigation strategies. Modelling historic events helps the community explain the long-term impacts of living with the constant fear of losing your home or your loved ones. Modelling mitigation strategies will help the town develop more resilient systems that can help protect them in the future.

The data will also be used to develop a 3-D heritage gaming and VR platform that will enable the community to share their history and their stories in their own words. Oral histories collected by the town in the past will be made available to the public as they virtually walk down the streets and pass the buildings that the histories reference. Historic images and documents curated by community members will be embedded into these environments to help digital visitors see what it looked like in the past.

Lastly, the data will serve as the base for the development of an archaeological program in the town. 2022 is the first summer to feature an archaeology and preservation field school. Excavations will mitigate the loss of architectural heritage as changes continue to be made to the town's landscape as site are demolished and new parks or structures take their place. The high-resolution base data will enable 3-D digital excavation documentation that seamlessly integrates with the modern environment and will enable the expansion if the town's heritage as forgotten elements of the past are unearthed.

The fundamental guiding principles of this project are in centring the community and supporting them as best we can. The skills we bring to the table are limited, but their capacity to have a positive impact is only limited by our ability to advocate for the projects they need to get done. There may be a boundary that archaeology does not touch, beyond which we would have no role, but it is doubtful. Archaeology touches the past, present, and future. Its Cyborg capacity enables it to adapt and address the desires of those with authority over the project. Relinquishing that authority has enabled our work to begin to make an impact beyond anything an archaeologist could have imagined alone.

Session 22. Traces of digital archaeological practises

Isto Huvila, Uppsala University

Zanna Friberg, Uppsala University

Lisa Börjesson, Uppsala University

Olle Sköld, Uppsala University

Room 14

Introduction	11:00 - 11:15
40. Translations and path dependencies between sources, made and given data *Roesler* and Hofmann*	11:15 - 11:40
57. Towards clarity and confidence in archaeological prospection and remote sensing archaeology *Banaszek*, Cowley, Geddes, Bjerketvedt and Killoran*	11:40 - 12:05
63. Follow the money: Tracing Alexandrian coinage in the digital record *Isaksen**	12:05 - 12:30
Lunch	
84. Known knowns, known unknowns and unknown unknowns: Strengths and weaknesses of reporting archaeological fieldwork and research in Scotland *McKeague**	13:30 - 13:55
94. Gathering and following traces: Towards a methodology of data reading *Sköld, Börjesson, Huvila* and Kaiser*	13:55 - 14:20
124. Archiving the third dimension *Kruse* and Schönenberger*	14:20 - 14:45
Tea/Coffee	
34. The impacts of digital devices on archaeological practices on field recording activities and archaeological archives production from 1980s: An historical and epistemological point of view *Tuffery**	15:30 - 15:55
Discussion	15:55 - 16:10
70. From analogic and legacy data to the digital geonumismatic database of the AugustaGIS *Bettineschi*, Reuter, Rheeder, Gairhos and Sojc*	Poster
96. 3D reconstruction of the early medieval stronghold in Santok: Educational and scientific significance of the visualisation in archaeology	Poster

Markiewicz and Zamelska-Monczak*

Introduction

Knowing about how archaeological work – from fieldwork to data collection, analyses, construction of models, visualisations and beyond – is conducted is essential for understanding its outputs whether they are 3D models, archaeological knowledge, digital or analogue data or books, articles or reports. There is an increasing body of research on the traces of archaeological, and in a broader sense, scientific and scholarly practises. These studies investigate how different traces—conceptualised, for example, as traces (e.g. Hug et al. 2011; Morgan & Eve, 2012), paradata (e.g. Gant & Reilly, 2017; Denard, 2012; Huvila et al. 2021) and provenance metadata (e.g. Huggett, 2014)—can inform data reuse, provide understanding and criticise archaeological practises, documentation and information, seek to understand the limits of archaeological knowledge, and much more. Thematically the work spans from the documentation of archaeological visualisations (Bentkowska-Kafel & Denard, 2012; Börjesson et al. 2020) to studies of the use (Wylie, 2017) and curatorial history of archaeological collections (Voss, 2012; Friberg & Huvila, 2019), archaeological documentation (Huvila et al., 2021), data reuse (Ullah, 2015; Sobotkova, 2018; Strupler, 2021), analysis of earlier data collection methods (Olson & Walther, 2007) and changing data practises (Montoya et al., 2019).

This session invites presentations of evidence-based, theoretical and reflective work relating to traces of digital archaeological practises. Theoretically, the session is open to perspectives drawing from the quantitatively oriented trace data analysis tradition and qualitative investigation of traces—including trace ethnography that enables identification and analysis of traces in semi- or unstructured documentary formats such as working notes, log files and oral communication (cf. Geiger & Ribes, 2011)—and beyond to bring different approaches and theoretical views into discussion with each other. Contributions to the session can, for example, describe qualitative and quantitative methods and experiences of collecting traces (including paradata, provenance metadata and beyond); discuss how traces can inform data reuse, analysis and use of archaeological information and knowledge in different forms; engage in theoretical ruminations of what counts and works as a trace; share experiences and considerations of e.g., what functions as a trace and why, what types of traces are informative and for what purposes, and what kinds of traces can be seemingly informative but in practice are less useful. Thinking of possible contexts, the discussed work can pertain to fieldwork and documentation of digital field practises, documentation of data creation (e.g. database design and curation), traces of practises in legacy data, metadata and paradata, automatic and manual documentation of practises in field and lab notebooks, databases and video diaries, annotation of 3D visualisations and documentation and archiving of software used in archaeological data capturing and analysis. The disciplinary background of proposers includes the whole CAA community from archaeologists to, for example, social and computer scientists, heritage, museum and information studies researchers and practitioners.

The format of the session (Standard session) consists of paper presentations and discussion, including a concluding open forum for sharing and collecting ideas for future research on and in relation to traces of digital archaeological practises.

The session is affiliated with the CAASIG-ARKWORK on archaeological practises and knowledge work in the digital environment.

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40. Translations and path dependencies between sources, made and given data

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Archaeological practice consists to a large extent of searching, translating and linking traces of the human past. In the archaeological research process, we start from the relic of past practices addressed as sources and collect a wide range of different data: Images and drawings, descriptions, measurements, indices, interpretations, typological determinations, etc. Most of these transformations usually take place through reductions of locality, particularity, materiality, variety and continuity, and lead to amplifications of compatibility, universality and standardisation (Figure 39). Since archaeological sources are often irretrievably destroyed or difficult to access and thus lost as a primary data resource, usually only the collected data as well as archived finds and samples can be used in the research process. In the course of research, the so-called primary data in particular are often queried several times with different research questions, under different research constellations and using different techniques, whereby the data can in turn be transformed (a process famously referred to as circulating reference by B. Latour).

In this handling of data, a semantic shift in the meaning of what we refer to as data takes place. Data are commonly understood as entities that are 'made' by procedures or instruments (such as measuring instruments or the computer). The source, however, as the primary resource of knowledge, is that which is 'given' and most closely corresponds to what is called fact. But as data are again the basis of further research, they become the given. Especially in technical and digital contexts, data are 'given quantities' that are worked with (Rheinberger, 2007).

In our paper, we would like to address this field of tension between given and made data using the example of some digital projects of the Römisch-Germanische Kommission (RGK) of the German Archaeological Institute (DAI). The notion of path dependency, which denotes past decisions that create a long-term commitment to a certain way of doing things, can be used to describe practices that transform made data into given ones and thus manifest the path of research on and with them (Hofmann et al., 2019). It is often non-explicit, perhaps even quickly made determinations that limit the space of possibilities in the further course. They arise, for example, in the choice of algorithms, data formats, software or database systems and show up as traces in the data selection, structure or context (Hacıgüzeller et al., 2021). They can establish research routines, whereby research follows well-trodden paths from which it is almost impossible to deviate.

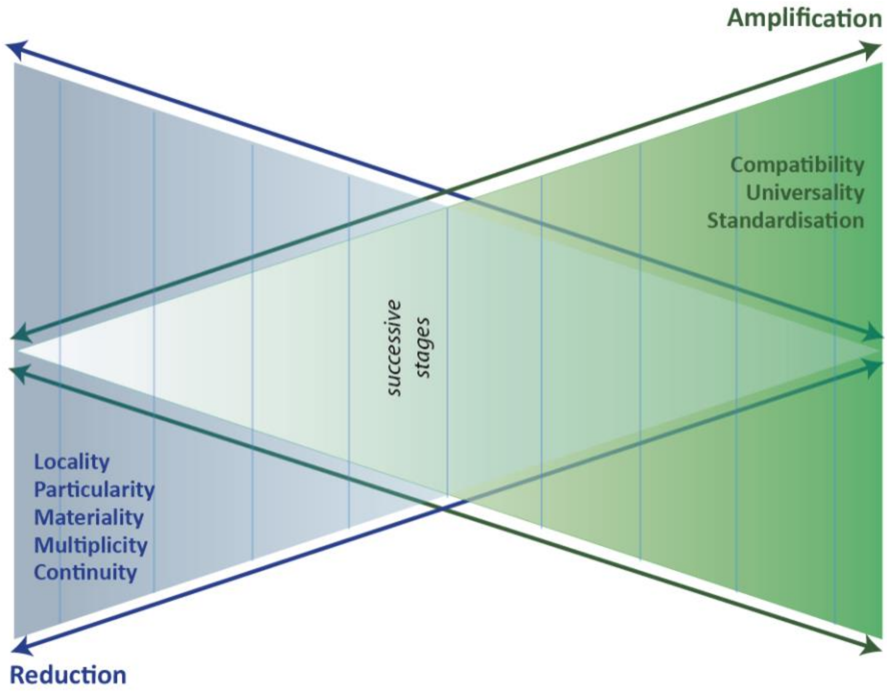

Figure 39. K. Hofmann after Latour, B. (2002). Die Hoffnung der Pandora (p. 86). Frankfurt: Suhrkamp.

Using a series of digital editions that gather fragmented and/or scattered things as data, we would like to point out in our paper various path dependencies that occur in the context of data collection in archaeology and show some approaches to collecting data that we are developing and pursuing in (interdisciplinary) projects using networking on the WWW (keyword LOUD). What all projects have in common is that they illustrate in one way or another the making and the made-ness of data by putting data in context with histories of people, knowledge and practices.

We will follow an object recorded in the Corpus of Roman Finds in the European Barbaricum (CRFB), a collection of spatial, temporal and typological data on Roman objects north of the Limes. How and in what granularity the data of this object are indexed and how they are presented in the CRFB was already determined in the 1980s and still influences the recording of data and the research that can be conducted with it today.

We will use Celtic coins to show how procedures developed for other, mainly Greek and Roman, coins influence their scientific analysis and representation today and how these path dependencies are altered in the interdisciplinary project ClaReNet - Classification and Representation for Networks (https://clarenet.hypotheses.org/) through epistemological and historico-scientific reflection and by incorporating artificial intelligence.

With the project PropylaeumVITAE: Actors - Networks - Practices (https://sempub.ub.uni-heidelberg.de/propylaeum_vitae/de), a biographical information system that collects not only the biographical data of actors in archaeology and heritage management , but also common research topics, fields of work and practices, we want to open up new thematic fields and questions for the history of archaeological sciences.

And finally, with an edition project in preparation called disiecta membra - Stone Architecture and Urbanism in Roman Germany, a data collection on Roman building elements, we want to reflect newly emerging path dependencies from the very beginning. We plan to create a dynamic and networked digital edition that incorporates the historical contextualisation and the histories of finds and collections. In doing so, we will 'make' the data taking into account different research traditions, standards and monument information systems and make it freely accessible, linkable and reusable.

Our main objective of our presentation, then, is to show that all data is made and it is important for its use to illuminate how and why it was made; something that is especially feasible in the digital environment. This insight also leads back to the semantic shift mentioned above: according to the Latin sense of the word, data is what is given (datum from Latin 'dare' = to give), whereas facts are what is made (factum from Latin 'facere' = to make, to do). At first glance, it seems as if we have foolishly reversed the meaning of the terms. But when we say that we conduct data-driven research, have we not returned to the original meaning? The data are given, now do we have to make facts?

