DigitCult | Scientific Journal on Digital Cultures

Cultural Heritage and ICT: State of the Art and Perspectives

Goffredo Haus
LIM – Laboratorio di Informatica Musicale
Dipartimento di Informatica
Università degli Studi di Milano, Italy

Abstract

This paper tries to outline the evolution of the role of ICT with respect to Cultural Heritage showing how, starting from the first digitization projects, ICT has gradually become the major driving force for both preserving and exploiting Cultural Heritage. Specifically, the key role of advances in automatic recognition within texts and multimedia information are considered.

Published 11 May 2016

Correspondence should be addressed to Goffredo Haus, LIM – Laboratorio di Informatica Musicale, Dipartimento di Informatica, Università degli Studi di Milano, Milan, Italy. Email: goffredo.haus@unimi.it

DigitCult, Scientific Journal on Digital Cultures is an academic journal of international scope, peer-reviewed and open access, aiming to value international research and to present current debate on digital culture, technological innovation and social change. ISSN: 2531-5994. URL: http://www.digitcult.it

 DOI:10.4399/97888548960242

Introduction

Information and Communication Technologies (ICT) have been giving a growing support to Cultural Heritage (CH) preservation and exploitation for many years.

In a first moment the focus was on the cataloguing of CH and related metadata, transferring paper cataloguing cards into the corresponding digital metadata, then on the digitization of documents and multimedia objects such as photos and audiovisual recordings.

More recent developments of ICT provide us with the possibility to enrich and augment the original preserved information, in order to make it easier to retrieve and explore such information.

Digital Acquisition and Preservation

CH digitization campaigns has four main goals:

- the preservation of CH information;
- the preservation of the original media carrying CH information;
- the management of CH information;
- the exploitation of CH information.

The first step is anyway the acquisition in the digital domain of CH information, a process often referred to as *digitization* (Lynch 2002, 131-145; Noerr, 2003).

Digital Acquisition

We have to distinguish between information that can be dematerialized and then resynthesized, and information that cannot, either for physical reasons (e.g., 3-D objects) or logical reasons (e.g., intangible information).

Audio tracks, photos, and video tracks belong to the former kind of materials; they can be completely dematerialized and then resynthesized as the original.

From this point of view, handwritten and printed documents are similar to the mentioned materials, but only if we consider them as “images” to be digitized, neglecting their physicality (Coyle 2006, 641-645; Lopatin 2006, 273-289). In fact, it is not allowed to synthesize for instance the specific kind of paper of the originals documents.

3-D Objects can be rendered in the digital domain through 2-D digital images. Furthermore, a limited number of 2-D images allows 3-D modelling software to represent a 3-D object as a virtual object that can be rotated and observed from any point of view; but there is still no device able to physically resynthesize a faithful copy of the original 3-D object. Recent technologies – such as 3-D printing – are likely to be improved in the near future, going beyond the current limits with respect to the kind of materials 3-D printers are able to process.

A special case concerns the acquisition of information from native digital media, which could occur to migrate from a media to a new one, due to the obsolescence of the media, the need to preserve its contents, etc.

In this case, the most relevant question concerns the state of conservation of the original digital media, and the possible related need for rescuing it by suitable restoring processes (applied to the media, leaving the information contents as they are).

Digitization projects have historically contributed to the rescue of CH. In this context, it is worth mentioning some important issues:

- The cataloguing of CH must be carried out before or simultaneously with digitizing activities: it is not possible to digitize at best before knowing what has to be digitized;
- While fiddling with original cultural assets, often it happens to identify which objects require pre-restoring actions – such as heat treatment for magnetic media – before their digitization;

- Lacks of metadata, as well as cataloguing errors, could emerge from digitization activities. A real-life example is the discovering of music encores performed at Bolshoi and La Scala theatres: the original fliers did not contain any information about them, but they were included in audiovisual recordings and discovered only during media digitization (Haus and Pelegrin Pajuelo 2001, 381-388);

- Digital objects allow the preservation of the physical integrity of the corresponding original objects. For example, it is possible to consult the content of an ancient papyrus without any physical contact. In this way, digital objects significantly increase also the life expectation of physical objects.

Metadata & Indexing

Cataloguing and digitization are generally considered as parallel activities, both originating their own metadata.

