From 3D surveying to replica, a resource for the valorisation of museum artifacts. The case of the bas-relief of Giovanni da Legnano in Bologna.

G Bitelli[1,3], V A Girelli[1], M Medica[2], M A Tini[1]

[1] Department of Civil, Chemical, Environmental and Materials Engineering (DICAM) – University of Bologna, Viale del Risorgimento 2, 40136, Bologna, Italy
[2] Istituzione Bologna Musei, Municipality of Bologna, Via Don Minzoni 14, 40121, Bologna, Italy

[3] Corresponding author: gabriele.bitelli@unibo.it

Abstract. This paper describes the experience carried out by the Geomatics group of the DICAM Dept. (Department of Civil, Chemical, Environmental and Materials Engineering) of the University of Bologna, in collaboration with the Civic Medieval Museum, about the digitization and reproduction by 3D printing of the bas-relief of Giovanni da Legnano. This artwork is one of the symbols of the University of Bologna, the oldest of the western world, and consequently of all European academic tradition. In the text, the 3D surveying and physical reproduction operations of this object are described. The faithful copy of the object was presented in Brussels in 2017, on the occasion of the inauguration of the House of the European History.

1. Introduction

In recent decades, the use of 3D modelling techniques increasingly versatile and widespread has offer the possibility to explore new opportunities not only in the documentation and study of Cultural Heritage, but also for the communication and museum use of objects and artworks [1, 2].

The immediate advantages of the availability of 3D models include documentation, virtual examination, study and research. In fact, the 3D model of an object ensures the memory of its current state, but there is much more beyond this. A virtual digital 3D model can be explored, transformed, sectioned, studied in all aspects, without touching or damaging the real object; for example, the decay can be mapped to plan the restoration [3], artworks in different locations can be compared with each other [4], a damaged object can be virtually bring back to the original splendor [5], the peculiar characteristics of the object can be emphasized, such as inscriptions [6], permitting new levels of knowledge to those offered by the real object.

All these aspects are now joined by the possibility of obtaining an exact copy of the object of interest, thanks to the spread of increasingly refined, widespread and low-cost as well 3D printing techniques.

Geomatics surveying techniques as 3D scanning and digital photogrammetry permit nowadays to obtain 3D models characterized by a very-high level of geometric and radiometric detail, optimized for the reproduction by means of 3D printing [7].

This possibility opens up to new possibilities, on the one hand to the institutions to communicate and share the artworks [8], on the other hand to scholars and general users to approach and study the art itself [9].

The work here presented describes the experience, carried out by the DICAM Geomatics group of the University of Bologna, about the integration of structured-light projection scanning and Multi-View Structure from Motion (SfM) photogrammetric techniques for the digitisation and reproduction of one of the three marble fragments of the ark of Giovanni da Legnano today preserved in the Civic Medieval Museum in Bologna. The bas-relief, dated back to the 1386, is one of the symbols of the University of Bologna, for two different reasons: it represents some students during a lecture, constituting a testament of the academic life of that time, and the importance of Giovanni da Legnano itself, jurist and lecture of canon law at the *Studium* of Bologna and fundamental figure in the history of Alma Mater Studiorum, the oldest University of the western world.

The aim of the 3D modelling was in this case the realization of a faithful replica in 1:1 scale of the artwork by 3D printing. The copy, realized in epoxy resin, was displayed in the exhibition set up in Brussels for the opening of the House of the European History in May 2017.

2. The case study: the bas-relief of Giovanni da Legnano in Bologna

Giovanni da Legnano (in Latin *Iohannes de Lignano*) was born in Milan around 1320. He moved to Bologna in 1350, motivated by a specific interest of cultural nature, being this city a well-known centre of legal studies.

Here Giovanni made a rapid career, standing out for his wide juridical doctrine. He became one of the most important jurists of his time and a highly appreciated intellectual, at the papal curia and at the major European university centres, for the vastness of his literary production and for his politic commitment. He was also a lecturer in canon law at the *Studium* of Bologna, capable of attracting to the city students from all over Europe. He died in January 1383 and was buried in the Church of S. Domenico, after making Bologna a model for law schools in Medieval Europa [10].

Three marble fragments of its monumental ark, masterpiece of the Venetian sculptors Pier Paolo and Iacobello Dalle Masegne, are now preserved in the Civic Medieval Museum in Bologna: a slab with the family crest, presumably one of the sides of the sarcophagus; the inscription placed between two other crests of the same family which shows the date of death of Giovanni da Legnano, February 16, 1383, and the bas-relief representing some students intent on the famous jurist's lesson, which has become one of the symbols of the University of Bologna (Figure 1). The last is the subject of this work, but the aim is to rebuild as much as possible the whole ark in the future.

