Virtual Archaeology Review, **8**(16): 22-34, 2017
http://dx.doi.org/10.4995/var.2017.4629

Received: February 2, 2016
Accepted: November 11, 2016

DIGITAL PRESERVATION OF CULTURAL AND SCIENTIFIC HERITAGE: INVOLVING UNIVERSITY STUDENTS TO RAISE AWARENESS OF ITS IMPORTANCE

CONSERVACIÓN DIGITAL DEL PATRIMONIO CULTURAL Y CIENTÍFICO: PARTICIPACIÓN DE ESTUDIANTES UNIVERSITARIOS PARA CONCIENCIARLES DE SU IMPORTANCIA

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Abstract:

Cultural heritage is a relevant issue in contemporary society. While its preservation is a challenge, its dissemination, can contribute for an economic balance between costs and benefits. Scientific heritage can be considered as a special domain of cultural heritage, not yet sought by the mass tourism, but worth being preserved as the roots of today's knowledge. Considering that university students of engineering and computer science traditionally do not address cultural or scientific heritage issues in their syllabus, and that they constitute a layer of young citizens that will come to be influential in the future of society, an effort was undertaken to focus on this theme in disciplines of different courses, allying the learning of technical skills with the natural interest of younger people for 3D and animation for the profit of heritage. The goal was to raise the awareness of this particular group to the importance of maintaining heritage issues, in particular, in a virtual way, both for documentation and for divulgating their existence. Raising funds for buildings' restoration, attracting the public to visit buildings and collections that are outside the usual tourism routes, contributing to revenue generation, or allowing virtual visits of not accessible issues, complementing physical visits on site, were the general aims of the proposed projects. A survey was undertaken under the participating students to evaluate how the projects influenced their attitude towards heritage. The obtained feedback was very positive: 76% agreed that the project alerted them for the importance of preserving historical and cultural heritage, while 72% considered it was interesting that the topic of digital cultural heritage was used for the assessments of the disciplines.

Key words: education, heritage dissemination, 3D modelling, animation

Resumen:

El patrimonio cultural es un tema relevante en la sociedad contemporánea. Mientras que su conservación es un reto, su difusión puede contribuir a un equilibrio económico entre costes y beneficios. El patrimonio científico puede ser considerado como un dominio especial del patrimonio cultural, y aunque todavía no es buscado por el turismo de masas, vale la pena ser conservado. Teniendo en cuenta que los estudiantes universitarios de ingeniería e informática tradicionalmente no abordan cuestiones de patrimonio cultural o científico en su plan de estudios, y que estos constituyen un grupo de ciudadanos jóvenes que serán influyentes en el futuro de la sociedad, se ha realizado un esfuerzo para centrarse en este tema en las disciplinas de diferentes cursos, uniéndose el aprendizaje de habilidades técnicas con el interés natural de las personas más jóvenes hacia el 3D y la animación para el beneficio del patrimonio. El objetivo era aumentar la conciencia de este grupo en particular en la importancia de mantener los temas de patrimonio. La recaudación de fondos para la restauración de edificios, atraer al público a visitar los edificios y colecciones que se encuentran fuera de las rutas turísticas habituales, contribuyendo a la generación de ingresos, o permitir visitas virtuales de cuestiones que no son accesibles, eran los objetivos generales de los proyectos propuestos. Se llevó a cabo una encuesta entre los estudiantes que desarrollaron estos proyectos para evaluar si estos tenían una influencia positiva en su actitud hacia el patrimonio. La información obtenida fue muy positiva: 76% están de acuerdo en que el proyecto les alertó de la importancia de la conservación del patrimonio histórico y cultural, mientras que el 72% consideró que sería interesante que se utilizara el tema del patrimonio cultural digital en las evaluaciones de las disciplinas.

Palabras clave: educación, difusión del patrimonio, modelización 3D, animación

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1. Introduction

According to the Council of Europe's Framework Convention on the Value of Cultural Heritage for Society, occurred 2006 in Faro, Portugal, and cited by Dümcke & Gnedovsky (2013) in a literature review about this theme, "[Cultural] heritage is a group of resources inherited from the past which people identify, independently of ownership, as a reflection and expression of their constantly evolving values, beliefs, knowledge and traditions."

As the large number of published papers and reports on the matter reflects, cultural heritage is a relevant issue in contemporary European societies (Directorate-General for Research and Innovation, 2015). Heritage conveys to the community a feeling of permanency, of knowing where we come from, of shared wealth and values. Its preservation is, most of the times, a challenge on many levels. It requires expertise, technology, time and money, which are not always available for projects that apparently do not revert immediately for the constantly sought progress of society.

In several articles about cultural heritage, references to particular sub-types of cultural heritage are found, like built heritage, movable heritage or archaeological heritage (Dümcke & Gnedovsky, 2013). Scientific heritage is one of these special sub-domains. According to Lourenço (2013), it can be described as "the shared collective legacy of the scientific community" perceived as its identity and "worth being passed on to the next generation of scientists and to the general public as well". It consists normally on functional buildings, instruments, collections and other materials related with scientific research or knowledge transmission.

Along with preservation, divulgation of heritage, especially of less known items, is of major importance for both researchers and public. Researchers become aware of the existence and availability of materials for their studies, potentially broadening knowledge, which consolidates one of the major reasons for heritage preservation (ICOM, 2013). General public, on the other hand, is attracted to heritage novelties and paying visitors contribute significantly for preservation costs compensation. As an example, web accessible annual reports of cultural heritage entities in Portugal show that more than 70% of the raw yearly financial income originates from the sold tickets for monuments, museums and palaces (PSML, 2014, *Direção Geral do Património Cultural*, 2015).

In the digital era, tangible cultural heritage has been revealed to broad audiences via web, by providing photographs, videos and text information. This kind of pictorial and sometimes dynamic information is also exhibited along visitors' tours in museums or monuments in kiosks as an additional information source to exposed heritage assets.

