Management of Cultural Heritage: Bologna Gates

A. Ippolito, C. Bartolomei

Abstract**—**A growing demand is felt today for realistic 3D models enabling the cognition and popularization of historical-artistic heritage. Evaluation and preservation of Cultural Heritage is inextricably connected with the innovative processes of gaining, managing, and using knowledge. The development and perfecting of techniques for acquiring and elaborating photorealistic 3D models, made them pivotal elements for popularizing information of objects on the scale of architectonic structures.

Keywords**—**Cultural heritage, databases, non-contact survey, 2D-3D models.

I. Introduction

SPEAKING about architectural survey for the process of data gathering means penetrating the most dynamic fields of research, particularly because of the intimate connection that links the discipline with the technological development. It's the relationship between software and hardware devices that help us to record the undergoing changes of the survey in an important moment of revision, from a traditional approach to one intimately connected with the huge potential provided by digital technologies [8].

In the last years the dense stereo matching or image based modelling technologies have become quite a valid instrument for surveying and representing Cultural Heritage.

Techniques and instruments of digitalization have made possible the large-scale production of three-dimensional objects belonging to artistic and Cultural Heritage.

Conversion of physical (material) objects into digital ones involves constructing photorealistic 3D models, whose close geometric, metric, structural, chromatic similarity to the real object is necessarily its main and characteristic feature. Models of this type provide a much more effective, articulated and complex representation than others because they can be used as bases to construct cognitive systems.

Digital visualization makes possible an integrated interpretation of heterogeneous data and a redefinition of the very concept of representation by linking it to the concept of information.

A 3D model can be considered a vast and structured out information database [20]. More 3D models of architectural element systems could compose a 3D database, which would also express relations between them and their location.

Digital archives ascribe to 3D models with the information typology that characterize them, heterogeneous data (images, texts, video materials, bibliographical documents) with the purpose to preserve, evaluate and popularize cultural heritage by devising an open system of knowledge [2]. We also think that it is not appropriate to focus our attention on a specific technique only for in order to achieve the objective it's important to consider the integration of the techniques, tools and methodologies, necessary to understand the analyzed subject. For this reason, drafting a procedure that uses the interaction between non-contact methodologies and their elaboration for the realization of 2D and 3D models would be a topic of great interest [1].

Taking into account the numerous campaigns of research carried out for years, this study suggests a modus operandi that seems to be essential for the standardization and the regulation of data collection, processing and recovery procedures applied by the research group, to make the final scientific results more objective and correct [9]. The experiment concerns a study focused on the Bologna Gates.

II. The System of Gates in Bologna

The ring road of Bologna is dotted with ten of the original twelve city gates, which in ancient times were part of the "third circle of city walls" [22]. These were built in the thirteenth century and completely destroyed at the beginning of the XX century. In the centuries between their erection and our times some of them have been preserved in their original form, others were partially demolished or rebuilt in a completely different style, while still others – were razed to the ground (Fig. 1). Today, they are just monuments of the past and do not belong to any unified system of architectural structures. Each of them tells its unique story composed of demolitions, superimpositions, and architectural interventions, undertaken also for social and economic reasons. A survey of them is intended as a process of acquiring a profound cognition whose objective is to represent the subject under study through graphic models. In this architectonic situation, the survey is an instrument that can probe into the unity of the place and into the unique identity of the buildings regardless of the superimpositions of later interventions, without the risk of abstracting from the architectonic reality fused into its spatial context – which would destroy the sense of these structures so unique for their collocation.

III. Data Management: Acquisition and Elaboration

The constant spread of informatics technologies not only helps take advantage of cultural heritage but also offers various modalities to diffuse it. The methodologies that serve information sharing are always more universal. They make use of the potentialities inherent in mobile devices, like for example restitution of high definition contents, and hence are

Alfonso Ippolito is Assistant Professor, PhD at DSDRA, Department of Hystory, Drawing and Restoration of Architecture, SAPIENZA Università di Roma, Italy (e-mail: alfonso.ippolito@uniroma1.it).

Cristiana Bartolomei is Assistant Professor, PhD at Department of Architecture, Alma Mater Studiorum Università di Bologna, Italy (e-mail: cristiana.bartolomei@unibo.it).

becoming a veritably indispensable instrument of communication [4]. In recent years there have developed new research areas concerned with: the speedy acquisition of data that contain a high quantity of information; use of low cost instruments that ensure results comparable to those obtained with the 3D laser scanner within a single acquisition and restitution campaign. This is precisely the principal area of enquiry of our research, which aims primarily at realizing models obtained through a survey that integrates traditional and low cost methodologies for non-contact surveying. The experiment seeks to integrate the process of surveying with that of cataloguing by structuring out models obtained through digital photographic images in a documentary archive. This makes it possible to control, get to know, explore, and diffuse objects belonging to cultural heritage [3].

