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DIGITAL DOCUMENTATION FOR ARCHAEOLOGY. CASE STUDIES ON ETRUSCAN AND ROMAN HERITAGE

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Abstract

Innovative tools which are constantly being developed make it possible for the researcher to adopt an integrative approach favorable to everyone involved in the whole process of documentation. Close collaboration of architects and archaeologists made it possible to understand the key elements of archaeological heritage based on considerations extracted from historical analysis and to have at disposal a large quantity of information gathered by taking advantage of the potentialities of technologically advances tools. The significance of constructing digital models in the domain of archaeology is already a well-established idea and only reinforces the theoretical bases of survey and representation. The objective is to present the way in which digital technologies allow us to document, preserve, evaluate and popularize cultural heritage by structuring out an "open" system of cognition and therefore always lending itself to implementation

Keywords

Archaeological heritage, survey, 3D Modeling, virtual restoration, Database, Metrology

1. *Introduction*

Any study concerned with archaeology involves delving into a field of endeavor in which it is more and more necessary to take an interdisciplinary approach. The work of documenting, analyzing and interpreting archaeological heritage is conducted by various types of professionals: architects, archaeologists, art historians, computer scientists, etc. precisely when a strong need is felt for sharing extensive knowledge still growing with the continuous progress and the potentialities inherent in digital systems. What has recently been taking shape is the all-comprehensive approach which can be adapted to comprehend archaeological artifacts on a large, medium and small scale and at the same time take into consideration all the different competences involved and optimize the results obtained through concerted effort. Within this framework studying, analyzing and contextualizing an element or an archaeological site becomes the basis for any research. The nature of each object becomes easier recognized precisely thanks to the synergy of various different forms of knowledge and the complementary nature of various studies which today are considered essential and directly related to the enquiry into and interpretation of *Archaeological Architecture* [1]. Obviously all the parts involved in studies of this kind benefit from the advantages inherent in the integrated approach: architects because they can better understand the key elements of the original design on the basis of elements derived from a more profound historical analysis; archaeologists because they have at their disposal information extremely detailed and reliable; and both because they can take advantage of innovative methodologies developed in the digital ambiance for interchanging, using and sharing heterogeneous data, both in the stage of acquisition and processing. Any study undertaken with the method that assumes the use of the above mentioned disciplines allows one to construct a large database structured in the way that integrates the modalities applied in each of them. The diffusion of information in the archaeological sector is founded essentially on representations focused on providing information concerning evolutive stages, stratigraphy of the terrain, documentation of structural remains and

Martina Attenni contributed to the draft of this article.
[1] Artifacts whose archaeological and architectonic values are inseparable (Bianchini, 2012)

materials recovered during numerous materials recovered during numerous archaeological excavation campaigns during field of surveying and representation - as long as they concern architectonic and urban heritage - two-dimensional and three-dimensional elaboration[2] become indispensable for getting knowledge of the artifacts. They provide not only data related to metric and dimensional aspects which also happen to concern the contextualization of the object under analysis, to material structure and the pathologies of degradation. The use of the two modalities and of different methods proves the importance of all efforts undertaken towards cataloguing the vast and heterogeneous quantity of data, which are constructed in the course of the studio experiments and research already referred to. These data include 1D[3], 2D, 3D models, archive documentation, photographic documentation and elaborations concerning the excavation processes that took place at a different time and in different places. Moreover, cataloguing that deserves the name of exhaustive ought to include a lot of rough data – just for its objective definition, as much as processed data – non objective, filtered though the knowledge, abilities and sensibility of the operator. In point of fact to think of a catalogue as complete is very risky in view of the fact that research is in general a continuous process and can never be considered completely concluded. This concerns especially archaeological research characterized by time consuming practical operations. The whole problem in its entirety, if it is to include different typologies of data, makes it indispensable to conduct a rich and orderly of all material relative to any research, specifically inasmuch as subjects of archaeological interest are concerned within a system that can be continually and quickly implemented and taken advantage of and this open from the point of view of diffusion and which rests on the basis of data scientifically valid and rigorous. Within this frame of reference the new technologies can play a significant role in different aspects of the term. Firstly, the techniques of mass acquisition make it possible to have at disposal objective survey datum which is exempt from selection. Then, the techniques for 3D acquisition, modeling, the modality for integral representation, techniques of interactive visualization all go to improve the knowledge level of the object under study. Moreover, the development of ICT (Information and Communication Technologies) favored all the more the use of digital technologies which encourage to use them and experiment with them because of reduced costs and easy application.

The objective is to implement and improve the activities that go to preserve, protect, valorize and popularize the Cultural Heritage where documentation has acquired a fundamental role. The digitalization of cultural heritage is today shaped to provide results mainly in different front lines: construction of three-dimensional models of real objects with a high level of similarity to reality, metrically correct and reliable, virtual reconstruction on different scales of objects that do not exist any more and construction of digital archives. Lately, the objective adopted is that of assembling and integrating all of this within platforms in order to be managed and utilized not only by those involved in the research but also by less specific applications. These considerations go to show that the potentialities and the advantages of various digital systems or archiving, data acquisition, model processing and communication have almost completely been understood. Consequently, it seems easy to understand the reasons which have gradually lead to a change in the concept of representation, almost directly connected to that of information as well as to the possibility of interrogating and to the modalities of communication that characterize various systems at our disposal.

Transparency of information, of the sources and processes followed becomes a necessity especially in the field of archaeology. The study of its elements, whether they be entire sites or fragments of objects, is largely based on indirect information, comparative analyses, interpretative hypotheses. The question of paradata[4] and

[2] Geometric models lean toward the geometrization of elements to be represented and yield information on morphology and spatiality of the object under study. Architectonic models describe reality through images of elements indicating the quality of surfaces and their state of conservation.

[3] All those textual, numeric and alphanumeric data describing object, that allow defining any three-dimensional and bi-dimensional ideal model in a virtual space.