In this context, 3D models of heritage buildings, spaces and other assets represent a benefit, since they are a highly intuitive means of representation and communication, especially when combined with animation or when supporting interaction. 3D modelling techniques have therefore invaded cultural heritage in the last years, also because of the possibility of virtually joining realities from different epochs in the same representation (Bruno & Spallone, 2015). Examples can be found in websites of several heritage sites and museums ("Santa Maria do Bispo 3D", 2015; "The Shipping Galleries", 2012; "Pompeii Reconstruite", 2016).

University students of more technical courses of engineering and computer science traditionally do not address heritage issues in their syllabus. Considering that they constitute a layer of young citizens that will come to be influential in the future of society, an effort was undertaken to raise the awareness of this particular group due to the importance of maintaining heritage in a virtual way and divulgating their existence to the public.

The chosen approach to achieve this was to involve students in the production of very diverse 3D materials that could be of interest for museums and other cultural spaces, attracting their attention to the particular objects and spaces as well as researching their historic context. Taking advantage of young people's natural interest for 3D and animation (Haddad, 2016), small projects could be succeded for the profit of heritage.

The 3D models presented in the next sections are the result of collaboration between the Faculty of Sciences of the University of Lisbon, Portugal, the University of Extremadura in Cáceres, Spain, and several museums in Lisbon.

Graduate and master students of Geospatial Engineering and Informatics Engineering were invited to develop individual and group projects in this context. The main intention of the projects was to contribute to museums' dissemination and to enrich the experience of their visitors (Cordovilla, 2010). 3D models might be included in museums' websites and, besides, can be shown in local info points. Additionally, a QR (Quick Response) code may be displayed near the objects in exhibition, providing supplementary information via smartphones. Also a 3D tool for supporting museum's staff in the planning of heritage or art exhibitions, as well as in the creation of virtual exhibitions was developed. All presented models were created as part of the students' assessments in subjects that focus on 3D modelling, such as Animation and Virtual Environments and Photogrammetry, under supervision of the authors in the role of instructors. The virtual models were built resorting to diferent techniques ranging from photogrammetry and laser scanning for creating virtual models after real objects, to tools that build the models from scratch. In order to evaluate the acquired sensitivity to cultural heritage, a questionnaire was made afterwards to students participating in this initiative.

The present paper is organised as follows. Section 2 presents works of other authors regarding building 3D virtual models. Section 3 is devoted to modelling of scientific heritage, describing work performed in cooperation with the National Museum of Natural History and Science (MUHNAC) of the University of Lisbon. Section 4, Modelling of cultural heritage, presents the results of collaboration with the Lisbon Museum and other cultural spaces of the city. Section 5 describes the already mentioned interactive tool to assist in the process of conceiving virtual or real exhibitions in closed spaces. Section 6 discusses the results of the experience, and finally Section 7 sums up the main goals achieved.

2. Building 3D virtual models

Different techniques can be used to create 3D geometrical models: procedural generation, 3D CAD tools, range-based and image-based modelling. The two last techniques require equipment that is more expensive and need the real existence of the object to be modelled. Often none of these techniques can fully satisfy all the requirements, specially when dealing with large dimension environments, and multiple techniques have to be combined to produce 3D reconstructions (Dylla, Frischer, Muller, Ulmer, & Haegler, 2010; Gabellone, Giannotta, Ferrari, & Dell'aglio, 2013; Lercari, Forte, & Onsurez, 2013; Micoli, Guidi, Angheleddu, & Russo, 2013; Muñumer & Lerma, 2015; Visintini, Siotto, & Menean, 2009; Xu et al., 2014).

Procedural modelling consists on modelling by rules and is very effective when dealing with a great number of similar objects in 3D (e.g. streets, buildings, trees of a city). According to the values of a number of attributes, the rule, a short routine, is applied to each individual object generating the 3D geometry and appearance. It is frequently used to produce virtual environments such as game scenery and 3D city models (Rodrigues, Magalhães, Moura, & Chalmers, 2014; Saldana & Johanson, 2013; Smelik, Tutenel, Bidarra, & Benes, 2014).

CAD modelling tools can be used to build 3D models based on blueprints, drawings, and/or site measurements. Although time consuming, these tools do not require expensive hardware. Moreover, they can reproduce objects and buildings that no longer exist, such as in archaeological sites. In this case, paintings and text documents can also be a source of information to create the virtual objects. There are several modelling tools, either commercial or freeware, that are often referred in digital cultural heritage literature, such as 3DS Max (3DS Max, 2016; Laycock, Laycock, Drinkwater & Day, 2008; Lercari et al., 2013), Maya (Maya, 2016; Kider, Fletcher, Yu, Holod, & Chalmers, 2009; Happa et al., 2009), AutoCAD 3D (Autodesk, 2016; Rao & Thakur, 2013), ArchiCAD (ArchiCAD, 2016; Haas, 2013), Blender (Blender, 2016; Kennedy et al., 2013) or SketchUp (De Paepe, 2014).

Range-based modelling deals with data acquired with 3D laser scanners, also known as LiDAR (Light Detection And Ranging). These follow different approaches for the range determination: triangulation or time of flight. From the acquired information and position and orientation of the sensor, a cloud of numerous 3D points on the surface of the objects is generated. To obtain the surface of a 3D model, these points must be converted into triangle meshes or adjusted to a mathematical surface. The procedure requires three main steps: 1st) the merging of several clouds taken from different locations to complete the object survey; 2nd) the elimination of inaccurate or unwanted sets of points; and 3rd) the triangulation operation, which corresponds to find the best way to connect the 3D points to create optimal triangles, each one defining an elementary surface. Alternatively, parts of mathematical surfaces, such as plans, cylinders, spheres and tori, are sequentially adjusted to limited sets of points recreating a neat form of the object surface from the dense cloud. In the acquisition process, different spatial resolutions can be used to obtain more accurate results in more detailed areas of the object (Callet, Dumazet, Leclercq, & Politi, 2010). Several examples of range-based modelling can be found in the literature (Cosido et al., 2015; Patay-Horváth, 2014; Artese, Altomare, Lerma, & Zinno, 2014).