Digital archives contain both metadata and the related digital objects. This can be implement in three different ways:

- Leaving cataloguing results in archives constituted by metadata only, i.e. separated from the related multimedia files;

- Implementing DBMS (Data Base Management System) instances which contain only metadata and integrating them with external multimedia files, generally by means of additional XML files in some standard format, such as MPEG7 or MAG files;

- Implementing MMDBMS (multimedia DBMS) instances which fully integrate metadata and related multimedia files. One of the first commercially available solution of this kind was developed by Oracle Corp. in the late 90s.

But, while a good MMDBMS solution could be fully satisfactory for preserving purposes, additional information is needed to improve information retrieval of CH metadata and related digital objects within MMDBMS instances. These kinds of entities should be both enriched through ad hoc relationships, either physical or semantic.

Early approaches were substantially based on hand-made integrations of additional information. Now the key improvement to make this approach effective and economically viable is the automation of the discovering of additional information. The most relevant advances of ICT are going in this direction.

Recent developments let us enrich MMDBMSs by:

- Relational data schema, coming from the analysis and design of DBMSs (Baca 2003, 47-55);

- Metadata tags, coming from taxonomies built up during the cataloguing process;

- Multimedia tags, coming from the manual and/or automatic recognition and indexing of multimedia contents.

Sounds, images, videos, and any other kind of multimedia objects could be classified according to their physical and semantic attributes. For example, in (Jaimes et al, 1999) a pyramidal structure of 10 indexing levels is considered for classifying images: 4 physical levels (type/technique, global distribution, local structure, global composition) and 6 semantic levels (generic object, generic scene, specific object, specific scene, abstract object, abstract scene). This framework integrates metadata with their digital objects by means of all the attributes belonging to the 10 indexing levels, making images distinguishable according to any combination of indexes, ranging from the lowest level (the kind of physical type/technique, i.e. the digital representation of colors) to the highest one (the abstract scene).

All these innovations, and particularly automatic multimedia tagging, strongly improve the retrieval, management, navigation, and exploitation of CH information.

Digital Platforms

Specific architectures for CH information systems must be considered to handle large CH archives, carefully distinguishing between preservation and exploitation needs.

Generally, a CH metadata archive is not too large; hypothetically, we can consider some thousands of data bytes per CH digital object. Then, we can consider as large metadata archives those having some millions digital objects inside, thus the corresponding storage dimension could be of some terabytes approx.

Multimedia CH archives are typically larger, at least 3 or 4 orders of magnitude. They are really “big data”, even if such a notion is dynamic: in the beginning – i.e. few years ago – some terabytes were considered big data, whereas today big data archives take up at least petabytes, more frequently exabytes, or even zettabytes. Since an ultra-high-definition video file (4K or 8K UHD) could be some terabytes large, CH digital archives requiring these space occupations are not uncommon.

Similar considerations can be done for images (with a roughly quadratic dimension growth as the quality increases) and audios (with a roughly linear dimension growth as the quality increases).

Therefore, a big amount of mass storage is needed to preserve CH multimedia archives, also because data formats for preservation should guarantee high quality and present no compression or a lossless compression. But the requirements of CH multimedia archives do not concern only the amount of mass-storage (Conway 2010; Crane 2002, 626-637; Haus and Ludovico 2006, 92-97); some additional aspects have to be considered, such as:

- The choice of the mass-storage solutions that assure the best life expectancy of archives: magnetic discs, magnetic tapes, optical discs, solid state drives, etc., or even a combination of them;
- The number of digital copies to produce, the more suitable memory technology for each copy, the logistic distribution of copies;
- The environmental conditions of archives;
- The system architecture for the exploitation;
- The performance tuning of the exploiting system, generally based on the expected number of clients and the desired response time;
- The choice of the MMDBMS and software applications to use, custom-made or already available;
- The level of adhesion to standards, in any component of the system architecture: cataloguing metadata, technical metadata, interoperability metadata, symbolic data, MM data, digital files, digital rights management, and integration formats;
- Digital monitoring, which implies controls on digital media to understand when refreshing, migrating, duplicating, or emulating actions are required to preserve information integrity.

A pragmatic suggestion could be to consider a solution as reliable when it is the most commonly adopted in the international context, as it regards the kind of media, media players, standards, formats: a large number of installations guarantees a better life expectation.

The question of security is multifaceted and must be considered too: accesses to archives by external visitors, technical staff, and managers have to be protected from unwanted actions, so proper user profiling policies must be defined and applied; moreover, data must be protected from intrusions, both in mass-storage and telecommunication devices, and in this sense encrypting technologies are commonly considered a good way to protect data flows.