[4] Paradata and metadata should be clear, concise and easily available. In addition, it should provide as much information as possible. (The Seville Principles, Principle 7, 7.3). Paradata is defined as: information about human processes of understanding and interpretation of data objects. Examples of paradata include descriptions stored within a structured dataset of how evidence was used to interpret an artifact, or a comment on methodological premises within a research publication. It is closely related, but somewhat different in

metadata[5] become more and more important for activities concerned with archiving, managing, sharing and utilizing digital resources related to cultural and architectural heritage. In order to resolve the problems involved in Archaeological Architecture one has to tackle them form the cultural point of view rather than for the technical one in such a way that operations and choices undertaken with the view to achieving the level of knowledge - more profound and structured – of the object of study will always be guided by scientific rigor. The sector of digital documentation of cultural assets is expanding and archaeology seems provide to it a vast field of application. Although its procedure has not yet been defined univocally, the processes of managing of the data in the stage of acquisition (surveying) and processing (survey) as well as the modality of information archiving and disseminating have been well outlined. Elements belonging to archaeological heritage have been objects of surveying campaigns carried out in recent years within the Department of the History of Drawing and Architecture Restoration at the Sapienza University of Rome. The application of the critical operative method in continuous evolution allowed the research staff to compare and put forward solutions and problems frequently confronted in the stage of data acquisition and processing. The approach adopted guaranteed the scientific character of the surveying and representation operations that underlie analyses and interpretation of elements under analysis.

Case studies presented here concern important ancient archaeological contexts: the city of Rome and the Etruscan Sanctuary of Pyrgi. Both are systems that are part of the urban system profoundly modified or non-existent today. Attention has been given to the study and analysis of archaeological elements that are parts thereof by applying methods and techniques which make for an understanding of of the objects o the urban scale and in full detail. Therefore presented here were the processes followed as well as the results of some experiments with the object to to bring out important aspects of the concerted efforts of architects and archaeologists. The studies presented here are situated within the ambience of intensive survey conceived as a structured system capable of organizing diverse information like tests, images, 2D and 3D models as well as of representation conceived as an instrument for describing, popularizing and communicating information related to cultural heritage.

2. *Temple A of Pyrgi*

The research presented here was possible thanks to the contribution of the Institute of Etruscology and Italian Antiquity of the Sapienza University of Rome[6]. It has studied for years the Etruscan sanctuary in its different aspects, from its urban and territorial ambience and its connections with the port of Caere to the analyses of the fragments of architectural terracotta.

Excavations conducted in 1957 brought to light a sacred area upon which there stood two temple complexes, named Temple A and Tempio B (Fig.1), endowed with rich architectonic ornamentation, area C well known as the place where gold folls were found and a rectangular edifice divided into cells places against the enclosing wall of the sanctuary. Only a few vestiges of the temple context survived on the site of the temple complex but numerous fragments of decorations have been found[7]. Part of the archaeological material discovered is today exhibited in the Museo Nazionale Etrusco di Villa Giulia in Rome and at the Antiquarium of Santa Severa.

The aim of the study is to valorize cultural heritage enquiring into the possibilities and the modalities for documenting and popularizing architectural heritage. The present endeavor was taken up with the intention to implement a process never before attempted in relation to the data concerning the Sanctuary of Pyrgi. Taken into account have been not only architectonicmaterials still existing but also historical documentation, data gathered by

emphasis, to “contextual metadata”, which tend to communicate interpretations of an artifact or collection, rather than the process through which one or more artifacts were processed or interpreted. (The London Charter, version 2.1).

[5] Metadata, considered as data about data, can help to organize information and provide digital identification.

[6] Prof. Maria Paola Baglione, Dott. Barbara Belelli Marchesini.

[7] Three documents carved on gold tablets found around Tempio B on July 8th 1964 during an excavation campaign go back to the VI or the beginning of the V century before Christ. The remains of considerable historical and linguistic interest for Etruscan archaeology are considered to be the first sources written in italic languages. Today they are housed in the Museo Nazionale Etrusco in the Villa Giulia in Rome.

Fig. 1: Archaeological site of Pyrgi

archaeologists, drawings made during various excavation campaigns, interpretative hypotheses, including in a vast cataloguing effort tangible and intangible elements of the heritage.

The present work has two principal purposes: to meet the current necessity to popularize data concerning archaeological heritage through digital technologies applied, starting with the stage of data acquisition; to provide a reconstruction in virtual ambience of the architectonic organism which is extremely fragmented and whose present state is irremediably damaged by the conditions of the place where it is located. The focus of interest is based on the definition of three-dimensional models and on the digital visualization. These are the basic elements of the communication strategy clearly in contrast to the modality of communicating information in the field of archaeology. In point of fact, even though more recently in the experiences undertaken we observe a passage from the techniques of analogue representation in favor of the digital ones, a major part of documentation still relies prevalently on texts while the graphic models are hardly included. Therefore an attempt is made at defining the significance of developing and applying a digital platform conceived as a place of expeditious consultation of data that integrate textual information with 2D/3D models for different users. The starting point were existing archaeological documents integrated with three-dimensional models of structural remains and the architectural terracotta stored in various museum sites. The models were obtained through operation of no-contact surveying and low cost instruments, which make use of the advantages provided by DSM technology[8]. Moreover, compared and integrated was the information derived from topographic survey of the structural remains and the information deduced by archaeologists and reported in their excavation notes today systematized into volumes indispensable for the knowledge of the object analyzed.

This type of process is oriented towards a systematization and diffusion of mixed information that include information gathered in order to diffuse as much as possible the knowledge of the object, documentation of the present state, reconstruction of reality completely lost.

The work presented here is focussed on Temple A and has been articulated into the following stages: recognition and analysis of all the material at disposal; arrangement of the existing documents according to the document typology (text, images, archaeologist's drawings, 2D paper models, physical 3D models); integration of information at our disposal with data obtained from surveying/survey of existing objects; semantic classification of material in relation to the case study updated until today; virtual reconstruction. The documentation thus obtained – of exclusively digital nature – makes it possible not only to recognize the state of conservation of the object studied and to preserve – be it solely in the digital mode - the site most probably destined to disappear, but also to reconstruct the original shape of the elements that already do not exist.