Image-based modelling, also referred as photogrammetric modelling, builds static 3D virtual models based on two or more images of the scene taken from different perspectives (Musialski et al., 2013). Although consisting on the oldest method to recover the 3D geometry of an object through interactive stereo or multiview acquisition of its 3D coordinates –a time consuming operation requiring a lot of expertise– it has, in the last years, regained popularity among non-experts. This is due to the development of automatic multi view stereo operators, SfM (Structure from Motion) and SGM (Semi-Global-Matching), which deliver dense 3D point clouds from a set of images. These operators, integrated in software such as PhotoModeler Scanner (EOS, 2016), Bundler (Snavely, Seitz, & Szeliski, 2006, 2007), 123D Catch (Autodesk, 2016), and VisualSFM (Falkingham, 2013; Wu, Agarwal, Curless, & Seitz, 2011), normally take advantage of multi-processors in graphic cards or are offered as web services to the client. Recently, panoramic photogrammetry has also been applied to generate cultural heritage 3D models (Adami, Cerato, d' Annibale, Demetrescu, & Ferdani, 2014)

Despite being based on real existing buildings (or other objects), image-based modelling may combine information from different periods in time and rebuild structures that no longer exist. An example is the work reported by Grussenmeyer & Yasmine (2004) regarding the 3D restitution of a structure destroyed by war. Another example is presented in Section 4, regarding the virtual reconstruction of buildings existing in the Port of Lisbon in 1938 that have since been demolished or remodelled (Redweik, Garzón, & Pereira, 2016).

A different image-based technique used for close range modelling of relative small objects is the structured light scanner that resorts to image correlation and photogrammetric bundle solutions.

The virtual models that will be presented in the following sections resort to 3D CAD modelling, range-based and image-based modelling techniques.

3. Scientific heritage models

The projects in this section were accomplished in cooperation with the MUHNAC, which comprises several buildings and a botanical garden. They were intended to provide virtual visits to an inaccessible building, the Astronomical Observatory that is under recovery, and to a recently recovered space, the amphitheatre of the Chemistry Laboratory, both constituting witnesses of the scientific culture communication and transfer in the 19th century. Although MUHNAC is an entity of the University of Lisbon, none of the students involved knew the issues in question, so it was an opportunity for them to get acquainted with the heritage associated to their own university, in particular, with the roots of both the Faculty of Sciences and Geospatial Engineering in Portugal. Some were touched by the bad preservation condition of the observatory, which drove them additionally to involve harder in the project.

3.1. Astronomical Observatory

Considered one of the architectonic highlights of the MUHNAC, the Astronomical Observatory of the Lisbon Polytechnic School is the only survival of the three teaching observatories built in the country in the 19th century, for the higher schools where Astronomy and Geodesy were taught (Cláudio et al., 2013). The original building of 1875 had to be replaced a few years later by a new one due to heavy subsidence, occurred as the consequence of a train tunnel construction under the site, which had made the domes inoperable for accurate geodetic astronomical observations.

The Astronomical Observatory complex consists of three buildings: i) the main observation building, with three domes and a meridian-room; ii) a three-storey building where several classrooms, a workshop, the library and the teachers' offices were located, which was known as the Mathematics Building; and iii) a small wooden building supposedly used for instrument calibration. The main building was rebuilt in 1898 following the plans of Victor Augusto Gomes da Encarnação and José Cecílio da Costa (Silva, 1998, p. 125-130) and maintains until today the architectonic design from that epoch. A collection of about two hundred 19th and 20th century instruments and a small archive and library complete the heritage of this complex. It served the teaching of Astronomy, Geodesy and related subjects for more than 150 years, first in the Polytechnic School and later, after 1911, in the Faculty of Sciences, before it was assigned to the MUHNAC in the year of 2000.

The elaboration of a 3D model of the buildings arose as the solution for two intents of the museum:

- To provide a virtual visit of the Observatory to the public of the museum, since it would be closed for a long period for rehabilitation; in this way, the visitor wouldn't feel deceived for not being allowed to see an important part of the museum during rehabilitation works.
- To serve as an appealing documentation to be included in a fund raising campaign for the reconstruction of the observatory.

Figure 1: Astronomical Observatory of the Lisbon Polytechnic School: a) 3D model obtained from a TLS point cloud; b) A view into the meridian room with the meridian circle; c) Mathematics Building; d) 3D model obtained from scratch.

Several techniques were used to obtain the models (Cláudio et al., 2013): multi-view photogrammetry and terrestrial laser scanning (TLS) for an as-built restitution of the observation building, including the exterior and the interior rooms, and 3D modelling from scratch for creating suggestions for the rehabilitation. The software used was PhotoModeler Scanner 2014 (EOS, 2016) and Trimble Realworks 6.5 (Trimble, 2016) for the first objective and Blender 2.62 (Blender, 2016) for the second. The modelling of the Mathematics Building was based on exact plans and elevations and was accomplished in AutoCAD 2011 (Autodesk, 2016). To embellish the interior of the observation building, the old meridian circle, a telescope used for determining the local latitude, has been captured on video, in a storage room where it has been kept, and reconstructed on base of an automatically determined 3D point cloud with VisualSFM V0.5.20 (Wu, 2015). Animations were created for all models including one interactive scene in X3D format (X3D, 2016) (Fig. 1).

3.2. Amphitheatre of the Chemistry Laboratory

The Chemistry Laboratory of the Polytechnic School is another jewel of MUHNAC. It was built in 1857 after a fire occurred in 1843 in the Polytechnic School that severely destroyed the former installations of the school. An important re-equipment of the laboratory took place in 1890. With its 860 m^2 and an amphitheatre for 200 students it had, since then, been admired by renowned 19th century European chemists for its vast space and combination of elegance and utility (Crato, 2003).