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57. Towards clarity and confidence in archaeological prospection and remote sensing archaeology

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It is rare for the processes that contribute to archaeological surveys to be made explicit – whether it is during field investigation (survey), from desk-based mapping, from research or a combination of these approaches. The processes that lie behind knowledge creation are often partially hidden, or 'taken as read'. Thus, at least some elements of the results of survey have to be taken on trust, whether in expertise, decision-making or scope. Since some survey processes are opaque it is difficult to judge a series of issues that are important for the re-use of information – how reliable or representative might the results be? This paper presents outcomes of work to introduce a greater degree of transparency and explicit documentation of survey process in recent archaeological surveys undertaken in Scotland.

Methods and materials

Recent surveys of islands of Arran and Luing, in the Rhins of Galloway, and in the Scottish Borders made extensive use of airborne laser scanning derived visualisations and aerial imagery, supplemented by field observation and the analysis of historic maps. The approach, which included multi-operator desk-based mapping and machine learning, explores the confidence and interpersonal variability in interpretation, both of which aided and affected the decision making in which sites to visit on the ground. Quality assurance, which has profound effects on the attribution of date and period, was undertaken as a final check.

Results

Documentation of the individuals involved, and the iterative changes in the results, was combined with GPS tracks of field visits to give a much fuller sense of the process of knowledge creation that underlie apparently straightforward outputs. Thus, the results, which must be strictly structured to feed Scotland's National Record of the Historic Environment (NRHE), are supplemented by layers of information that describe archaeological works and investigated sites beyond the basic requirements of NRHE.

In addition, newly designed recording forms with automated and replicable data processing steps have contributed to developing a workflow that can be used in future investigations. Finally, a comparison of desk-based assessment results, field interpretation, and outputs of machine learning has demonstrated that while bias, an inherent characteristic of archaeological investigations, differs in character across the prospection methods used, its impact can be mitigated if multiple data sources and methods are used and cross-examined.

Discussion

Our development of explicit workflows is ensuring that bias introduced by interpersonal variability and the use of various prospection methods, operating at different scales, is documented and understood. This has important implications for citizen science projects building on multiple interpreters of remote sensing data. In addition, our research enhances information added to the NRHE by providing background information to anyone reusing project data and outputs. It is planned to release the recording forms and workflow for all to use, to encourage coherent data collection, analysis, and interpretation.

63. Follow the money: Tracing Alexandrian coinage in the digital record

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The mass digitization of national and local archaeological and antiquarian databases and publications has opened up new opportunities for the reappraisal of longstanding archaeological debates, as well as new problems. This paper explores a case study of 'Greek' coins produced in Egypt that have been found across Britain and continental Europe, the ways in which they have been included or rejected as part of the archaeological record, and the implications for the interpretation of 'questionable' finds. In particular it focuses on how the treatment of these coins as separate from other material has limited our ability to review them collectively and consider alternative hypotheses.

In 2019 the author came across five Roman coins in a cabinet in a museum in northeast Scotland that were attributed without secure provenance to the local area. RTI analysis showed four of them to be Alexandrian tetradrachms, a billon issue that formed the principal coinage of the closed Romano-Egyptian economy throughout the 1st to 3rd centuries AD. As Egyptian coins were not legal currency in the rest of the Empire, the interpretation of such discoveries on British soil has long been the subject of debate. Several British numismatists have pointed out that in addition to the conflicting historical testimony, such coins are never found among the material retrieved from excavations on British Roman sites (e.g. Casey 1986, 108-9). Consequently, they are interpreted as 'modern losses' brought back by travellers, sailors and soldiers in the 19th and 20th centuries as keepsakes, then misplaced and 'rediscovered' by gardeners and metal detectorists. Other scholars, while accepting these difficulties, have expressed discomfort at such a generic explanation and note many well-documented discoveries from remote or improbable locations, including deep burials, cliff-sides and riverbanks. Such finds continue to be documented, but often separated from other Roman material, and with cautionary warnings. In an attempt to determine whether further evidence could help resolve this debate, the author conducted a survey of digitized and print archaeological and antiquarian material in order to map the results (Figure 40). The outcome has proven surprising in several regards which, if by no means conclusive, raise questions about how increasingly available digitized evidence nonetheless continues to bias and obscure our picture of the archaeological record.

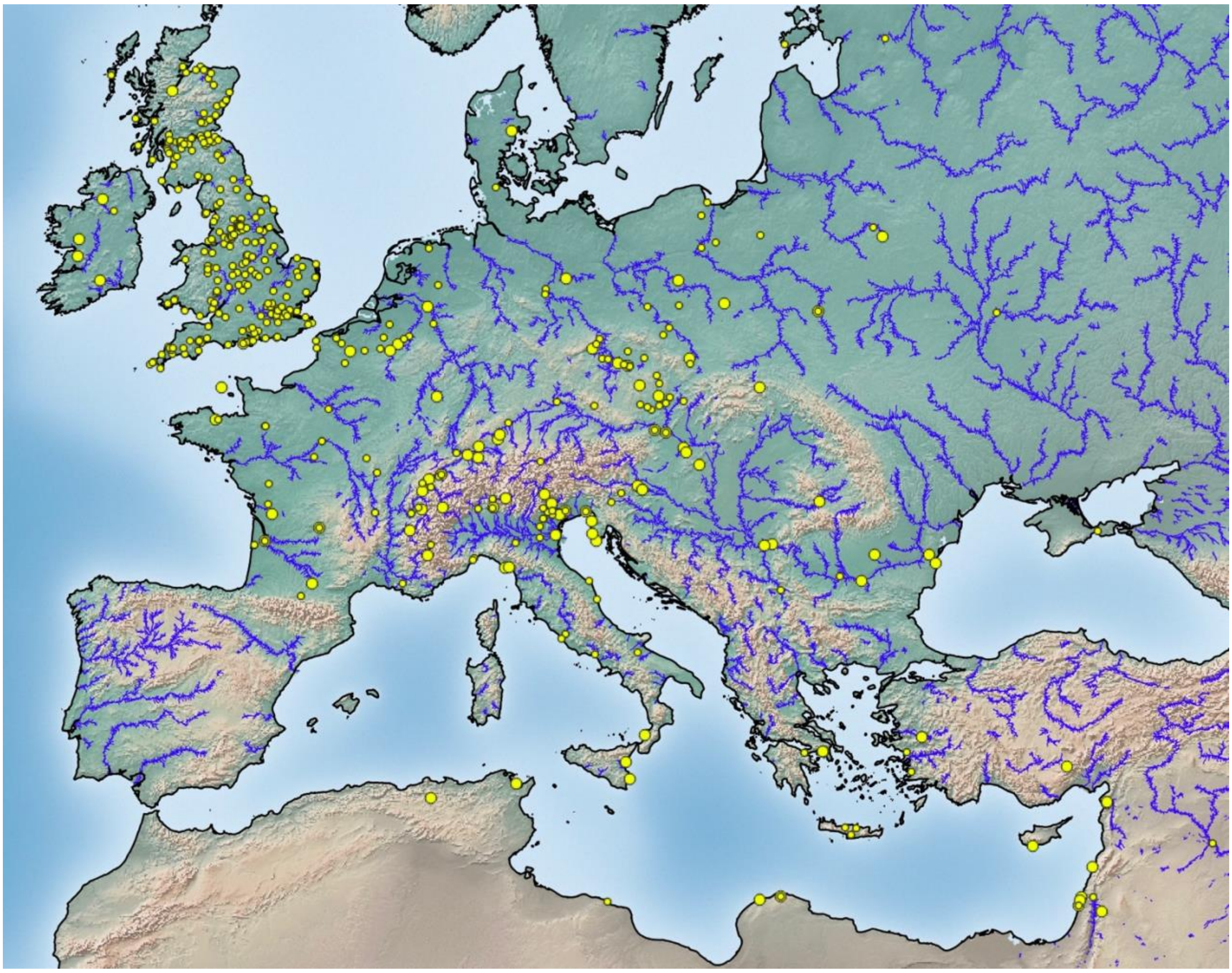

Figure 40. Known distribution of Alexandrian tetradrachms outside of Egypt.

The first observation is that the dispersed nature of reporting and lack of integration within other catalogues means that many more Alexandrian tetradrachms have been reported in Britain than previously recognized. A key paper by George Hill (1930) referenced 42 known to the British Museum. The author has now identified over 360 separate findspots reported in sources ranging from large public databases to the proceedings of Victorian scientific societies. More are almost certainly present in local museum collections, which are generally hard to access online. The pattern of their distribution does not appear to be random, and a large proportion are known from 'aquatic' contexts (especially rivers, coasts and islands) or close to Roman towns or roads. However, they are also found in areas which saw little or no integration with the Roman economy, and show no correlation with the spread of Roman coin finds in the UK.

The second observation is that surprisingly little account has been taken of continental scholarship. Several attempts have been made by non-British scholars (most recently, Savio & Marsura 2012) to document discoveries across Europe and over 230 individual finds are now known. The scale of the task, and the widely differing recording and publication histories of individual countries, make the results necessarily more superficial and uneven. For example, the publication above notes only 49 finds in Britain based on publications available at the time (i.e. < 15% of those now known). Nevertheless, it demonstrates clear areas of spatial patterning that transcend national borders, with notable concentrations in Britain, Belgium, Italy and Czechia, but ranging from Ireland to Ukraine. Once again, they bear little relation to the Roman economy or limes, but frequently occur in association with major rivers, coasts and ancient communication routes. They show that no interpretation of the British material can be made without seeing it in its broader context, and raise questions about the comparability of distribution maps across different archaeological jurisdictions.

A third aspect is the occasional discovery of this material in association with other Alexandrian coinage, including Ptolemaic material and Byzantine copper-alloy coins. Such finds are illuminating not only because they hint at a post-Roman terminus post quem, but because similar debates have been held about both these types of coins as well. Ptolemaic coins are known from secure Early Medieval contexts, and views on Byzantine copper-alloy coins – until recently written off as modern losses as well - have recently tilted towards accepting that at least some were deposited in Late Antiquity. While the presence of 7th century Egyptian coins in Britain remains hard to explain, the presence of contemporaneous ceramic material, such as St Menas ampullae, lends at least some credence to the possibility. These ampullae may also hint at potential explanatory factors, including the largescale migration of Christian Syrians and Egyptians to the central Mediterranean following the Persian and Arab wars, and the subsequent influence of the (increasingly Greek) Vatican on the Anglo-Saxon, Celtic and Merovingian Churches in this period. A notable example is the appointment in 668 of Theodore of Tarsus, a Syrian refugee, as Archbishop of Canterbury.

This paper does not aim to propose a definite explanation for the deposition of this material, nor implicitly critique the methods or arguments of numismatic scholars. Rather, it will reflect on the ways in which key debates have hinged on a fraction of the available evidence, which continues to be locked as traces within heterogeneous digitized material that is not amenable to automated processing, frequently separated from other archaeological material, and generally considered as a contaminant of the 'pure' archaeological record. How and whether 'difficult' material such as this should be resurfaced for the consideration of alternative hypotheses, and potentially much longer and richer object biographies, remains a key task for the digital archaeology community.

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84. Known knowns, known unknowns and unknown unknowns: Strengths and weaknesses of reporting archaeological fieldwork and research in Scotland

Peter McKeague, Historic Environment Scotland

Scotland has a long tradition of promptly reporting summary accounts of archaeological fieldwork through an archaeological yearbook: Discovery and Excavation in Scotland (DES), the flagship publication of Archaeology Scotland. The format of the volume ensures that each entry documents who undertook the work, the site name, location, type of site, method(s) of investigation and summary results. Entries may also state the (intended) place of deposit for any project archives though some entries provide the only account of a piece of fieldwork. DES entries are routinely added to the National Record of the Historic Environment, published online through Canmore. This paper will review the evolution of fieldwork reporting across the Scottish archaeological community from traditional reporting processes and publication to consider the added value brought by online reporting forms. The development of standardised project reporting forms to systematically document technical metadata for selected techniques will be explored.

DES has grown from a nine-page typescript listing work undertaken in 1946 and work proposed for 1947, to bound volumes reporting around 1,000 fieldwork projects annually. The early 1990s saw a significant increase in contributions reflecting strengthened planning guidance coupled with most local authority planning services having dedicated archaeological officers. The challenges of accessing the results of ever-increasing volumes of fieldwork, much of it born digital, were recognised in England in the late 1990s and addressed through the development of the OASIS online reporting form by the Archaeology Data Service (Hardman and Richards 2003; Richards and Hardman 2008). Launched in England in 2003 and adopted in Scotland from 2007, OASIS ensures that key information documenting a project is entered systematically. Unlike DES which presents an immediate summary of project work, OASIS ensures that the detailed project report could be uploaded by the researcher and shared with the relevant Local authority Historic Environment Record, national agency and published online through the Archaeology Data Service. Project reporting very much reflects traditional approaches to fieldwork - documenting the WHO, WHAT, WHY, WHERE and WHEN of fieldwork. This is information essential to document traditional approaches to fieldwork from survey to excavation and present summary accounts of fieldwork to a broad audience. This level of detail is also sufficient for most users of the national record presenting short summary accounts of work undertaken, online through Canmore.