A basic idea is that good exploiting policies can give a decisive contribution to get the resources needed for preserving CH. This is the reason why some CH archives are not free, rather they are used to generate economical revenues from CH, especially when CH is in the digital domain. When the economical front is opened, IP (Intellectual Property) has to be managed through DRM (Digital Rights Management) technologies: for sales/purchases,

allocation of rights, taxes, and so on.

Digital CH owners are increasingly interested in avoiding unauthorized content copies, virtually identical to the originals, that could be easily created and distributed, preventing right holders to collect their profits. The two most common remedies consist in downgrading the quality of the digital copies for exploitation – which are generated from the top-quality digital objects stored for preservation - and the protection of digital contents by DRM technologies. In order to prevent copyright infringements, a DRM system is a system of ICT components and services along with corresponding laws, policies and business models which strive to distribute and control intellectual property and its rights.

DRM systems implement two main functions: the management of the rights, assets, parties and licenses, and the processing of protecting functionalities, such as cryptography, watermarking and fingerprinting techniques are usually adopted to ensure either secure content identification, packaging and distribution, or copyright-infringement tracking and monitoring (Ku and Chi 2004, 391-403).

An advanced model for the management and protection of digital contents is described in (Ludovico et al. 2015, 10.1109/MMUL.2015.92). In this paper, multimedia CH information is modelled at different - but integrated and synchronized - levels of representation, i.e. by a multilayer approach based on a new concept – the *synchronization right* – that can be applied to any kind of timed multimedia information.

A further relevant topic is about accessibility, i.e. how “to lead the Web to its full potential to be accessible, enabling people with disabilities to participate equally on the Web” as it is defined and supported by the W3C WAI (Web Accessibility Initiative).

Finally, a large scientific literature is available about standards and recommended practices concerning how to do cataloguing, pre-restoring, digitizing, coding, indexing, organizing, preserving, downgrading, distributing, protecting, exploiting activities. From this point of view, it is worth mentioning the MPEG experience (Pereira and Ebrahimi 2002), and its main steps:

- MPEG-1 ISO/IEC11172 (1993), MPEG-2 ISO/IEC13818 (1995), and MPEG-4 ISO/IEC14496 (1999), concerning multimedia coding technologies;
- MPEG-7 ISO/IEC15938 (2002), concerning multimedia content description interface, i.e. indexing and tagging;
- MPEG-21 ISO/IEC21000 (2001), concerning IP management and protection.

Digital platforms consist in all this, and much more.

Exploiting Cultural Heritage by ICT

While acquisition and preservation in the digital domain are well acknowledged and established processes for CH, a more dynamic context concerns the exploitation of CH (Arnold and Geser 2008). Exploitation is gaining increasing importance for both dissemination and improvement of the economic resources for CH. A virtuous circle will, hopefully, happen so that revenues from exploitation will support preserving costs for CH.

It is very timely to consider a portfolio of relevant opportunities such as exploiting CH by means of digital communication channels, publishing campaigns that combine traditional and digital media, implementing integrated CH information environments based on the systematic application of standards for the sake of interoperability among digital archives.

Traditional and Electronic Publishing

All 2D digitized objects – such as text documents and images – can be considered for both traditional and electronic publishing media. So, a complete integration of publishing products could involve printed paper, optical discs (CD-ROM, DVD-ROM, BD-ROM), and web sites.

All digitized objects – including audio and video tracks too – can be considered for electronic publishing media. So, further integration of publishing products could be considered for optical discs and web sites only.

Furthermore, publishers have already begun to produce virtual CH products, i.e. publishing products only available in the web domain, without any physical media for the distribution of CH

information, such as textual and multimedia files, interactive applications, digital archives and portals, etc.

One of the most explored publishing products subject to technological evolution is the book, with many examples of integrated traditional/electronic vs. web-based trade policies.

Exploiting CH on the Web and Mobile Devices

A further relevant topic concerns special characteristics of CH exploitation by combining the web and mobile devices. Mobile devices are more pervasive than laptop and desktop computers, thus they must be considered as fundamental instruments for exploitation. However, user experience changes noticeably with so different technical characteristics, e.g. regarding screen size and interface controls. Publishing digital contents on mobile devices requires a great design effort, above all for visual elements.

Combining the web and mobile devices can result in relevant improvements to the distribution and integration of digital contents, also for communication purposes. Many web sites of both institutions – e.g. La Scala theatre – and companies – e.g. publishers of newspapers and periodicals – can be cited as examples.

A special field of interest for further developments concerns the use of geo-referenced information systems, e.g. the integration of maps in browser and mobile applications, because spatial information can support and enrich the virtual navigation of CH digital representation models (Baus 2005. 193-209).

