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Twenty-five years of digital conversion. Current situation[1].

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1 Introduction. A combined approach to the current situation

Our world is in the midst of a period in which the mass digitisation of collections of documents of all types is becoming increasingly common in many different spheres of activity. This is only natural in an information or knowledge society, as this era is often known, characterised by the widespread use of information technologies and in particular by one of its greatest developments: the Internet. Economic activity, the consumption of information and culture and social interaction increasingly depend on this channel. Anything that is not in digital form and published on the Web seems less and less relevant. It might be said that today, in 2011, scientific and technological activity and the availability of culture are closely linked to the domain of Internet-accessible digital information. Consequently, the community in charge of safeguarding the cultural heritage has not been able to remain indifferent to this process: to open up this heritage to society, digital versions of its content must inevitably be obtained and served on the Web through inclusion in a digital public library service, collection or archive.

For the last two decades, public institutions have been promoting the digitisation of the cultural heritage. Since the mid-1990s, for example, a variety of official European Union plans and programmes have included objectives aimed at promoting the production of digital content as a way to making the cultural and scientific heritage more accessible to society at large. One of the greatest initiatives was the creation and

[1] This study was conducted with the support of the Project "Los Medios Audiovisuales en la Transición Española (1975-1985): las imágenes del Cambio Democrático". Ref. CSO2009-09291. Ministerio de Ciencia e Innovación.

gradual implementation of Europeana[2], the European digital library, which focuses on integrating digital content provided by numerous institutions representing the wealth of Europe's documentary heritage into a common Web-based dissemination platform. The World Digital Library[3] is another instance of the creation of a collaborative international platform to publish cultural content on the Internet, and these are only two examples. The extensive and priceless photographic heritage held by museums, libraries, archives and collections cannot be marginalised from this trend toward digitisation and the establishment of common platforms to disseminate cultural assets. Clearly also, to rise to this challenge, the criteria and protocols relating to the technical and theoretical methods and approaches used in creating the digital versions that will be published on the Web must be standardised. In the absence of uniform practices, the results will be uneven in quality and respect for the originals, possibly leading to confusion and hindering the understanding and use of the asset published. The need for standardised criteria is especially acute in the fields of use where digital images must be held to the highest standards: education and scientific research.

Therefore, it is imperative that two social demands be met: the mass digitisation of the photographic heritage and the reaching of a consensus on the philosophical, technical and ethical criteria on which this practice should be based in the context of cultural assets of this type. However, the fact that the digitisation of the cultural heritage began prior to the advent of the Internet must not be overlooked. Many institutions have been gradually digitising their assets since at least a decade before the exponential growth of the Web in the late 1990s. Digitisation at organisations of this type has also been used for other purposes. One of the primary reasons behind the earliest digital conversions at major cultural institutions was the preservation of heritage assets whose inherent physical characteristics or poor condition made direct access by users inadvisable. Another use that was soon found for digital images was the reproduction of originals for copy services, exhibitions or the printing of catalogues, posters or other forms of cultural dissemination. This technology was also immediately identified as suitable for restoring images without having to physically work on the originals, or for supporting other functions essential to the preservation of the heritage, such as documenting and monitoring deterioration processes and safeguarding texts, images and artwork in case the originals are lost. Because of the magnitude of the

[2] Europeana. URL: http://www.europeana.eu/portal/.
[3] World Digital Library. URL: http://www.wdl.org/en/.

Internet's effect and the push to disseminate heritage collections, other perspectives on digitisation that involve certain quality and systematisation requirements may have been neglected in favour of some of the approaches that are becoming widespread in many institutions.

The rush to mass digitise materials may be a double-edged sword, and even more so when it appears that a consensus on the three types of criteria mentioned in the preceding paragraph has not yet been reached. The haste to place large collections on the Web or in internal query systems may have caused many institutions to lose sight of a more global approach to digitisation that would meet the comprehensive needs of this heritage and would take into account the uncertainty caused by a constantly evolving technology and chemically unstable materials difficult to preserve over time, for which the digital capture process may pose a significant risk to their integrity.

One peculiarity that must be kept in mind is the multifaceted context of the photographic heritage. A variety of situations is determined by multiple factors relating to the origin of the collections and also by the nature and conditions of the work at the centres where they are kept; different criteria may be used even within the same type of collection, depending on its origin and content and on the stage in the document's life cycle when the digital capture is undertaken. In the case of a press photograph, for example, in the context of its primary use in a journalistic medium, digitisation may be guided by the quality criteria prevailing for print or digital publication; however, in a context of cultural use, the digital conversion of the same photograph may be governed by very different criteria if it belongs to a collection donated to an institution. In a very broad geographic context, there is also a great disparity in access to economic resources, training and technology.

That the application of very strict criteria would entail a high cost per photograph to be digitised is a fact that cannot be ignored. In some contexts, the criteria to be applied may be a result of budget availability or the possibility of commercially exploiting the collections, rather than of the value of the materials. If criteria valid for any geographic, political or administrative area are to be established, this diversity must be understood and accepted. The imposition of strict and inflexible quality criteria for all cases would be questionable, as it would lead to the risk that certain collections might never be digitised and thus never disseminated via the Internet. Any proposal must be efficiently implemented to make digitisation cost- and time-effective; otherwise, it will be useless for voluminous photographic collections or in cases where the economic situation is not

conducive to the undertaking of cultural projects. Nevertheless, the fact that this diversity of circumstances must be addressed is no excuse for laxity in digitisation; at least some minimum criteria should be met to make this digital conversion feasible and ensure that the resulting images are suitable for their varied uses and are a worthy and accurate representation of heritage assets with great social value.