[8] Dense Stereo Matching. This techinique 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. 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 (De Luca, 2011).

The systematization of these data within a single system/platform as well as their diffusion are part and parcel of Digital Heritage defined by the Charter on the Preservation of the Digital Heritage published by UNESCO in 2003 as well as "technical, medical and other kinds of information created digitally, or converted into digital form from existing analogue resources including different kinds of products such as texts, databases, images, audio, graphics, software and web pages". Preservation of cultural heritage through digital modalities for managing and visualizing raises problems of a different order linked to the transparency of operations carried out in the different stages of the process. It therefore concerns all the disciplines for acquiring involved.

In the first place the initial data have to be as clear as possible as they delineate the criteria adopted for cataloguing; secondly, they have to guarantee correctness and scientific nature[9] of the processed followed for acquiring and processing surveying and survey data within the framework of digital reconstruction; finally, appropriate modality has to be found that will guarantee the use of the system structured in this manner in function of various interpretation levels.

The recourse to systems for acquiring and extracting heterogeneous information (graphical, textual, historic-biographical, 1D, 2D 3D models) which make use of the potentialities of methods, techniques and instruments adequate for the digital era is considered to respond to the problems connected with information diffusion within the field of archaeology, putting forth innovative and interactive modalities for the diffusion of new contents.

A complete and organized collection of archived documentation – graphic and textual – as well as cataloguing of data at our disposal were necessary to maintain unchanged the informative contents while passing from archaeological documentation, mainly textual, to that with a large number of graphic models. The criteria adopted for cataloguing objects are strictly connected to the characteristic properties of archaeological objects: registered name, historical period to which the object belongs, a list of documents concerning Temple A. Such a classification made it possible to structure out a documentation that having started with semantic classification of the component parts of the object of study links indissolubly their cognition to the study of the sources at our disposal and to archaeological interpretation, the objective being the construction of models as objective as possible. Familiarity with the methods and techniques for data acquisition legitimized an a priori assessment of the results to be obtained through surveying various existing objects (structural remains and fragments of architectural terracotta) which in turn constitute a solid basis for understanding the whole organism but also through the survey of the intangible carried out by studying texts for the purpose to construct theoretical models. Such an operation aims at implementing the documentation already available though incomplete and heterogeneous, at times composed of information contradictory to valid 2D/3D models. Recourse to three-dimensional models in archaeology can have quite a number of repercussions for the diffusion of information, not always achieved on a large scale for reasons of space and costs. That is exactly why integrated methods for low cost surveying have been adopted. The processes of acquiring and elaborating data have been conducted through integrated surveying with the application of photomodeling[10]. to construct models and to carry out direct surveying for controlling measurements. Data acquisition and processing through photomodeling concerned two typologies of elements. On the one hand were those useful for ideal reconstruction of Temple A, from which profiles have been extrapolated and geometries reconstructed; on the other hand were sculpted

[9] An inquiry into a phenomenon is considered scientific when it is conducted through an assemblage of techniques based on a collection of observable, empirical and measurable data with a definite uncertainty level which is controlled and stated; such data should be able to be archived, shared and subjected to assessment independently; the procedures applied ought to be replicable in order to acquire a new aggregate of comparable data. For further reading see Bianchini, 2012.

[10] Photomodelling derives from the theoretical assumptions of photogrammetry and makes it possible to create three dimensional models by integrating survey stages, modeling and representation, extracting from coordinated photos distances, apices and profiles. It can be considered an innovative methodology because of a high level of automation of the process and the possibility to obtain an extremely high number of information at a given time. The output is a model that is analogous and comparable to the one created through laser scanning which includes geometric and qualitative features of the object analyzed

criteri per la catalogazione / elementi archeologici	PERIODO		CLASSIFICAZIONE			MATERIALE ARCHIVIO			EL.FISICO		LOCALIZZAZIONE			ACQUISIZIONE		ELABORAZIONE				MODELLO		
	580-480 A	480-230 B	livello costruttivo	livello funzionale	livello decorativo	modelli grafici	testo	immagini	si	no	Antiquarium Pyrgi	Museo Nazionale Etrusco Villa Giulia	Santuario Pyrgi	rilevamento non a contatto	virtualizzazione dato archeologico	nuvola di punti	3D	2D	1D	liv.0	liv.1	liv.2
stereobate muri perimetrali	●	○	●	○	○	●	●	○	○	●	○	○	○	○	●	○	●	●	○	○	●	○
stereobate muri trasversali 	●	○	●	○	○	●	●	○	●	○	○	○	●	●	●	●	●	●	●	●	○	○
stereobate muri interni 	●	○	●	○	○	●	●	○	●	○	○	○	●	●	●	●	●	●	●	●	○	○
stereobate pavimento in tufo	●	○	●	○	○	●	●	○	○	●	○	○	○	○	●	○	●	●	○	○	●	○
terrazza	●	○	●	○	○	●	●	○	○	●	○	○	○	○	●	○	●	●	○	○	●	○
podio	●	○	●	○	○	●	●	○	○	●	○	○	○	○	●	○	●	●	○	○	●	○
copertura	●	○	●	○	○	●	●	○	○	●	○	○	○	○	●	○	●	●	○	○	●	○
ordine tuscanico fusto 	●	○	○	●	○	●	●	●	●	○	●	○	○	●	●	●	●	●	●	○	●	○
ordine tuscanico base 	●	○	○	●	○	●	●	●	●	○	●	○	○	●	●	●	●	●	●	○	●	○
ordine tuscanico capitello 	●	○	○	●	○	●	●	●	●	○	●	○	○	●	●	●	●	●	●	○	●	○
architrave lastre rivestimento 	○	●	○	○	●	●	●	●	●	○	●	○	○	●	●	●	●	●	●	○	○	○
architrave lastre rivestimento 	○	●	○	○	●	●	●	●	●	○	●	○	○	●	●	●	●	●	●	○	○	○
architrave lastre rivestimento 	○	●	○	○	●	●	●	●	●	○	●	○	○	●	●	●	●	●	●	○	○	○
architrave lastre rivestimento 	●	○	○	○	●	●	●	●	●	○	●	○	○	●	●	●	●	●	●	○	●	○
spiovente sinistro lastre rivestimento 	●	○	○	○	●	●	●	●	●	○	●	○	○	●	●	●	●	●	●	○	●	○
spiovente sinistro lastre rivestimento 	●	○	○	○	●	●	●	●	●	○	●	○	○	●	●	●	●	●	●	○	●	○
altorilievo quadro A	●	○	○	○	●	○	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
altorilievo quadro B 	●	○	○	○	●	●	●	●	●	○	○	●	○	●	○	●	●	●	●	○	●	○
altorilievo quadro C	●	○	○	○	●	○	●			○	○	○	○	○	○	○	○	○	○	○		○
altorilievo frontonale 	●	○	○	○	●	○	●	●	●	○	●	○	○	●	○	●	●	●	●	○		○
altorilievo frontonale 	●	○	○	○	●	○	●	●	●	○	●	○	○	●	○	●	●	●	●	○		○