It was later spared from a devastating fire, occurred 1978, due to the providential actions of a chemistry professor who lived just a few blocks away and soon heard, middle in the night, about a fire happening at the Faculty of Sciences. Under her instructions, the firefighters successfully concentrated their efforts on defending the Chemistry Laboratory where some dangerous quantities of high explosive materials (by contact either with fire or with water) were stored under the amphitheatre benches, putting a whole city department at risk in that fateful night (Lourenço, M., personal communication, May 6, 2014). The laboratory was intensively used for teaching and research activities for about 150 years, never receiving any refurbishment works. This fact, felt from students and teaching staff in the latest years as a burden, turned out to be a blessing as 2007 the MUHNAC was able to recover a teaching chemistry laboratory from the mid-19th century in all its original functionality and beauty.

In order to promote the visits and the eventual use of the space for scientific events on a Web site, the amphitheatre was totally surveyed with a Leica C10 (Leica, 2016) TLS. Three stations were needed to cover the entire space, two at the lowest level of the amphitheatre and one at the highest. Since the distances were short, the obtained point cloud is very dense and was directly used to produce a 3D animation showing the room with a great level of detail (Fig. 2).

Inside the amphitheatre, there is a 19th century coloured panel illustrating a manufacturing facility used to produce sulphuric acid (Fig. 3d), analogous to the ones described in the book "*Les Merveilles de L'Industrie*" (Figuier, 1877, p.1873-1877).

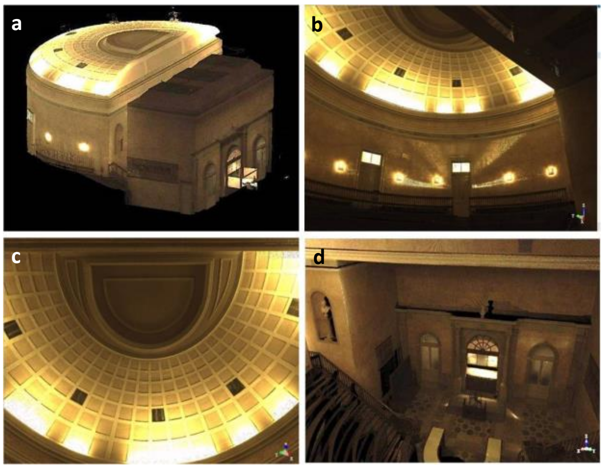


Figure 2: Scenes of the animation of the amphitheatre of the chemistry laboratory: a) Complete TLS point cloud with true colour; b) View from the inside; c) Ceiling; d) View from the last row towards professor's work bench and fume hood.

This coloured panel was a pedagogical masterpiece of its time and today it is, no doubt, an important testimony in the History of Science. The panel hangs exactly on the same place where it was in 1891 (Figs. 3a, 3b, 3c) and it illustrates the lead chambers production process. This process started by burning pulverised pyrites inside brick ovens warmed with an air intake (Fig. 4a). The resulting combustion gases were conducted to the first chamber of a pipeline composed by 3 up to 12 chambers, passing successively through each one (Figs. 4b and 4c). Inside the lead-chambers, the gases received a certain amount of air allowing reactive gases to mingle. Reaching the end of the pipeline, the gases were washed with a cooled concentrated acid in a facility called Gay-Lussac tower (Fig. 4d). This stage leads to the final products: sulphuric acid, some components that continued in the cicle of the manufacturing process and others that were simply released into the air (Figuier, 1877, p. 1873-1877).

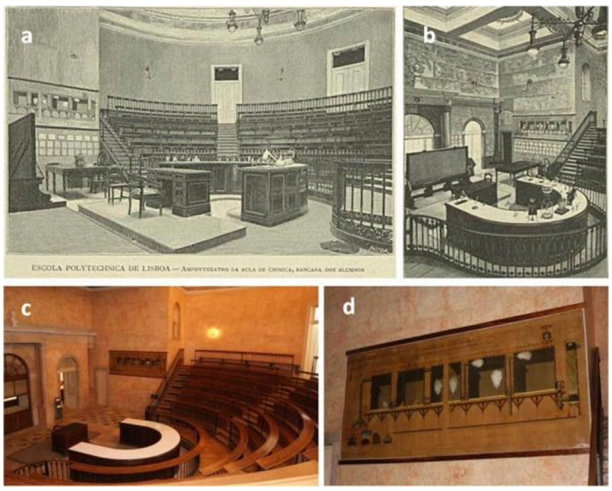


Figure 3: Amphitheatre of the Chemistry laboratory: a) and b) Pictures from 1891 showing the just re-equipped amphitheatre (O Occidente, 1891); c) The 2007 recovered amphitheatre; d) 19th century panel showing the contemporary sulphuric acid production process.

A 3D virtual model of the panel and an animation of the process were created from photographs, having in mind its exhibition side by side with the panel itself or its inclusion in a Web site together with further related information accessible via a QR code for smartphones. This art of enliven artwork or artefacts consists in a very effective way of communicating scientific issues. The model presented in this paper is an improvement of a former one (Cláudio, & Alves, 2012).

The 3D model was made from scratch in Blender (Blender, 2016) having in consideration the depiction in the panel and the descriptions and similar illustrations in Figuier's book. The model maintains the longitudinal cut observed in the illustrations and some textures were added as well as elements that gain life in the animation, such as steam and fire. To produce the animation, the virtual camera follows a path around the whole industrial installation, offering a front view with the longitudinal cut and a back view with the closed lead chambers (Fig. 4).

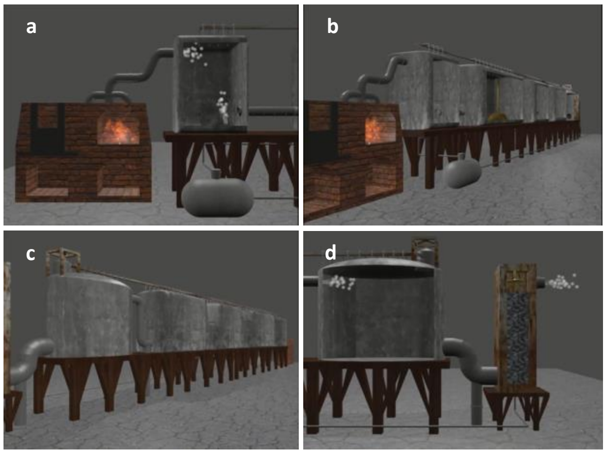


Figure 4: Frames of the animation illustrating the 3D model of the lead chambers in a sulphuric acid production pipeline: a) Oven burning the pulverized pyrites; b) Front side of the lead chambers pipeline; c) Rear side of the pipeline; d) Last chamber and Gay-Lussac tower.

