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Accessing and Information System

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DIGITAL SURVEY AND 3D DIGITALIZATION

3D imaging system for the digitization of the Argentine museums' collections

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The 3D image acquisition techniques most commonly used for 3D recording of museum objects are the laser or structured light scanning. These techniques are usually expensive and some complex for handling. But since a few years ago, results obtained with digital photogrammetry and appropriate image processing software are leaving behind traditional techniques, with the advantage of a lower cost, easy access and simple execution. This new option allows a really massive access to the use of the 3D resource and it is beginning to impact very strongly in diverse areas, such as cultural heritage.

In the latter case, 3D images are increasingly used in the museums of the entire world for documentation, for monitoring the state of conservation of an object, for the recording of deteriorations that are not detectable, for carrying out virtual reconstruction of lost elements and for dissemination. They also allow real-scale measurements without the need for physical manipulation and the production of copies from originals.

Although these applications have been carried out for a long time at an international level, in Latin America and particularly in Argentina the use of these technologies is still very limited. In the Argentine museums, documentation and dissemination systems are generally photographic and do not include recording by 3D images. This is the case of more than 400 museums of the Province of Buenos Aires. Given this situation, in recent years, the Laboratory of Laser Ablation of the Centro de Investigaciones Ópticas (LALFI-CIOp) has been investigating the use of 3D technology in cultural heritage and since the beginning of 2017 is carrying out a four-year project called "Digitization of Cultural Heritage by 3D Images". This Project is funded by the Scientific Research Commission of the Province of Buenos Aires and the Ministry of Culture of the Nation.

In this context, the LALFI has developed a 3D recording system for museums, based on digital photogrammetry and free software. This system, called "Mu3D", is very accessible to conservators.

The overall objective of the project is to produce an innovation in museums by incorporating the 3D digitization of their collections, transferring to them the Mu3D system developed, training their staff in the use of this technology and offering advice for the implementation of digitization programs and conservation actions. Also, this project contemplates virtual access to the museum collections, allowing visualizing in 3D, for example, objects that are not exhibited. On the other hand, museums often need to study the state of the objects of their collections and to do restoration strategies and material analysis. In the majority of cases, these museums do not have access to the appropriate techniques to perform these tasks, due to lack of knowledge or budgetary reasons. In this sense, the project also aims to provide advice and service for this type of studies, making the infrastructure of the LALFI-CIOp available to the museums in order to apply novel photonic techniques.

The Mu3D system

The developed 3D recording system, Mu3D, is based on digital photogrammetry and 3D image processing using free software. It consists of a user manual that includes procedures for 3D recording of collections and the software required for processing and visualization.

Digital photogrammetry is the most suitable option, compared to other techniques such as laser or structured light scanning, for the digitization of museum collections. It has the advantage that only a standard camera and a computer are needed, it does not require a complex setup and it can be easily implemented by museum employees not specialized in image processing techniques. In addition, digital photogrammetry reaches the same resolution as the laser scanning technique using low-cost instruments [Morita, 2017]. The procedure is very easy: the user takes a sequence of photos of an object in different positions and angles, and with a software provided by the system he can generate a 3D model with colour texture.

One of the most appropriate techniques to automate the process of photogrammetry is Structure-from-Motion (SfM) [Snavely *et al.*, 2008], which was used in our project. There are several pieces of software for performing this technique. In the Mu3D system, the VisualSfM software [Wu, 2011] is used to make the correspondence between the images and to generate a 3D point cloud; the CMP-MVS software [Jancosek *et al.*, 2011] is used to make a textured

mesh from that point cloud; and the MeshLab software [Cignoni *et al.*, 2008] is used to edit the models, visualize them interactively and perform damage mapping and virtual measurements, among other things.

In order to apply the SfM technique, many images of the object are taken in a wide range of orientations and positions, with an overlap of more than 70 %, a fixed focal length and a depth of field that allows having most of the object in focus. The lighting should be diffuse and uniform, making sure that the images are very clear and have high resolution. The algorithms in the SfM software detect common characteristic points among all the images and calculate the position of each one in the form of three-dimensional coordinates. The result is a point cloud. By using image processing techniques, it is possible to transform that point cloud into a textured mesh, which will be the final 3D model. MeshLab's surface and texture reconstruction filters [Hoppe, 2008; Dellepiane *et al.*, 2010] or the CMP-MVS software can be used for this purpose.