Fig. 2: Analysis and cataloguing of archaeological data

excessively fragmented and unattributable to any architectural typology. On the basis of this choice such elements could be catalogued not only through photographic images or survey elaborations executed by applying traditional methodologies, but also with the help of three-dimensional model correctly scaled and placed in the Cartesian conception of space. They are useful for putting forth reconstructive hypotheses on the basis of data objective metrically, geometrically, chromatically and materially (Fig. 3).

The example presented below (Fig. 4, Fig. 5) shows operative procedures employed in the stage of acquiring and elaborating all existing fragments. The object of study is a mythological high relief situated on the back side of Temple A. Its archaeological aspects have been studied for a long time now because of it complexity, the significance of the theme analyzed (that of Seven against Thebes) or for a very particular and orienting photograms obtained from the chosen software to process images with the polychromy, which is its characteristic feature. After numerous efforts the element has been completely restored efforts the element has been completely restored and is now treasured in the Museo Nazionale Etrusco di Villa Giulia in Rome. By carrying out the project of the shootings it was possible to establish the minimum number of photograms to be used taking into account the overlapping of at least 30% in order that the software could recognize homologous points in different photos. Detail and uncertainty levels are linked to the intrinsic characteristics of the camera as well as to the external conditions of lighting and accessibility to the context in which the object is immersed. In order to adequately recover all the elements of the object, the distance of the shots has been calculated on the basis of the lens focus and the typology of the camera used. Uncertainty has been managed not only through measurements acquired by direct surveying but also by correcting optical aberrations of particular photograms – the stage preceding the construction of the three-dimensional model.