What traditional approaches to project reporting fail to address is the systematic documentation of increasingly sophisticated investigative techniques across projects. The need for standardised approaches is further complicated by the range of researchers from commercial archaeological units to academia and community projects working in Scotland. Shortly after the launch of the OASIS form in Scotland, the potential for extending the OASIS application to systematically capture the technical metadata documenting a range of remote sensing techniques was recognised. It is common practice to routinely document the techniques and instrumentation settings used in geophysical surveys in the project report but the potential value in reusing that data is not realised in understanding and comparing survey results at a landscape scale. In consultation with domain specialists at The University of Glasgow and English Heritage, the basic OASIS form was initially extended to develop a dedicated 'Geophysics module' to systematically document the technical metadata about a range of geophysical techniques. Wessex Archaeology subsequently extended the module to cover a range of marine remote sensing techniques. The systematic capturing of technical metadata enables potential users to explore and evaluate the potential usefulness of the survey data. However, the filters and techniques used to refine and visualise the raw survey data often remain opaque. By also encouraging researchers to upload vector files of the survey grid extents through OASIS, a spatial index for a range of remote sensing surveys could be developed (McKeague 2012).

Development of online forms may also be tailored to systematically capture the results from scientific dating programmes. DES routinely compile and publish lists of radiocarbon dates from across Scotland and Historic Scotland (Historic Environment Scotland's predecessor body) maintained a database of the results – mostly funded through their Radiocarbon dating contract. Building on the OASIS form, a radiocarbon module was developed in 2012-13 to manage the workflow from applicant through the approval process to the laboratory. Again, user requirements were defined with the domain specialists at the Scottish Universities Environmental Research Centre (SUERC) to provide a transparent, auditable application process. By transforming a paper application process to a digital form the reporting process is streamlined. The researcher is responsible for submitting project details, drawn from the OASIS form, along with details about the individual samples. This data can be reviewed by the funding body and, if approved, shared with the radiocarbon laboratory. After analysis the Laboratory shares the results with the applicant and funder and added to Canmore upon project completion.

Scotland is confident in the knowledge that the majority of projects undertaken each year are reported promptly to reach a wide audience (the known knowns). The need to systematically document increasingly sophisticated digital techniques can be addressed through working with domain experts to develop and refine reporting tools (known unknowns). Although essential for a critical evaluation of digital datasets, the processes applied to manipulate the data are all too often undocumented (unknown, unknowns).

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94. Gathering and following traces: Towards a methodology of data reading

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Jessica Kaiser, Uppsala University

How to facilitate data reuse is a long-standing topic of research in archaeology. Data reuse offers many advantages (e.g., increasing the efficiency of the research process; facilitating knowledge exchanges; generating new findings) but is also associated with a range of obstacles that have to be circumvented before data reuse can become part of the fabric of archaeological research praxis and infrastructural support to a greater extent than it presently is. One of the major obstacles is the many difficulties involved in understanding how the data-to-be-reused has come into being. Recent work indicates that information that might support data reuse is present in the form of 'traces' found in research documentation and archaeological literature (e.g., Authors et al. forthcoming). These traces provide information about the research processes underpinning the creation of the data that can be crucial in evaluating if, and if so how, data can be re-used for a particular purpose. Previous research also shows that the purposeful use of trace information in a data-reuse scenario requires – just like the generation of original data – a meticulous approach and particular efforts and skills (Kansa and Kansa 2021). Here there exists a research gap: archaeology lacks a cohesive data reuse methodology to apply in research and use for educational purposes.

Main argument

The aim of this paper is to address the research gap outlined above by proposing a methodological framework for reading traces in archaeological data reuse. The methodology draws on the state-of-the-art on the necessary steps in data reuse processes (e.g., social trace data discussed by Morgan and Wright 2018) and is empirically informed by the authors' previous research on archaeological trace data (e.g., Authors et al. forthcoming), including specifically work on the paradata categories of knowledge-organisation paradata and knowledge-making paradata.

The creation of a methodological framework for reading archaeological trace data would serve two main purposes. Firstly, it would reflectively systematise insights into and experiences from working with archaeological trace data as they have emerged in the literature and in the authors' own work into an operationalizable methodological outline that facilitates the use of traces as ingredients in new archaeological knowledge and knowledge on archaeological practices. Secondly and from an educational viewpoint, a better and more systematic understanding of what the traces of digital archaeological practices in descriptive and analytical accounts look like and how they can be used has direct implications to informing future documentation practices and data-sharing infrastructure developments.

Applications or Implications

The methodological framework for reading archaeological trace data presented in this paper is provisional and a work in progress, but is all the while possible to apply when identifying and documenting traces of digital archaeological practices in scholarly and professional settings. The paper's core outcome is a trace data typology consisting of trace data type descriptions and associated methodological reflections and recommendations.

Beyond 'practical' applications, the framework also directs attention towards how documentation ideals pertaining to trace data can and should be codified in archaeology, e.g., how information about data creation serves specific purposes and connects to different modes and resources of description. In this light the methodological framework for reading archaeological trace data also becomes a communicative device telling of appropriate ways of doing, and so offers an opening to discuss which ways of documenting and reading data traces that should be canonised and taught to students, researchers, and data management professionals. In closing, this paper reflects on data traces – what they represent; what can be known on the basis of them – and methodologies – what types and what understandings of methodologies would be most suitable in the context of archaeological trace data – from an epistemological viewpoint as a way to inform what the next step in the present line of inquiry.

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124. Archiving the third dimension

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Esther Schönenberger, Archaeology and Heritage Management for the Canton of Zurich

In 2017, the Archaeology Department of the Canton Zurich defined 3D photogrammetry in Agisoft Metashape as a new standard. The years have shown the advantages of the method, especially when documenting complex 3D structures, like skeletons or ruins, on site. While generating 3D models was a well-trodden path, the storage of 3D models needed some exploration. The first challenge was to incorporate 3D data into a pre-existing archive system. The second challenge was to secure both easy access for everyone and long-term storage at the same time. We propose a solution where access and storage are treated as two separate issues. This allows the content to be viewed without technological restrictions (e.g. as 3D PDF or VR application). While independently the same models are stored in a normalised geometry file (e.g. OBJ file) for long term use. Since long-term standards for 3D data have yet to be established, we have decided to provide a temporary backup system by keeping the raw data (photos) together with the processing report for replication purposes. Our solution comes with a lot of redundancy. However, this is still a trial and error approach, one that we would like to work on with fellow 3D enthusiasts.

34. The impacts of digital devices on archaeological practices on field recording activities and archaeological archives production from 1980s: An historical and epistemological point of view

Christophe Tuffery, Inrap

The relationships between archaeological professionals, archaeological traces, and excavation archives, which include documentation and finds collected, are very profound and varied. They have evolved considerably over the discipline's history due to the major differences in excavation methods and in the production, management and conservation practices of these archives. This article looks back at this evolution, starting with a historiographical approach. During the 1960s, the appearance of computers in the human and social sciences, and their increasingly widespread and rapid deployment since the 1980s with the development of personal microcomputers, led to a major change in the conditions of production of these archives, from the field to their restitution on various media, including those in the digital regime. It is true that digital devices offer undeniable opportunities for the dissemination of old and recent excavation archives, as shown by certain projects mentioned here. But they also imply changes in the practices of production, management, indexing, conservation and sharing of excavation archives which, for the sake of technical and semantic interoperability, impose constraints on the formalisms and contents of these archives in the digital regime.

In the framework of my Ph.D started in 2019 at CY Cergy Paris Université, in partnership with the Institut national du patrimoine, I rely here on various research projects. They adopt a reflexive point of view practices of researchers from various disciplinary fields in order to put into perspective the different archives sources mobilised and my observations during 40 years. My research is a contribution of observing, describing and analysing "What the digital is doing to archaeology and archaeologists". My analysis is based on my own practice as an archaeologist since the late 1970s, on the analysis of numerous archives collections. I also use my observations in the field, carried out in the context of my current position as a research engineer in charge of survey and recording techniques and tools at the Scientific and Technical Department of the Institut National de Recherches Archéologiques Préventives (INRAP). INRAP is the French national institute of rescue archaeology, cofounded by the French Ministry of Culture, the French Ministry of Research. Among the sources I use, there are some archaeological excavation archives, in various forms, both analogue and digital, dating back to the 1970s (Figure 41).

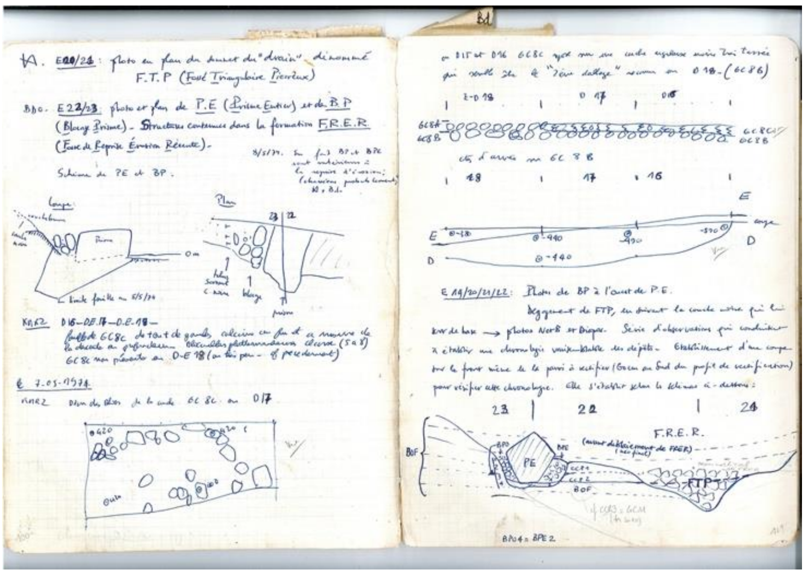

Figure 41. Analogue records.

This period corresponds to a threefold major evolution in archaeology: appearance and considerable development of preventive archaeology, especially in France: creation of the Association pour les Fouilles Archéologiques Nationales (Afan) in 1973, law on preventive archaeology in 2001, creation of the INRAP in 2002, major renovation work in city centres, development of linear infrastructures (motorways, high-speed train lines, canals, business and commercial zones, etc.), peri-urbanisation of the urban periphery, etc.; professionalization of the archaeological professions and institutionalisation of archaeology organisations; the appearance and development of personal micro-computing from the mid-1980s onwards, used in archaeology both on sites and in laboratories and research centres. For a decade, various excavation archives sets have been digitised and indexed and then were put online on the Web (e.g. "Aux sources de l'archéologie nationale" of Musée d'Archéologie Nationale).

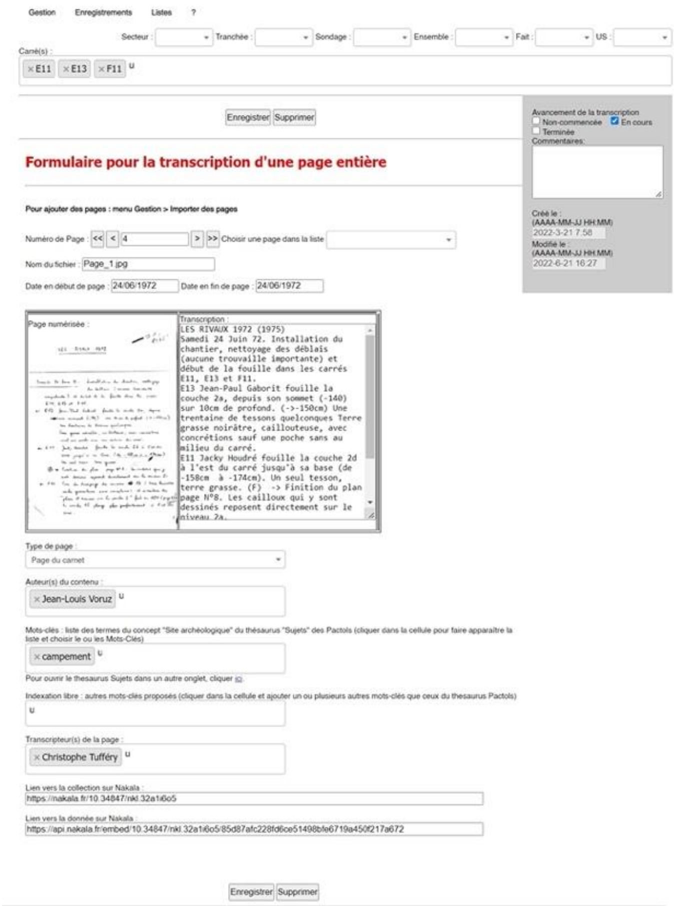

Figure 42. Archeotext.