Mobile devices could even improve the way digital services are provided, for example by means of licensing policies based on user-tailored customization of the service itself (Haugstvedt and Krogstie 2012).

Interoperability

A key to success is certainly to invest in interoperability of CH digital archives. Interoperability implies that the owners of different CH archives agree to join their digital contents, so that users can navigate multiple archives transparently as a single, larger one. For example, let us mention the complete production of a great painter: probably his paintings are exhibited in a number of different museums and art galleries, but they could be experienced in a single virtual gallery thanks to the interoperability among institutions' archives. A similar example in the music field is the corpus of works referring to a composer, i.e. handwritten and printed music scores, audio and video recordings of relevant performances, iconography, musicological studies, books, and so on.

Interoperability is the only way to achieve synergy among digital archives, so that owners of CH goods can improve dissemination of their contents, and – on the other side – users can take advantage from enriched services. Interoperability produces added value when the exploitation of CH is pursued (Osello et al. 2015).

For the sake of interoperability two main issues have to be considered: agreements among owners of CH contents, and technical feasibility.

The best way for getting complete interoperability among digital archives is to preventively design their architecture so that they can act as a single one. Unfortunately, this is unlikely to happen. Consequently, a realistic solution is based on the downgrading of the cataloguing records of the archives to the intersection of their metadata. In this field the Dublin Core Initiative gave a relevant contribution: the Dublin Core metadata element set, described in the ISO 15836 (2009) specification, is substantially a standard for cross-domain resource description. In general, the adoption of well-known and widespread international standards for both cataloguing metadata and multimedia digital contents is a good starting point. The Library of Congress website contains interesting discussions about these topics, and the strategic plans they periodically publish are useful guidelines in this field.

Future Trends & Perspectives

So far, ICT has mainly supported preserving goals, but the most relevant developments we can expect in the near future surely concern improvements in the exploitation of CH.

The most spread approach in CH digital projects consists in a weak application of the dated concept of relational DBMSs: in those cases, cataloguing metadata "are" the archive and multimedia information are hung up in some way to related metadata.

A better approach adopts an extended concept of relation, by indexing multimedia contents through metadata, and importing digital contents into DBMS instances.

The most advanced approaches try to fully integrate cataloguing metadata and related digital contents, placing both metadata and multimedia files into the data schema together with additional indexing data (Veltman 2005).

In the following, some positive effects achievable through the last approach will be outlined. Some examples refer to music because music knowledge and the related information can be seen as a paradigm for the most complex CH modelling and representation issues: music information includes metadata, handwritten and printed documents, audio and video recordings, images, time-spatial information about people, instruments, and sounds.

Preserving and Exploiting Intangible CH

While traditional CH concerns information mostly related to the material world – such as buildings, monuments, books, artworks, artefacts, and even natural heritage such as landscapes and biodiversity – in the virtual domain another kind of CH can be preserved and exploited: intangible cultural Heritage (ICH).

UNESCO states that ICH "means the practices, representations, expressions, knowledge, skills – as well as the instruments, objects, artefacts and cultural spaces associated therewith – that communities, groups and, in some cases, individuals recognize as part of their cultural heritage. This intangible cultural heritage, transmitted from generation to generation, is constantly recreated by communities and groups in response to their environment, their interaction with nature and their history, and provides them with a sense of identity and continuity, thus promoting respect for cultural diversity and human creativity".

The most relevant domains in which ICH is manifested, according to UNESCO, are the following:

- Oral traditions and expressions, including language as a vehicle for ICH;
- Performing arts;
- Social practices, rituals and festive events;
- Knowledge and practices concerning nature and the universe;
- Traditional craftsmanship.

Typical examples are performances such as singing, music, dance, drama, but also cuisine and crafts' skills.

What has been orally transmitted can be digitally represented by symbols and signals, and then preserved and exploited. A number of EC research projects aiming to model, preserve, and exploit ICH has been funded in the last years. A recent work which discusses this topic from the educational point of view is (Ott et al. 2015, 1314-1319); a comparative study about web specificities can be found in (Severo and Venturini 2015).

Navigating, Retrieving, Interacting, Processing

Larger and larger amount of information are at the disposal of anyone over the web; therefore, accessing to what one is interested in becomes potentially slower and slower. Many efforts have been done for improving information searching and retrieval within the web.