This is a time of great tension, produced by the uneasy coexistence between the requirements of a rigorous approach for the digitisation of the photographic heritage that would meet the needs of both the collections (in terms of the wide range of types of material, genres and content) and the user community (with regard to the variety of profiles and training levels) and the urgent demand for many institutions to make these photographs available in an information system and to do so quickly and at an affordable cost. Also contributing to the tension is the pervading yet false sensation that the use of document digitisation technologies is easy. Digitisation has become firmly established in the domestic and amateur environments: owning a scanner, digital camera, photo printer and image editing software is as normal in many countries as having Internet access or one or more television sets. Digitisation also seems fairly simple and natural. Image capture devices and editing programs make this tremendously complex technology transparent; they are sold factory-configured and their automatic settings produce a very acceptable digital image in terms of contrast and colour saturation. There are many institutional circumstances that make it difficult to enforce the principle that the most appropriate tools, work protocols and quality criteria should be used in the digitisation of photographic collections that are heritage assets.

Further to the argument set out in the preceding paragraph and given the vast variety of types of images comprising the photographic heritage, the risk involved in trying to over-simplify the complex process of digitising that heritage must be acknowledged. This problem is evinced by the fact that some digital capture guidelines or recommendations are far too general, advocating a single standard configuration for certain technical variables applicable to broad categories of materials that fail to take account of the specific characteristics of some types of materials or individual items. This generalisation also results in a simplification of the number of technical decisions provided for in these specifications, which are limited to a few variables (spatial resolution, channel bit depth, colour system, file format and compression method), with no regard for other key factors whose omission negates the value of these variables as a quality parameter. These include the state of the digital image, colour space, device

calibration and characterisation techniques, colour space conversion procedures, guidelines for the use of digital editing processes, technical metadata and the evaluation of devices and images through the application of physical parameters (resolving power, uniformity, noise, colour encoding error, chromatic aberration and so forth).

Fortunately, considerable scientific research has been conducted in the last 25 years in the area of the digitisation of the cultural heritage. Significant efforts have emerged to provide the community with a rigorous corpus of criteria and recommendations that systematically and globally address digitisation requirements for heritage document collections, including photographs. Some of these efforts have yielded printed or electronic documents that have been widely distributed.

Publications on the use of digital images in the heritage domain, especially in relation to museums, have been commonplace since the mid-1980s. Around that time, digitisation began to be seen as a very effective alternative to traditional reproduction using physical-chemical photographic media (photographs or microfilm) because of the possibility of providing on-line access to digital images of objects described in information systems. Subsequently, dozens of national and international consortia, in which museums, universities, libraries and archives participate, began to proliferate. Their purpose was to provide collaborative platforms with an eye to addressing the challenge of digitising materials and creating on-line query systems to access them. At the same time, many institutions were undertaking initiatives aimed at attaining the necessary level of conceptual and technological development to rigorously create these systems, supporting them with the establishment of research departments dealing with these issues.

In the early 1990s, mass digitisation projects were first proposed, involving the digital capture of tens of millions of documents or works of art. This trend triggered debate on the best method for ensuring that such projects are effective, efficient and feasible. The reflections, criteria and methods for capturing the heritage that came about as a result of the first experiments involving the mass digitisation of collections led to important papers that were published and disseminated through workshops, national and international conferences, professional journals, books and institutional websites. Even though many of them were meant to resolve the needs of specific institutions, they are applicable beyond the contexts for which they were intended and contribute as a whole to the creation and dissemination of a well-defined working model valid for a variety of institutional environments and situations. Many of these pioneering works adapted the

philosophy and technical criteria that had been used in creating preservation surrogates using traditional means to the characteristics of the digital medium and the new possibilities it affords. These criteria have been fine-tuned over the years to tailor them to a constantly evolving technology; therefore, there is now a high-quality, up-to-date corpus of work.

Significant contributions have been made in this vein toward the definition of specific criteria for the digitisation of photographs, such as the ones promoted by professionals belonging to the Rochester Institute of Technology's Image Permanence Institute (IPI) (Reilly and Frey, 1996; Frey and Reilly, 1999 and 2006; Frey 2000; Süsstrunk, 2002) or the approach made to digitize the collection of wet collodion glass plate negatives of the Pacific Scientific Commission (Martínez, 2002). Other initiatives and projects have made an effort to encompass the wide range of documents typical of library and archive collections, although specific criteria for photographs were also included. Because of their great influence on the heritage community on an international level, mentioned should be made of the workshops and tutorial organised by the Cornell University Department of Preservation and Conservation[4]; the work carried out by the now-defunct Research Libraries Group (RLG), especially the valuable *Guides to Quality in Visual Resource Imaging*[5]; the guidelines from the U.S. National Archives and Records Administration (NARA, 2004; FADGI, 2010); and the manual entitled *Moving Theory into Practice: Digital Imaging for Libraries and Archives* (Kenney and Rieger, 2000). A rigorous and exhaustive analysis of the situation in this field that offers a chronological view of the evolution of the criteria for the digitisation of the documentary heritage, including photography, was authored by Puglia (2007) in the journal *RLG Diginews*, unfortunately now discontinued. Another initiative that must be mentioned is the creation of platforms for the integration of knowledge and the dissemination of digital imaging technologies and practices in the heritage and educational spheres. One of the most significant was the Technical Advisory Service for Images (TASI), now JISC,[6] and another, specific to heritage photographs, was the project, since cancelled, known as *Safeguarding European Photographic Images for*

[4] *Moving Theory into Practice: Digital Imaging Tutorial*. Available on the Internet: http://www.library.cornell.edu/preservation/tutorial/contents.html

[5] Initiative carried out from 1998 to 2000 by the RLG in cooperation with the Digital Library Federation and the Council on Library and Information Resources.

[6] *JISC Digital Media*. URL: http://www.jiscdigitalmedia.ac.uk/

Access (SEPIA), under the auspices of the European Commission on Preservation and Access (ECPA).