For my Ph.D, I was able to access several excavation archives, especially those of an archaeological site Les Rivaux in France, on which I have participated as a young digger during seven campaigns in 1980s. To identify the traces of the archaeological activities of the excavators on this archaeological site, I developed the Archeotext application (Figure 42) This application allows the digital transcription of the paper field notes archives of this site, after their digitisation. After transcription, I have used various tools and methods (text mining, GIS, etc.) in order to identify different types of contents of these field books which were written by various diggers. These contents include scientific observations, sketches, photographs pasted in, but also jokes, puns and comments on the members of the excavation team, on the weather, on activities outside the excavation site. I also used of my observations on hundreds of rescue archaeology operations of INRAP, and some of land planning private or public institutions. My observations clearly show that some of the archaeologists use paper documents at the same time as they use digital tools to record their field observations. But some archaeologists have also started to abandon the recording of some of their observations on paper and prefer to record them only in digital form. The transcription of the contents of some of digitized archives of the archaeological site of Les Rivaux demonstrates the progressive modification of the production of this type of archives because of the use of a computer program for field data recording. On this site, it started at half of the 1980s and it was quite pioneer experience. Gradually, the traces of the activity and life of the excavation teams left in traditional paper archives moved more standardized contents due to the use of recording paper forms and then of field recording digital programs (Figure 43).

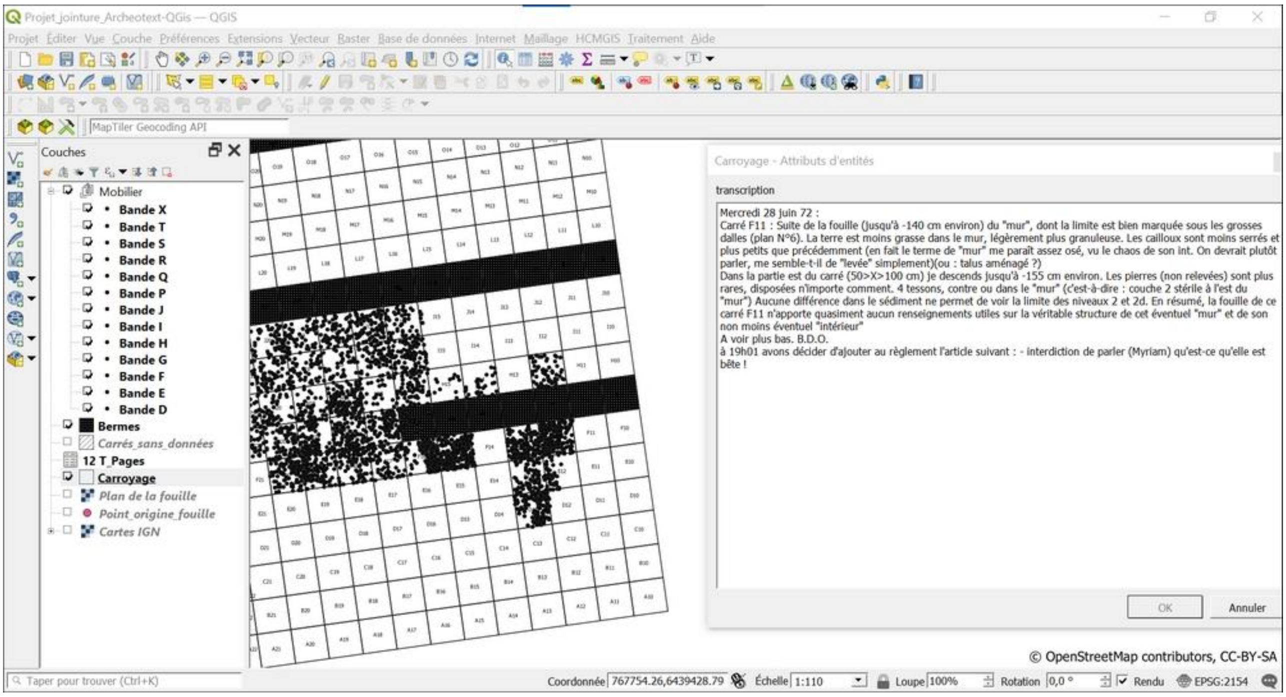

Figure 43. Digital records.

My observations and interviews with a hundred archaeologists clearly show that, over the last forty years, the evolution of digital practices has consisted of a 'hybridisation of practices' coupled with a 'hybridisation of skills'. Hybridization is a term proposed by the sociologist and anthropologist Bruno Latour in the context of actor-network theory to designate the coexistence of human and non-human actors. This point of view, which focuses on the study of the interaction relations between these various types of 'actors', makes it possible to go beyond the usual dualism between human and non-human, between nature and technology, and between a science that would be inhuman and societies that would be inhuman by nature. Even if I do not adopt this theory totally, I nevertheless believe that there are indeed interactions between the actors and the technical devices that they design, implement, and adopt by adapting them, which mark them in their ways of doing things. In this sense, they are socio-technical devices. This hybridization also translates into processes of "bricolage" and "poaching", which consider that archaeologists are reconfiguring their practices within a perimeter of knowledge and know-how. With the 'poaching' of their digital practices, archaeologists go and see elsewhere, in other disciplines, how others do things and import elements of know-how. At the same time as they adopt them, archaeologists partially adapt these practices that are initially foreign to them, according to processes of translation, i.e., of transformation to make them compatible with their needs and their own practices, and to transmit these new practices to other actors in their discipline.

If the use of digital devices for the production of digital data in the field gradually brings about the emergence of new social norms in practices, they also bring about the appearance of new discourses, new language practices, mixing technical mastery and scientific expertise. These new discourses also tend to categorise individuals according to their digital skills. For some, this is a 'generational phenomenon' which implies waiting for the fifty-somethings to retire so that the thirty-somethings, and a fortiori the younger ones, can take over the definitive change in field survey methods and techniques. The new digital skills linked to these devices are sometimes perceived as new injunctions that are added to others in the execution of archaeological sites, a fortiori in preventive archaeology where the constraints and obligations are already numerous and strong. Many authors talk about the "digital revolution" in archaeology. For some, it is already here. For others, the notion of a revolution in the discipline remains to be questioned rather than demonstrated, since it has not introduced any new paradigms. The digital devices used in archaeology have profoundly modified the production of knowledge in this discipline. They are part of the new conditions of possibility of this knowledge, of what Michel Foucault called the "epistemes", namely the traces of the "discursive practices" of archaeology as a human science. My research on digital devices in archaeology has allowed me to observe that these "manufacture" the archaeologists as much as the latter "manufacture" these devices: there is thus interaction between the devices and the actors. Digital practices in archaeology affect all generations of archaeologists and all archaeological professions.

70. From analogic and legacy data to the digital geonumismatic database of the AugustaGIS

Cinzia Bettineschi, University of Augsburg

Stefan Reuter, Stadtarchäologie, Augsburg

Annalize Rheeder, German Archaeological Institute, Berlin

Sebastian Gairhos, Stadtarchäologie, Augsburg

Natascha Sojc, University of Augsburg

The Stadtarchäologie Augsburg (City Archaeology Department of Augsburg) preserves a massive archival documentation related to the historical excavations in the city, including detailed plans, trench sections, pictures, drawings, context, and material sheets. In an attempt to promote the digital preservation, reuse, and the advanced analysis of these materials, the University of Augsburg and the local Stadtarchäologie joined the forces in the "Mapping Roman Augsburg" project.

In this poster, we will present the potential of the approach for handling the approximate ten thousand Roman coins unearthed within the Roman city of Aelia Augusta, and the type of historical reconstructions that can be achieved thanks to a profitable combination of GIS, database systems, and ontological reasoning within the interdisciplinary framework of digital numismatics and digital archaeology (Breier 2011; Favretto and Callegher 2017; Celesti et al. 2017). We will also briefly discuss the issues of integration between material, archival, and digital records in the perspective of preservation, research, communication, and dissemination.

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96. 3D reconstruction of the early medieval stronghold in Santok: Educational and scientific significance of the visualisation in archaeology

Małgorzata Markiewicz, Institute of Archaeology and Ethnology of the Polish Academy of Sciences

Kinga Zamelska-Monczak, Institute of Archaeology and Ethnology of the Polish Academy of Sciences

This poster presents the stages and results of the work on a 3D reconstruction of the medieval stronghold in Santok. Located at the confluence of the Warta and Noteć Rivers, Santok is an example of a settlement founded on the drained bottom of a swampy valley, with well-preserved cultural layers, functioning between the eighth and the fifteenth century. Convenient water connections to the Baltic Sea area resulted in Santok becoming a local marketplace on a transregional river route. This important fortress was captured by the growing and territorially expanding Piast State (Zamelska-Monczak 2013, 267-277; 2019).

The 3D reconstruction of the early medieval stronghold in Santok is part of the project Regni custodiam et clavem – Santok and clavis regni Poloniae – Milicz as an example of two border towns carried out by the Institute of Archaeology and Ethnology of the Polish Academy of Sciences (grant no. 11H 11 018480). The 3D visualisation of the early medieval fortified settlement in Santok is the result of an analysis and in¬terpretation of sources obtained during archaeological excavations. Its aim was to create a 3D image of the stronghold's architecture divided into individual phases and to verify the data collected during archaeological investigations (Markiewicz 2019, 142-149).

The 3D visualisation of the stronghold was developed using 3D graphics software – Autodesk 3ds Max with the V-ray Adv for 3ds max (Chaos Group) rendering engine. The images were created as 2D illustrations prepared for the book that presents the research results of the discussed project. The process of modelling the 3D visualisation of the stronghold in Santok began with an extensive survey of sources in compliance with the guidelines contained in the London Charter. We had plans and drawings of individual features (in digital and analogue versions), photographs (including aerial photographs) and descriptions. Vector contour plans and orthophotographs of the terrain model were extremely important for the reconstruction of the topography of the area. At this stage, consultations with specialists and the search for iconographic analogies were also important. During this work, paradata was acquired, i.e. the load of knowledge that is gained during virtual reconstruction in the process of analysis and interpretation of the source material, as well as the analysis of the missing data. All the collected traces, which became a basis for further works on the digital reconstruction of the stronghold, were catalogued and archived.

Visualisation is a message, a carrier of information about the past. Computer imaging is a tool that allows us to "tell" the history of Santok in an accessible manner. Nevertheless, it should be noted that digital reconstructions remain the representations of the researchers' hypotheses, based on their analysis of documentation and theoretical assumptions. A 3D visualisation is an aid to the interpretation of research results and can also be used to verify data obtained throughout the research process. The image of the stronghold's spatial development, together with a supplementary description, provides a means of disseminating and popularising knowledge about the past and cultural heritage. A thorough and comprehensive study of sources ensures that 3D reconstructions are historically reliable. The researchers also took care to properly archive and document the reconstruction process. The digital images are designed for a large group of viewers, and they provide added value to the analysis of the past.

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Session 23. Computational archaeology and seafaring theory

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Marisa Julia Borreggine, Harvard University

R Helen Farr, Southampton University

Katherine Jarriel, Purdue University

Justin Leidwanger, Stanford University

Crystal El Safadi, University of Southampton

Ben Davies, University of Utah

Karl Smith, University of Oxford

Room 6

Roundtable	15:30 - 17:00

Introduction

Archaeologists and anthropologists have long discussed the spaces of human movement over larger bodies of water. In the past several decades, with the advance of computational analysis, this conversation has expanded to include how modelling sea travel might lead to new insights about societal organization, technology development, and communication methods. At institutions across the globe, scholars are using numerous methods to address research questions about movement by sea, ancient and historical ocean resource usage, and the broad role of human-ocean interaction in past communities. We have newly entered the United Nations Decade of Ocean Science for Sustainable Development (2021 - 2030), which aims to "change humanity's relationship with the ocean". Ocean navigation is an inherently collective, social process. This roundtable will address what modelling methods are currently being employed or are needed to capture past maritime mobilities as well as show how to incorporate the social dynamics of interaction in maritime spaces. As we become more confident in our methods and move beyond solely relying on least-cost pathways and other methods that raise questions of environmental determinism, we are simultaneously co-constructing our practice and theory. This session aims to bring together a diverse and interdisciplinary cohort of archaeologists and anthropologists to collectively assess the state of computational archaeology and seafaring practice and theory in order to establish a next phase of future research that can address these major challenges in our field.