Fig. 1 Overview of the area and location of the gates

A. Data Acquisition

Modelling today is considered a creative, cognitive, modifiable and amenable to research in real time: “The computer allows to build very easily and three-dimensional numerical models to observe them from every possible point of view, as if they were really in our hands. [...] The computer screen is thus an open window on the virtual space of the model, which allows us to observe and interact with it, moving it and changing it" [21]. Thus the definition and managing of the 3D model become the crucial point of the problem for the solution of which it is fundamental to define an operative methodology, for it would be possible to refer to it in a standardized manner. The concepts of scientific data and quality alongside that of uncertainty control turn out to be fundamental in the processes of acquisition and elaboration. Quality is here understood as a description of contingent or permanent properties of an object. It designates any concretely determined formal aspect of a given reality. Lord Kelvin claims that: “when we can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind”. Thus, a metrological setting is qualitatively described by an aggregate of parameters that define the characteristic of measure: uncertainty, repeatability, accuracy. The stage of data acquisition should always be considered as an application of a scientific method based on a collection of empirically observable and measurable data, which can be archived and subjected to external verification to be validated. The applied procedure should be replicable in order to acquire a new aggregate of data comparable to the preceding one. [7].

The study of the gates of Bologna is based on the process that integrates traditional surveying techniques with those of low cost, non-contact ones. This methodology makes it possible to ascertain that the direct survey control the measurements and the Dense Stereo Matching techniques control model construction. This technique offers the possibility to generate 3D content from photographic images without the need of high-cost hardware.

The DSM technology originates in the theory of photogrammetry and makes it possible to draw 3D graphic models on the basis of photographs. This operation becomes comprehensible if one knows the relation between perspective and measurement. However, surveying objects by photogrammetry is done by specialized professionals and the tools used are not always low-cost ones. The new technologies, on the other hand, open up enormous possibilities to collect, elaborate and share data much faster and automatically [13].

Through DSM technology it is possible to obtain a realistic three dimensional rendition of architectural elements on the basis of “a global and coherent integration of all survey, modelling and the stages: coordinates, distances, vertices and profiles for the reconstruction of 3D models, texture” [12], profiles and 2D models obtained through section planes. Regardless of software used, the procedure to follow is always the same and it consists of the following stages:

- Photographing the object surveyed, including the possibility to do shots from various angles in order to cover the whole object and the lighting conditions.
- Acquisition of photo images, ensuring that part of them overlap. Thanks to this, an algorithm can recognize homologous points in various photograms.
- Photography orientation: the homologous points in the photos are automatically transformed into points in space characterized by Cartesian XYZ coordinates and the chromatic RGB ones. The operation is indispensable to establish the exact position of the centre of the projection, i.e. that of the photo camera in relation to the scene at the moment of acquiring the image; it determines precision as well as the number of points taken successively.

- Construction of the numeric model: this results in a three dimensional point cloud analogous to that obtained with the laser scanner technology. The cloud point is transformed into a 3D polygonal mesh that constitutes the surface of the object and makes it possible to vary the degree of detail. The mesh can be transferred onto other 3D editor software (http://meshlab.sourceforge.net/) to make corrections like removing standing out or redundant points or closing holes inside the polygonal mesh.
- Restoring the outward look: here texture is added to the 3D model. This passage is done automatically and guarantees the perfect correspondence between geometric and chromatic data avoiding manual texture mapping operations, which might result in an elevated level of uncertainty of the 3D model.

The experimented procedure was aimed at constructing qualitatively controllable 3D and 2D graphic models where it is essential to define the uncertainty level of the model scale. This led to the theoretical definition of the concepts of surveying and of the survey, confused mainly because of the great popularity of laser scanner technology.

The surveying stage corresponds to that of data acquisition and has been conducted first by means of direct surveying and then by acquiring photo images in order to work only with low cost methodologies. The procedure yielded a numeric model (point cloud) – an objective datum which avoids conscious schematization done by the operator and is configured as the departure point for further elaborations. Data elaboration belongs with the stage of survey, a term signifying a cultural process that leads to a critical interpretation of the object through discretization. The procedure involves a realization of graphic models and is defined as 'a process of selection which makes it possible to highlight elements of interest" [17] in the object of study respective to the scale of representation. The quality of the data obtained, with several software which work with DSM technology has been verified by attributing to each model a scale reference that describes its capacity to reproduce reality digitally in relation to its geometric and perceptive characteristics [8].

In order to verify the accuracy of the survey data as well as to control the level of uncertainty of the model scale, it is fundamental to confront the data obtained by making photo images with those obtained by direct surveying. We take photograms with a reflex NIKON D300 camera with CMOS sensor of 12 Megapixels with automatic focalization and manual zoom procedures. The procedure followed a scheme that guaranteed cover of the whole object and each photograph overlapped with the successive one in at least 60-70 %.

