FiRe²: an online database for photographic and cinematographic film technical data

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Among the great variety of our Cultural Heritage, photographic and cinematographic materials are fundamental and direct witnesses of the past. As often happens when dealing with materials of cultural interest, even photographic and cinematographic films can undergo severe deterioration, aging, and color fading throughout the time, leading to the need for proper restoration, conservation, and preservation of these materials. In this context, even though the digitization process is becoming more and more essential, analyzing and studying the analog materials remains fundamental to perform a retrieval or a correction faithful to the original material. For this reason, the lack of technical information (especially for the oldest materials) and the absence of open-source archives of the producing companies underlines the actual and concrete need for a database of physical, chemical, and sensitometric data of both cinematography and photographic films.

The aim of this work is the creation and the promotion of FiRe², a big and unique database of cinematographic and photographic materials to support the work of conservators, restorers, and researchers, as the availability of information and the cooperation between institutions and professionals are essential for preserving our Cultural Heritage.

CCS Concepts: • Applied computing → Digital libraries and archives.

Additional Key Words and Phrases: Film Restoration, Color in Film, Photographich Film, Cinematographic Film, Sensitometry, Film Gamuts

ACM Reference Format:

1 INTRODUCTION

Film restoration is a complex process involving many different fields, from the physical and chemical aspects to the cultural background in which the film has been produced. In this way, the first step in film restoration is the historical and philological research, because, unlike other kinds of Cultural Heritage objects, usually many different copies of the same photograph or motion picture are available, but all of them could differ in their state of conservation or content: e.g. a copy may be censored, another may present intertitles, another may introduce unreleased sequences. This aspect of film restoration is widely studied, and today many researchers focus on film philology reconstruction or on the analysis of a specific historical period or movement [2].

Researchers and restorers often rely on public archives to collect all the information needed for their work, as the documentation process is fundamental to performing a correct film restoration. However, the lack of strict international guidelines makes this task to be hard for the professional figures working on photographic and cinematographic collections, as film restoration still struggles to establish a binding professional code comparable to those already in place in fine art restoration and heritage conservation [3]. And this is especially true because
of the absence of the availability of technical information and scientific knowledge in this field: while there are plenty of historical archives, the retrieval of scientific data is often hard. Producing companies provide informative datasheets of each film produced, including all the technical features of the product as well as their sensitometric curves and the information for the film stock characterization. Nevertheless, these datasheets are not always available, especially for the oldest materials. Moreover, many archives do not have public access or only provide partial information. In this way, this work aims at supporting the work of conservators, restorers and researchers, and at starting to fill the lack in technical knowledge concerning film materials. In the first part of this paper, we want to underline the importance and the need for acquiring and collecting scientific data that has led us to the creation of FiRe², a completely free open-source database for cinematographic and photographic films, which is introduced and discussed in the second part of this work. Finally, in the last part of this paper, we invite the readers to join our project promoting the collaboration between both privates and institutions to retrieve technical data that may be otherwise be lost.

2 THE NEED FOR A TECHNICAL DATABASE

Every restoration project should be characterized not only by the study of the history of the film but also by an in-depth analysis of the original material. Very often, the movie or the photography contents are considered more important than the analog film itself. However, all the images are nothing but the result of the radiation-matter interaction between the film material and the light. This means that the physical and chemical properties of the material composing the film (with its specific emulsion, dyes, and sensitivity) determine the intrinsic characteristic of each image. In this way, it is also important to consider that over the years, the film industry and the various producing companies developed different films with different emulsions and dyes. For this reason, thinking about the images as separate and independent entities from the material of which they are composed is deeply wrong and can lead to incorrect conservation or unfaithful retrieval of the cultural object. According to the material they are made of, every film has a different response to the light interaction and can have a different gamut (i.e. the subset of color that can be reproduced within a color space or by a device).