The scholarship on seafaring modelling is undertaken by scholars who are otherwise dispersed among various academic departments and geographical locations worldwide. Often scholars working on similar methods are unaware of one another due to these divides. Lack of discoverability of relevant scholarship has been a hindrance in developing a unified field of seafaring modelling. We see a timely need to define the state of the field, establish its future directions, and bridge gaps in scholarly networks to uncover connections or disconnects in how we address both computational methods and practice as well as the underlying anthropological theory that is critical to future modelling of seafaring space. We aim to challenge prior conceptions of computational modelling as a field devoid of human perspective and solely focused on environmental determinism, to reference how the human element and inherently social practice of seafaring can be incorporated into various modelling strategies from isochrone approaches to agent based modelling. We recognize that the sea is a space of being and meaning, and that discussions of human motivation, social structures, and technological capabilities all play a role in not only the movement of peoples across the sea but also in how researchers can model diverse uses of these spaces.

One focus of this session will be on the methods currently employed by researchers to model maritime mobility. This includes working through the basic elements of importance related to what climate (forecasted, sub sampled, etc.) data sets are used within different frameworks, what technological aspects of vessels need to be considered as base factors within computational models, how many runs is enough runs, what are the positives of using different computational approaches (isochrone vs. least-cost pathway vs agent-based modelling), etc. In addition, though similar to previous sessions and the current session 27 "name of Phadeon's session" that have devoted space to modelling past movement across the seas, this roundtable seeks to also discuss the challenges faced by the field to capture the humanist elements of past voyages through discussion of those actively engaged in this research. We aim to review in depth the balance between computational and humanistic elements of seafaring modelling, and promote the integration of diverse ways of knowing, mapping, and experiencing space. Interaction across and with the sea is a deeply social process. There are many factors that affect relationships within vessels on the sea, people on land, and the water around them. The underpinning computational models must engage with human agency, decision making, and past seafaring practice. During the roundtable, we will hold a discussion between panellists and the audience to address the relationship between computational modelling and anthropological theory. We will consider the ways in which researchers can understand human agency in the past and use it to build computational models that reflect a more nuanced human experience. For example, panellists will touch on how navigational skill and knowledge impact seafaring choices (and thus the basis for a navigational model). Many computational tools are built upon western assumptions of spatiality, so moving our field to incorporate indigenous, non-western, and other culturally-specific understandings of space can allow for the production of models that deliberately tie together cultural context and spatial patterning. Through this initial discussion, we seek to build the groundwork for approaches that can help decolonize or de-westernize the discussion of past seafaring efforts by focusing on Indigenous perspectives, breaking down constructs of national land boundaries, and acknowledging the existence of multiple seascapes within modern mapped seas or oceans. Other topics include: sea spaces as embodied 'land'scapes, the role of phenomenology in evaluating mobility, the ways knowing or wayfinding impact routes taken, the effect of stochastic environmental conditions on human decision-making, and consideration for how to discuss the lives of past climate refugees.

Once the general bounds of theory and computational strategies are defined, in part within this session, those present will be asked to help define the state of the field moving forward from this roundtable. We want our participants to recognize that the tools we use and outcomes we observe from modelling serve mainly as a basis to ask more questions about the human experience, and as such we hope to push the field towards a broader evaluation of how theory affects computational modelling. This roundtable will also serve as space to discuss topics needed for future discussions, particularly those held at an upcoming Computational Archaeology & Seafaring Theory (CAST) workshop to be held at Stanford University in late Fall 2022. For questions regarding this workshop, please email castworkshop2022@gmail.com. Additionally, this session will be the first to tie into the new Special Interest Group Computationally Modelling Water-based Movement (CMWM).

The goal of this roundtable session is to foster broader discussions of connections between modelling practice and theory, as well as aspects of how to further develop and support effective computational seafaring modelling. By bringing together interdisciplinary archaeological practitioners from around the globe, this session will develop a vibrant network of scholars, who not only innovate in maritime computational modelling, but who actively work toward developing the future of the field. In connecting people doing similar research, the roundtable will foster collaborations for future scholarship. Experiencing the diverse disciplinary, geographical, theoretical, and methodological perspectives of peers will further revitalize the work we are currently doing. Once in the same space, these researchers can not only identify key areas still needed to be discussed in the field, what practices are effective or ineffective in modelling water based mobility, who is focusing on this topic and in what contexts, and how we can move forward as a field as a community.

We invite those who wish to be members of the roundtable to submit either a written position statement (maximum 1000 words plus references) that can be read in advance of the session by other participants.

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Session 27. Modelling prehistoric maritime mobility

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Elias Gravanis, Cyprus University of Technology

Stella Demesticha, University of Cyprus

Christian Reepmeyer, University of Cyprus

Theodora Moutsiou, University of Cyprus

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Angelos Chliaoutakis, Foundation for Research and Technology – Hellas

Vassilis Zervakis, University of the Aegean

Kostas Theodorou, University of the Aegean

Elena Xoplaki, Justus-Liebig-University Giessen

Daniel Montello, University of California Santa Barbara

Room 6

Introduction	09:00 - 09:15
97. Simulating Pleistocene sea crossings by human agents out of Africa *Hölzchen*, Hertler, Willmes, Anwar, Mateos, Rodríguez, Berndt, Reschke and Timm*	09:15 - 09:40
14. Maritime mobility at the end of the Stone Age: First interpretations of Kiukainen culture sites *Roiha**	09:40 - 10:05
175. SaRoCy: Delineating probable Sea Routes between Cyprus and its surrounding coastal areas at the start of the Holocene: discussing the archaeological evidence *Reepmeyer*, Moutsiou, McCartney, Demesticha, Kassianidou, Bitsakaki, Kyriakidis and Bar-Yosef*	10:05 - 10:30
Tea/Coffee	
163. Drift-induced versus directed-paddling-induced potential connectivity between Cyprus and its surrounding coastal areas at the onset of the Holocene *Leventis*, Kyriakidis, Nikolaidis, Panagiotos, Akylas, Michailides, Moutsiou, Reepmeyer, Demesticha, Kassianidou, Zomeni, Bar-Yosef and Makovsky*	11:00 - 11:25
162. Simulating prehistoric maritime mobility potential: Overview and challenges *Kyriakidis*; Gravanis, Moutsiou, Reepmeyer, Chliaoutakis, Zervakis, Theodorou, Xoplaki, Montello and Sweeney*	11:25 - 11:50
178. Modelling ancient Maya long-distance, canoe-based trade around the Yucatan Peninsula *Glover*, Slayton and Risollo*	11:50 - 12:15
Lunch	

98. Where did the ships sail? Simulating European shipping routes before the age of steam *Litvine, Lewis* and Starzec*	13:30 - 13:55
Discussion	13:55 - 14:20
39. Stegodon SEAcross-ing: Swim, Shrink, and Disperse *Hertler*, Hölzchen, Reschke, Janwar, Iwan van der Geer, Büscher, Ngetich and Puspaningrum*	Poster
46. Simulating the relation between Stone Age sites and relative sea-level change along the Norwegian Skagerrak coast *Roalkvam**	Poster

Introduction

Seaborne movement underpins frontier research inquiry in archaeology, such as water-crossings in the context of human dispersals, seagoing, seafaring and island colonisation (Anderson, 2010). Yet it also controls the degree of seaborne-interaction between origin and destination locations, which in turn is essential for understanding maritime networks, such as raw material circulation or trade networks (Leidwanger and Knappett, 2018). Maritime mobility is broadly controlled by geographical context, weather conditions, demographics, motivation for undertaking a trip which in turn controls destination selection and possibly risk attitude, navigation capabilities, as well as marine, e.g. vessel, technology. Mobility in general can be distinguished into potential and realized mobility, the latter being typically associated with verified presence of common or similar material culture at origin and destination locations corroborating movement between these locations.

Modelling efforts focusing on seaborne movement based on computer simulations, closely related to agent-based models (Romanovska et al., 2021) – although not always explicitly stated as such, have been often used to test archaeological hypotheses related to colonisation, migration, and culture contact (Davies and Bickler, 2015; Montenegro et al. 2016; Norman et al., 2018; Bird et al., 2019). In such simulations, multiple "virtual vessels" embark from coastal locations and interact in a stochastic or deterministic way with winds and currents according to their structural characteristics and the motivation (destination) of the navigator. Such "vessels" could equally well represent individuals swimming or paddling (Hölzchen et al., 2022). The frequency and location of successful landings, as well as the trajectories followed, offer valuable insights in terms of probabilities of connections between possible origins and destinations along with the pattern of maritime routes followed.

A second family of models employ Least Cost Path (LCP) analysis modified to account for the maritime environment (Gustas and Supernant, 2017; Kealy et al., 2018; Gal et al., 2021a, b; Arcenas, 2021; Perttola, 2021, McLean and Rubio-Campillo, 2022). In LCP analysis, one first defines a "cost surface" pertaining to the cost (in terms of effort or time required) associated with moving from one location/node to an adjacent location. An "accumulated cost surface" is then computed, corresponding to the cost of moving from a particular starting location (source) to any other node of the domain. Lastly, the optimal sequence of steps along the nodes is determined, a shortest or fastest path, linking the source location with a given destination node. Closely related to LCP approaches are models based on the concept of isochrones, tracing the locus of potential arrivals over a given time interval (Slayton, 2018; Safadi and Sturt, 2019).

A third family of models pertains to the estimation of the intensity of potential mobility between network nodes based on information on node characteristics (e.g. settlement size) and intervening distances, and includes adaptations of gravity-type models in a maritime context (Knappett, 2018).

Existing computational models of maritime mobility, however, are not without problems. LCP approaches, for example, implicitly assume perfect knowledge of weather conditions, typically reporting a single optimal route without exploring the variability of the remaining solutions (Dickinson et al., 2019). Often the application of models is undertaken using rather coarse spatial resolution data of weather variables, and/or time-averages of those data; this often results to overly smooth trajectories and travel time underestimation. In addition, most models use present day descriptions of weather conditions, which serve as proxies for the corresponding conditions in times; exceptions are model applications that are cast explicitly in a paleoenvironmental context, such as the colonization of Sahul. Agent-based models of seaborne movement do not typically incorporate cognitively-informed parameterizations of navigation capabilities, such as visibility, landmark recognition, or path planning strategies. Lastly, computational models of potential maritime mobility are not yet coupled to models of realized mobility (maritime networks of material culture), or to models of (meta)population dynamics, and furthermore to models of (meta)population genetics; the latter two families of models represent frontier research in fields such as ecology and biology (e.g. Bradburd and Ralph, 2019; Bradshaw et al., 2021).

With this session we aim to showcase state-of-the-art methods pertaining to modelling maritime mobility, and in conjunction with roundtable session #23 (Computational Archaeology & Seafaring Theory) provide a forum for presenting new modelling efforts. We particularly invite Early Career Researchers and student presenters to share with us new ideas and ongoing projects. Participants are invited to present their research in a 20 minute format (15 min presentation and 5 minutes discussion) and also consider contributing to roundtable session #23 – Computational Archaeology & Seafaring Theory.

