RECORDING CULTURAL HERITAGE*

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Abstract – Complete recording of Cultural Heritage is a multi-disciplinary and multi-dimensional process. It does not only address the problem of three-dimensional (3D) digitization of objects and monuments but involves all the aspects of this new digital content management, representation and reproduction. It addresses issues affecting the whole life cycle of the digital cultural content. All involved processes have their own needs for advanced algorithms, new hardware and more sophisticated software implementations. In this paper we briefly review methods from all these fields, as an attempt to provide with an all-in-one approach to the problem both from a technician and a humanitarian point of view.

INTRODUCTION

Complete recording of Cultural Heritage is a multidimensional process. It does not only address the problem of three-dimensional (3D) digitization of cultural objects but involves all the aspects of this new digital content management, representation and reproduction. It addresses issues affecting the whole life cycle of the digital cultural content. Five main processes can be identified in digital recording. All there processes have their own needs for advanced algorithms, new hardware and more sophisticated software implementations:

- Digitization in 3D
- Processing and storage of 3D data
- Archiving and management of 3D data
- Visualization and dissemination of 3D data
- Replication and reproduction of 3D data

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3D digitization of cultural heritage is the first step of the overall process of the complete recording of objects. It consists of multiple processes and exhibits variations in accordance with specific application requirements. Due to the complexity of the digitization needs that emerge from the objects themselves, there is a plethora of methods and technologies. The target of every such technique is to address successfully a particular type of objects or class of objects or monuments, or to fulfill particular demands and needs of a specific digital recording project (i.e. complete recording for archiving, digitization for presentation, digitization for commercial exploitation). The plethora of available 3D digitization systems is the result of three main factors that influence the suitability and the applicability of a method:

1. Complexity in size and shape
2. Morphological complexity (level of detail)
3. Diversity of raw materials

Size and material are crucial factors for the chosen technique. More specifically, there are techniques that produce satisfying results for *microscopic* objects, others for *small*, *medium* and *large* objects. Different techniques are used for *ceramic, stone, metallic* or *glass* objects. It should also be noted that techniques with satisfying results for one group of objects is often proven inappropriate for other. An extensive study on the available methods for 3D digitization of cultural heritage has resulted on some essential criteria that can be used as guidelines to choose the most appropriate methodology or technique. The Nine-Criteria-Table (Table I) summarizes the most important parameters for choosing a 3D digitization system for cultural heritage applications.

Table I. The nine basic criteria for the selection of a 3D digitization methodology

No	Criterion
1.	Cost
2.	Material of digitization subject
3.	Size of digitization subject
4.	Portability of equipment
5.	Accuracy of the system
6.	Texture acquisition
7.	Productivity of the technique
8.	Skill requirements
9.	Compliance of produced data with standards

3D DIGITIZATION

3D digitization of cultural content can be mainly categorized by the size of objects it is applied to. Due to technical limitations and application requirements, there must be a distinction between the digitization of *objects* and the digitization of *monuments*. Digitization of monuments is, in many cases, based on methods that involve traditional topographic techniques (due to the scale in this problem). On the other hand digitization of objects is a field of continuous research and development that can offer many possibilities, again under the scope of a specific digitization plan. In Table II we briefly review some of these methods.

Table II. 3D digitization techniques

Laser scanning	Laser scanning techniques are based on a system with a laser source and an optical detector. The laser source emits light in the form of a line or a pattern on the surface of the objects and the optical detector (usually a digital camera) detects this line or pattern on the objects. By applying the well known triangulation principle the system is able to extract the geometry of the objects [1]-[5].
Structured light	This method is based on projecting a specific pattern on the surface of the objects and trying to extract geometry information from the deformations of this pattern [6]-[33].
Shape from silhouette	This technique is based on multiple photographic capturing of the object from different viewing angles, and deducing the geometry from the object's silhouettes [34]-[44].
Shape from stereo	Main goal of this method is the extrapolation of as much geometry information as possible from only a pair of photographs taken from known angles and relative positions, simulating the human visual system [45]-[47].
Shape from video	Shape from video is a variant of shape from stereo. Here the two photo cameras are replaced by a video camera that captures the object in a sequence of images from different views. A basic requirement for the application of this method is that the object is at complete rest and with no movable parts [48]-[49].
Shape from shading	This method requires the capturing of the object from one viewing angle under varying light source position, which causes the shading to vary (in size, shape and position) on the surface of the object. This way, special algorithms could deduce the geometry of the surface of the object by using multiple photos of different shading conditions [50].
Shape from texture	The idea in this method is to identify small structuring texture elements (texels) and to find their possible transformations in order to reproduce the whole surface of an object. These identified transformations can then be used to extract the actual 3D surface geometry [51].
Shape from photometry	Shape from photometry is a variant of shape from shading. Here the photos show the object from one viewing angle but varying lighting conditions [52]-[54].
Shape from focus	The method is recursive and is based on taking photos of an object while adjusting, continuously, the focus plane. By knowing the position of this focus plane (from the whole setup and the positioning of the system) we are able to map the focused pixels in an image on the correct position in the 3D depth map [55]-[57].
Shape from shadow	Shape from shadow rebuilds the 3D model of an object by exploiting the deformation of the shadow of a known object which is projected onto the surface of the subject of digitization, when the light is moving [58].
Contact systems	These systems are based on continuous contact with the objects while measuring their position in 3D space [59].