The final representation scale of the data was fixed in advance at 1:100 while – in order to get all the elements of the object precisely in the selected scale, the distance was calculated based on the lens focus and the characteristics of the camera used.

B. Data Elaboration

The data obtained were elaborated by comparing the data acquired by photo modelling with a commercial software, Agisoft Photoscan, and software open source, Photosynt, Arc3D, 123d Catch, with the aim of calculating uncertainty and the geometric deviation when using the same dataset. The table synthesizes the characteristics of the software used with the results obtained in the elaboration process.

The tests conducted demonstrated that a homogeneous distance from which photos are taken determines the construction of the model [5]. In the main cases, it has been observed that among software open source: Microsoft Photosynth yielded a point cloud too scattered to define a mesh coherent with the surveyed structure; Arc3D proved to be insufficient to define a partially constructed model; 123D Catch turned out to be the most precise in constructing models and textures. It yields a mesh to which it is possible to attribute three definition levels, although the resolution approximation was not left to software. (Fig. 2) Verifications have been conducted on the model obtained with the Agisoft Photoscan and 123D Catch in order to control metric accuracy, i.e. to compare model measures with those acquired with direct surveying [6] (Fig. 3). Prior to effecting metric verification – done with the Blender 3D modelling - horizontal section planes had been created. This made it possible to obtain a profile thanks to which the model could be oriented and establish scales in order to compare the dimensions. In both cases the waste – in comparison to the quantities surveyed with traditional methods – reached maximum 20 cm. Considering that in any surveying operation it is necessary do determine the level of uncertainty also in relation to the representation scale, fixed preventively at 1:100, the difference would amount to 2 mm, a value perfectly acceptable because it falls within the graphics error (11). Extra confirmation has been obtained by calculating the deviance value with CloudCompare, an open source software used for elaborating and comparing 3D cloud points: also in this case the value obtained from the section of the surfaces that make up the model in the two dimensional plane, proves to fall within millimeters (Figs. 4, 5). Thus, the research proved this methodology to be suitable for filing, cataloguing and representing objects of study [18].

Three typologies of 2D and 3D models of these objects have been realized with the aim to communicate all knowledge acquired with surveying operations. The geometric model – devoid of any chromatic characteristics makes it possible to understand the geometry, the proportions and reciprocal positioning of elements. Texturized or characterized model is based on the elaboration of digital images: it defines formal aspects and the conservation state of the object through texture mapping. Thematic model uses the symbolic character of color and yields various information about the homogeneous area of the object – be they associated with the chromatic treatment or with the state of conservation.

	processade images	surplus images	calculation time	mesh	goal
Porta Maggiore elevation: 1/4 incomplete 3d data	38	21	12 min	408085 vertex 204659 faces	○
Porta Galliera elevation: 2/4 incomplete 3d data	113	-	32 min	37854 vertex 71625 faces	○
Porta S. Vitale elevation: 2/4 incomplete 3d data	92	6	27 min	11591 vertex 21753 faces	○
Porta S. Felice elevation: 3/4 complete 3d data	63	-	13 min	222238 vertex 443399 faces	●
Porta Saragozza elevation: 3/4 complete 3d data	77	22	19 min	378006 vertex 752650 faces	●
Porta Castiglione elevation: 4/4 complete 3d data	27	9	11 min	86009 vertex 169045 faces	●
Porta Mascarella elevation: 4/4 complete 3d data	53	-	12 min	293397 vertex 684952 faces	●
Porta S. Donato elevation: 4/4 complete 3d data	73	7	22 min	455464 vertex 908422 faces	●
Porta Lame elevation: 4/4 complete 3d data	43	-	13 min	22840 vertex 43155 faces	●

Fig. 2 Cataloging of the results obtained, software 123D Catch. The table shows that in some cases the photos did not yield data sufficient for constructing a 3D model on the assumption that sufficient data allow us to recover three perspective images out of four

Constructing a high quality 3d model – the effect of surveying and object or an architectural structure – comprises a series of different steps which are partially independent.

The main steps of the procedure necessary for constructing a 3D object are the following: acquisition of the geometry as well as the material and chromatic component, managing the forms of representation, systematization of LOD (Level Of Detail) [19].

The results achieved shows that the models obtained with Agisoft Photoscan can be considered better.

The 123d Catch software has a limitation in terms of megapixel: regardless of their megapixel of the photographic image, in the upload, the image is still reduced to 3 megapixels. This obviously affects is the quality of the 3D models created in terms of resolution and quality of information.

The stage of photogramme positioning and 3D model constructing were carried out very quickly.