Photomodeling imposes the integration of

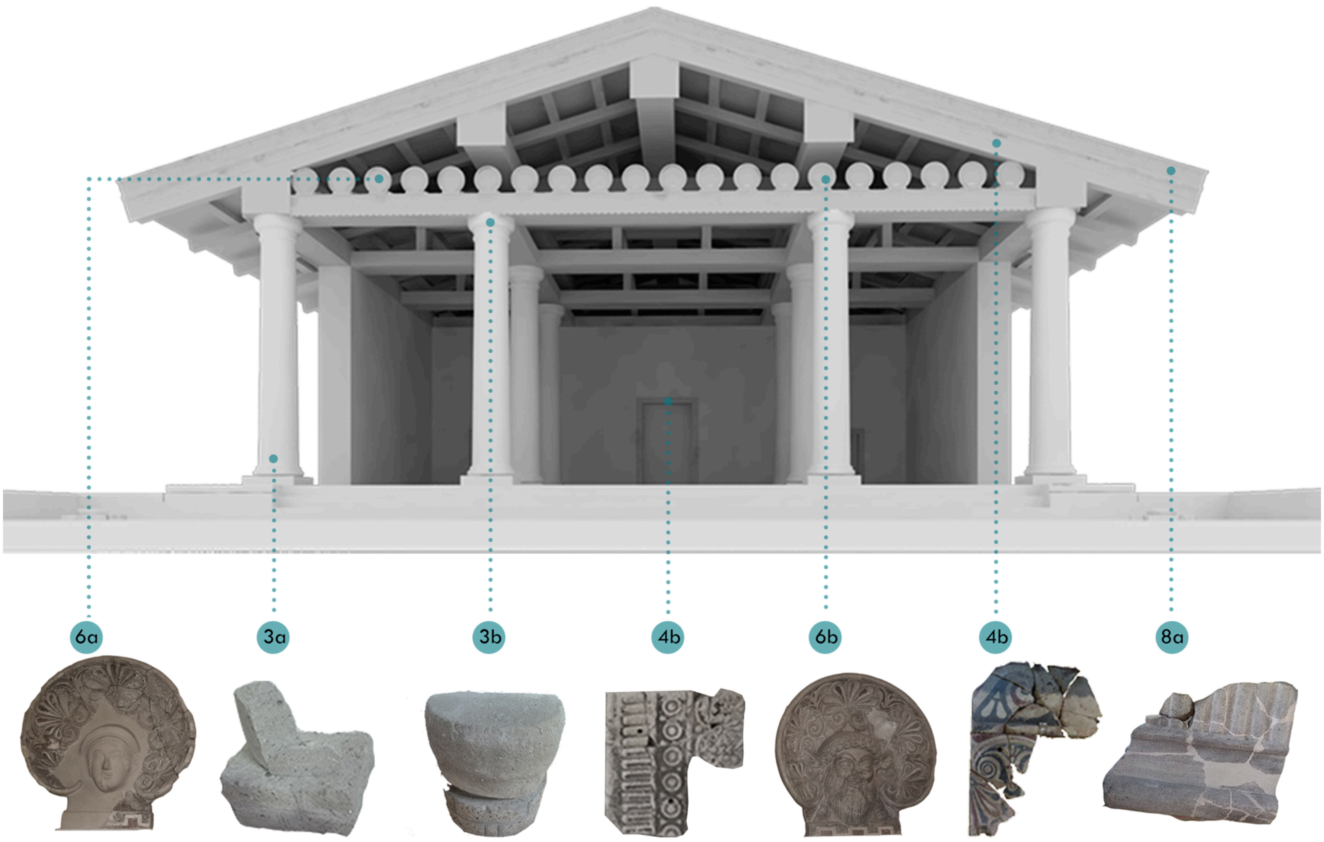

Fig. 3: Some architectural terracottas

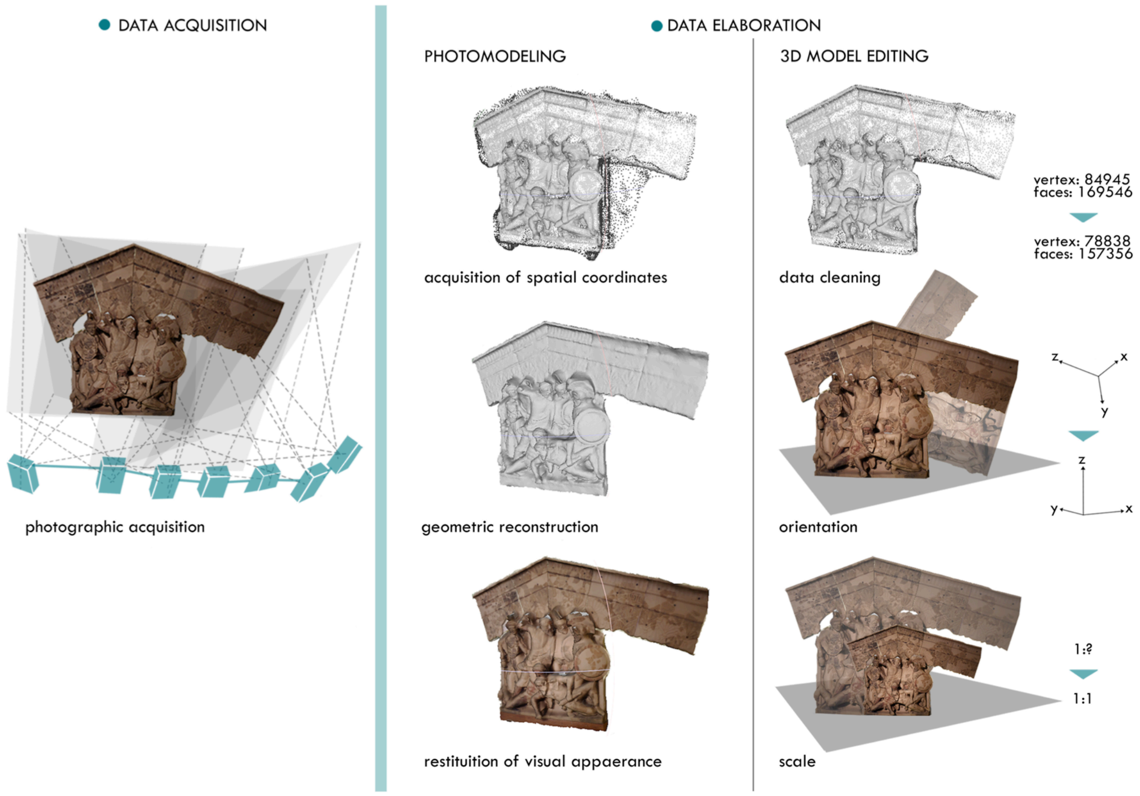

Fig. 3: Mythological high relief. 3D Data acquisition and elaboration

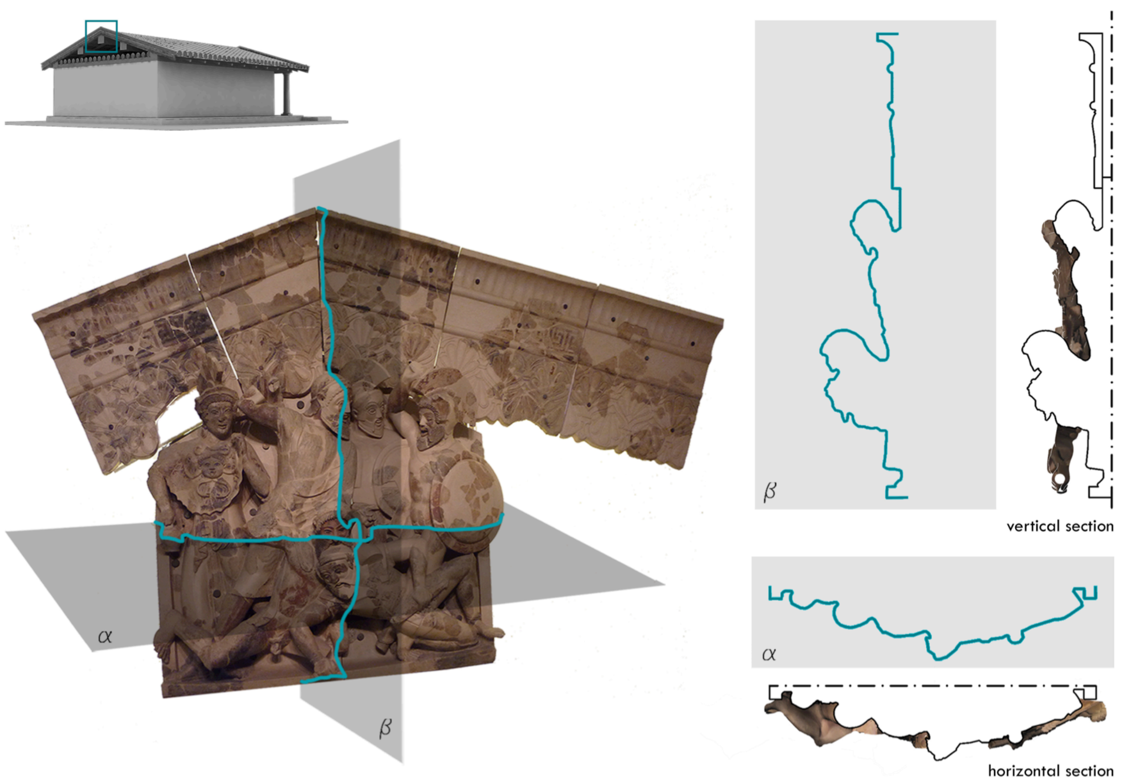

Fig. 4: Mythological high relief. Horizontal and vertical profiles

automatic procedure for align procedure in which the operator must have a full knowledge of the determining processes: data purification, mesh optimization, orientation and scale of the model. In this way a 3D model of high fidelity to the real object is constructed and makes it possible to recognize even the minutest discontinuities and distortions and applied to grasp the geometric and qualitative characteristics of the object and to to extrapolate 2D profiles and models. In this stage, conceived for reconstructing partial models, all the problems connected with the acquisition process have been addressed: defining the number of photograph shots in relation to the dimensions and complexity of the objects, to their accessibility as well as to the lighting conditions in the museum where they are exhibited.

The successive stage, however, concerns three-dimensional reconstruction of Temple A in virtual ambience. The model – the synthesis of the knowledge derived from the study and analysis of the data gathered – had been defined in the construction elements and then in the decorative ones. At this stage a confrontation between researchers who work in different fields of endeavor – archaeology and architecture – is considered fundamental. Archaeologists' contribution was fundamental in order to determine geometric matrices of objects while thanks to surveying and representation it was possible to construct the model in accordance with scientific criteria.

The construction of an ideal model, based essentially on virtualizing archaeological data, rested upon digital methodologies for two-dimensional representation and for three-dimensional modeling. Defining generating and directing profiles and curves made it possible to reconstruct the most probable original aspect conceived for Temple A at the time when it was built. The problems addressed in strict collaboration with archaeologists are related to the interpretation of the dichotomies between data obtained from different sources in the total composition of the object, between the passage from the complexities of the architectonic object to that of single pieces and decorative elements, the choice of detail level.