4. Cultural heritage models

This section presents projects done in collaboration with the Lisbon Museum (http://www.museudelisboa.pt) and other cultural spaces of the city, which are considered related to industrial history, city history and archaeology rather then to science. The objective of the projects was, on the one hand, virtually reviving a city area as it was more than 75 years ago, as in the case of the Port of Lisbon. On the other hand, promoting the visits to existing heritage spaces such as the Burnay Palace and the Pimenta Palace, and contributing for the documentation of endangered urban architectural heritage such as in the case of Villa Sousa. For the palaces, students had to plan themselves the field survey and worked in groups. Burnay Palace was totally unknown to the students and is rarely visited by the public, since it does not house a particular museum. As for Pimenta Palace, it belongs to the Lisbon Museum and has a regular amount of visitors but, although situated adjacent to the University Campus, most students were just acquainted with the street façade and never got inside nor explored the gardens. The initiative was an opportunity for them to get acquainted with the heritage surrounding the faculty and their history, while contributing for their preservation through the production of divulgation materials for the respective Web sites. The model of the Port of Lisbon was a sub-project of a greater one that took the involved student virtually back to the thirties of the 20th century in order to recover information to the present. The model shall be presented in an exhibition at the Port's facilities as a testimony of the past.

4.1. Buildings of the Port of Lisbon in 1938

This project consisted on the virtual reconstruction of a part of the buildings existing in the Port of Lisbon in 1938 and was based on the photogrammetric stereo plotting of a collection of aerial photographs of that time. Most of these buildings do not exist anymore or were transformed in restaurants and discos. The aerial photographs used in this project are glass plates with a very high resolution and constitute the oldest aerial photo collection of the Port and one of the first aerial stereoscopic coverage made in the country. The digitalisation and organization of the whole collection were made in 2013 by the Faculty of Sciences of the University of Lisbon on request of the Port Administration. In this context, the 3D modelling of the Port facilities as they appear in the old photos has been proposed to a student. The stereo pairs of this flight present the particularity of having been taken with convergent camera axes, a technique used in the early photogrammetric flights in order to obtain greater stereoscopic areas with the small photograph formats (13 cm x 13 cm) of the cameras of that time (Redweik et al., 2016). The eight photographs used for the 3D model were georeferenced by aerotriangulation based on ground control points coordinated on details of the 1938 cityscape still existing at present, for instance church stairs and fountains.

The photogrammetric software PHOTOMOD LITE 5 (Racurs, 2016) was used for the triangulation, as well as for the generation of a digital terrain model, for the stereo plotting of ca. 300 buildings, for the generation of the 3D geometric models and assignment of the respective textures (Fig. 5). Roof and façade textures for the main buildings and warehouses have been collected from archived amateur photography of the same epoch existing at the Port administration. The complete model has been exported to the software CityEngine 2014 (ESRI, 2016) in order to be completed with additional assets and information.

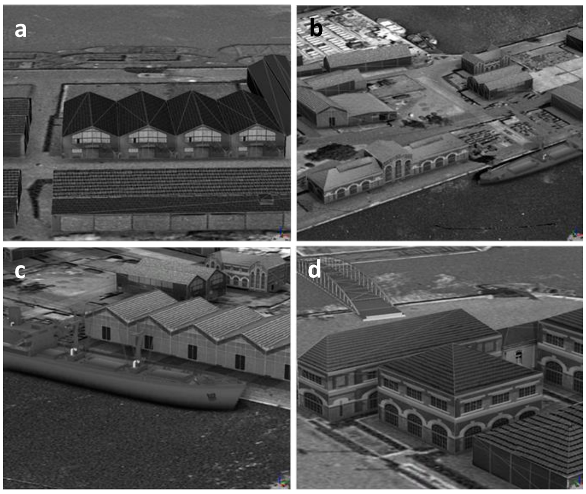


Figure 5: Views of the 3D model of Lisbon Port in 1938: a) Warehouses; b) Passengers terminal and warehouses; c) Ship in front of a warehouse row; d) Customs building and rotation bridge.

4.2. Burnay Palace

The origins of the Burnay Palace situated in West Lisbon not far from the Tagus riverbanks, date from 1701, but its architecture suffered substantial changes in the late 18th and 19th centuries according to the wealth and wishes of the owners at each epoch. In fact, church patriarchs, royals, masters in finance and bankers owned successively the palace. When the project was performed, the Tropical Research Institute occupied the higher stores of the building, including the palace rooms, while the lower part belonged to the University of Lisbon. A tropical garden embellishes the rear side of the palace. The four characteristic square towers in the central part of the building and the symmetrical appearance of its two inner courtyards were probably built around 1855 (IICT, 2007). The central tower with an octagonal dome shows the need for restoration. Particularly interesting in this symmetric building are the two small greenhouses integrated in the courtyards, presenting an elegant half cylinder shaped glass and iron roof. The 3D model of the palace was made by multi view interactive photogrammetry with PhotoModeler Scanner (EOS, 2016) using a set of 150 photographs taken in the same day by five groups of students (Fig. 6).