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97. Simulating Pleistocene sea crossings by human agents out of Africa

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Since the beginning of the Pleistocene, humans and their precursors expanded from Africa to Eurasia. Research in recent years has shown that there were several expansion events at different times in the Pleistocene, involving different representatives of genus Homo. To understand the complex processes leading to these expansions, simulation models help to test different hypotheses and distinguish between more likely and less likely scenarios. An application of simulations is the reconstruction of the routes that early representatives of the genus Homo took out of Africa. Possible routes include the terrestrial route via the Levant as well as sea routes such as the Gibraltar Strait, the Sicily Strait, and the Bab-al-Mandab Strait. In most models, the terrestrial route via the Levant is assumed to be the most likely route, based on fossil and archaeological findings in this region and the assumption that, for the most part, this region offered favourable environmental conditions for early humans. However, alternative routes across sea straits in the context of Pleistocene expansions of early humans have not been exhaustively explored, especially with the possibilities offered by agent-based simulation. Agent-based simulation can help here to test initially hypothetical environmental and behavioural scenarios and compare them quantitatively. Previous simulation models either do not consider sea crossings at all or only binary where crossings are either possible or not. However, if we consider that early humans expanded from Africa to Eurasia from the beginning of the Pleistocene, where massive environmental changes occurred several times, and that early humans acquired additional cognitive and cultural skills over time, then a more differentiated assessment is required to evaluate the role of sea crossings in the context of "Out of Africa" expansions. Previously, there was no method to quantitatively evaluate sea crossings in a differentiated way with respect to environmental conditions and behavioural capabilities of early humans. To fill this gap, we developed the hominin sea crossing ABM (Hölzchen et al., 2021), which allows a quantitative and differentiated assessment of chances of crossing by introducing the output variable crossing success rate (CSR). In a follow-up study, we applied the agent-based model to sea straits in the context of "Out of Africa" expansions and calculated CSRs for the Last Interglacial (LIG) and Last Glacial Maximum (LGM). The simulations showed that the Gibraltar and Sicily Straits were barriers to early humans having no rafting technology. In contrast, the Bab-al-Mandab Strait could be crossed by a variety of modes of movement. In this talk, we introduce the hominin sea crossing ABM and demonstrate, by the example of the Bab-al-Mandab Strait, how the model is applied to simulate sea crossings by human agents and discuss possibilities for follow-up studies.

Methods and materials

We developed the hominin sea crossing ABM in NetLogo. It simulates human agents moving across a landscape being divided by a sea strait. The environment can be either artificial or a geographic reconstruction. In this presentation, the model is applied to the region around the Bab-al-Mandab Strait. The agents move on land and enter the water. In the water, the agents move according to pre-defined behavioural scenarios that represent different skills in moving in the water, ranging from passive drifting to directed rafting. Simulation runs are analysed by the CSR which takes into account the number of crossing attempts and successful crossings. Crossing attempts are considered successful, when they result in a minimum number of individuals reaching the target area. The outcome is a value between 0 and 1, whereas 0 means that none of the attempted crossings were successful and 1 means that all attempts resulted in successful crossings.

Results

The CSR results for the LIG and LGM were interpolated along with the oxygen isotopic curve which represents global climatic changes (Lisiecki and Raymo, 2005) to produce a continuous Pleistocene CSR record. CRS of "Out of Africa" expansions proposed in the literature were then checked. Based on the CSRs, we identified 19 episodes in the Pleistocene when sea crossings were more likely and/or less likely. Our results illustrate that Pleistocene humans should have been capable of crossing the Bab-al-Mandab Strait at various times in the Early Pleistocene and the second half of the Late Pleistocene, while throughout the Middle Pleistocene chances of crossing were comparably low.

Discussion

The fact that there were several times in the Pleistocene when crossing the Bab-al-Mandab Strait was possible indicates that future research should further examine this route as an additional option for early humans expanding out of Africa. Future studies will show if and how sea crossings affected expansions towards Eurasia. For this purpose, the CSR can be integrated as a linking variable in large-scale "Out of Africa" simulation models. The resulting simulated expansions can then be validated by the fossil and archaeological record. In addition to analysing CSR, the model quantifies why crossing attempts failed by monitoring the causes of disappearance (CoD). These include fatal causes, such as death of hypothermia or exhaustion, as well as non-fatal causes, such as leaving the map at the borders.

This study serves as a blueprint of how the hominin sea crossing ABM is applied to gradually assess chances of crossing taking into account local environmental conditions and capabilities of early human in crossing water barriers. Future applications of the model will also address a variety of fields beyond the context of "Out of Africa":

- Hominin expansions across further sea straits, e.g., Wallacea
- Sea crossings by terrestrial mammals in the Pleistocene
- Adapt the model to estimate CSRs for further barriers, e.g., deserts or mountain ranges

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14. Maritime mobility at the end of the Stone Age: First interpretations of Kiukainen culture sites

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Kiukainen culture was the end phase of the Stone Age in southwest Finland between 2500/2300–1800/1500 BC. Settlement sites of Kiukainen culture are located on the coast, islands and river deltas. So far, only very little research has been done on those settlement sites (Haggrén et al. 2015, 84). Kiukainen culture is named after the Kiukainen pottery type and the culture is believed to be merged from Pyheensilta Ware and Corded Ware cultures. This study aims to determine the geographical distribution of Kiukainen culture. The second aim of the study is to determine what type of environment the settlement sites of Kiukainen can be found in.

First Kiukainen pottery was identified and analyzed from the Finnish archaeological collections. Locations of those sites where Kiukainen pottery was found were then collected from the Finnish register of archaeological sites (Muinaisjäännösrekisteri). The register includes all the known archaeological sites in Finland and coordinates of those sites in point format. After mapping all the sites three areas where settlement clusters were clear were chosen for more precise environmental comparison. Inside those three areas of interest, the Stone Age shoreline was visualized by using the elevation model by the National Land Survey of Finland. Reconstructing ancient shoreline displacement is a key element, especially in the Ostrobothnia region, where land uplift and environmental changes have been rapid. Also, information about the soil types was collected from the Geological Survey of Finland database where it was available.

By mapping all known sites that have confirmed connection to Kiukainen culture, it is possible to make new interpretations of this very poorly known coastal culture in Finnish prehistory. Almost all Kiukainen sites were located directly or very near the coastal area with access to the sea or water routes. The main area where the culture seems to be most active is the coastline between Espoo and Kristiinankaupunki. As the study of prehistoric coastline habitation in Norway concluded (Damm, Skandfer and Jordan 2021, 24), good landing possibilities, easy monitoring of surroundings and shelter from the wind have been important factors in habituating coastal areas. The same interesting factors can be seen in Kiukainen culture settlement site locations in those three areas where previous shoreline elevation was visualized together with site locations.

This simple basic research is needed to establish future research. The importance of maritime mobility can be seen by mapping the settlement sites of the Kiukainen culture. Easy access to the sea and marine resources seems to have been a priority, alongside shelter from the harsh wind and soil type suitable for the housing. However, mapping of the Kiukainen sites also revealed errors and biases in the data. Not all fieldwork and archaeological surveys have been done systematically and the data (the register of archaeological sites in Finland) includes many uncertainties. The register is mainly collected and used from the authorities' perspective and from the research point of view the data quality is not optimum.

Because of the lack of previous research, the study raises the question of how and what data should be collected from the very beginning to use it in different models, like for example Least Cost Path analysis. However, simple site mapping and area comparisons revealed surprisingly much new information, as for example all sites in one study area were oriented east and not south, which is usually expected from stone

age sites in Finland. The study worked well as a starting point for future research. The study also highlighted how important it is to view culture or phenomena from the wider geographical area instead of making interpretations for example only after one excavated settlement site.

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175. SaRoCy: Delineating probable Sea Routes between Cyprus and its surrounding coastal areas at the start of the Holocene: discussing the archaeological evidence

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Island and coastal archaeology has recently become the centre of global archaeological attention for its value in understanding colonisation pathways, maritime technological capacity and human behaviour in newly colonized environments. The study of island colonisation and seafaring activities has allowed archaeologists to address two significant issues: when did humans develop the cognitive/technological capacities necessary to take to the sea and why did they take the risks associated with maritime travel to unknown areas. New insights from various parts of the world are showing that island colonisation has been undertaken by peoples in the Pleistocene for exploitation to obtain raw materials or information on new landscapes, and are offered as likely reasons behind these early dispersals into insular environments.

Furthermore, the timing and processes of emerging seafaring technology is of crucial importance to understand early colonisation movement and the spread of people and innovations at the boundary of the Terminal Pleistocene – Early Holocene in the Eastern Mediterranean. New research has challenged age-old paradigms that associated the early colonisation of Mediterranean islands with the emergence of agricultural societies in the Near East.

Main argument

The only way humans could have reached Cyprus at the end of the Pleistocene was via seafaring, as Cyprus is considered to be a 'true' island, never connected to the mainland since the Miocene. Cyprus can be regarded as an 'easy target from the mainland', since it lies not too far from the mainland shores of west Asia, and it is visible (depending on weather conditions) from various locations.

Recent and exciting discoveries on Cyprus over the last two decades have rewritten the island's earliest prehistory. The discovery of sites such as Akrotiri Aetokremmos, Nissi Beach, Vretsia Roudias and Akamas Aspros demonstrate that foragers/hunter-gatherers visited Cyprus at least on a short-term basis. Furthermore, new sites such as Ayia Varvara Asprokemmos and Ayios Tychonas Klimonas also show that an earlier variant of the Neolithic without pottery existed on the island contemporaneously with developments on the mainland. These new discoveries have debunked views of Cyprus and insular Mediterranean in general as little more than a footnote within the broader Neolithic world. Unfortunately, the ephemeral archaeological signature of the first visits and/or settlements to Cyprus conducted by non-sedentary peoples at the beginning of the Holocene results in low-visibility sites which are extremely difficult to be identified (and to which very little research attention has been placed to date). As a result, our knowledge of Cyprus's earliest occupants remains limited.

Inevitably, the traditional view of the Near East as the 'cradle of civilization' from which Neolithic cultural changes diffused to the west, strongly influenced opinions with regards to the first Cypriots' origins, with the Near East (Levant) and/or Anatolia suggested as the most likely locales. Similarities in the later Neolithic material expression, such as architecture and lithic technology, between Cyprus and these regions are usually regarded as evidence of the first Cypriots' 'homelands' even though such similarities do not necessarily extend further back in time.

On the other hand, the Eastern Mediterranean is unique in that, based on the fairly steep topography of the coastal shelf in large parts of the Eastern Mediterranean, the coast did not change substantially during the transition from the last ice age, when global sea-levels were approximately 120-130m lower. Compared to other parts of the world, particularly in the Indo-Pacific region, archaeological research is not challenged by significant inundation of coastal environments including most likely crucial locales to understand early post-glacial maritime adaptation of Pleistocene people. With the exception of one area of high potential for being the starting point of colonisation of Cyprus, the Gulf of Iskenderun, missing research in coastal areas is the main determinant for our lack of data to resolve questions of cultural contact and migration in early Cypriot prehistory.

Applications

This paper discusses the archaeology evidence for the SaRoCy project, a new modelling approach to understand early Holocene seafaring in the Eastern Mediterranean. This paper is seen as a parallel contribution to 'Drift-induced versus directed-paddling-induced potential connectivity between Cyprus and its surrounding coastal areas at the onset of the Holocene' by Leventis et al which presents a model of computational seafaring modelling in the Eastern Mediterranean.

The specific scientific objectives of the SaRoCy project are 1. To estimate the degree of sea-borne connectivity between coastal areas on Cyprus and those on its surrounding mainland in the early Holocene and thus reconstruct the most probable/efficient sea routes to reach the island of Cyprus and suggest the most likely/potential origins of the first humans who visited Cyprus on a short term basis; and 2. To bring together a team of experts spanning diverse scientific disciplines, ranging from archaeology, physics, oceanography, geospatial analytics, hydrodynamics engineering and geocomputation, to address the multidisciplinary problem of modelling early prehistoric seagoing/seafaring in the Eastern Mediterranean region around Cyprus.

163. Drift-induced versus directed-paddling-induced potential connectivity between Cyprus and its surrounding coastal areas at the onset of the Holocene

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Over the last two decades, the delineation of geographical patterns (and their temporality) relating to prehistoric marine migration in the Eastern Mediterranean has received global archaeological attention within the framework of island and maritime archaeology (Dawson, 2014). Cyprus was connected to the mainland at least as early as the Epi-Paleolithic period, around 20,000 years ago, and continuing into the Neolithic period and long beyond. Settlements on the island and archeological evidence for human activity attest to this. Without a doubt, people had to sail the Mediterranean to reach the island. Therefore, understanding the early visitors and residents of Cyprus as well as how Neolithic cultures spread throughout the region requires looking at the beginning of the Holocene (around 12,000 years ago). Anatolia and/or the Levant have both been suggested as possible places of origin for these visitors/inhabitants based on similarities of material nature, such as architecture and fauna/flora. However, there still is great deal of debate as to where these visitors/inhabitants came from and how they arrived on the island. Following and taking into consideration previous study conducted by the authors, the current approach provides new insights into the ancient maritime connections between Cyprus and other Eastern Mediterranean coastal regions at the start of the Holocene.