![Comparison of the spectral sensitivity curves of two reversal film stocks: Fujichrome Provia 400X Professional [RXP] (PCRFUJFP4) by Fujifilm and the Kodachrome 64 (PCRKODK64) by Kodak.](image)

Fig. 1. Comparison of the spectral sensitivity curves of two reversal film stocks: Fujichrome Provia 400X Professional [RXP] (PCRFUJFP4) by Fujifilm and the Kodachrome 64 (PCRKODK64) by Kodak.

In order to have a clear and complete idea of this concept, figure 1 and figure 2 show the spectral sensitivity curves and the spectral dye density curves respectively of two reversal: Fujichrome Provia 400X Professional [RXP] (PCRFUJFP4) by Fujifilm and the Kodachrome 64 (PCRKODK64) by Kodak. The spectral sensitivity describes how the three emulsion layers of the film are sensitive to the electromagnetic radiation. Since higher values...
Fig. 2. Comparison of the spectral dye density curves of two reversal film stocks: Fujichrome Provia 400X Professional [RXP] (PCRFUJFP4) by Fujifilm and the Kodachrome 64 (PCRKODK64) by Kodak.

Fig. 3. Comparison of the gamut of two reversal film stocks: Fujichrome Provia 400X Professional [RXP] (PCRFUJFP4) by Fujifilm and the Kodachrome 64 (PCRKODK64) by Kodak. On the left the gamuts are represented in two-dimensions in the CIE Chromaticity Diagram, on the right in three-dimensions in the CIELab color space.

indicate a more light-sensitive emulsion, Fujichrome Provia 400X Professional is significantly more sensitive than Kodachrome 64 and can more emphasize the colors. Moreover, the other parameter that matters in the spectral sensitivity representation is the wavelength where two sensitivity curves cross. That is because every emulsion layer act as a band-pass channel filter and so a wider curve overlapping means a lower color saturation. The spectral dye density describes the percentage of absorbed and transmitted radiation as a function of wavelength. As before, a wider overlap in the curves and the evident differences between the two films lead to less-saturated colors in the resulting images: for example, higher values of the cyan and magenta curves in the blue region of the spectrum (400 – 450 nm) of the Kodachrome 64 implies that these two emulsion layers transmit less the incident radiation than those of Fujichrome Provia 400X Professional, leading to less saturated color in the blues.
All of these differences reported in the spectral sensitivity and in the spectral dye density curves imply that the two film stocks will have a different subset of colors that they can or cannot reproduce. This is the definition of gamut, whose comparison for Fujichrome Provia 400X Professional and the Kodachrome is represented in figure 3. Fujichrome Provia 400X Professional has a wider gamut more saturated in the regions of blues and yellow but less advanced in the region of cyans.

Fig. 4. Comparison of the gamut of two reversal film stocks: Fujichrome Provia 400X Professional [RXP] (PCRFUJFP4) by Fujifilm and the Kodachrome 64 (PCRKODK64) by Kodak. Please, note that images colors can be subject to changes depending on the visualization device or the printing system.

The same image produced by the two film stocks is different as well, and an example is shown in figure 4. Here the two images are obtained applying the ICC color profile of the two reversal films within an absolute colorimetric intent. That means that every in-range colors are not modified, while the out-range colors are clipped to the closest color upon the gamut surface. The color comparison is supported by the spatial distribution of the color differences. The increase of color difference is coded by a set of false colors, for which purple and
green correspond to no difference at all and a color distance hard to perceive by the human eye \((0 \leq \Delta E < 2)\); yellow, orange and red are used for perceptible differences \((\Delta E < 5, \Delta E < 7\) and \(\Delta E > 7\) respectively). In light of this comparison, it became clear that the differences in the two images are the direct result of the differences between the material they are made of. Since every object has a diverse response to the light interaction, different formulations of films lead to distinct properties as well as dissimilar gamuts. Consequently, for every film there will be colors that can be reproduced and others that will not.