The model worked out was then applied to verifications connected with metric-proportional (Fig. 6) and structural aspects and as the spark for reflection leading towards the definition, description and understanding of decorative elements. This seems to recognize the features of the whole complex making easy a critical interpretation based and facilitated by as exhaustive representation as is possible. The road taken was to "[...] *to recompose the spatial 'box' , analysis of its constitutive parts, their classification and description as well as, finally, the verification of possible rules underlying diverse combination of elements*"[11](Fig. 7, Fig. 8).

Transparency of reconstruction determines the quality level and the scientific rigor of all applications and studies of virtual archaeology, therefore the criteria followed were delineated by inserting them inside the informative database pertinent to Temple A.

In order to guarantee scientific nature and reliability of the procedure, three typologies of elements have been distinguished: certain (remains of the archaeological site), secure or highly probable elements repeatable or speculative, possible to extract from surviving structures or decorations; elements extractable from prior reproductions whose possible errors or misinterpretations have to be ascertained); deduced elements (possible to determine from structures or decorations belonging to similar edifices or by typology, characteristic features and historical epoch).

Both typologies of models achieved, totally reconstructive and partially derivative from surveying, have been used as an instrument of communication between various professionals involved in the research before the instrument in question was applied by external users.

The bases of data described above constitute modalities for gathering and presenting - in a transparent manner - the whole process to be carried out objectives, methodology, techniques, arguments, characteristics of research sources, results and conclusions[12]. Such a principle reaffirms the necessity to prepare the documentary objective and exhaustive basis that concerns the whole research process related to creating digital contents in projects of virtual architecture. The base of data constituted represents the point of departure for the road leading to a complete knowledge. Digitalization makes it continuously and immediately applicable useful for faster and simpler dissemination of

[11] (Docci, 1989)