A user's manual for museums was elaborated and distributed to the institutions that participate in the project that contains a protocol to perform the photogrammetric recording and post-processing of the 3D models. Also, a flash drive that contained the software and theoretical material on the SfM technique and the photographic practice was also distributed to the participants.

Training of the museum staff

In order to participate in the Project, the museums have to fulfill the following conditions:

- an institutional compromise to participate in the project;
- the designation of a suitable person for the digitization tasks who could also participate in the training course;
- the selection, by the museum management, of the type of collection and the estimated number of objects to be digitized within a period of two years;
- having a camera and a computer with an appropriate processor and graphics card for 3D image processing.

Till the date, 25 institutions have participated, exceeding expectations for the first period of the project. Table 1 shows the list of the institutions that took the training course.

Two training courses were offered on the use and possibilities of the Mu3D system. The first edition was carried out at CIOp on July 2017 (fig. 1). The second one was in the Ferrowhite Museum, Bahía Blanca, Buenos Aires, on August 2017. In both courses, theoretical contents and practical training in computers were given (16 hours in total), to which they were added the tasks of the individual practical work of those trained, required for the approval of the course.

Tab. 1
List of institutions that have participated in the project "Digitalization of Cultural Heritage by 3D Images"

No.	Institution / Museum
1	INCUAPA (Instituto de Investigaciones Arqueológicas y Paleontológicas del Cuaternario Pampeano), UNICEN
2	Museo de Arte Contemporáneo Latinoamericano (MACLA)
3	Museo de Instrumentos Musicales Emilio Azzarini
4	Facultad de Bellas Artes – Área Museo, exposición y conservación
5	Museo Taller César Bustillo
6	Dirección de Museos y Preservación Patrimonial de la Provincia de Buenos Aires
7	Museo de Ciencias Naturales de La Plata
8	Museo de Bellas Artes Provincial Emilio Pettoruti
9	Complejo Museográfico Provincial Enrique Udaondo
10	Quinta de Perón – 17 de Octubre
11	Museo Histórico Provincial Guillermo Enrique Hudson
12	Museo del Juguete
13	Museo de Física
14	Museo de Astronomía y Geofísica de la Facultad de Ciencias Astronómicas y Geofísicas
15	MEDA Museo etnográfico Dámaso Arce
16	Museo del Cabildo y la Revolución de Mayo
17	Museo Y Biblioteca Juan d. Perón
18	Museo Libres del Sud
19	Museo Ferrowhite
20	Museo del Puerto de Bahía Blanca
21	Museo de Arte Contemporáneo / Museo de Bellas Artes de Bahía Blanca
22	Museo de Ciencias de Bahía Blanca
23	Departamento de Humanidades, Universidad Nacional del Sur
24	Habemus Grupo facilitador para museos (Bahía Blanca)
25	Museo Histórico de Bahía Blanca

The contents were:
- introduction to 3D recording. Fundaments of digital photogrammetry and the Mu3D system;
- workshop on digital photography for 3D recording;
- practice with an object provided by the LALFI-CIOp;
- Structure-from-Motion software (VisualSfM and CMP-MVS). Edition of the 3D model with MeshLab. Scale, alignment and interventions. Exercises on PC;
- discussion about the collections that each museum had proposed to digitize.

An open laboratory for 3D recording training

An open laboratory was set up at CIOp so that the participating museums could train in 3D digital photogrammetry, test their own systems and adjust the technique (photographic acquisition and data processing). The laboratory is permanently available for participants who have completed the course and it has the support of the LALFI team. The facilities are equipped with three computers suitable for 3D image processing. In addition, a laser scanner and a Reflectance Transformation Imaging (RTI) system [Mudge, 2005] were set up when required.