This is complicated by the fact that, over the years, the film industry has faced a lot of innovations: the development of different film base materials, the advancement of many acquisitions and projection instruments, as well as printing and developing machines. One of the most tangible and rapid changes has been the continuous introduction of new coloring techniques: indeed, since the invention of film, one of the great hurdles has been adding color to black-and-white motion pictures. Attempts to color films have been numerous and various during the years and many different techniques and dyes have been used [7, 8, 10, 12]. Every (motion or still) picture is the result of the interaction of different cameras, film stocks (with their specific emulsion, dyes, and sensitivity), printing machines, and projection technologies. The varied combination of all these elements produces a different final image. In this way, analyzing, studying and understanding the chemical and physical properties of materials that compose the film and the technical features behind the photographic and cinematographic filmmaking are fundamental to setting up a solid restoration workflow faithful to the original materials. Nevertheless, today there is a lack of documentation and research in the field of cinema technical history, in particular in the study of the materials which composed the film base, colorant or dyes over the years. This lack of knowledge is even more dangerous today, in the digital era, where the introduction of digital technologies and digital intermediates, which today completely changed the technologies to acquire, restore and access the films. Since the superior manageability and reversibility of digital intermediate, more and more archives are embarking on massive digitization initiatives to improve the access to their materials. However, most of the time, the conversion from analog to digital is made without effective color control and management. This leads to issues in color reproducibility in digital systems, since not all the current display and projection devices have the same gamut and can reproduce the same color palette of an analog film, and this is clearly visible when comparing the original analog film and the digital. Reconstructing the exact set of colors of the original films is a challenging task, complicated by the lack of technical information that leaves the experts to perform a subjective manual color correction or a restoration with a visual comparison. Consequently, it is fundamental to analyze, study and understand the technical history of photographic and cinematographic films, to set up conservation, restoration and preservation workflows that are faithful to the original materials even if employing modern acquisition and fruition tools.

The availability of technical and sensitometric data about the film would support the preservation and restoration work, making the whole process easier and more objective: some errors in tones and color reproduction could be avoided and the specific film features could be supported by mathematical and physical models and this would be the next step of our project as well. In this way some attempts have already been made in the works of Gschwind [5], and Rizzi [11] but many improvements need to be achieved in order to reproduce a faithful color film perception. The creation of this platform is also intended as a base for growth and integration with future studies as the development of sensitometric analysis and scientific investigations on new materials.

3 THE DATABASE
To catalog and organize the different techniques and materials used along with the history of photography and cinema, many works have been already realized and published [4]. Nevertheless, much technical information on film sensitometry and emulsions has been lost, and even if some efforts have been made to create dataset
collections and catalogs, very few works are open source and have been published [9], and the available archives could be incomplete or deal only with historical information.

Starting from this need, different existing archives have been merged and different sensitometric and technical information about films have been added to create a unique open-source database available for every researcher. First of all, we made an evaluation and a classification of the films collected by Rudolf Gschwind in Historische Kleinbildfilm Datenbanke archive [1]. Those data have been subsequently updated with the technical information included in Barbara Flueckiger’s database Timeline of Historical Film Colors [4] and with the private technical dataset made by Nicola Mazzanti in his career [6].

Together with the technical information listed in the database, we also collected technical files of various kinds (e.g., images, white papers, technical reports). These files are mainly technical datasheets and sensitometric graphics, that are useful to define the qualitative aspects of a film such as exposure, sensitivity, optical transfer functions or dyes spectral densities. All those files have been classified in the database as well and are downloadable from the website.

![ER model built to develop the database.](image)

According to the material collected, the logical structure of FiRe² is shown in the Entity Relationship Diagram in figure 5. The Film entity and the Attached file entity are the most important entities of the database. The first one is made up with the list of film stocks and their main features, whose list of attributes are described in 1. The second one consists of the collection of all the technical datasheets and documents related to the film material. Since these two entities would be related to each other with a many-to-many relationship, the Film source entity serves as joining table. The Additional Material entity collects all the general information not related to a specific film. The Marketing entity consists of all the materials related to marketing and advertising. Finally, every entity has a relationship with the Source, which collects all the references to the archive we have referred to in order to collect our data.