Early efforts about this topic concerned data mining in digital libraries (Jadhav and Kumbargoudar 2007); when considering the web, dimensions and complexity dramatically increase. To do the job, cataloguing and technical metadata have been enriched first through symbolic indexes – i.e. by tagging textual contents with words as in the hypertexts – and then through multimedia contents – i.e. by tagging sounds, images, and videos by signals' physical and semantic features (Lew et al. 2006, 1-19) (Hess et al. 2015).

The state of the art of CH DBMSs includes two typical cases:

- Extensive databases, geographically distributed but poor in relationships among contents or scarcely enjoyable from a multimedia perspective;
- Databases rich in heterogeneous materials and semantic relationships among them, but having a data amount limited and intrinsically difficult to increase.

There are two key improvements for the exploitation of CH information that allow to overcome such limitations: i) the adoption of advanced approaches for metadata and multimedia contents indexing, and ii) interoperability. A comprehensive example of the results achievable in this way is described in (Baraté et al. 2012, 170-178): an innovative approach to online experience of theatre performances that allows users not only to passively watch the show through a viewer/player, but also to interact with the show in real time, manipulate multilayer contents and create new media. The premise is to digitize a number of heterogeneous materials in order to describe a single performance comprehensively, e.g. different video and audio takes from different perspectives, and a number of related materials such as scripts, fashion plates, playbills, etc. The format adopted to encode such information is based on the XML international standard known as IEEE 1599 (Baggi and Haus 2013). The final result of the project was an advanced web player with three operating modes:

- Experience of performance-related digital contents;
- Interaction with performance-related digital contents, structured and synchronized according to the IEEE 1599 multilayer modelling approach;
- Creation of new digital contents starting from the original ones.

The application of the concept of multilayer modelling is based on representation layers of CH information, the number and the kind of which depends on the particular CH field considered. A multilayer approach can be profitably applied to any kind of CH knowledge representation.

Indexing strategies can be applied manually, but in general they are very resource-consuming due to the amount of human work needed. Therefore, it is desirable to get automatic indexing tools from ICT advances. Scientific and technological research in this direction has begun since the nineties, but it is still far from completing the process. The most relevant lines of research concern:

- Algorithms to extract semantic features from literary texts;
- Algorithms to extract vocal and music audio features;
- Algorithms to extract physical and semantic features from images (Jaimes et al, 1999);
- Algorithms to extract locations, movements and other features from videos;
- OCR (Optical Character Recognition);
- OMR (Optical Music Recognition);
- Integrated approaches that combine different algorithms; for example, OMR within music scores and music features extraction from audio (Haus et al. 2004, 1045-1052).

Automatic structuring and indexing of heterogeneous digital contents (Baggi and Haus 2013) will certainly provide humankind with great and innovative opportunities in the medium term.

Today, examples come from the automatic application of classification criteria and generation of search indexes, glossaries, structured lists, etc. Tomorrow, no one can exactly predict what it will be possible, but an important role will be played by the automatic indexing through symbols and layers of knowledge representation.

What's New: Enriching CH by ICT Advances

The issues mentioned in this paper belong to such a wide and heterogeneous field that this paper can provide only a short survey of the topic. Nevertheless, it is worth making some final remarks.

Digitization projects allow owners of CH collections to preserve in the digital domain their goods without delegating preservation activities to third parties. Conversely, exploitation should be carried out by specialized digital companies, mainly devoted to web and related services, which are to give less expensive and more efficient globally centralized services (Bachi et al. 2014, 786-801) (Go et al. 2003, 55-68). Up-to-date exploiting services are characterised by increasing customization properties (Ardissono et al. 2012, 73-99).

The already existent CH "market" can take advantage from ICT innovations, and the material and the virtual world can synergistically coexist (Petrelli et al. 2013, 58-63).

The new abilities in automatic indexing come from advances in automatic recognition within both symbolic and sub-symbolic (signal) information. It is even possible to conceive synesthetic approaches, such as the representation of visual information by sounds or vice versa; an example is presented in (Haus and Morini 1992, 355-360).

Even if the era of digital CH has begun many years ago, so far we have been witness to a little part of what we can expect.

Acknowledgements

Many thanks are due to Luca A. Ludovico for his very careful revision of the paper.

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http://www.culturalheritage.net
Cultural Heritage Search Engine

http://dublincore.org
Dublin Core Metadata Initiative (DCMI)

http://www.digitizationguidelines.gov/guidelines/digitize-technical.html
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http://emipiu.di.unimi.it
IEEE1599

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https://www.loc.gov
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http://www.mpeg.org
MPEG official site

http://www.unesco.org/culture/ich/en/what-is-intangible-heritage-00003
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