So far, 13 of the 25 institutions that attended the course have regularly used the CIOp laboratory to complete the training of their staff. All of them have already managed to digitize pieces of their respective collections. Figures 2 and 3 show some examples of the digitization of several objects made during the project.

Digital repository for the museum's 3D images

We developed a digital repository where all the 3D models made by the participating museums could be placed and shown next to the technical or historical information of the object. It is under construction and was designed as an independent site, linked to the museum's websites (if they have it) and with free access (find Mu3D project on the website www.ciop-cic-conicet.gob.ar).

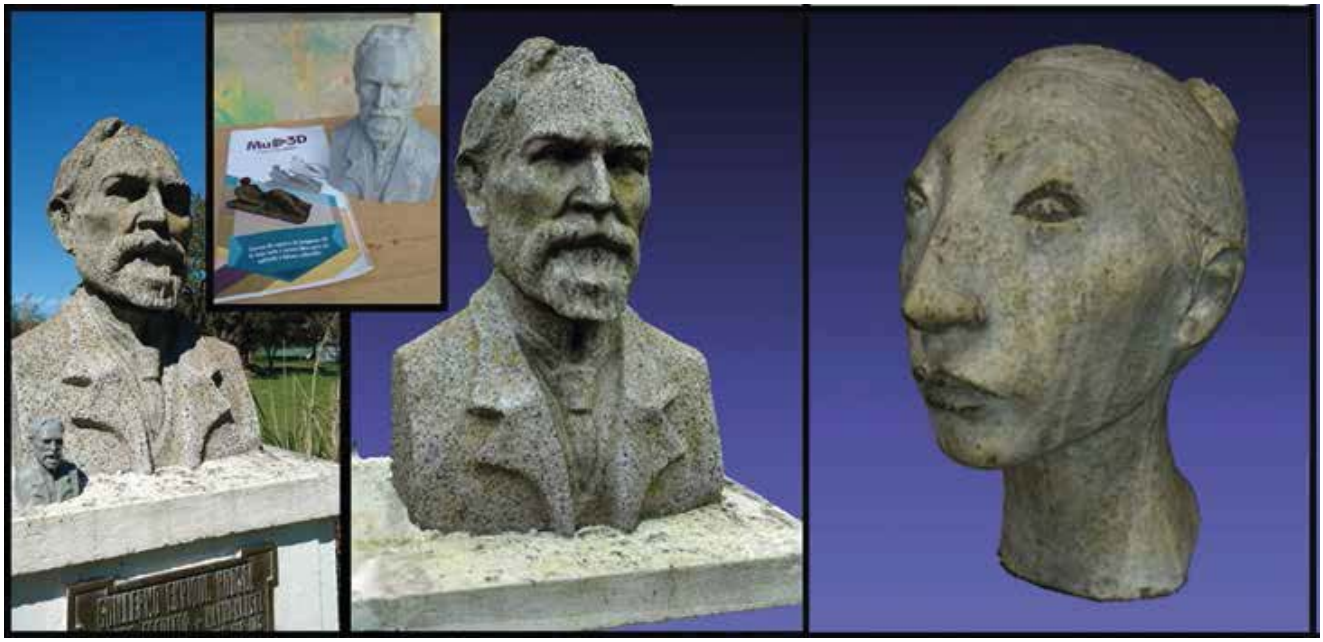
The 3D models could be visualized in GIF format and some of them could also be visualized using the 3DHOP interactive software, developed by the CNR-ISTI Visual Computing Lab [Potenziani *et al.*, 2014].

3D printing laboratory

A set of 3D printers will be assembled at CIOp as a facility for the production of small replicas of cultural heritage objects, support elements and containers for conservation and exhibition. This facility will be offered to museums that want replicas for educational purposes. On the other hand, the designing of support elements and containers will be explored, with the aim that museums could learn this technology and take action to implement it with their own financing.

1

Fig. 1. Course given at CIOp, Gonnet, La Plata.



2

Fig. 2. Monument of Guillermo Enrique Hudson next to a 3D printed replica on a small scale in the inset (left); 3D model of the monument displayed in MeshLab, made by the participants of the Museo Histórico Provincial Guillermo Enrique Hudson (middle); 3D model of a sculpture from the collection of the Museo Provincial Emilio Pettoruti de La Plata, made by participants of the Dirección de Museos y Preservación Patrimonial de la Provincia de Buenos Aires (right).