Paleoenvironmental Reconstruction and Particles Simulations

For the purpose of modeling drift-induced sea-borne movement, simulation-based algorithms are used that are based on data and assumptions regarding prevailing paleo-geographical conditions (reconstructed coastline using global mean sea level curves) and sea circulation conditions parameterized by near-surface wind magnitude/direction and sea current magnitude and direction as well. The overall assumption is that general conditions of atmospheric and ocean/sea circulation in the early Holocene were similar to modern ones (Bar-Yosef Mayer et al., 2015). Under this premise, hourly reanalysis data on the size and direction of sea currents were used (downloaded from the Copernicus Marine Service https://marine.copernicus.eu /). Additionally, we used current COSMO REA-6 reanalysis data on wind speed and direction at a height of 10m above the sea surface on an hourly basis with a spatial resolution of 6km (downloaded from the University of

Bonn's Hans-Ertel- Center for Weather Research, Climate Monitoring, and Diagnostics: https://reanalysis.meteo.uni-bonn.de/). To reconstruct the paleo-coastline at the start of the Holocene we made an estimation by tracing the -60m isobath (derived from global mean sea level curves for the period of interest) on modern-day bathymetry data; the latter bathymetry was synthesized using EmodNet's (https://www.emodnet-bathymetry.eu/) and SRTM's (2004) bathymetry, land topography, taking also into consideration an R/V Marion survey of the Eratosthenes mount, sub-sampled at a 0.01 arc degree grid.

The above-mentioned sea current and wind parameters were used in conjunction with salinity data to feed the OpenDrift Lagrangian particle tracking model (Dagestad et al., 2018) in order to replicate sea-borne movement. However, the specific model simulates only a drift-induced movement, hence for purposes of studying a more directed approach and comparing the outcomes, we enhanced the model using Python to encapsulate a forcing parameter (paddling). The paddling force that affects particle movement was taken into account along with the wind parameter as follows: i) for a wind of <=2 on Beaufort (BF) scale, the paddling force is set at 0.3 m/sec., ii) for a wind of close to 4 BF, the paddling force is set at 0.175 m/sec, iii) for a wind of around 6 BF, the paddling force that impacts the movement is set at 0.05 m/sec. while for iv) winds over 6 BF we set the forcing value to 0 as we consider the winds and currents are so strong that any attempt to paddle would have minimum or no effect on the sea-borne movement. Additional experiments were also conducted in the context of sensitivity analysis.

Results

The simulation scenarios included one hundred particles released at the same time within a 5km radius from several Eastern Mediterranean coastal locations and from Cyprus. The experiments cover a period of one year, starting daily at 6am (local time), and lasting for 5 days. As far as the no-forcing scenario is concerned, the results showcased two main periods; winter and summer, where the environmental conditions favor the unintentional movement (i.e., reaching Cyprus and/or mainland), while as can be seen from the figures below, the number and the probability of successful trips is highly increased when paddling is applied to the movement (direct forcing scenario) for the similar periods.

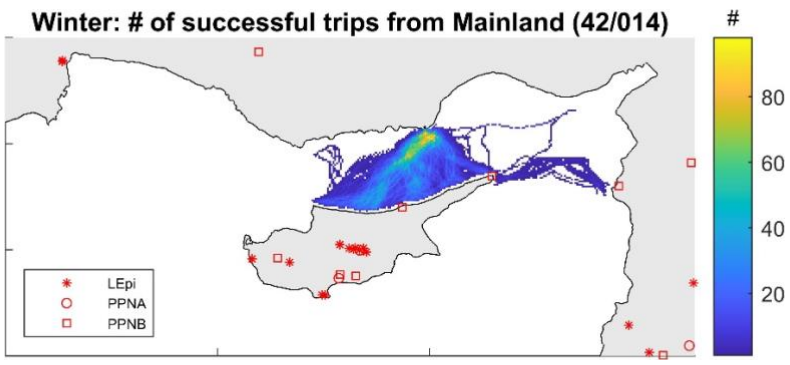

Figure 44. Trajectories of sea travel during winter from mainland to Cyprus (no forcing).

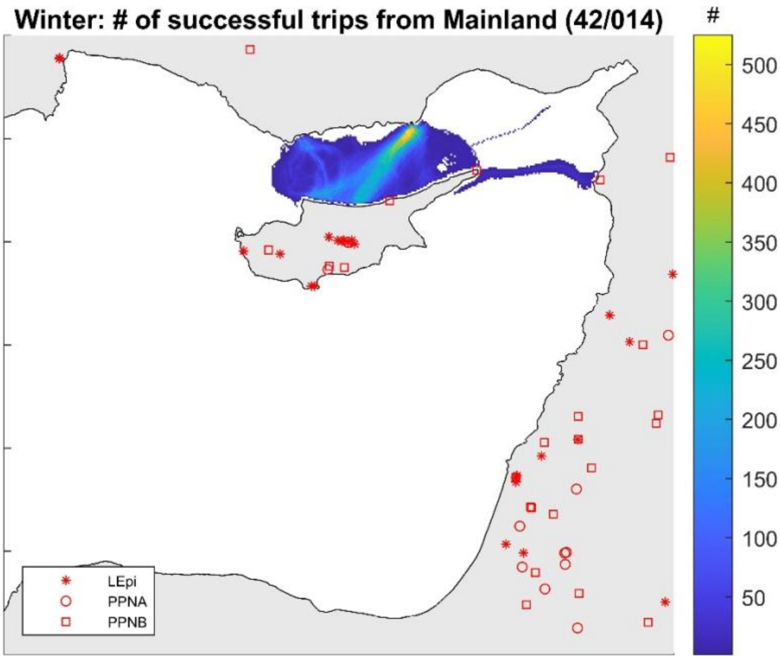

Figure 45. Trajectories of sea travel during winter from mainland to Cyprus (direct forcing; paddling).

One of the most interesting simulation scenarios tend to form during spring period, where the winds and currents appear to be more weakened, impacting the seaborne movement to Cyprus. Results show that the possibility of reaching the island from the mainland doubles when directed forcing is applied to the movement. During the same period, the trip from Cyprus to the mainland coasts applying force is at some points more than 10 times the number of successful trips if on drift.

Discussion

Seaborne movement can only be examined in full within a multidisciplinary scope by combining geospatial technologies, computer simulation, and physical-based modeling to support and test existing hypotheses in order to extract meaningful conclusions that can attest to the origin of the first inhabitants in Cyprus and more specifically on the possible maritime routes used. This work builds upon authors' previous work that was presented at CAA 2021 (unintentional/drift-induced movement) and extends it further by employing a more realistic model of seaborne mobility (direct forcing scenarios) to examine and shed light on hypotheses regarding the maritime routes from/to Cyprus on Holocene period.

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162. Simulating prehistoric maritime mobility potential: Overview and challenges

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Prehistoric maritime mobility underpins frontier research inquiry in archaeology, ranging from water-crossings and exploration in the context of early human dispersals, to seafaring, island colonisation and abandonment, to the formation of maritime networks of raw material circulation and/or trade, as well as to cultural transmission and evolution. Mobility in a maritime context is controlled by a multitude of factors, including geographical context defining origin/destination locations and coastal morphology, weather and ocean conditions, demographics, resources availability, trip motivation, risk attitude, navigation capabilities, social and cultural traits, as well as marine, e.g., vessel, technology. Some of these factors are unique to the maritime environment, rendering methods and algorithms for modelling/simulating maritime mobility distinct from similar methods in a terrestrial context.

Seaborne movement modelling efforts based on computer simulation, closely related to agent-based models (Romanovska et al., 2021) – although not always explicitly stated as such, have been long ago used to test archaeological hypotheses related to colonisation, migration, and culture contact; classical example are simulation models for the colonization of Oceania and the Pacific. In such simulations, multiple "virtual vessels" embark from coastal locations and interact in a stochastic or deterministic way with winds and currents according to their structural characteristics and the capabilities of the navigation to reach a particular destination. Vessels could equally well represent individuals swimming or paddling in the context of crossing water straits (Hölzchen et al., 2022). The frequency and location of successful landings, as well as the trajectories followed, offer valuable insights in terms of probabilities of connections between possible origins and destinations along with the pattern of maritime routes followed.

An alternative family of models employ Least Cost Path (LCP) analysis modified to account for the maritime environment. Closely related to LCP approaches are models based on the concept of isochrones, tracing the locus of potential arrivals over a given time interval. On the opposite direction of LCP analysis, whereby the environment is assumed to be completely known, lie methods based on circuit theory (CT) aiming to explore all possible avenues between origin and destination locations assuming minimal environmental (wind and ocean currents in this case) knowledge. Between these two ends (LCP and CT) lie randomized shortest path methods, incorporating only partial environmental knowledge, which however have yet to be employed in a maritime mobility modelling context.

Last, models from the domain of network science focus on the structural and throughput characteristics of maritime networks constructed from the verified presence of common or similar material culture at network nodes. The degree of pairwise similarity between findings at network nodes can serve as a proxy for realized connectivity between origin and destination nodes, although a binary (unweighted) network is by far the most common maritime network definition adopted in practice.

Main arguments

Existing models of maritime mobility pertain mostly to individual-level, seaborne movement potential, and often place attention on environmental (wind/currents) controls of movement as well as the intricacies of LCP analysis in a maritime context; present day descriptions of weather and ocean current conditions are typically used. Exceptions are studies cast explicitly in a paleoenvironmental context, such as the colonization of Sahul. In such cases, however, the available wind and ocean current data are often limited to coarse spatial and temporal resolutions; this might result in overly smooth trajectories and travel time underestimation particularly in coastal areas.

Moreover, cognitively-informed parameterizations of navigation capabilities, such as visibility, landmark recognition, or path planning strategies, are often missing from existing model formulations of prehistoric maritime mobility. On the contrary, it has been repeatedly argued in spatial cognition and behavioural geography contexts that humans do not necessarily make shortest path decisions in wayfinding endeavours; they rather follow simple rules, such as holding a heading or avoiding turns.

Apart from the cases of exploratory movement and drift-induced mobility, destination choice is of paramount importance to mobility modelling as it dictates the number of trips to be made between origin and destination locations. This modelling component, however, is sorely lacking (not only due to data scarcity) from most existing modelling efforts in an archaeological context; on the contrary, it is prevalent in ecological and geographical models of present-day terrestrial mobility where the use of methods from optimal foraging theory, human behavioural ecology, discrete choice and spatial interaction modelling is widespread.

At the heart of destination choices and decisions to embark from origin places lie demographics. Indeed, estimates of past human population (along with its demographic and possibly cultural characteristics) are necessary to convert the potential of an individual to complete a single trip once at sea into maritime flows (numbers of trips) of people or goods. Although paleo-demography has been increasingly providing prehistoric population estimates, such estimates have not yet been employed towards estimating demographic (aggregate) maritime connectivity.

Lastly, apart from few exceptions (Bradshaw et al., 2021), computational models of potential maritime mobility are not coupled to process-based models of (meta)population dynamics and to models of disturbance (e.g., disease, information, cultural traits) spread; such models constitute frontier research in fields such as ecology and biology (see, for example, the surge of spatially interconnected dynamical models of disease spread developed in the context of the recent COVID-19 pandemic).

Implications

Prehistoric maritime mobility is an example of highly complex human-environment interaction, influenced by a multitude of factors varying over several spatial and temporal scales. Its modelling calls by definition for a multidisciplinary perspective and associated expertise. Efforts towards simulating maritime mobility are more likely to have a greater scientific impact once they are explicitly linked to dynamical process, such as population dynamics or information/disturbance transmission. Doing so requires new models that distinguish between individual and group-level mobility, and formally account for destination choice, path planning and cognitive factors influencing decision-making. Such models are more likely to ultimately shed light onto the links between potential and realized mobility, and the effects of the former on dynamical models of population dispersal and growth as well as cultural transmission.