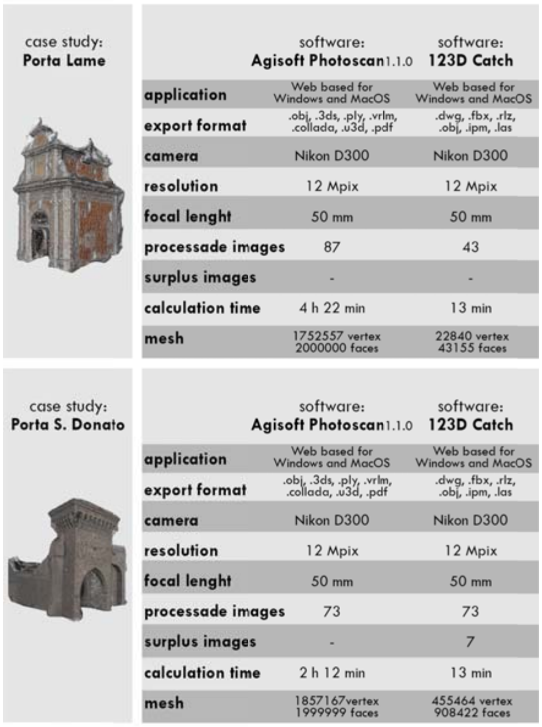
The point was to acquire and process as much information as possible to obtain the maximum amount of information in a short span of time.

The software being fully automatized, it is not possible for the operator to control significantly the accuracy of the model. However, it considerably shortens the time of processing.

The level of uncertainty has been managed by correcting the optical aberrations of individual photogrammes and this stage directly preceded the creation of the 3D model.

The data gained from the survey have been cleaned by MeshLab visualizer. Then the numerical model obtained by processing photographs had first been positioned and properly scaled in CAD environment on the basis of the measurements acquired during the campaign of direct surveying.

The 3D and textured models worked out (Fig. 6) were taken as the point of departure for constructing 2D models (Figs. 7 and 8).



case study: Porta Lame	software: Agisoft Photoscan1.1.0	software: 123D Catch
application	Web based for Windows and MacOS	Web based for Windows and MacOS
export format	.obj, .3ds, .ply, .vrlm, .collada, .u3d, .pdf	.dwg, .fbx, .rlz, .obj, .ipm, .las
camera	Nikon D300	Nikon D300
resolution	12 Mpix	12 Mpix
focal lenght	50 mm	50 mm
processade images	87	43
surplus images	-	-
calculation time	4 h 22 min	13 min
mesh	1752557 vertex 2000000 faces	22840 vertex 43155 faces

case study: Porta S. Donato	software: Agisoft Photoscan1.1.0	software: 123D Catch
application	Web based for Windows and MacOS	Web based for Windows and MacOS
export format	.obj, .3ds, .ply, .vrlm, .collada, .u3d, .pdf	.dwg, .fbx, .rlz, .obj, .ipm, .las
camera	Nikon D300	Nikon D300
resolution	12 Mpix	12 Mpix
focal lenght	50 mm	50 mm
processade images	73	73
surplus images	-	7
calculation time	2 h 12 min	13 min
mesh	1857167vertex 1999999 faces	455464 vertex 908422 faces

Fig. 3 Comparison of elaborated data with commercial software (Agisoft Photoscan) and open source software (123D Catch)

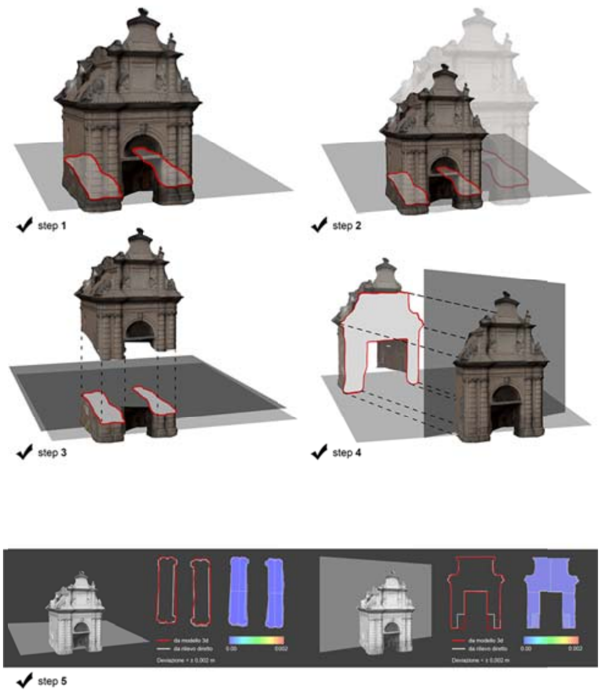


Fig. 4 Porta Lame. Step 1: profile extracted from the horizontal section of the model; Step 2: departing from the profile, the model is scaled and oriented; Step 3: metric datum verification in relation to horizontal sections; Step 4: metric datum verification in relation to vertical sections; Step 5: deviation verification – horizontal and vertical sections