Contributions of this type have been aimed at addressing the various challenges relating to the digitisation of collections, including a comprehensive proposal that would encompass every aspect of a digitisation project, from its philosophical basis to the use of the latest advances in imaging technology. They obviously do not ignore one of this field's main facets: imaging science and technology and its sub-disciplines, among which colour technology is very relevant for the digitisation of photographs. As far back as the mid-1990s, certain approaches showed an interest in providing a scientific basis for the digitisation of the photographic heritage supported by such imaging technology contributions as the aforementioned works by Frey and Reilly, which proposed the incorporation of methods and metrics to gauge the performance of photographic capture equipment through the application of physical parameters. Other papers from that period even explored the possibility of applying technologies other than the ones created for the graphic arts market, the dominant model in many of the digitisation processes at that time, to works of art and valuable documents, and proposed the use of multispectral image capture techniques. Since the beginning of this century, other interesting papers have been published regarding the introduction of quality assessment techniques from the field of imaging engineering, based on objective measurement methods for capture devices and for the images themselves, in heritage digitisation projects (Williams, 2000, 2002, 2003 and 2010; Berns and Frey, 2005; Puglia, Reed and Rhodes, 2004; FADGI, 2010; Still Image Working Group, 2010).

The work carried out in the standardisation of a variety of technical issues relating to the characterisation and quality control of capture devices and of images has played a key role in the definition of systematic criteria for the digitisation of the documentary heritage. Especially active in this field is ISO Technical Committee 42, Photography (ISO/TC42), which has issued some important standards (ISO, 2000; ISO, 2003a; ISO, 2003b; ISO, 2004a; ISO, 2004b; ISO, 2009a; ISO, 2009b; Loebich and Wueller, 2001; Williams, 2003). As a result of these efforts, over thirty technical standards applicable to the digitisation of the photographic heritage are now in place. One development that is worth highlighting is the creation of a unified quality assessment chart, intended to evaluate the main physical quality parameters to measure the performance of image capture devices and digitisation processes: the Universal Test Target (Wueller, Dormolen and Jansen, 2009). These efforts have also led to the development and

marketing of software packages and standardised test targets that enable assessments of this type to be performed relatively simply, such as the Golden Thread system by Image Science Associates[7], IE Analyzer by Image Engineering[8] and Imatest[9].

Only a few relevant contributions have been selected here, the ones that have had the most influence on the development of stricter criteria for the digitisation of the documentary heritage in many institutions. They were primarily chosen on the basis of their applicability, to a greater or lesser extent, to photographs, and because of the fact that they were widely disseminated and thus served as a model for the development of the digital image capture specifications on which much of the most rigorous digitisation activity now seen in a great many geographic and institutional settings is based. Other very good initiatives that should have been mentioned have necessarily been omitted, and apologies are due to those institutions, professionals and organisations whose meritorious work has not been acknowledged.

While these important, high quality contributions are very useful, this community's commitment to the heritage should lead it to continue advancing along the lines they established, for two reasons. Firstly, as pointed out in some of the aforementioned papers, a great many important issues relating to the digitisation of the documentary and artistic heritage have yet to be resolved, which means that more research work is required. Secondly, the technologies involved in the capture, processing and storage of digital images evolve very quickly, and therefore, professional standards and practices must constantly be adapted.

2 Defining a corpus of criteria for the digitisation of the photographic heritage

This section briefly summarises some of the main issues that should be taken into consideration at this time with a view to defining a corpus of rigorous digital conversion criteria in keeping with the needs of the photographic heritage. Many of the ideas set forth are included in some of the papers mentioned in the preceding section. The wide range of issues arising from the technical and organisational complexity of a digitisation process made it necessary to severely limit the selection, and only those considered high

[7] Website at http://www.imagescienceassociates.com/
[8] Website at http://www.image-engineering.de/index.php?option=com_content&view=article&id=137&Itemid=50
[9] Website at http://www.imatest.com/

on the agenda at this time are discussed. This type of summary may be useful in diagnosing the current situation as a guide for future areas of research.

a) *Determining the scope of digitisation*

Decisions relating to the technical elements of the work flow involved in digital capture and storage greatly depend on the perception of the scope of digitisation, i.e., what those concerned believe should be represented in the digital versions in terms of degree of precision and purpose. A clear definition of this scope would make it possible to suggest exhaustive and explicit criteria to guide every decision relating to which technology to use and how its different variables should be configured. Many questions arise during the process of establishing digital conversion criteria for the heritage, for many of which a solution remains outstanding. Furthermore, not all of the answers provided have led to consensual, widely followed procedural guidelines. A discussion of some of these questions follows.

Should the complete photographic item be represented or only the image or images it contains? An effort should be made to arrive at a sufficiently detailed criterion for the many types of photographic processes and circumstances that determine the intrinsic value of the item in terms of both its physical and semantic properties. For example, should an accurate digital representation of the case or frame protecting a nineteenth-century direct-positive photograph be considered in same light as the film containing a negative from the mid- to late-twentieth century whose photographic process, manufacturer and state of preservation are perfectly documented? What if the negative forms part of an unpublished series by a very prominent photographer? For certain types of photographic items, the aesthetic and functional aspects of some of their elements, over and above the images they contain, may be very relevant to understanding them as iconic messages and cultural artefacts, or to delighting in their artistic value. A digital representation that is sufficiently complete and does not alter the physical state of the photograph at the time of its digital capture may also be of great use in preservation work. The *digital image is not the original item*, however; it is merely digitally encoded visual information about the captured views of the item. It is not a question of clarifying the value of these physical elements in order to interpret and preserve the photographic item, but of defining the value of the digital representation of these elements as necessary visual information about the item, and to what extent some of this physical

data can be consigned to a text description of the item or can be inferred once the photographic process used to create it has been identified.