Table 1. Description of the attribution of the Film entity

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>Film Identification Code</td>
</tr>
<tr>
<td>Name</td>
<td>Film stock name</td>
</tr>
<tr>
<td>Brand</td>
<td>Film production company</td>
</tr>
<tr>
<td>Date</td>
<td>Date/period of film stock production</td>
</tr>
<tr>
<td>Origin</td>
<td>Production country</td>
</tr>
<tr>
<td>Photo/Movie</td>
<td>Photographic</td>
</tr>
<tr>
<td>Type</td>
<td>Positive</td>
</tr>
<tr>
<td>Principle</td>
<td>Additive (2 or 3 colors)</td>
</tr>
<tr>
<td>ISO</td>
<td>Film speed</td>
</tr>
<tr>
<td>Grain</td>
<td>Film granularity</td>
</tr>
<tr>
<td>Latitude</td>
<td>Film exposure latitude</td>
</tr>
<tr>
<td>Contrast</td>
<td>Film final contrast</td>
</tr>
<tr>
<td>Format</td>
<td>8 mm</td>
</tr>
<tr>
<td></td>
<td>16 mm</td>
</tr>
<tr>
<td></td>
<td>35 mm</td>
</tr>
<tr>
<td>N° Camera Film</td>
<td>Number of motion picture camera film</td>
</tr>
<tr>
<td>Soundtrack</td>
<td>With Soundtrack</td>
</tr>
<tr>
<td></td>
<td>Without Soundtrack</td>
</tr>
<tr>
<td>Use</td>
<td>General film use</td>
</tr>
<tr>
<td>Update</td>
<td>Data of last update</td>
</tr>
</tbody>
</table>

As can be seen in table 1, in order to classify and identify the different film stocks, we developed a unique identification code, illustrated in figure 6. It consists of a unique alphanumeric code of nine-character length, that summarizes the main characteristics of each film: the use (1 character), the type (2 characters), the production company (3 characters) and the specific film name (3 characters). For example, in the figure, the Fujicolor Positive Film Eterna-CP 3521 film stock has been classified as M-CP-FUJ-FPC, where M (Movie)-CP (Color Positive)-FUJ (Fujicolor)-FPC (first letters of the film-stock name).

After the preliminary analysis of data collection and identification and database creation, we created a specific website to make the results of this research available to the community of restorers, archivists, and professionals in the field of film restoration. The website, available in English or Italian at https://mips.di.unimi.it/photofire/, is divided into six main sections: Homepage, About Us, Archive, Help Us, Contacts and Partnerships.

The About Us section provides an overview of the FiRe² project and briefly explains how the archive section works. The Archive section presents three subsections: Film database, Marketing&Advertising and Additional material.
The **Film database** subsection is the core of the website because it allows the user to search for specific film stocks and access the collected information. It is possible to search film stock by name, ID code, brand, type or photo/movie. Alternatively, it is possible to access the full film collection by selecting "view all". Figure 7 show, for example, some of the results of the films by Kodak we have collected. It is important to notice that the last column, enclosed in red in the figure, provides the links to visualize and download for free the attached file (i.e. the technical datasheets of the film like the example in figure 8) we have collected. Unfortunately, due to the lack...
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Fig. 8. Example of attached file in the Film database section and downloadable from the PhotoFiRe² website: some pages of the technical datasheet of the Fujicolor Superia X-Tra 800 film.

of information available, not all fields could be completed for all the films.
The Additional material subsection contains general information about the film stock, unrelated to the singularity of a specific film (see an example in figure 9).
Finally, the Marketing & Advertising subsection contains non-technical materials, like images, or advertisement fliers. Some examples are showed in figure 10.