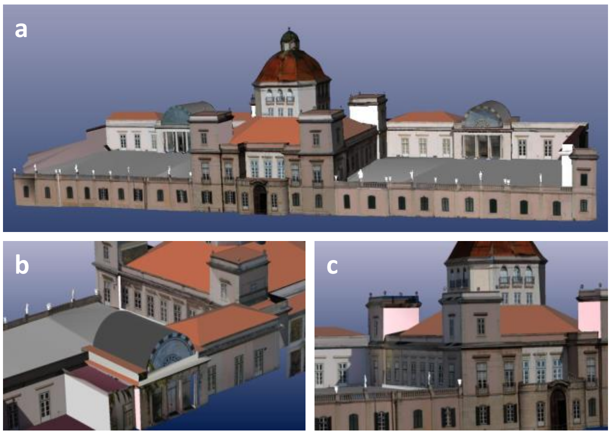


Figure 6: Views of the 3D model of Burnay Palace in Lisbon: a) Whole model; b) Detail from the rear side; c) Detail from the front side.

Each group modelled a section of the building, being the projects merged at the end to yield the whole building. Since the octagonal tower was visible from all sites, it was used to link all partial projects, dispensing the setting of a topographic local network. Stairs and other assets of the towers were also geometrically modelled to give the object a realistic appearance. The collection of statues over the street façade has been modelled in a low level of detail in order to keep the flexibility of the model when explored interactively (Fig. 6).

4.3. Villa Sousa

Villa Sousa is a two story house, now belonging to the municipality of Lisbon, which was built in 1912 and awaits a well-deserved rehabilitation as a cultural space. In the year it was built, it was awarded the Valmor prize of architecture from the municipality, a renowned prize for the most beautiful and original architectural project of the year. Its architect, Norte Junior, authored several other residential projects in Lisbon, most of them still existing as a memory of a vanishing style in the rapidly changing city.

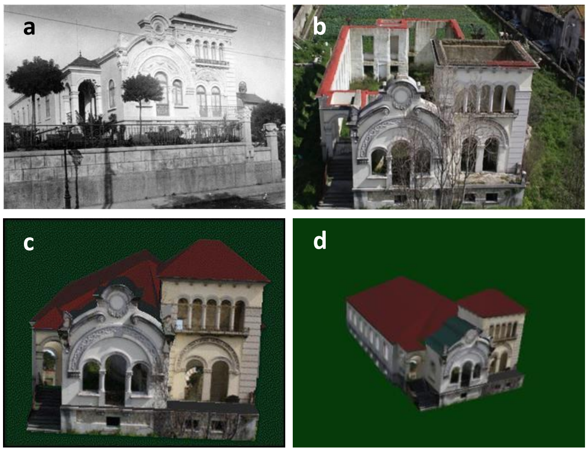


Figure 7: Villa Sousa: a) In 1912 short after construction; b) In 2010; c) and d) Views of the reconstructed 3D model.

From the once *petite bourgeoisie* residence of the Sousa family, from which it retains the name, only the exterior walls are still standing including the front façade adorned with carved stone and arched windows, showing a glimpse of passed glare. The challenge of the virtual reconstruction of this building laid on the absence of any roof structure. The 3D model was reconstructed by interactive multi-view photogrammetry integrating some old photographs, where parts of the original roof were visible, with a recent coverage taken from the street and from the terrace of a seven story building on the opposite side of the street. The final product was a 3D animation showing a suggestion for the reconstruction (Fig. 7).

4.4. Pimenta Palace

The Pimenta Palace was allegedly built by the Portuguese King João V (1689-1750), in the first half of the 18th century, to accommodate his favourite mistress who happened to be a nun of a nearby convent. Since then several noble families owned the palace and it is since 1961 property of the Lisbon municipality, being nowadays occupied by the Lisbon Museum. Its simple but elegant rural manor architecture together with its location adjacent to the University Campus makes it the favourite laboratory for students' 3D modelling experiences welcomed by the museums direction. Its façades have been stereo plotted by several generations of students and a 3D model of the complete principal building has been achieved by multi-view interactive photogrammetry. Also here, each group of students took care of a part of the building modelling. Unlike in Burnay Palace, there is no sight continuity between façades due to a high wall on both sides of the front façade. Therefore, there was a need for a topographic network to be established in order to provide some coordinated control points on the façades, creating a common georeference for all partial models (Fig. 8).

Besides accommodating the principal assets and administrative services of the Lisbon Museum, the Pimenta Palace complex consists also of an involving garden where two pavilions, used for temporary exhibitions, stand in opposite corners: the Black and the White halls. These halls present a rather modern architecture dating from 1994 and 1995, respectively, and achieve a strong contrast with the main building (Faria, 2010). The White Exhibitions Hall has been modelled by the students in AutoCAD (Autodesk, 2016), both the exterior and the interior, from plans and elevations (Fig. 9).

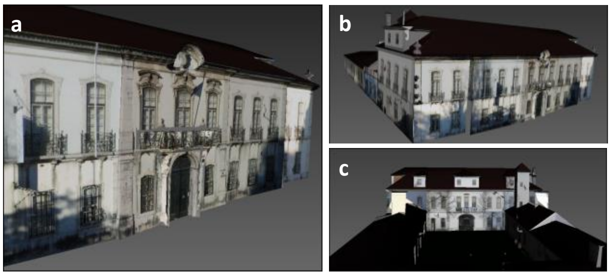


Figure 8: 3D model of Pimenta Palace in Lisbon: a) Main façade showing the modelled relief of the main entrance; b) Main and south façade; c) Façade in the courtyard.