Another important issue would be what degree of detail it is useful and feasible to achieve in representing the spatial, tonal and colour information of the image or images in a heritage photographic item. The degree of detail in the representation determines which values will be selected for the digital capture and storage variables (sampling resolution, bit depth, colour system and space), or the need to use equipment with a high performance level for physical parameters relating to resolution or tonal capability (SFR, signal-to-noise ratio, chromatic aberration and dynamic range, to name a few). Therefore, it is very relevant to determining the feasibility of a heritage digitisation project that entails the capture of large volumes of material. Should the representation be limited to visible details or go further? For example, in a screened image, is it necessary to capture the screen, barely visible or invisible to the naked eye, or should it be eliminated during digital capture so as not to cause a moiré pattern in the reproduction? Or, how should the grain of a photographic print be handled during the capture process? Will it always be possible to determine whether it is artistically significant? And should it be included in the digital image only in such cases? Other no less relevant issues refer to the views to be taken of each item: how many should there be? To what degree should three-dimensional features be taken into consideration, and what angle of light should be used to highlight them? In the case of direct-positive images, should there be views of the full plates removed from the protective case in order to have a digital representation of the complete image? How should the physical complexity of an autochrome plate be digitally documented? The great diversity of materials found in heritage collections as a result of the various types of physical-chemical photographic processes used gives rise to these and a host of other questions. Providing overly general criteria can be risky, not only because of the aforementioned diversity, but also as a result of constraints that may arise due to different production and use contexts, states of preservation, volumes of materials and the value that both individual items and specific collections may have acquired because of a variety of historical circumstances.

b) Maintaining the state in which the photographic material to be digitised is presented

Closely related to the questions discussed earlier is another equally important issue, for which uniform criteria are still needed: what physical-chemical image state should be represented? Should the state of the image in the item to be digitised be represented as is, or should it be adjusted to reflect the originally intended medium?

Figure 1. Different ways of understanding the digital capture of a glass plate negative.

In the last two decades, standard practice has entailed changing the state of the image during the digital capture process for both modern and historic negatives and slides: the image obtained is digitally processed so that its graphic and artistic content reflects the properties that the image might have had if it had been reproduced in the reproductive medium for which the original photographic material was intended. In other words, the visual properties of the image in the photographic material being scanned are not preserved. The need for a criterion that governs this situation is essential in the case of the digital conversion of photographic materials that require an additional step for reproduction, such as slides and negatives, to cite two examples. The change of state during digital capture is not always very evident in modern slides. Their contrast conditions are designed to ensure that the image is pleasing when it is being projected in a dimly lighted room. Excess of contrast incorporated during processing compensates for the loss of contrast during projection. How should the digital image of a slide be captured and encoded? Using an estimation of how the slide would typically be seen when projected in a dark room, or with colours respectful of the chemical image subjected to the capture process? The latter may produce an image with sharp contrasts, little detail in the shadows and a colour cast, and as a result, would not be suitable for direct viewing. It would also be inaccurate if the digitisation criteria to be followed specified that the graphic content that is aesthetically acceptable when printed or viewed on the screen should be obtained directly from the digital capture with no need for

further processing. Many software applications for the creation of ICC colour profiles for present-day slides include the means for compensating for this excess contrast right in the profiles. If the masters are converted to a certain colour space for storage through the use of these slide profiles, a reproduction criterion that cannot be reversed is applied to the master image. In the case of a modern colour negative, the difference between the state of the image in the negative photographic material and the state in which it might be represented in the medium in which it was designed to be reproduced is much greater. Therefore, account must be taken of the implications of digitising the negative with either its actual appearance or with that of a positive, or both, on the efficiency of the digital conversion project. Modern negative scanners are designed to produce a digital representation that reflects the appearance of a positive print of the photographed image. Is this approach valid in scanning heritage materials? If not, in what cases might it be acceptable?

Another related issue is to what degree it is acceptable to digitally eliminate the effects of the deterioration of the materials to be digitised to bring them to a certain state of preservation, if no supplementary digital master is kept (and made accessible to collection users) that represents the state of the item prior to its digital restoration.

Answering these questions in the context of heritage materials is much more difficult than it would be in other situations, such as a scan intended exclusively for graphic arts production. However, this criterion would be very risky in this particular context if it were devoid of other considerations. If the aim is to produce a digital representation of heritage materials according to a specific reproduction criterion that would liken the digital image to a particular state (for which the photographic material was originally intended or similar), guidelines would have to be followed that would ensure an image respectful of the conditions of the original reproduction medium. This would require in-depth knowledge of the technology used to create and reproduce the digitally captured photographic items. The application of an aesthetic principle guided exclusively by the intent to produce images pleasing to the eye should not be permitted, at least for a master image, as this would involve reinterpreting the contrast, colour and spatial attributes through a process that hinges on the subjective criteria of the digitisation equipment operator. This would make it impossible to achieve an accurate portrayal of the physical characteristics of the original at the time of the digital capture and to determine whether the operator correctly interpreted the image or not.

c) *Selection of digital image states and colour encoding systems*

The extensive literature on colour management from the colour technology field identifies two major states in which a digital image can be encoded: input/scene referred and output referred. The former state is commonly known as unrendered, and the latter as rendered. Visual information is encoded for images in the input/scene-referred state according to the colorimetry or dynamic range of the real or hypothetical original photographed scene (Giorgiani, Madden and Spaulding, 2003). In this case, it would be the view of the digitally captured document. A capture in digital camera RAW format processed prior to its rendering in an output color space, an image encoded in HDR (high dynamic range) format or in RIMM or ERIMM RGB colour space would be so classified. In the output-referred state, the colorimetry on a specific output device or type of device is represented, such as a printer or monitor display. A capture converted to an sRGB or Adobe RGB colour space and adjusted so that it is appropriately displayed on a monitor would be output-referred.