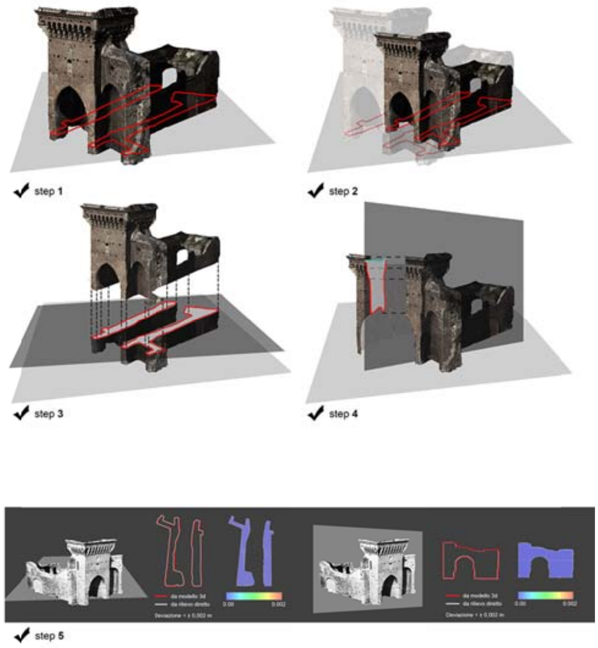


Fig. 5 Porta San Donato. Step 1: profile extracted from the horizontal section of the model; Step 2: departing from the profile, the model is scaled and oriented; Step 3: metric datum verification in relation to horizontal sections; Step 4: metric datum verification in relation to vertical sections; Step 5: deviation verification – horizontal and vertical sections

Fig. 6 Porta Lame and Porta S. Donato. Different Typologies of 3D models

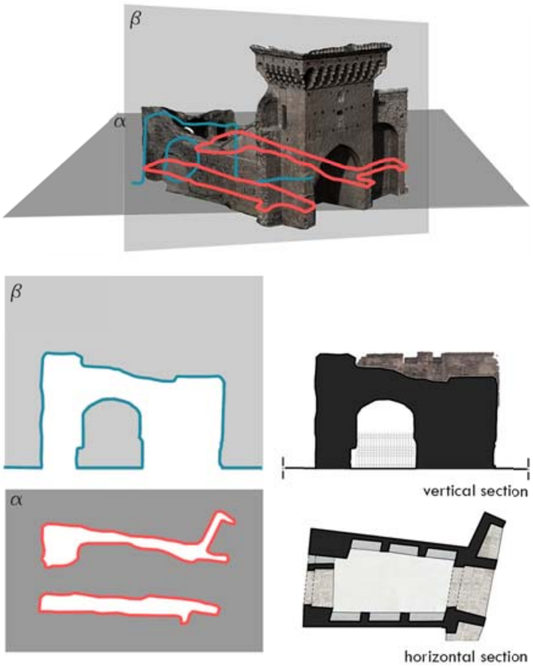


Fig. 7 Porta S. Donato. Extrapolation of 2D vectorial profiles from mesh 3D model

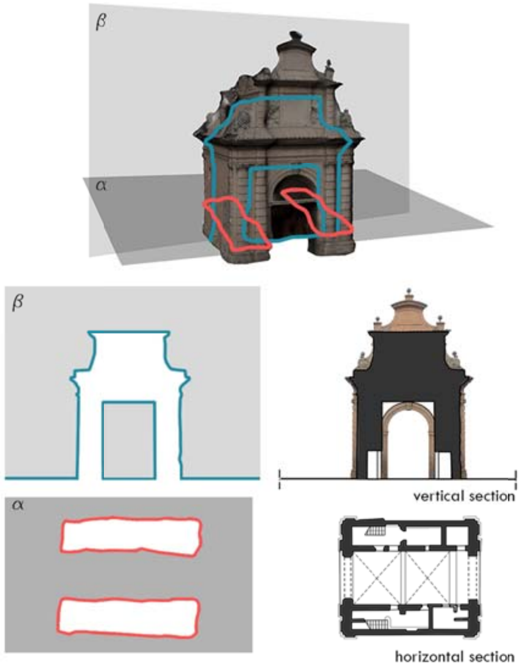


Fig. 8 Porta Lame. Extrapolation of 2D vectorial profiles from mesh 3D model

IV. Conclusions

DSM technologies make it possible to obtain results comparable to those obtained with the laser scanner. Although they do not allow us to elaborate the surveying on any scale, they still offer significant advantages: shorten the time of acquiring and elaborating data, offer an opportunity to create 2D models more accurate than those that can be constructed by direct surveying and also the use the model of high informative content. This technology proved to be efficient, fast and simple to use and hence suitable for documenting and sharing architectonic and archaeological heritage. Surveys can be conducted in a short time while certain processes are automatized. This makes it possible to construct a dynamic and interactive digital model. Although it is only accessible on the computer screen, it makes it possible to perceive and understand the geometric and qualitative character of the architectural structure [10].