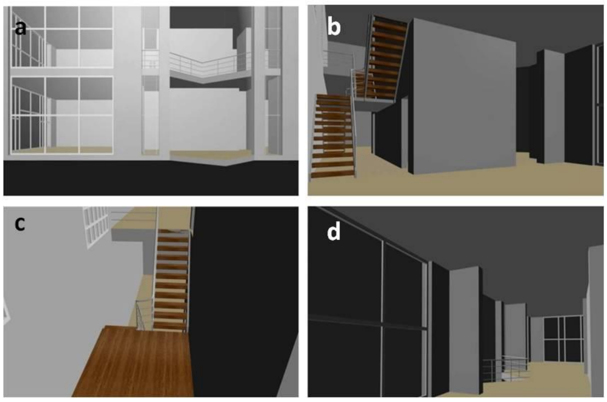


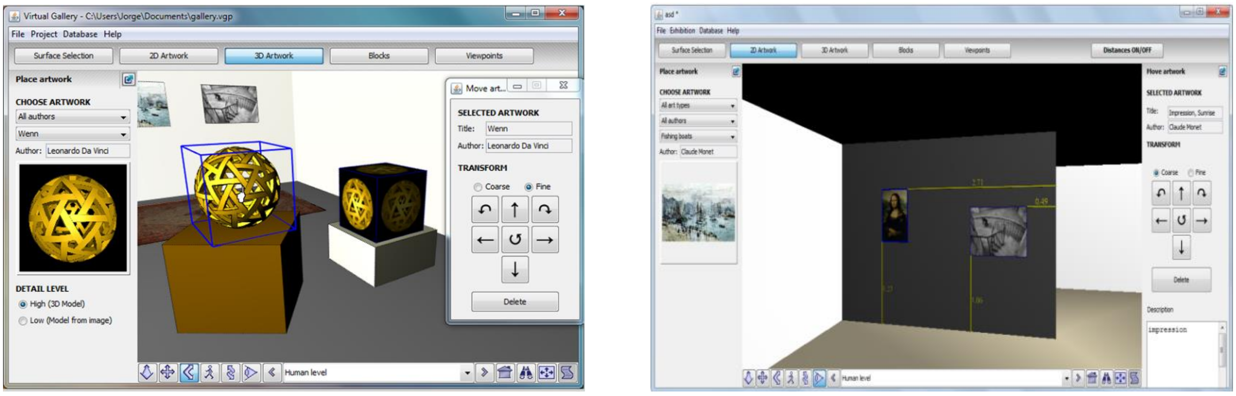
Figure 9: The White Exhibitions Hall by Pimenta Palace: a) An exterior view; b), c) and d) Details of the interior.

5. An application for planning exhibitions

A simplified model of the White Exhibitions Hall has been used to test the Virtual Exhibition Builder (VEB) application software in collaboration with museums staff, who gave relevant inputs to this software (Carmo, & Cláudio, 2013).

VEB is an interactive software tool whose main purpose is to assist museum curators in the process of conceiving exhibitions of artwork, heritage or archaeological pieces. Given a 3D model of a physical interior environment of the museum described in an X3D file, and pictorial information about the artworks or pieces with associated dimensions, which are normally gathered in a database for each particular exhibition, the user can apply the tool to try different approaches to arrange the pieces within the exhibition space and visualise the resulting layout (Gomes, Carmo, & Cláudio, 2011).

The tool allows the placement of 2D (e.g. paintings and tapestry) and 3D artworks (e.g. sculptures, pottery) in chosen locations in the virtual space that reproduces the actual space of the exhibition (Fig. 10a). Relative dimensions of the artworks and of the exhibition space are preserved. It is also possible to insert removable structures, such as dividing walls or plinths to display 3D objects. It is possible to edit previously created virtual exhibitions, to select eligible locations for artworks based on user criteria as well as to include navigation aids through the definition of viewpoints for analysing the result. It is also possible to plan visitors' paths. By



(a) (b)

Figure 10: User interface of VEB: a) Interface for the placing of a 3D artwork inside a vitrine; b) Showing actual distances of two paintings to the floor and to the edge of the wall for mounting support.

means of the tool, preliminary proposals of the curator can be discussed both among the elements of the team and the artists or historians whose artworks or pieces are going to be exposed at the exhibition. Once the intended result is achieved in the 3D model, an output with several views and actual measures of the relative position of objects to reference lines (e.g. distance to the floor or to an edge on the wall) (Fig. 10b) can be useful for guiding the actual process of mounting the exhibition.

Inputs by museum staff lead to the conclusion that photorealistic images are not an important issue at this stage, since the main concern is to decide about the harmonious arrangement of the artworks. Therefore, the ability to dispose and simulate light sources was not a mandatory request.

The creation of virtual exhibitions to be available on the Web was also considered an interesting functionality of the application. Thus the exhibition could be extended even after it is over at the museum as a result of its virtual existence on the Web. In this way, the cultural activity of the museum can be enhanced and expanded in time.

6. Discussion

The results of the initiative of involving university students in the digital preservation of cultural and scientific heritage can be analised on the base of three perspectives:

- View of the instructors.
- View of the students.
- View of the curators.

These aspects were evaluated based on direct observation and on the answers of the students to a questionnaire distributed online. Since the experiment started several years ago and is still ongoing, some of the students answered the questionnaire right after finishing their project while others gave their opinion about a project executed some years ago. Curators were also invited to express their opinion answering an open question about the experiment.

The view of the instructors is based on direct evaluation and personal opinion about the projects along the years. The instructors as a group made the contacts with curators or with responsibles for the heritage assets. Projects were delineated, prepared and presented to the students, whenever possible in the presence of heritage responsibles who also explained their requirements. This was important because it positively increased the engagement of the students, when they saw that other people from outside the Faculty were depending on their results. The projects were very distinct, each student normally participated in just one project and, at the end of the semester, there were final presentations within each discipline, so that all became aware of the 3D modelling techniques used by each one or each group and got acquainted with the alternatives or the reasons for the choice. The presentations included the brief historical research done by the students framing the object of study. Most of the projects presented in this paper were semester projects but there are some final projects among them (from Bachelor's or Master's), which demonstrates the interest that the students have acquired for the theme, after having already worked with heritage once in earlier years during their course.

To evaluate the view of the students, a questionnaire was sent via Web to a sample of students who had worked in a heritage project in the last years. 21 answers were collected, 67% from Computer Science and Informatics Engineering, 28% from Geospatial Engineering and 5% from other areas. The questionnaire consisted on four closed questions with a scale for the answer ranging from 1 (fully desagree) to 5 (totally agree), one closed question with a Yes/No answer, and one open question. The first three closed questions were about how the project influenced the personal attitude towards cultural heritage and the remaining two about the assessments. The open question allowed the students to express their opinions about the project, pointing strengths and weaknesses. Table 1 presents the first four questions and the percentage of answers classified according to the scale, while Table 2 shows the median, mean and standard deviation of the results.