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178. Modelling ancient Maya long-distance, canoe-based trade around the Yucatan Peninsula

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The Caribbean and Gulf of Mexico coastlines represented the edge of the conceptual world for the ancient Maya. The sea was associated with the primordial creation of the world, the source of valuable and precious materials, but also recognized as a dangerous realm, home to frightful creatures and powerful forces (see Taube 2010). Much like today, special skills and knowledge were needed to make a living by the sea, which produced distinct cultural traditions for coastal Maya peoples. Coastal communities in the Maya Lowlands played a myriad of roles in the ebb and flow of political, economic, and social formations over the past 3000 years, yet these roles have remained along the periphery of Maya studies. While often small in size when compared to their inland neighbours, Maya coastal sites were integral to the early development of complex polities in the Formative period, provided refuge following the Classic Maya "collapse" in the 9th century A.D., and were home to cosmopolitan residents engaged in long-distance trade on the eve of Spanish contact.

Integral to these long-distance, trade connections was the seafaring toolkit that facilitated the movement of people, goods, and ideas around the Yucatan Peninsula. The best description we have for long-distance trading canoes comes from Columbus' 4th voyage to the Americas in the early 1500s. There is an account of meeting a large dugout canoe that held 25 paddlers, elite family member passengers, and cargo from across Mesoamerica. The canoe was reported to be 8 ft wide and as long as a galley, which based on the size of Columbus' fleet could mean that the canoe was upwards of 20 m in length (Keen 1992). There are other 16th century sources that corroborate the size of these ships – one of the more well-known was written by Bernal Diaz del Castillo who remarked that the canoes that came out to greet the Grijalva expedition in 1518 held 40 or 50 people. Another history of the same event said there may have been 100 such canoes in Campeche Bay. So, not only were these canoes large, they seemed to be numerous as well. Yet, no large, ocean-going canoe has been recovered in an archaeological context in the Maya (see Fitzpatrick

2013 for a broader discussion of seafaring capabilities in the Caribbean) nor do we have a detailed understanding of how these watercraft moved around the Peninsula (a distance of some 1500 km).

Based on ethnographic and ethnohistoric data, Adams (1978) proposed an average speed of 3.5 km / hour for dugout canoes across slow-moving water in the Maya area, which has been supported by more recent ethnographic research in the Caribbean (see Bérard et al. 2016). Relatively few have tried to actually model canoe movement along these coastlines in a more sophisticated way that takes into account currents, wind, and other factors (see Callaghan 2003 for a study on the Pacific coast). In this paper, we take an initial step in modelling long-distance, canoe-based trade using the sophisticated, digital tools now available to us in the 21st century. We will use known ancient Maya port sites as starting points and estimate the length of time for the total journey around the Yucatan Peninsula. In the process we will evaluate how the proposed routes match with the location of other known port sites (see Andrews 1990; Clark 2015) or how they might provide insight into the location of potential port sites that have yet to be identified. In sum, by bringing together a modeler of ancient seafaring with Maya archaeologists, we hope to provide new insights into the possibilities of long-distance, canoe-based exchange in the Maya area.

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98. Where did the ships sail? Simulating European shipping routes before the age of steam

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Maritime commerce has been a major driver of European expansion and economic growth since the sixteenth-century, and coastal shipping played a fundamental role in the development of the British economy, enabling both rapid urbanisation and increasing regional specialisation (Pascali 2017; O'Rourke and Williamson 2002). Yet, very little is known of the precise routes used by ships transiting over the seas, which makes any measurement of increasing shipping productivity hazardous.

In this paper, we show that a multi-criteria simulation of historical routing using least-cost path analysis can reveal the most likely European shipping corridors of the past. In order to simulate rational routing behaviour for an eighteenth-century pilot, we based our model on: (1) basic thermodynamic principles of sailing adjusted to fit historical parameters, and (2) long-run historical environmental time series for key determinants of navigation (wind, waves, currents, visibility, and seasonality). Our model draws on a broad range of criteria for the modelling of sea conditions: bathymetry, coastal visibility, wind speed and direction, wind variability, frequency of extreme weather conditions, wave height, direction and period, and current speed and direction.

We adopted a dual approach to modelling, combining deterministic and stochastic routing calculations (Perttola 2021). In the first case, we calculated for each historical port-pair (i.e. documented maritime connection) the optimal path in each direction for each month of the year, producing for each port-pair 24 different routes. The second approach iterates the calculation of each route, using a random selection of hourly data for each month, thus producing a series of most probable corridors for each of these pairs. This probabilistic model accounts for the variability of weather events and sea conditions not captured in averaged data.

Our work aims to demonstrate the usefulness of combining dynamic environmental modelling with rigorous historical enquiry to provide key evidence where sources are lacking or unrepresentative. We anticipate our work will unlock major new research questions and approaches, allowing social scientists to measure shipping productivity in the age of sail with unprecedented precision.

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39. Stegodon SEAcross-ing: Swim, Shrink, and Disperse

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Elephants are known as ardent, skillful, and persevering oceanic swimmers. Smaller sea straits between the mainland and an island or between islands therefore do not represent major barriers for dispersals. Stegodon, phylogenetic relative of the family Elephantidae, followed a similar pattern. The fossil record of Stegodon in insular Southeast Asia and Wallacea illustrates a wide distribution area ranging from Java, through Flores and Sumba, to Timor, and stretching north to Sulawesi and the Philippines (van der Geer et al. 2016). Simultaneously, proboscideans underwent island dwarfing. En route to remote islands in Wallacea, dwarf Stegodons in Flores for instance evolved c. 50 % body mass reduction relative to the ancestral species in mainland Southeast Asia. Reductions in body size have an impact on swimming performances and thus dispersal capabilities.

In order to examine the capabilities of Stegodon to disperse across insular Southeast Asia and Wallacea we applied the hominin sea crossing ABM developed by Ericson Hölzchen (Hölzchen et al. 2021). Because Stegodons show island dwarfism, we developed a dwarfing scenario and determined crossing success rates (CSR) for a range of size categories.

We used oceanographic maps to determine critical features of sea straits: width, and current velocity and direction. We did not consider sea surface temperatures as they do not vary widely in an annual range in the tropics. The three parameters were applied to configure a standardized environment for each sea strait.

With respect to the Stegodon agents, we applied a physiological swimming model which allows to calculate optimum swimming speed and maximum distances by quadrupedal paddling from the relation between costs of transport and energy storage available (Meijaard 2001). In this model, both variables, optimum swimming speed and energy storage, are dependent on size parameters, in particular head body length and body mass. Small-sized Stegodons therefore have less energy at their disposal and swim with lower optimum speed. Consequently, they are less successful in crossing sea straits. Progressive dwarfing may render it impossible to cross a particular sea strait.

Our results identify and illustrate potential routes for Stegodon across the Sunda Shelf and Wallacea. We furthermore determine the maximum geographic distribution range in reach of Stegodons of various size categories when moving across the focal islands.

Our experiments moreover demonstrate the flexibility and usefulness of the hominin sea crossing ABM, which can be applied to a wide range of scientific questions.

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46. Simulating the relation between Stone Age sites and relative sea-level change along the Norwegian Skagerrak coast

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The post-glacial relative sea-level fall that characterises large areas of Fennoscandia is fundamental to its archaeology. This follows not only from the dramatic changes to the landscape that this process has represented throughout prehistory, but also from the fact that if archaeological phenomena were situated close to the contemporary shoreline when they were in use, a reconstruction of the trajectory of shoreline displacement can be used to date these phenomena based on their altitude relative to the present day sea-level. This method, also called shoreline dating, has long history of use and is frequently applied to assign an approximate date to Stone Age sites in the region (e.g. Bjerck 2008; Solheim and Persson 2018). The relationship between sites and shoreline is therefore important to the temporal framework on which our understanding of the period is based, but also because the method of shoreline dating is only applicable so long as people have settled on or close to the contemporary shoreline. Consequently, adherence or deviation from this pattern also has major implications for the socio-economic foundations of the societies in question.

Subject

The aim of the proposed poster is to present a systematic review and method for quantifying the degree to which radiocarbon dates from 67 Stone Age sites located along the Norwegian Skagerrak coast indicate that the sites would have been situated by the sea. The problem thus involves the combined evaluation of three major analytical dimensions. One is the questions of when the sites were in use, the second pertains to the reconstruction of the contemporaneous sea-level, and the third follows from the fact that the relation between site and shoreline is inherently spatial. To integrate these spatio-temporal dimensions and their associated uncertainty in the analysis, a Monte Carlo simulation approach is employed (cf. Crema et al. 2010).

Discussion

While the method will in this case be used for evaluating the distance between sites and the prehistoric shoreline, the framework can be extended to a wide range of use-cases where one needs to visualise, and quantitatively or qualitatively evaluate the relationship between archaeological phenomena, the prehistoric sea-level, and the uncertainty inherent in this reconstruction. The poster should therefore be of relevance to the wide range of practitioners that deal with archaeology in relation to ocean systems and environments.

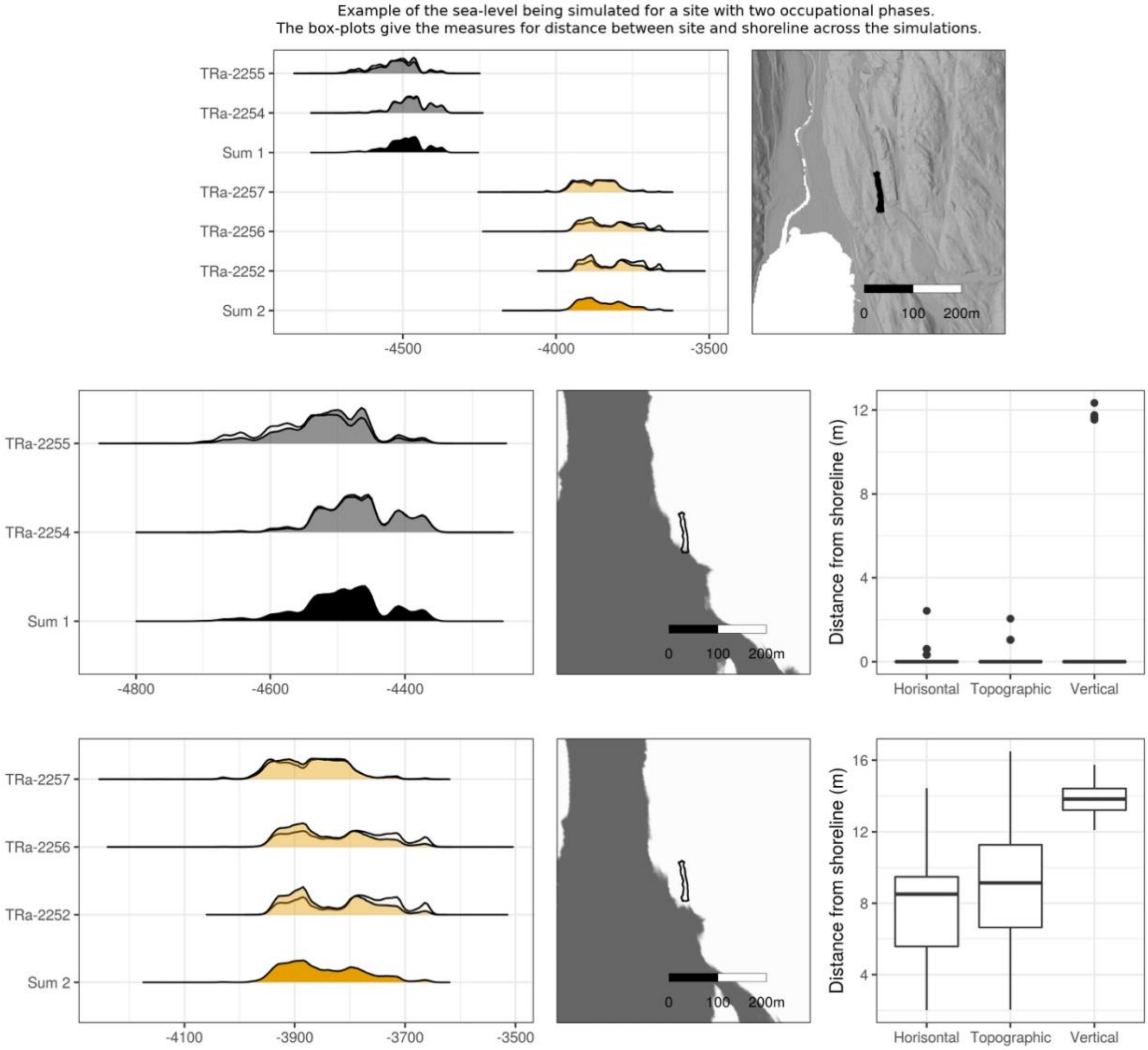

Figure 46. Example Site.

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Index

E

F

G

H

I

J

K

L

M

N

O

P

R

S