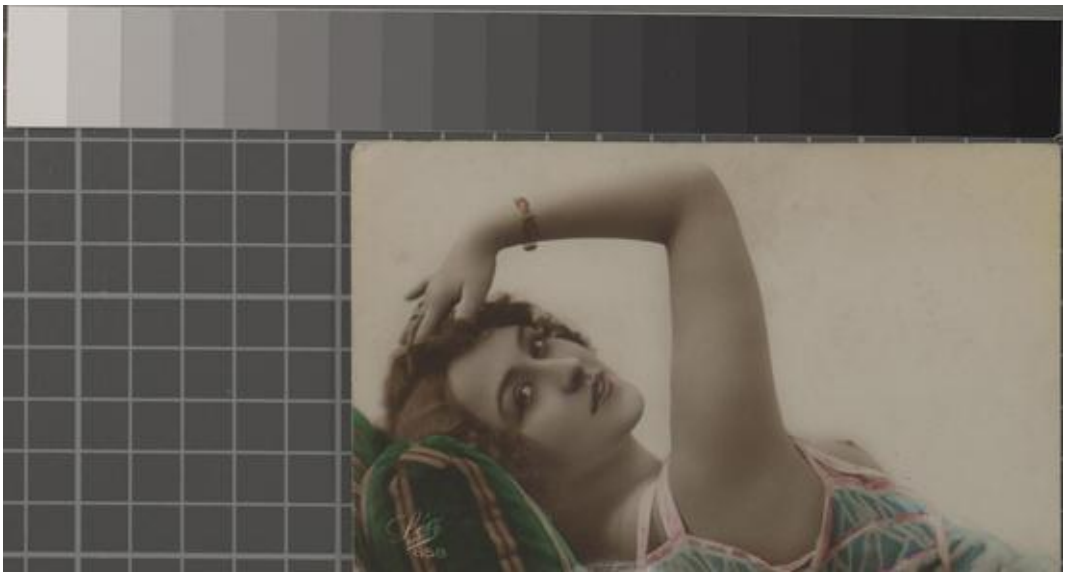

Figure 2. Simulation of a direct visualization on a monitor of two different digital image states from the same view of photographic image on paper: unrendered (up) and rendered (down).

Input/scene-referred images have the advantage of representing the tonal and chromatic features of the originals with greater richness, as the information has not yet been processed to adapt to the dynamic range and gamut restrictions of a specific device or type of medium. This additional information may be critical if the aim is for today's digital conversions to remain functional in a yet-to-be-defined technological future, or to be able to determine with some degree of accuracy the optical characteristics of the original image from its digital versions. The disadvantage of unrendered images is that they cannot be directly viewed or printed; they require additional processing for adaptation to the colour space of an output device. If this image status is chosen for the masters, the purposes for which the heritage is digitised mean that supplementary rendered versions must be created, which would entail an additional burden in terms of time and resources in the digital conversion process.

The two image statuses may require different capture devices and methods, processes and encoding systems. The consequences of selecting one or the other are very significant in terms of ease of access and knowledge required to use these technologies, the efficiency of the digitisation process and the need to increase storage and digital preservation resources. Therefore, it is essential to arm the heritage community with the criteria it needs for decision-making in this regard.

Different encoding options are in place for unrendered images, which may be useful in cases where conventional RGB capture cannot effectively duplicate the richness of

tone or colour of the original images. One of these is HDR capture and encoding, which can be used for quality scans of images with large density margins, especially when capture devices with the necessary dynamic range capability are not available. When this technology is used for the digital capture of heritage materials, several questions arise for which criteria should be defined, such as the most suitable HDR encoding and capture methods, the tone mapping methods that are closest to the originals for creating printable or viewable versions, or how to make these captures compatible with ICC colour management technology. A colorimetric or multispectral capture method may be required for greater precision in representing the colour of certain originals. Most scanners with RGB capture used nowadays to digitise photographs are designed to accurately reproduce modern photographic materials. However, for other materials with different types of colorants with varying spectral absorption characteristics, the colours will not be represented as accurately. In a colorimetric encoding system, colours are represented according to measurements from the spectrum visible to the human eye. One advantage of this method is that it is based on well-established, standardised colour measurement recommendations from the CIE [International Commission on Illumination], such as CIELAB or CIE XYZ (Giorgiani, Madden and Spaulding, 2003). In a multispectral system, colour encoding is based on the capture and representation of the light spectrum from each sample taken from the image. Multispectral capture has some obvious advantages in the context of the heritage: it is the most complete method for capturing the physical colour attributes of the item to be digitised. This wealth of information makes it possible to eliminate problems that complicate the accurate reproduction of colour, such as metamerism or difficulties in producing reproductions with the appearance that the digitally captured item would have with different illuminants. The drawbacks of these techniques in the current state of the art are also evident: the high volume of data to be stored digitally in order to have a complete enough spectral representation of an item, the limited access to equipment and software for creating and working with images of this type, the lack of commonly used file formats for storing this type of data and the need for additional, technically complex processing beyond the capabilities of readily available commercial products in order to achieve versions viewable or printable in conventional RGB colour representation systems. However, compact spectral encoding is an option that can mitigate the problem of the large amount of data to be stored, as it uses only five to eight channels. The

benefit of compact spectral encoding is that it ensures compatibility with today's colour management models (Bala, 2003).

To encode in a colorimetric or multispectral system, the RGB densitometric data obtained from the conventional capture device must be transformed. Complex device characterisation and transformation methods must be used to acquire the exact colorimetric or spectral data from each of the samples that will later form the image pixels. The only efficient option available is the application of techniques that facilitate the capture of these data through the use of conventional cameras and scanners. The literature on the subject is extensive, resulting from numerous research projects on the colorimetric or multispectral digital capture of works of art, documents and other types of items that require a high degree of accuracy and versatility in colour representation. These techniques are also used in the digital restoration or rescue of texts in historic documents.