The sculptor decided to show the students in class during a lecture: two in the front row are concentrated in reading, one in the middle is absorbed in his own thoughts, while the others are focused on the teacher. This artwork (size about 80 x 70 x 12 cm) constitutes an extraordinary testament of the academic life of that time and, given the importance of Giovanni da Legnano in the history of the University of Bologna, can be considered one of the symbols of European academic culture.

Figure 1. The bas-relief of Giovanni da Legnano, preserved in the Civic Medieval Museum in Bologna.

3. Digitisation and reproduction

The high-detailed 3D model of the bas-relief of Giovanni da Legnano was obtained by integrating 3D scanning and digital photogrammetry. The use of the two techniques was necessary to solve some problems related to the characteristics of the object, such as the complex geometry, rich of small details and hidden areas, and the shiny material, made further problematic by the lighting system in the museum.

The survey required a relatively great numbers of scan (23) considering the object size; the chosen instrument was the structured-light projection scanner Artec MHT, a handheld 3D scanner characterized by a nominal accuracy of 0.1 mm and a working distance between of 0.4-1 m (Figure 2).

The final 3D model, obtained after the classic steps of scanning data processing (scans alignment and fusion realized in Artec Studio software, mesh optimization performed using the tools implemented in Geomagic) presented some criticalities due to the above difficulties, such as surface noise and holes.

Figure 2. A phase of the 3D scanning (left image); the acquired scans, each differently coloured (right image).

In order to partially answer these problems, digital photogrammetry using Multi-View Structure from Motion approach was performed, acquiring about 100 images with a Canon EOS 6D full-frame camera and then processed within Agisoft Metashape software. The average acquisition distance of the images was about 40 cm, producing a Ground Sample Distance in the order of 0.1 mm; the final accuracy of the alignment phase was of the same order of magnitude.

A first quick medium-quality model obtained by photogrammetry was used to study and planning the 3D printing operations, that is to choose the most appropriate material and printing technique and to prepare an estimate of time and cost. The high-detailed photo-textured 3D model permits to integrate the data derived from scanning. The alignment between the two obtained 3D models was realized by ICP algorithm and then the two meshes were merged together.

After this, the preparation of the final model ready for the 3D printing was performed in order to comply the requests of the company in charge of 3D printing: a perfectly closed and topologically correct model with a resolution of 0.5 mm. The processing required a significant manual intervention by the operator in order to guide and assist the software used for the mesh editing in many semi-automatic tools, as for example the noise smoothing, the detection and correction of defects in the mesh, the filling of small residual holes (Figure 3).

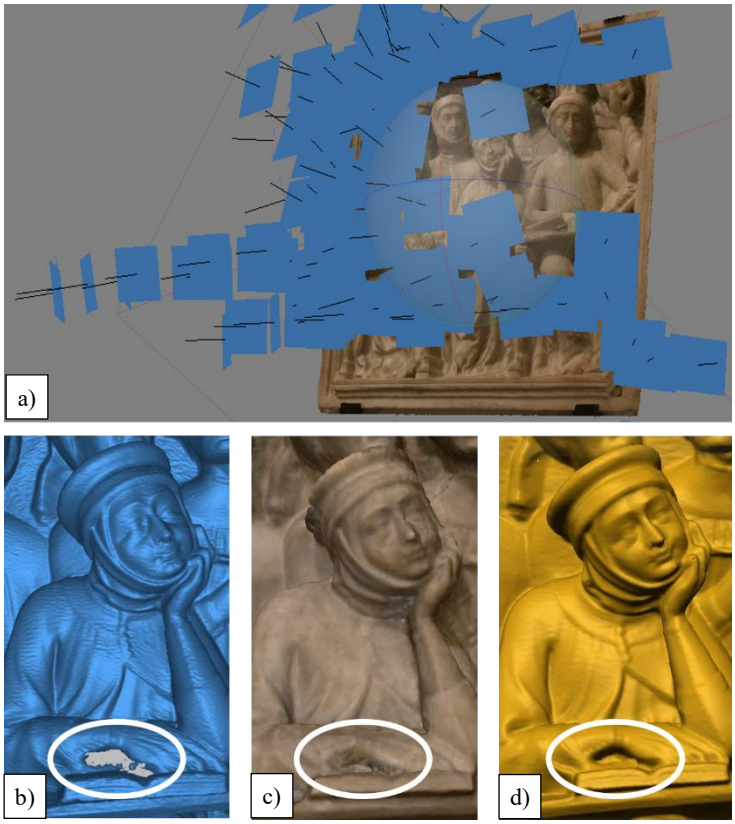

Figure 3. Supplementing the 3D scanning by photogrammetry in some problematic areas: the images block (a); an example of lack of data in the 3D model by Artec scanner (b); the same area reconstructed by SfM (c); the integrated 3D model after ICP, merging and meshes optimization (d).