Modelling proved considerably advantageous in the next stage, that of documentation, the result of the output being an informative model which can become a place of enquiry for further elaborations leading to critical interpretations.

The modality of representing and achieving metrical and thematic data concerning object of cultural heritage turns out to be particularly complex among others for lack of unequivocally adopted standards. An information system that divulges connections and links turns out to be an extensively articulated structure. It must be able to acquire and modify spatial data in order to archive, maintain, analyze, and present them in the alphanumeric and/or graphic form. Building up an archive whose objective is to preserve and popularize objects of cultural heritage imposes an interaction of many different competences with the view to addressing problems involved in working out the conceptual model, data acquisition modalities, visualization, navigation and access to the contents. The integration of various data typologies within digital archives leads to a definition of meta-data serving to qualify elements of a database with the objective to digitally preserve cultural heritage. Managing meta-data consists in documenting all interventions and transformations of the object of study, providing details of the files, showing their origin and authenticity. All this allows us to integrate and use the digital object [14]. In this context, the modality most efficacious for popularizing objects of architectonic heritage has been provided by WebGIS 3D systems. They offer the advantage of describing real objects and spatial relations thought bases of numeric, alphanumeric and graphic data, integrating topological information with that of semantic nature.

The concept of information structured within a database lies at the very centre of the present research. Each digital model has been transformed into a database element characterized both by metric, geometric and proportional attributes and by topological and architectonic properties, which can be applied to a thematic reading, e.g. regarding its history, material, colour as well as to iconographic comparisons and studies monographic-historical studies. (Fig. 9) In this experimental enquiry, the research team used data organizing instruments – either stand-alone ones or those incorporated inside the GIS3D of visualization, with the ultimate goal of sharing and spreading information. Most importantly, however, the research resulted in elaborating the data acquisition card that meets all the criteria of standard cataloguing of architectural structures. It integrates successfully the descriptive aspects with the object's location through real coordinates and some images of the material analysed. Clicking on the selected part of the photographic image, one can obtain a wide gamut of information and various types of models. Special tables have been drawn up while the database fields and the graphic interface of the web page contains a form for inserting data. A click on the choses part of the image opens a description card which localizes the object of interest at the same time comparing the unequivocal code number with some models (1D ones) that identify the object in the context of Bologna. The card presents the historical-descriptive aspect and in its first part contains a series of fields grouped into sections that give information concerning its geometry, materials, colours, etc. enough to conduct a targeted analysis. Digital archives are considerably advantageous for disseminating information concerning cultural heritage. They can be used alongside of or complementary to physical archives: they offer photorealistic visualizations of models of existing objects; they can be used by different clients (specialists, generic) since it is possible to filter the contents; data are ready to be used directly for analyses based on geometric and formal data provided by different representation scale. It is possible to get to know the object completely moving with ease from the general to the particular, from the simple to the complex (and vice versa) by breaking down the objects into sub-components organized hierarchically. Taking advantage of the newest technologies, languages and communication protocols, that facilitate information exchange and sharing; it is nowadays possible to manage information on a much larger scale as well as construct instruments thanks to which information can be really exchanged and fully shared [15]. However, in order to diffuse and popularize data through digital archives, several problems have to be addressed. They are linked to the concept of sharing 'crude' data, to using data publicly, to inoperability and availability of exchange between commercial software and the open source one, which is the point where information can be lost. Activities for preservation have the role to collect, organize, preserve, and make available past and present cultural resources. Today digital objects have become a tradition in the cultural production and a business cycle with the objective to disseminate and communicate cultural data. The management of cultural heritage is linked with the development of new methods of acquisition and transmission of knowledge, and it passes through an ever- increasing quantity and complexity of metadata [11]. The application of ICT (Information & Communication Technologies) to cultural heritage is certainly one of the most interesting frontiers of activity since object characteristics can be extracted from 3D images and models and can be made interactive. The future development towards which we aim concerns the implementation/importation of database on smart phones and other mobile devices, its final objective being a complete knowledge of the Gates of Bologna while "walking" along the city's streets [16].