3D DIGITAL DATA STORAGE

Data produced by the process of 3D digitization are usually large files, the size of which depends on both the size of the digitized subject and the resolution of digitization [60]-[64]. The raw material delivered by the 3D digitization hardware (3D scanner) most of the times is available in a file format which is recognized only by the software used for the acquisition of that data and it is initially stored on the local hard drive of the digitization workstation. Afterwards, that raw material must be collected and adequately processed, in order to produce the anticipated for each application result. More or less, the procedures involved after the end of 3D scanning are:

1. Storage of raw material for archiving purposes. Accompanying metadata information is mandatory.
2. Construction of a unified form from the raw material, representative of the digitized subject. Metadata must not be excluded from the storage of that form.

3. Conversion, of the outcome from the 2nd stage, to a file format more common to the 3D computer graphics industry. Storage including metadata information is compulsory for the products of this stage also.
4. Further conversion to file formats that are more adequate for the needs of a specific application.

Depending on application, metadata information can be determined by the following three basic categories [65]-[67].

1. Descriptive information on the subject, provided by the user.
2. Information for the administration of the data (i.e. version control etc)
3. Algorithmic description of the data, for the purpose of content based search and retrieval of the information. Therefore the results from a content based database query are not affected by the error prone user based description of the data.

For the selection of the device which will be used for the storage of the huge amount of digital information, produced by the 3D digitization process, we must take into consideration the following characteristics:

1. Data access time.
2. Data transfer rate, from the storage device to the computer memory and vice versa.
3. Multi user access capabilities.
4. Digital storage capacity
5. Utilization frequency.
6. Data retention lifetime of the storage medium.
7. Required environmental conditions for the storage and operation of the storage device / medium.
8. Cost per digital storage unit (Megabyte / Gigabyte).

In order to conserve a digital collection as much as possible, we have to keep up with the rules prescribed by the manufacturer of the selected storage medium. Appropriate handling and storing of the storage medium is vital for its lifetime and consequently for the survival of the stored information too. In order to prolong data's lifetime even more, periodic storage medium check ups and precautionary copying of their data to a newer medium of the same type is a good practice. However, due to the frenzied evolution of computer hardware, both storage devices and their storage mediums are rendered obsolete before reaching even the half of their lifespan. Thus, data migration to a tested modern storage solution is the best practice. The following table depicts some of the characteristics of today's storage media.

3D DIGITAL DATA REPRODUCTION

The reproduction of a 3D digitized subject is feasible via two different ways:

1. Digital reproduction of data. The most common devices for making multiple copies of digital subjects, in order to make that information available to computer users without access to broadband internet connection, are the optical disc (CD / DVD) multiplication devices.
2. Physical reproduction of data. 3D printing, or solid imaging, is another way for reproducing the information gathered from the process of 3D digitization. 3D printing is the process of creating a tangible copy of intangible digital data, us-

ing a special device, which is able to construct the material representation of the 3D dataset.

3D DIGITAL DATA VISUALIZATION

For the electronic presentation of 3D digitized subjects we can choose from a wide variety of electronic display equipment, depending on the specific requirements of each application. The parameters that we must consider for the selection of the most adequate imaging device are [68]-[70]:

- The number of people that are watching simultaneously the presentation. That determines the size of the display device.
- Stereoscopic presentation of the 3D subject, in order to set the 3rd dimension perceivable by the user.
- User interaction degree. For example, whether the user will be able to wander freely in the virtual 3D world or be restricted in a certain course. That parameter of presentation determines the type of hardware, which will provide the images to the electronic display device. In the case of the predetermined course, that device could be a simple video player, which costs less than 100 €. In case of free wandering in the 3D world, however, the image supplying device could vary from a simple personal computer, with cost of a couple of hundreds €, to a visualization workstation that costs a lot of thousands €.

A significant number of companies use projectors in various ways in order to construct special display devices, such as walls, caves, domes etc. These display devices are known as immersive displays and their cost is usually huge. Depending on the application, the cost usually starts form a couple of thousands € and can easily surpass 100,000 €. Except the common 2 dimensional display systems, there are electronic devices that are able to display true 3D information, without demanding the use of special accessories, like glasses, in order to achieve that. These devices are known as active 3D displays and are available in three different types:

1. Flat panel displays (Plasma and TFT), which provide the sense of depth via special lenticular filters in front of the display.
2. 3D Volumetric displays, where the third dimension is produced by projecting the appropriate sequence of images on a very fast moving semitransparent surfaces.
3. Head mounted displays (HMD). These are wearable devices which provide a small display screen in front of each eye. Those displays are independent, so by feeding them with the appropriate images it is possible to achieve the required effect of true stereoscopic vision.

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