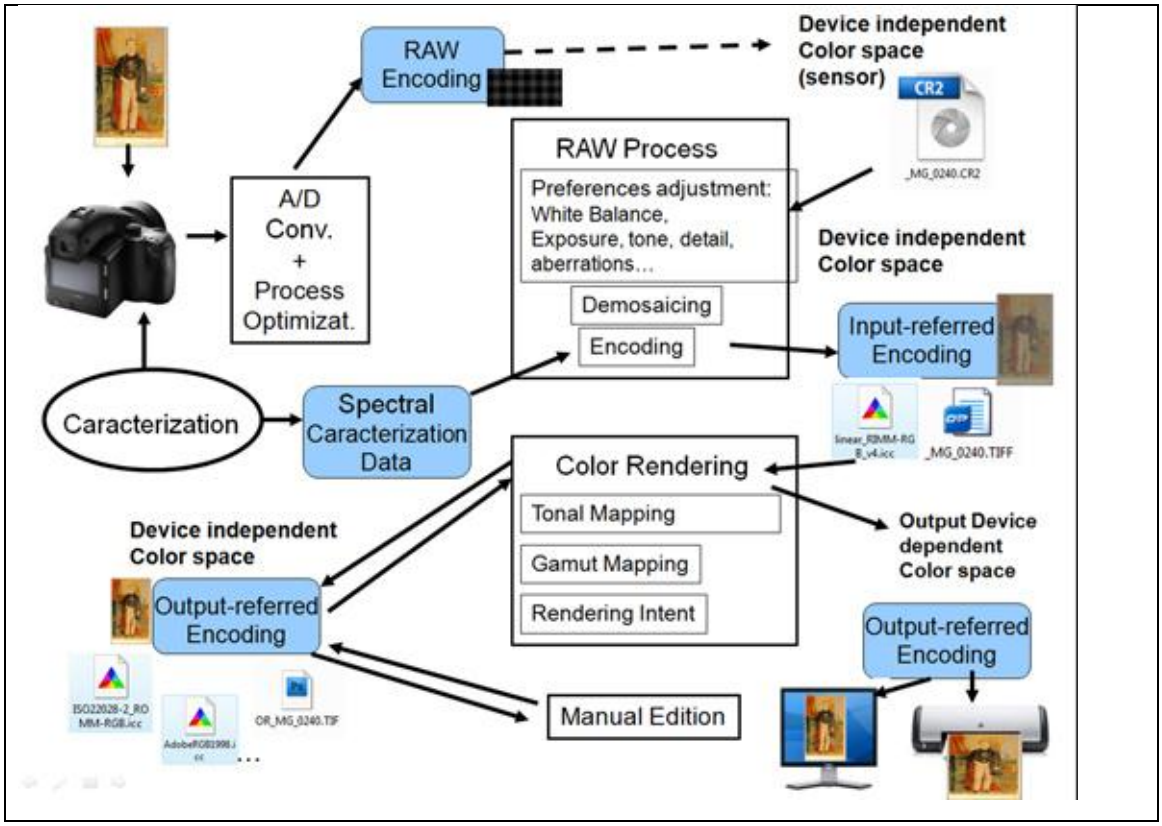

Figure 3. Typical workflow using a digital camera.

d) Preservation masters, production masters or both?

Two major master file concepts can be distinguished, one or both of which can be used for the digital capture of the heritage: preservation masters and production masters[10]. The former are used to create digital representations that can replace the originals, and there should be some strict requirements governing the accuracy of the information to be represented in terms of colour, tone and space. The aim of the latter is to directly produce visually acceptable versions that can be viewed on a monitor or printed, mainly to support the dissemination of the collections and their reproduction in print or photographic form. These two approaches vary greatly in terms of the technical and efficiency implications for digitisation projects. Experts in the digital conversion of the heritage unanimously acknowledge the considerable difficulty involved and the technical demands and resources required to meet the ideal standard for preservation masters.

A preservation master should accurately reflect the state of the image material to be scanned, regardless of whether the image represented in the digital version greatly differs from the appearance it would have in a typical reproduction medium or of its state of preservation. In order to maintain as much capture information as possible in a preservation master, the image data must also be kept in raw form, in other words, with minimal processing. Metadata characterising the tonal, colour and spatial performance of the device must be kept with the raw data, so that the raw information can be processed to produce visually accurate viewable or printable output; they should at least help determine, in an objective manner, to what degree the digital representation is different from the physical characteristics of the original. Supplementary versions transformed to a colour space suitable for the printing or viewing of the image must be created from the raw masters. These versions may also require tonal and colour adjustment to adapt their representation to the characteristics of a specific output medium. At first glance, an unrendered digital image seems to be the best technological option for masters of this type, as long as the capture device has this capability.

[10] The terminology contained in Appendix A of the U.S. National Archives and Records Administration (NARA) Technical Guidelines for Digitising Archival Materials for Electronic Access: Creation of Production Master Files – Raster Images (2004) has been used. This document contains one of the most concise yet systematic descriptions of preservation master requirements, as compared to those of production masters. One of its advantages is that it is specific to the photographic heritage. It is modelled after the Technical Requirements for the Duplication of B&W Negatives: Shadow Normalization Tone Reproduction (2001), accessible on-line (http://www.archives.gov/preservation/formats/bw-copying-specs.pdf), which describe some very demanding requirements for achieving densitometric characteristics that closely match those of the originals for the creation of photographic reproductions of historic negatives on chemical media, so that the duplicates can be used and copied the same as the original negatives themselves (Puglia, 2007).

The advantages of a preservation master for meeting heritage digitisation needs are great: raw image data are saved so they can be adjusted to the dynamic range, contrast and gamut of a specific viewing or print colour space. These data represent all of the image information that the device was able to register during capture. With this information, it is easier to reconstruct the tonal, colour and spatial characteristics of the originals. Thus, master images can be used for a wider range of devices and applications, and technological developments in the viewing and printing of images can be confronted with greater confidence. However, the disadvantages of these masters are also evident: the consumption of resources in digital capture, storage and processing skyrockets. An additional problem is that the technology that must be used to meet the requirements of a preservation master is not easy for those outside of the community of scientists and digital colour technologists to understand, and even less so with the device characterisation and capture tools that are most commonly available to many institutions holding the photographic heritage. More progress should be made toward exhaustively and precisely outlining the advantages and requirements of a preservation master for heritage photographs, describing detailed digital capture, processing and storage protocols through which images of this type can be generated and developing or more widely disseminating digital capture, equipment characterisation and processing software and hardware.