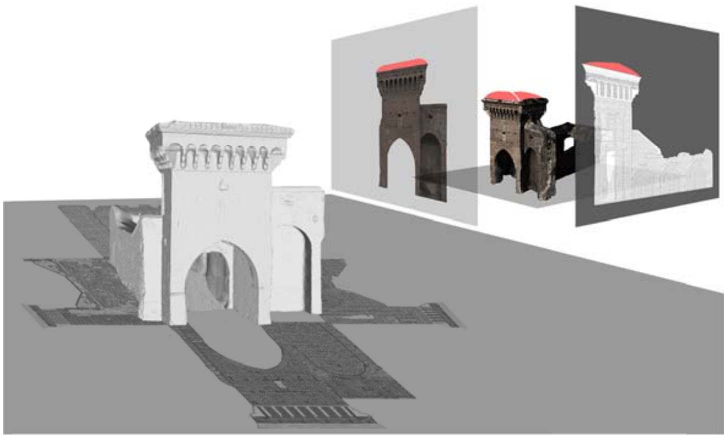


Fig. 9 Data system: the 3D mesh model without texture allows reconstruct prospects geometric newsstand ; model 3D meshes with texture and the photo rectified allow to build the architectural perspectives identifying also the state of degradation. Layout contains also historical documents and images

ACKNOWLEDGMENT

Martina Attenni contributed to the drafting of this article.

REFERENCES

[1] F. Remondino, S.Campana, "3D Recording and Modelling in Archaeology and Cultural Heritage - Theory and Best Practices". Oxford: Archaeopress BAR Publication Series 2598, 2014.
[2] E. Siotto, M. Callieri, P. Pingi, R. Scopigno, L.Benassi, A. Parri, D. La Monica, A. Ferrara, "From the archival documentation to standardised web database and 3d models: the case study of the camaldolese abbey in Volterra (Italy)", CHNT 18 - 18th International Conference on Cultural Heritage and New Technologies, 2014, pp. 1-9
[3] F. Costantino, S. Durazzani, D. Poggi, M. Callieri, M. Dellepiane, R. Scopigno, "San Leonardo in Arcerti: innovazione tecnologica per la gestione integrata dei beni culturali", in ASITA 2014, 18 Conferenza Nazionale ASITA 2014, 2014, pp. 381-388.
[4] S. Minto, F. Remondino, Online access and sharing of reality-based 3D models, in SCIRES-IT SCientific RESearch and Information Technology Ricerca Scientifica e Tecnologie dell'Informazione, 2014, 4(2), pp. 18-27.
[5] A. Ippolito, C. Bartolomei, "La gestione del dato di rilievo attraverso software open souce: il sistema delle porte bolognesi", in P. Giandebiaggi e C. Vernizzi, Italian Survey & International Experience, a cura di Roma: Gangemi Editore Roma,2014, pp. 897-906.
[6] C. Bartolomei, A. Ippolito, "Low-cost Cataloguing Methodologies for Architecture: the System of Gates in Bologna", in M. Ioannides, N.

Magnenat-Thalmann, E. Fink, A. Yen, E. Quak, E. Way, EuroMed 2014, Digital Heritage: Progress in Cultural Heritage, Documentation, Preservation and Protection, , Hockley, SS5 4AD. United Kingdom, Multi-Science Publishing Co. Ltd, 2014, pp 249-257.
[7] C. Bianchini,"La documentazione dei teatri antichi del mediterraneo". Roma: Gangemi, 2012.
[8] Bianchini, F. Borgogni, A. Ippolito, L.J. Senatore, E. Capiato, C. Capocefalo, F. Cosentino, "From Surveying to Representation. Theoretical background, Practical Issues, Possible guidelines", in VSMM 2012, 18th International Conference on Virtual Systems and Multimedia, IEEE Press, New York, 2012, pp. 507-513.
[9] Bianchini, F. Borgogni, A. Ippolito, L.J Senatore, "The Surveying and Representation Process Applied to Archaeology: A Quest for Invariants" in A Highly Variable Context, Computational Modeling of Objects Presented in Images, 2014, pp. 1-29.
[10] Lo Buglio, L. De Luca, "Representation of architectural artifacts: definition of an approach combining the complexity of the 3D digital instance with the intelligibility of the theoretical model", in SCIRES-IT SCientific RESearch and Information Technology Ricerca Scientifica e Tecnologie dell'Informazione, 2012, 2(2), pp. 63-76.
[11] Apollonio, M. Gaiani, S. Baldissini, "Construction, Management and Visualization of 3D Models for Cultural Heritage GIS Systems", in Digital Media and its Application in Cultural Heritage, CSAAR Press, Amman, 2011, pp. 283- 299.
[12] L. De Luca, "La Fotomodellazione architettonica". Palermo: Dario Flaccovio Editore, 2011.
[13] Barazzetti, L. Binda, M. Scaioni, P. Taranto, "Photogrammetric survey of complex geometries with low-costsoftware: Application to the "G1" temple in Myson, Vietnam", in Journal of Cultural Heritage, 12(3), Elsevier Masson, 2011, pp. 253-262.
[14] E. Bonacini, Nuove tecnologie per la fruizione e la valorizzazione del patrimonio culturale. Roma: Aracne Editrice, 2011.
[15] B. Ducke, D. Score, J. Reeves, "Multiview 3D reconstruction of the archaeological site at Weymouth from image series", in Computers & Graphics, 35(2), Pergamon Press, Inc. Elmsford, NY, USA, 2011, pp. 375-382.
[16] Rua, P. Alvito, "Living the past: 3D models, virtual reality and game engines as tools for supporting archaeology and the reconstruction of cultural heritage - the case-study of the roman villa of Casal de Freiria", in Journal of Archaeological Science, 38(12), Elsevier B.V, 2011, pp. 3296-3308.
[17] M. Docci, M. Gaiani, D. Maestri, "Scienza del disegno. Manuale per le facoltà di architettura e ingegneria". Novara: CittàStudi, 2011.
[18] B. Cantrell, W. Michaels, "Digital Drawing for Landscape Architecture: Contemporary Techniques and Tools for Digital Representation in Site Design", Hoboken: New: John Wiley & Sons, 2010.
[19] L. De Luca, C. Busarayat, C. Stefani, N. Renaudin, M. Florenzano, P. Véron, "An Iconography-Based Modeling Approach for the Spatio-Temporal Analysis of Architectural Heritage", in Shape Modeling International Conference (SMI '10), Washington, USA, 2010, pp. 78-89.
[20] M. Gaiani, B. Benedetti, "A responsible modelling framework for a 3D GIS archaeological prototype (The Pompeii case study)", in EVA 2010 Florence Electronic Imaging and the Visual Arts Proceedings. Bologna: Pitagora Editore, 2010, pp. 102–107.
[21] Riccardo Migliari, "Geometria dei modelli", Roma: Edizioni Kappa, 2001.
[22] A. Vianelli, "Mura e Porte di Bologna", Bologna: Tamari, 1976.