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Fig. 3. 3D models of objects that belong to collections of some museums that have participated in the project. An archaeological ceramic from the Museo de Ciencias Naturales de La Plata (left); a molar from *Stegomastodon platensis*, Museo de Ciencias de Bahía Blanca (middle); a sculpture by César Bustillo, Museo Histórico Provincial Guillermo Enrique Hudson (right).

Non-destructive analysis service by using photonic techniques

In addition, a facility for applying photonic techniques to the study of patrimonial objects is offered to the participating institutions: in particular, Laser Induced Breakdown Spectroscopy (LIBS) [Anglos, 2001], Laser and Structured Light Scanning [Sansoni, 2009], Reflectance Transformation Imaging, Laser Cleaning [Fotakis *et al.*, 2006; Bilmes *et al.*, 2007] and Optical Coherent Tomography [Morel *et al.*, 2013].

Among the ongoing works, we can mention the one of the Faculty of Fine Arts, where the objective is to study the effectiveness of laser cleaning for the various cases of plaster patinas. Other works were developed in collaboration with the INCUAPA (Institute of Archaeological and Paleontological Research of the Pampean Quaternary) and the Recoleta Cemetery of Buenos Aires. In these studies, the Reflectance Transformation Imaging was used. In the first case, RTI was applied to the study of marks in archaeological bones, and in the second one, it was used to read the inscriptions of a tumulus, relevant for the historical identification.

Conclusions and perspectives

During the first year of the project, we achieved 90 % of the objectives and tasks proposed for this phase. A survey in order to know the opinion of the participants regarding the project was performed. Most of them were very satisfied with the contents and the dynamics of the course. Possibly this is due to the fact that training of these characteristics (free and with constant support) have rarely been offered in the cultural heritage field in Argentina.

The possibility for the participants to attend a laboratory at CIOp to use the computers allows overcoming some issues regarding the limitations of the Argentine museums, as the minimum equipment required (hardware) to work with the Mu3D system.

After having some experience of the application of the Mu3D system, we found some new challenges to work on. Some of them were suggested by the participants of the project. Therefore, we are developing new versions of this system including changes in the protocol and in the software, in order to improve it and create more possibilities.

Finally, 3D recording techniques together with Virtual Reality technologies are having a strong impact on the conservation of Media Art and installations, allowing a new method of documentation that provides virtual access to works of art rarely exhibited or already destroyed by the obsolescence of materials [Muñoz *et al.*, 2016; Morita, 2017]. We are planning to incorporate virtual and augmented reality technologies soon into the training courses and into the 3D recording protocol for museums.

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BIBLIOGRAPHY

Anglos D., *Laser-induced breakdown spectroscopy in art and archaeology*, "Applied Spectroscopy", 55, 2001: 186-205.

Bilmes G.M., Freizstav C.M., Cap N., Rabal H., Orsetti A., *Laser cleaning of 19th century papers and manuscripts assisted by digital image processing*, in Castillejo M., Moreno P., Oujja M., Radvan R., Ruiz J. (eds. by), *Lasers in the Conservation of Artworks: Proceedings of the International Conference Lacona VII*, 2007: 361-365.

Cignoni P., Callieri M., Corsini M., Dellepiane M., Ganovelli F., Ranzuglia G., *MeshLab: an open-source mesh processing tool*, in *Proceedings of Eurographics Italian Chapter Conference*, 2008: 129-136.

Dellepiane M., Callieri M., Corsini M., Cignoni P., Scopigno R., *Improved color acquisition and mapping on 3D models via flash-based photography*, "ACM Journal on Computing and Cultural Heritage", 2, 2010: 1-20.

Fotakis C., Anglos D., Zafiropulos V., Georgiou S., Tornari V., *Lasers in the Preservation of Cultural Heritage: Principles and Applications*, New York, 2006.