The median answer value for each of the questions Q1 to Q4 was 4, indicating a good agreement with the statements. As a summary, we conclude from the questionnaire that most students were motivated to visit or revisit the site (Q1: 58% in answers 4 and 5), the interest for the history of the site was aroused for the majority of them (Q2: 57% in answers 4 and 5), 76% agreed well and very well with the project having alerted them for the importance of preserving the historical and cultural heritage (Q3: answers 4 and 5), and 72% think it was very interesting that the topic of digital cultural heritage was used for the assessments of the disciplines. Question five required a Yes or No answer and had asked if the student prefered to have worked in a different topic: 81% answered 'No'.

Table 1: Students' answers to questions Q1 to Q4

	1	*2*	*3*	*4*	*5*
Q1- motivated me to visit / revisit the site	9%	5%	28%	29%	29%
Q2- aroused / rose my interest in the history of the site	9%	5%	29%	38%	19%
Q3- alerted me to the importance of preserving the historical and cultural heritage	5%	10%	10%	33%	43%
Q4- I found very interesting that digital cultural heritage was used for the assessments	5%	10%	14%	24%	48%

Table 2: Metrics of answers to questions Q1 to Q4

	Median	*Mean*	*Standard deviation*
Q1- motivated me to visit / revisit the site	4	3.6	1.2
Q2- aroused / rose my interest in the history of the site	4	3.5	1.1
Q3- alerted me to the importance of preserving the historical and cultural heritage	4	4.0	1.2
Q4- I found very interesting that digital cultural heritage was used for the assessments	4	4.0	1.2

As for the open question, as weaknesses of the initiative, apart from several references to technical difficulties, such as working with less user-friendly software, finding appropriate station points for the camera, the big dimensions and complexity of the object and the lack of time to perform a quality project, some students also stated their disappointment with the poor conservation condition of the surveyed heritage objects, although this fact embodies rather a motive for the initiave than a weakness.

As strengths, students pointed the fact of having spent time in historical research (which they were not used to), the positive experience of achieving a realistic looking and detailed model, the opportunity of learning several techniques used in cultural heritage, the contact with the diversity of cultural heritage, and also the discovery of beautiful buildings and pleasant spaces they did not know before.

As for the view of curators, the 3D models found great acceptance from museum's staff, which were open to future similar projects.

In the case of the Lisbon Museum the support of curators was decisive for the fine tuning of the VEB, a tool designed for planning exhibitions in actual interior museum spaces modelled in 3D. A prototype was tested by the director of the museum and her team. The aim was to get an expert opinion about the tool and to verify that it can be used by people with no specific expertise in informatics. All members of the team considered that this interactive application was a valuable tool to prepare an exhibition and were enthusiastic about further developments.

As another example of curators view, we quote M. Lourenço from MUHNAC who accompanied the works at this museum:

"Museums look forward to collaborations such as this one for multiple reasons. The first is that new interdisciplinary perspectives always enrich the collections, making them more accessible for research and display to broader audiences. In this particular case, the Museum acquired a new innovative visual tool to promote the Astronomical Observatory among the general public and potential fundraisers. The second reason is that collections are usually used for exhibition and for display, but rarely as a resource for higher education teaching. As a university museum, this is a very important dimension of our mission. Finally, the Faculty-Museum collaboration regarding the 3-D modelling of the Observatory created an extraordinary 'real world' opportunity for students, professors and museum staff to actively engage in the actual preservation of the scientific heritage of the University of Lisbon" (Lourenço, M., personal communication, June 6, 2016).

7. Conclusion

The goal of the initiative was to raise the awareness of university students of computer science and engineering to the importance of digital heritage preservation. The chosen approach has included their involvement in the generation of 3D models and animations of cultural or scientific heritage issues with the aim of transmitting information to the public about spaces and objects in a highly comprehensive and even entertaining mode, either locally or via the Web. To illustrate the diversity of aims, a 3D model can be used for in the context of heritage divulgation. The reconstructed objects ranged from panels and small objects to interior spaces, buildings and even building complexes. Although most of the spaces were accessible and the respective models would be used for attraction of the visiting public, some of the modelled spaces are currently not visitable and in risk of ruin, such as the Astronomical Observatory and Villa Sousa; others do not exist in this form any more, such as the Port of Lisbon which industrial character led to irrecoverable changes over time. Students got aware that the created 3D models constitute a way to revive those spaces, preventing them to disappear from the collective memory. Also the animation of scientific artwork such as the sulphuric acid panel in the Chemistry Amphitheatre was intended to help the prevention of a whole process of 19^{th} century industrial production to vanish from our scientific memory.

This experience shows ultimately a worth mentioning symbiosis between heritage wardens and university: while providing interesting themes for the students' final projects, museums profit from the results obtained with very few resources and students have the reward of producing something useful for the promotion of scientific and cultural heritage.

The facts that the 3D models and animations made by the students are presently being included in MUHNAC's application for European funds for the reconstruction of the Astronomical Observatory, and that a collaboration protocol is being signed between the Portuguese General Directorate for Cultural Heritage and the Universities of Lisbon (Portugal) and Extremadura (Spain) regarding 3D documentation of heritage buildings, involving directly a part of the authors, demonstrate that the initiative also paid off to the side of heritage wardens.

Acknowledgements

We acknowledge the students Pedro Lopes, Fernando Berenguer, Bogdan Rosu, Robin Burgess, Vitor Pinto, Marine Granger, Inês Gomes, Jorge Gomes, Rui Flores, João Moreira for their work in the models presented in this paper. The projects were partially supported by the R&D Unit BioISI, UID/MULTI/04046/2013 financed through FCT/MCTES/ PIDDAC, by the project PTDC/EMSENE/4525/2014 from FCT, Portugal, and by NEXUS, Spain.

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