Alfonso Ippolito, in 2006 degree of Ph.D and in 2007 research into the methodologies and development of 3D digital models for architecture. Since 2008 research worker ICAR 17 at the La Sapienza University in disciplinary project: innovative survey methodologies and techniques, modelling and methodologies of representation. Works on and with new surveying techniques taking advantage of the 3D laser, both of short and long range, on the elaboration of data, on the successive modelling of surface from point clouds, on the optimization of the latter in relation to architectural and archaeological surveying and in relation to designing. Works actively on the problems concerning protoptyping, managing and optimizing surveying procedures. Among the cultural heritage objects researched mention must be made of the San Pietro Dome, the wooden model of San Pietro made by Antonio da Sangallo the Younger, the Claudio's Temple and the Giano's Arch in Rome; the Roman theatre and amphitheatre in Merida, Spain; the El Khaseneh theatre and the royal tombs at Petra, the theatre in Jarash, Jordania. Participated in the PRIN and Firb financed research and in the European Project entitled Higher Education Curricula Development Project (HECDP – the Tempus CARDS Programme). He wasTechnical Manager for the ATHENA Project (in Euromed Heritage IV Programme). Assistant Professor at the courses of higher education and courses for the the degree of Ph.D. in research. Maintains contacts with and acted as chairman at international and national conferences in such cities as: Canton in China; San Francisco, Las Vegas, Washington in the USA; La Plata in Argentina; Amman in Jordania, in Madrid and various other cities. Since 2007 sits on the editorial board of the periodical "DISEGNARE. IDEE IMMAGINI". Since 2012 sits on the scientific committee of the MAVNA Museum (Virtual Archaeological Museum of Narce) in Mazzano Romano (Rome).

Cristiana Bartolomei Graduated in Civilian Building Architecture at the University of Bologna. M.A. In „Architecture for the Spectacle" at the Department of Architecture, Genova. Specialized in the restoration of historical monuments at the Department of Architecture, Genova.
Ph.D. in sketching and surveying works of architectural heritage.
Since 2010 – researcher ICAR 17 at the Department of Architecture at Bologna University.
Research embraces two main domains concerning extreme developments in the evolution of representation processes with two principal subjects: - innovative theories and methods of architecture surveying with new non-contact technologies and informative systems created for architecture; - innovative principles, theories, methods and processes of representation;
Conducts research in various fields of architecture designing and projecting. These include innovative surveying technologies and techniques, modelling, methodologies of representation and informative systems developed for architecture. The research concentrated mostly on Italian lighthouses, the field in which she is regarded internationally as one of the most outstanding experts.
Participated in financed PRIN research projects.
Participated in international and national conferences, among others, in Canada, Argentina, Portugal, etc.
Lecturer in Architecture Design for the master's course in Architecture and Building Engineering.
Author of 80 publications.