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Quantitative Benchmarking in Agricultural Robotics

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***Abstract*—The aim of ACRE (Agri-food Competition for Robot Evaluation) is to provide a set of benchmarks for agricultural robots and smart implements. While involving capabilities of general application, ACRE puts a special focus on weeding, identified as one of the tasks where it is easier for robotics to demonstrate its potential. ACRE, as the other three robot competitions that are being organised by European project METRICS, is built on the established idea of benchmarking through competitions. In this paper we present the framework of ACRE and examples of its benchmarks.**

***Index Terms*—Agricultural Robotics, Robotics Benchmarking, Performance Evaluation**

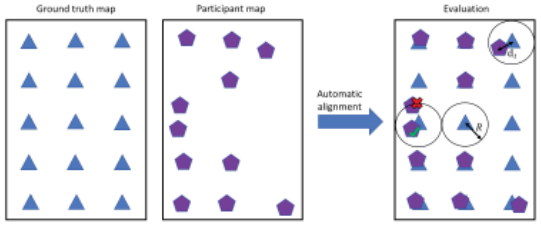

Fig. 1. Extract from the the ACRE Evaluation Plan: Crop mapping TBM.

I. Introduction

Companies producing agricultural machinery are well aware that artificial intelligence and robotics have the potential to revolutionize their field; yet they are wary of technology that is very far from their area of expertise. Even today, agricultural machines -with few exceptions- include very little in terms of ICT technology, and their users are rarely used to interacting with such systems in the field. Thus, introducing AI and robotics into agricultural machines needs much more than the addition of new systems and components: it requires a radical change in the way such machines are designed, built, and employed.

An additional difficulty is linked to the size of the companies producing machinery for agriculture, which is often (especially in some countries, such as Italy) comparatively small and sometimes bordering on the artisanal. Such companies, in fact, do not have the resources to embark in "clean slate" R&D projects. Finally, the potential benefits that robot-based precision agriculture can bring are significant, but so far theoretical. Farmers, i.e. the market for agricultural robots, are currently on the fence: waiting for such benefits to become clearly visible -and measurable in terms of yields and costs- before committing to radical changes to their modes of operation.

For the reasons outlined above, many companies are currently torn between a strong perceived need to "put their toes in the water", i.e., to start the development of agricultural robots, and the fear of wasting resources due to lack of expertise and market. At the same time, there is considerable effort going on in research on the development of algorithms and systems for agriculture, yet so far technology transfer to industry has been scarce, and mainly concentrated in spin-offs of research groups.

Quantitative benchmarking has the potential to change this scenario, enabling companies to quantitatively gauge the performance of research results before committing to implement them into their products, and providing farmers with tools to measure how much agricultural robots can enhance their production before considering their purchase.

II. Agri-food Competition for Robot Evaluation

The aim of ACRE: Agri-food Competition for Robot Evaluation [1] is to provide a set of benchmarks for agricultural robots and smart implements. While involving capabilities of general application, ACRE puts a special focus on weeding, identified as one of the tasks where it is easier for robotics to demonstrate its potential. ACRE, as the other three robot competitions that are being organised by European project METRICS [2], is built on the established idea of *benchmarking through competitions* [3].

ACRE calls research and industry to demonstrate the capabilities and performance of their machines by executing *benchmarks* that take two forms [4]:

- **Functionality Benchmarks (FBMs)**, focused on specific capabilities of a robot and designed to make the benchmark as independent as possible from other features of the robot not directly involved in the functionality under examination (*Plant discrimination*, *Field navigation*, *Leaf area estimation*, *Weed destruction*, *Biomass estimation*)
- **Task Benchmarks (TBMs)**, evaluating the execution of complex tasks involving multiple functionalities, where

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Fig. 2. Example of cultivated rows; the crop is maize, two different growth stages (left row, right row) are shown.

Fig. 3. Example of image segmentation.

the final result depends both on these individually and on system-level properties of the robot such as integration between functionalities (*Intra-row weeding*, *Crop mapping*)

ACRE benchmarks, with detailed information on their execution and on the evaluation metrics applied to robot performances, are described by the ACRE Evaluation Plan [5]. A hint to the contents of the Evaluation Plan is provided by Figure 1. The key events in ACRE's timeline are its evaluation campaigns, comprising:

- **field evaluation campaigns**, which take place in real-world environments representative of the agri-food domain (see Figure 2);
- **cascade evaluation campaigns**, which are data-based competitions that teams participate remotely to.

The datasets that the cascade campaigns are based upon are collected during the field campaigns. Thus, when the same benchmark is used by both, it is possible to directly compare the performance of teams participating to field campaigns and cascade campaigns.

III. ACRE ACTIVITIES

On October 17th 2020, the *1st ACRE workshop* [6] publicly presented the competition. Since ACRE intends to maximise its usefulness to stakeholders, it is currently in the process of **collecting feedback and suggestions from stakeholders**, which will be carefully discussed and -when feasible- incorporated into the design of the competition.

The 1st ACRE Cascade Competition [7], launched at the workshop, is ongoing and accepting participants. This data-based competition focuses on the Plant discrimination FBM, and -in this first edition- uses data provided by the ROSE Challenge [8], a French initiative organised by two partners

Fig. 4. The experimental farm of INRAE in Montoldre (FR), location for the 1st ACRE Field Campaign of June 2021. The highlighted 4ha area is where the ACRE benchmarks will take place.

Fig. 5. The experimental farm of Università degli Studi di Milano in Cornaredo, where the 2nd ACRE Field Campaign will take place in June 2022. The image shows an area of 800 m x 700 m approximately.

of METRICS. Figure 3 illustrates the image segmentation problem that participants are asked to tackle.

ACRE Field Campaigns take place in actual farm locations: ACRE benchmarks, in fact, take care to closely match actual agricultural settings and tasks. Figures 4 and 5 show aerial views of the locations of the ACRE Field Campaigns 2021 and 2022. Each of these will generate data that will be used by subsequent Cascade Campaigns.

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