Production masters are encoded in a rendered colour space appropriate for editing, which is usually a device-independent RGB space that simulates the performance of an average output device, such as sRGB or Adobe RGB. Therefore, the image does not directly represent the captured view of the original, but the image that will be viewed or printed. The conversion of the device colour space to the final colour space is usually performed through ICC colour profiles, or by directly editing the image obtained in the final colour space, or by a combination of these two approaches. A change in image status in production masters may be justified under some circumstances and with certain materials, as long as the criteria used in the transformation are documented.

The advantage of production masters is readily apparent: storage and the process of capturing, disseminating and reproducing images are vastly simplified; as a result digitisation costs are lower, which means that a greater volume of materials can be converted. The fact that most image editing and digitisation software and equipment on the market are designed and configured to facilitate this approach must also be taken into consideration. Many default settings for tools of this type yield results that are

visually acceptable in commonly used output devices and image editing and viewing software; therefore, "turnkey systems" that can be used directly with a minimum of configuration are readily available. The disadvantage is also clear: these masters save less information and are less likely to be adaptable to future device representation possibilities, which may be much greater than the current ones. The production master approach is well suited to the functions of disseminating the heritage via the Internet and making printed copies. The question is whether this approach, which may be seen as more practical for achieving the aim of disseminating the photographic heritage to society, would meet all of the digitisation objectives in the context of the cultural heritage or not, and whether it would always be applicable to heritage values.

e) *Comprehensive characterisation of capture devices*

Generally speaking, conventional scanners and digital cameras are based on a capture system that encodes colours in terms of red, green and blue densities. The encoding represents the response of the capture device to colour; therefore, the accuracy of the colour data depends on a precise characterisation of its colour registration system, and in particular its spectral sensitivity, the illuminant used and the spatial uniformity of its response. With this characterisation, the colour profile, which is used for the transformation from device-dependent RGB values to values in a standard colour system, such as CIE XYZ, can be found with reasonable accuracy. Fortunately, the literature dealing with systematic device characterisation methods is becoming increasingly abundant. An essential reference on spectral characterisation is the digital still camera standard, in which various methods are addressed (ISO, 2006). This standard is geared more to manufacturers or experts than to users of these technologies, as its application requires access to the raw image data generated by the device as well as complex software and equipment. However, products for characterisations of this type are already available in the market and are becoming more and more affordable.

A comprehensive characterisation should go beyond evaluating and registering the way the device responds to colour. It must take a series of physical quality parameters into consideration, essential not only for choosing devices that meet the quality criteria required for a heritage-related project, but also for subsequently determining to what degree the digital image differs from the original items. In the last two decades, numerous procedures, tools and standards have been developed to objectively measure the image quality performance of digital cameras and scanners. These methods make it

possible to assess a variety of quality-related issues arising in the registration of tonal, colour and spatial information: uniformity of document illumination, geometric distortion, chromatic aberration, depth of field, dynamic range, resolution capability, noise, artefacts, colour encoding error and so forth. As mentioned earlier, a wealth of research has been conducted in this area by imaging scientists and technologists, especially the systematic approaches intended for use in the digitisation of the documentary heritage (Williams, 2010; FADGI, 2010). This type of research highlights the tremendous complexity involved in systematising this process through guidelines feasible for use with the photographic heritage. When these techniques are applied, not only quality standards and measuring methods but also criteria for establishing acceptable ranges for the values resulting from the measurements are needed. It is not always easy to define an acceptance threshold in the context of the heritage, especially when the quality approach to be followed has not yet been fully clarified and outlined: should the criterion be good performance relating to physical parameters or a subjective visual perception of quality? The former does not always result in the latter, and this may be frustrating if the aim is to obtain aesthetically acceptable images. The correlation between human perception in judging the quality of an image and performance with respect to physical parameters is very complex and far from linear; therefore, finding a solution is no insignificant matter, and further progress is still needed.

The only way to ensure that device characterisation becomes a systematic practice in the photographic heritage community is by creating products for the evaluation of physical parameters that are accessible and suitable for use by laypersons. Although complete commercial packages including all of the elements necessary to perform characterisations are currently available, as mentioned earlier, there is still much to be done toward making these practices and products known in the heritage community.

The fact that a device has passed some performance tests with regard to physical parameters does not mean that the individual images captured with it will be free from quality problems, as there are many variables involved in the configuration of the device and the capture process itself, as well as the subsequent digital processing, that can reduce image quality, even if the equipment is known for its good performance. This means that images must undergo an assessment process involving the use of parameters, methods and test targets that are the same as or similar to the ones used for the device. However, a new group of what might be called “mechanical” parameters must be added,

related to the handling of the document during digital capture. It would include such aspects as the curvature of the document, its angle of inclination with respect to the sensor, the presence of reflections, folds, incorrect orientation or a “dirty” image.

f) *Capture device*

In the matter of the selection of a capture device, a dialogue should be opened between the heritage community and the manufacturers of imaging software and equipment to develop commercial solutions that are affordable to all types of institutions and are appropriate to the needs of heritage materials. In this way, risks can be minimised during capture and digital representations in accordance with the criteria for preservation and production masters can be facilitated.

g) *Colour management*

Colour management is inherent in the image capture, processing, viewing and printing paradigm presently in place. At some point in the digitisation-viewing/printing process, there must be some type of colour management, whether performed automatically by software or manually by a human operator editing the image using his own subjective criteria to adjust the colour and tone to match what he has in mind or a reference material. However, this always takes place in a colour space defined in accordance with a known ICC (International Color Consortium) standard. Therefore, the established colour management technology standardised by the ICC cannot be overlooked when digitising heritage materials. The current colour management paradigm was not created to ensure that images are an absolute colour match with the originals, whether in a file or in the medium in which they are viewed or printed, but to produce images that are pleasing to the eye or perceptually similar. This is why a properly performed colour management process may often result in a reproduction whose colour and tone do not exactly correspond to the digitised image. On occasion, achieving a visual result that is respectful of the original image requires additional, extensive manual editing after conversion to a colour space suitable for this process, or the editing of the ICC colour profile obtained for the device. However, the act of adjusting the image to a viewing or print medium by editing or converting colour spaces is irreversible; a great deal of information must be eliminated and transformed in the process, and there is no going back. This explains the many precautions taken in the context of the heritage in this type of master processing.