The optimized 3D model, consisting of approximately 10 million triangles with an average side of 0.5 mm, is characterized by an estimated intrinsic precision of the same order of magnitude (Figure 4).

Figure 4. The digital model of the bas-relief, optimized for the 3D printing.

The physical model in 1:1 scale was realized, in epoxy resin, by the Materialise company (https://www.materialise.com/) in Belgium (Figure 5). It was deliberately chosen not to simulate the natural color of the work but to adopt a more artificial white coloring that recalls the concept of copying but at the same time enhances the work in the final installation.

The copy was exhibited in Brussels in May 2017, in the area assigned to the birth of the first European universities during the exhibition "Interactions", organized on the occasion of the opening of the House of the European History. In Figure 6 the setting up of the replica is shown.

Figure 5. The replica in 1:1 scale realized by 3D printing in epoxy resin (a); a detail of the replica (b); the same detail in the 3D model (c).

Figure 6. The setting up of the replica of the bas-relief exhibited in Brussels for the opening of the House of the European History (2017).

4. Conclusions

This work presents the activities of surveying and data processing involved in the digitization process of an important artwork, a symbol of the University of Bologna and of the whole European academic culture.

3D scanning and digital photogrammetry were integrated to obtain a high-detailed 3D model of the object, then optimized for the generation of a faithful replica in 1:1 scale by 3D printing. The copy was specifically realized for the temporary exhibition “Interactions”, organized in Brussel in May 2017 in parallel to the opening of the House of the European History. The possibility to “move” the artwork, that is its exact replica, so far from its usual location made it accessible to a much wider audience, contributing, thanks to new technologies, to the valorization, dissemination and sharing of the object itself, and consequently to the history of the oldest university in the western world.

It is the intention of the authors in the near future to virtually reconstruct, as far as possible, the monumental ark of Giovanni da Legnano by scanning other parts that still exist.

References

[1] Matthew L, Vincent M L, López-Menchero Bendicho V M, Ioannides M. and Levy T E 2017 Heritage and Archaeology in the DigitalAge. Springer International Publishing.

[2] Bitelli G, Balletti C, Brumana R, Barazzetti L, D'Urso M G, Rinaudo F and Tucci G 2019 The GAMHer Research Project for metric documentation of Cultural Heritage: current developments *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.* **XLII-2/W11** pp 239-46

[3] Girelli V A, Tini M A, Dellapasqua M and Bitelli G 2019 High resolution 3D acquisition and modelling in Cultural Heritage knowledge and restoration projects: the survey of the Fountain of Neptune in Bologna” *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.* **XLII-2/W11** pp 573-8

[4] Girelli V A, Tini M A, D’Apuzzo M G and Bitelli G 2020 3D digitisation in Cultural Heritage knowledge and preservation: the case of the Neptune statue in Bologna and its archetype *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.* **XLIII-B2-2020** pp 1403-8

[5] Francolini C, Girelli V A and Bitelli G 2020 3D image-based surveying of the safe of the Obellio Firmo domus in Pompeii *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.* **XLIII-B2-2020** pp 1389-94

[6] Bitelli G, Borghi B, Francolini C and Galletti F 2020 New hypotheses and interpretations regarding the Longobard Basin in the “Jerusalem” of Bologna supported by 3D surveying methodologies *J. Cult. Herit.* 46 pp. 226-34

[7] Balletti C and Ballarin M 2019 An Application of Integrated 3D Technologies for Replicas in Cultural Heritage *ISPRS Int. J. Geo-Inf.* **8 (6)**

[8] Di Franco P D G, Camporesi C, Galeazzi F and Kallmann M 2015 3D printing and immersive visualization for improved perception of ancient artifacts *Presence-Teleop Virt* **24** pp 243-64

[9] Neumüller M, Reichinger A, Rist F and Kern C 2014 3D printing for cultural heritage: Preservation, accessibility, research and education *Lecture Notes in Computer Science* **8355** pp 119-34

[10] Pio B 2018 *Giovanni da Legnano. Un intellettuale nell'Europa del Trecento* (Bologna: Bononia University Press)

Acknowledgments

Our acknowledgments to: Civic Medieval Museum in Bologna, DG-COMM House of European History – European Parliament, and Mirko Dellapasqua, who supported data acquisition and processing.