[12] Principle 7.1 of the Carta di Siviglia

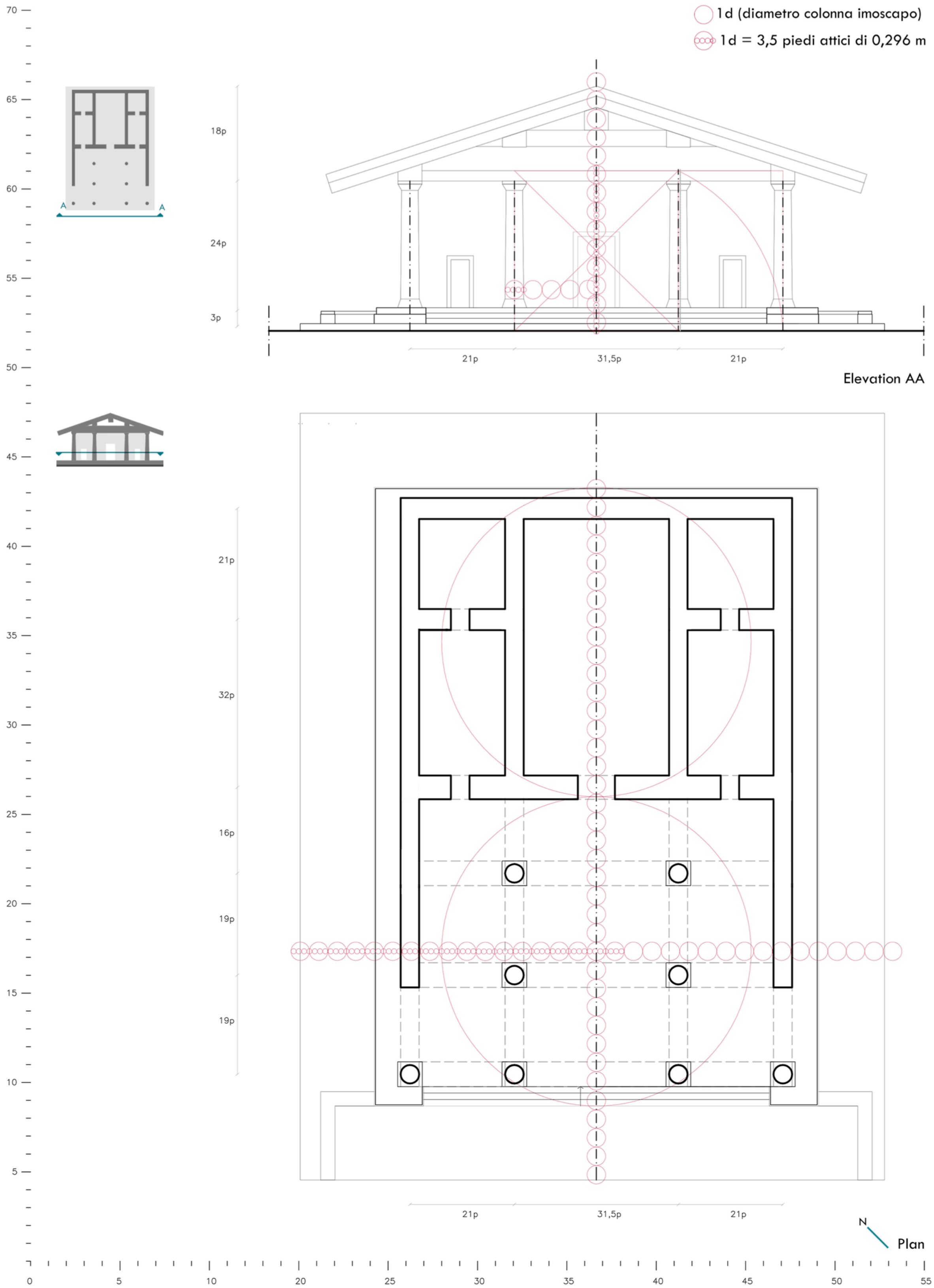

Fig. 6: Metrological analysis

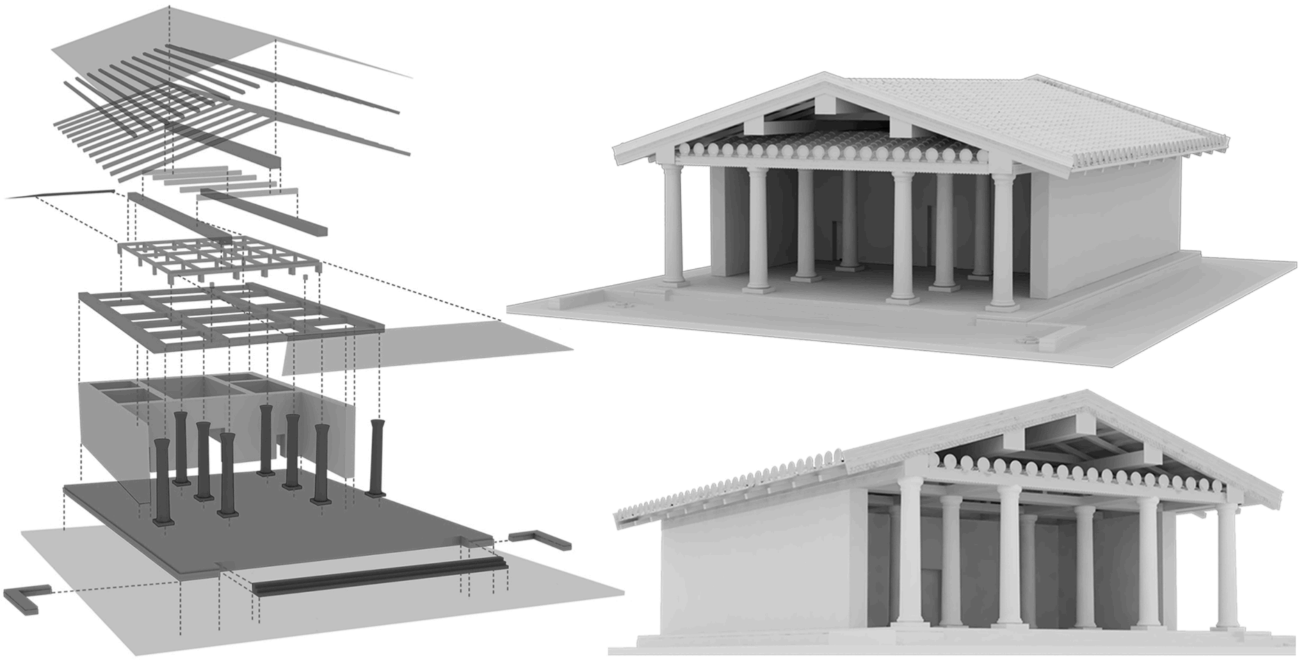

Fig. 7: Virtual restoration of Temple A. 3D model

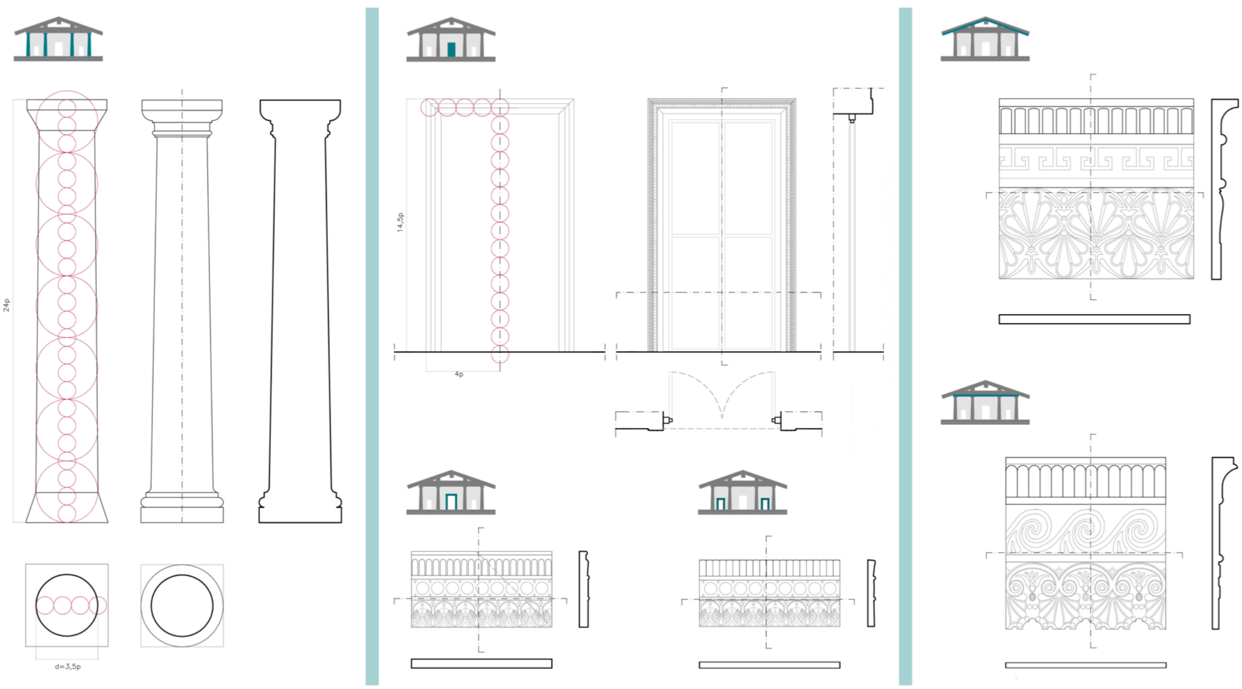

Fig. 8: Virtual restoration of Temple A. 2D model, details

heterogeneous contents: data sheets with information on existing objects, graphic 2D elaborations, 3D models, photographic images, multimedial contents, virtual itinerarie Constructed in this way a digital archive opens up the possibilities to score important results in the field of documentation and valorization of archaeological heritage elements useful for achieving objectives purely didactic and valuable for institutions and professionals involved in the protection of cultural heritage.

3. Temple of Divine Claudius

This experimental research is linked to the work undertaken for Imago Urbis[13], an informatized system for archiving published data (biographical and cartographic) and unpublished ones about the monuments of Rome. The structure of such a system is articulated into two great archives: alphanumerical one and the archive of graphic documentation. Both merge in the Informative Archaeological System (Sistema Informativo Archaeologico, SIA) constituted by an articulated system of levels of different information contents. The aim of the experiment was to realize a series of elaborated procedures to be implemented and defined in more and more detail in the field concerning graphic documentation, manages in a way to address satisfactorily different application modalities which should access Imago Urbis. The study presented below concentrates on the Temple of Divine Claudius constructed in A.D.54 at the will of his wife Agrippina on the demise of the emperor. The temple was destroyed by Nero and rebuilt by Vespasian. Although nothing remained of the temple, its structure is documented in the Forma Urbis as a monument following the temple typology of prostyle esastyle, composed of three columns at the front and the northern side. However what survived are sizable remains of the substructure whose large part is visible today (Fig. 9). These have been selected as the subject of the study. It aims at identifying a procedure for restituting of elaborates useful for specific studies within the field of archaeology taking advantage of various surveying and representation technologies. This is a system capable of managing information acquired through surveys has been defined. Its characteristic feature of a series of models, which decline shape, geometry, topology and texture of the case study through different representation modalities. In the study of archaeological elements on large and medium scale, the metric/proportion aspect is certainly one of the most interesting and always topical. In fact it works for a better understanding of the object of study and of the rules underlying its construction as well as of the relation between its parts, but – what is more – between its parts and