The current colour management model entails a series of problems that cannot be ignored, such as the possibility that the ICC profiles being created today will quickly become outdated, the incompatibility between different versions of the ICC standard, the difficulty or high cost involved in finding the right ICC profiles and even the fact that the ICC colour management model itself will likely become obsolete. Renowned experts have pointed to efficiency-related issues in the processing and representation of digital images and to security as possible factors leading to the obsolescence of the ICC profile standard, which would mean that a standard common RGB colour space would have to be defined for the digital encoding of images (Frey, 2002; Martínez Verdú, 2002), such as the standardised sRGB space. The sRGB space is greatly limited for the encoding of masters because of its narrow colour gamut; therefore, it should not be a technical option at this time.

h) Technical metadata

Extensive technical documentation in the form of metadata is required for both the digital preservation of converted images and a better understanding and use of the process. Today's metadata standards make it possible to amply document the technical features of digital images and the files that contain them: Exif for digital still camera images and NISO Z39.87, *Technical Metadata for Digital Still Images*, for any other capture medium. Nevertheless, further research should be conducted in this vein in order to achieve standards through which the data obtained from comprehensive device characterisations and from the quality control process for images can be encoded without ambiguity. For example, no technical metadata standard as yet includes assessment data for physical parameters in the necessary detail. On several occasions it has been claimed the need to attach this information to the digital images of the captured phtographs (Ruiz, 2002). A technical metadata standard must make it possible to embed metadata in file headers in the file formats customarily used in digitising heritage materials. It must also provide for the incorporation of a variety of metadata schemes, whether standardised or developed specifically for the purpose, to allow for the different types of metadata necessary for the contextualisation, identification, management and digital preservation of digital image files. At this time, the Adobe XMP system may constitute a metadata encoding model based on standards that provides for the incorporation of any metadata scheme, and meets the two aforementioned requirements. Its RDF/XML encoding affords it the necessary

flexibility to ensure interoperability. It appears to be a feasible option for consideration as a basis for the development of a system valid for the photographic heritage.

3 Conclusions: current needs and proposed future research

Scientific contributions regarding the digitisation of the documentary heritage and photographs in particular have established the basis for systematic research in this specific field of activity, and have ensured that this systematic approach is feasible and applicable rather than merely an elegant theory that is difficult to implement in the actual context of photographic collections. Much has still to be done to achieve unanimity and uniformity in some criteria, and to ensure transparency in the complexity inherent to technology in software applications and work protocols that can easily be used by the cultural heritage community. The difficulty at present lies in being able to apply this systematic approach in a variety of geographic and institutional contexts. A need is felt for more intense dissemination of criteria, more training initiatives and, in some cases, a change in mentality to head off the erroneous perception that superficial, low-cost digitisation solutions are acceptable for the photographic heritage.

At this time of great tension, the opportunity presented by the International Conference *"30 Years of Photographic Conservation Science"* is undeniable. Now is the best time to reflect on and propose the criteria that the heritage community needs and wants to follow to achieve far-reaching digitisation, to demand this type of digitisation, and to explain why it should be this way. Now is the time to propose future actions to define and reach a consensus on this subject and to use this consensus to create, or to identify and select, a corpus of international guidelines or standards for the heritage that would serve as a professional reference to prevent the problems referred to in the foregoing. Standards-based digitisation would not only benefit the preservation of photographic heritage assets, but would also promote their rigorous dissemination through the collaborative cultural platforms that are already becoming a reality on the Internet. The many standards now in place relate directly to the technical aspects of digitisation and can be applied; however, there is no single framework standard to incorporate all of the issues dispersed among this multitude of guidelines. This constitutes an obstacle to the application of existing standards, especially because many

of them are too complex to be understood and put into practice outside of the digital imaging and colour technologies community.

Furthermore, the community of experts in the diverse areas of the photographic heritage should reach a consensus establishing certain minimum quality requirements, certified compliance with which would guarantee that digitised images are suitable for the preservation and dissemination of this heritage, in a multidisciplinary context that would include experts from the various imaging science and technology disciplines that are developing the technology used in this field. The foundations for future work and the raising of awareness established during this international conference could be a starting point for achieving this consensus and the institutionalisation of this certification. Certification should provide for several levels of compliance, but all should guarantee rigor and complete validity for the heritage context, while taking into consideration the two major digitisation perspectives discussed earlier: preservation and production masters. This is a necessary requirement in light of the current diversity of circumstances and priorities among the organisations in charge of the safekeeping and transmission of the photographic heritage. Without some degree of flexibility, the dissemination of the valuable collections whose content should be made available through the Internet could be stalled.

Technology evolves very quickly, and the impeccable masters created today by dint of great effort may be light years from the state of the art within two decades, and the criteria in use at this time may even have become obsolete by then. Even though seemingly appropriate criteria are being used for the digital conversions currently taking place, a great deal of the photographic heritage may well have to be re-digitised in the future. Therefore, at least the most valuable photographic items should be digitised to the highest standards with very careful documentation, so that when drastic technological change does take place, it is more likely that the graphic information in digital format can be efficiently transferred to the new systems. Photographs are very delicate items, and their preservation is very difficult and costly. In a few dozen years, many of these valuable items may have lost a great deal of the information that is still stored.

Fortunately, science and know-how evolve, and a more refined and powerful technology will gradually become available to meet the objectives of this heritage. The market is sometimes far behind such advances, and many of the developments that could be implemented are not immediately evident. Unless the heritage community

keeps abreast of this progress, an abrupt technological paradigm shift could quickly make the criteria now being used obsolete and diminish the possibilities of using the digital collection so painstakingly constructed. Therefore, technological advances must be very closely followed to keep the community up-to-date. However, remaining up-to-date, be it not forgotten, entails a constant review of criteria, guidelines and standards.

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