Hoppe H., *Poisson surface reconstruction and its applications*, in *Proceedings of the 2008 ACM symposium on Solid and physical modeling*, 2008: 10.

Jancosek M., Pajdla T., *Multi-view reconstruction preserving weakly-supported surfaces*, in *Proceedings of the 2011 IEEE Conference on Computer Vision and Pattern Recognition*, 2011: 3121-3128.

Morel E.N., Gutierrez M., Mirnada H., Torga J., *3D OCT imaging for non-contact metrology of materials*, in *Proceedings of the First International Symposium on Optical Coherence Tomography for Non-Destructive Testing*, 2013.

Morita M., *Registro en 3 dimensiones de bienes culturales. Aplicaciones al arte contemporáneo*, Ph.D. thesis, Universidad Nacional de La Plata, 2017.

Mudge M., Voutaz J.-P., Schroer C., Lum M., *Reflection transformation imaging and virtual representations of coins from the Hospice of the Grand St. Bernard*, in *Proceedings of the 6th International Conference on Virtual Reality, Archaeology and Intelligent Cultural Heritage*, 2005: 29-39.

Muñoz Morcillo J., Faion F., Zea A., Hanebeck U.D., Robertson-von Trotha C.Y., *e-Installation: synesthetic documentation of Media Art via telepresence technologies*, in Boştenaru Dan M., Crăciun C. (eds. by), *Space and Time Visualisation*, Basel, 2016: 173-191.

Potenziani M., Corsini M., Callieri M., Di Benedetto M., Ponchio F., Dellepiane M., Scopigno R., *An advanced solution for publishing 3D content on the web*, in Proctor N., Cherry R. (eds. by), *Proceedings of Museums and the Web 2013*, 2014.

Sansoni G., Trebeschi M., Docchio F., *State-of-the-art and applications of 3D imaging sensors in industry, cultural heritage, medicine, and criminal investigation*, "Sensors", 9/1, 2009: 568-601.

Snavely N., Seitz S.M., Szeliski R., *Modeling the World from internet photo collections*, "International Journal of Computer Vision", 80/2, 2008: 189-210.

Wu C., *VisualSfM: A Visual Structure-from-Motion System*, 2011: http://ccwu.me/vsfm/.

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KEYWORDS

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digitalizzazione 3D, Structure-from-Motion, fotogrammetria, musei argentini

ABSTRACT

3D IMAGING SYSTEM FOR THE DIGITIZATION OF THE ARGENTINE MUSEUMS' COLLECTIONS
3D images are increasingly used in the documentation of cultural heritage. The Laboratory of Laser Ablation of the Centro de Investigaciones Ópticas, La Plata, Argentina, is carrying out a 3D digitization project of the collections of the museums of the Province of Buenos Aires, by using digital photogrammetry. A system called Mu3D was developed, that uses free software for Structure-from-Motion (SfM) and 3D image processing. A combination of three software systems has been chosen in order to achieve a 3D model with the same accuracy of the results obtained by laser scanning techniques.
The system, including a protocol for image acquisition, is being transferred to the museums for free, by training their staff and providing them assistance for the development of digitization programs and conservation actions.

3D IMAGING SYSTEM PER LA DIGITALIZZAZIONE DELLE COLLEZIONI MUSEALI ARGENTINE
Le immagini 3D sono sempre più utilizzate nella documentazione del patrimonio culturale. Il Laboratorio di Ablazione laser del Centro de Investigaciones Ópticas di La Plata (Argentina) sta svolgendo un progetto di digitalizzazione 3D delle collezioni dei musei della provincia di Buenos Aires, usando la fotogrammetria digitale. È stato sviluppato un sistema denominato Mu3D che impiega software liberi per Structure-from-Motion (SfM) ed elaborazione di immagini 3D. È stata selezionata una combinazione di tre sistemi software così da ottenere un modello 3D che avesse la stessa accuratezza di risultati delle tecniche di scansione laser. Il sistema, che include un protocollo per l'acquisizione di immagini, viene consegnato gratuitamente ai musei, formandone contestualmente il personale e fornendo loro assistenza per l'elaborazione dei programmi di digitalizzazione e per operazioni conservative.