The Help Us section is another very important section of the website because it is devoted to creating collaboration between institutions, sharing new film material on the website and updating the database. This section provides a quick form to complete for all the researchers who want to share their film materials. A more specific description of the procedure to contribute to the database is in the last session of this paper.

The Contacts section contains information about the website and database developers and curators. There is also the possibility to subscribe to the website newsletter to receive news and updates.

In conclusion, the Partnerships website section presents a list of researchers, institutions and archives, who joined the project and took part in FiRe².

The database is in constant growth. The last updates come from two personal archives: one from Lénia Oliveira Fernandes, Photograph Conservator at the Rijksmuseum of Amsterdam, and the other from Prof. Alessandro Rizzi, one of the authors of this paper. With the last 203 updates, we have currently collected 78 items for additional materials and 601 photographic and cinematographic films (233 of which have attached files with technical data) from 22 producing companies used from 1935 to 2018.

Since the database is conceived to be always in continuous evolution and growth, the next step will be the introduction of the addition of the Digital index (DX). It is a standard encoding for 35 mm and APS photographic...
Fig. 9. Example of attached file in the Additional Material section and downloadable from the PhotoFiRe website: some pages of A Guide to Identifying Year of Manufacture for KODAK Motion Picture Films.

Fig. 10. Example of advertising posters by Kodak and Ferrania in the Marketing & Advertising section and downloadable from the PhotoFiRe website.

film and cartridges. It was first introduced by Kodak in 1983 and consists of a barcode for the automatic setting of ISO sensitivity.
4 CONTRIBUTING TO THE DATABASE

The website, Photo FiRe² aims, not only at being a permanent and updated database of film technical data but also at being a reference point for researchers and experts. In fact, the proposed framework wants to promote the exchange of material to encourage the sharing of knowledge in film restoration by inviting users to participate in the project.

This feature of the website is represented by the Help us section. Here, everyone can contribute to the database sharing technical material, which will be subject to a process of examination, and then uploaded to the website with the corresponding reference. To share the material users should just complete the very simple form in figure 11, and subsequently we will contact them for the material (analog or digital) sending. Everyone that would take part in this project will receive their credit appearing in the Partners section of the website. Nevertheless, in this process there is no need for registration and the users can remain anonymous if they want to.

![Fig. 11. Screenshot of the Help us section from the PhotoFiRe² website.](image)

At the moment, as described in the previous sections, in the database we aim at sharing official material and information from different brands, thus it will be just subject to a simple process of validation and classification. Anyway, in the future, we will evaluate also the possibility to share documents and best practices coming from experts’ personal experiences concerning the handling of film materials in developing and printing steps, as well as technical advice and recommendations. Nevertheless, this extension will require a longer and exhaustive step of validation and a different classification.
5 CONCLUSIONS

This work intends to raise awareness of the need for retrieving and acquiring scientific data among conservators, restorers, and film professionals. Analyzing, investigating, and comprehending the chemical and physical composition of films is crucial to properly conserve the film and obtain a faithful reconstruction for digital restoration.

In this work, we focus mainly on the technical material collection, classification, and divulgation that lead to the creation of a wide open-source technical database of cinematographic and photographic materials used along with the history. In this way, this work aims also at supporting the work of conservators, restorers, and researchers and at starting to fill the lack of technical knowledge concerning film materials.

This research led to the cataloging of 601 films, each one with useful specifications and 233 of them also with attachments, including photographic images, illustrative sheets, links to useful sites or sensitometric curves; and 78 documents of additional materials.

However, this study encountered several issues, such as the difficulty in finding technical data, both online and on the archives of the production houses, sometimes nonexistent or often inaccessible.

The realization of this preliminary website wants to provide an access point for the sharing of knowledge, a key aspect of scientific research. Thus, the archiving and classification of any kind of material are also fundamental activities in the field of Cultural Heritage, not only to maintain a trace of the past but also to support the activities of restoration and conservation itself.

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