Fig. 9: Temple of Divine Claudius, Rome

the human being. In this way archaeological architecture is considered in terms of its relation between designed space and those who make use thereof. It is exactly within this framework that comes to the specific nature of the present study carried out with two objectives in view. One to search for the geometric matrix and design module underlying the construction of the Temple of Divine Claudius. The other one – to compare the results obtained by integrating techniques of low cost surveying with the process already tested out and assessed as optimal (laser scanning and topography).

Surveying operations were carried out in two stages. The first one assumed a survey with a laser scanner; the other one envisaged the application of low cost methodologies for data acquisition and open source software for their elaboration and processing. Finally, the results obtained were compared in order to verify survey quality in terms of accuracy and accessibility of measured data.

The first thing to prepare was the topography profile of 26 points physically marked by Target set up on an open polygonal composed by three stations. The procedure was indispensable to adjust the point clouds within a single Cartesian frame of reference. The next stage was the acquisition of surfaces with the scanner 3D Leicas ScanStation2 (Flight time instrument), positioned

[13] Imago Urbis. Museo Universitario Virtuale della Città e del Territorio di Roma. Research developed by Institute of Archaeology e History of Greek and Roman Art, Prof. A. Carandini.

on the same topographical stations. In this way, scanning with different levels of precision has been obtained and - with operations of rototranslation - was joined to the topographical points. This allowed also to check the error of recording at each point, trying to keep it below values consistent with the definition of the 3D scan (in our case the values of error registering is below 3mm), making is also possible to get all the basic data necessary to reconstruct the entire building in three dimensions. When this first phase of data acquisition had been completed and after a cleaning or eliminating excess data, the total point cloud was exported from software Cyclone to Geomagic Studio 9. This operation was effected optimizing all the parameters of control in such a way as to maintain a high quality of the final result. Sections of more interesting points have been extracted from the Mesh model. These first bi-dimensional elaborations have become the basis for putting forward metric-proportional interpretations of the whole complex. Sections of more interesting points have been extracted from the Mesh model. They then served as a basis of support for preparing plans, tables and geometric sections. These first two-dimensional elaborations have become the basis for putting forward metric-proportional interpretations of the whole complex.

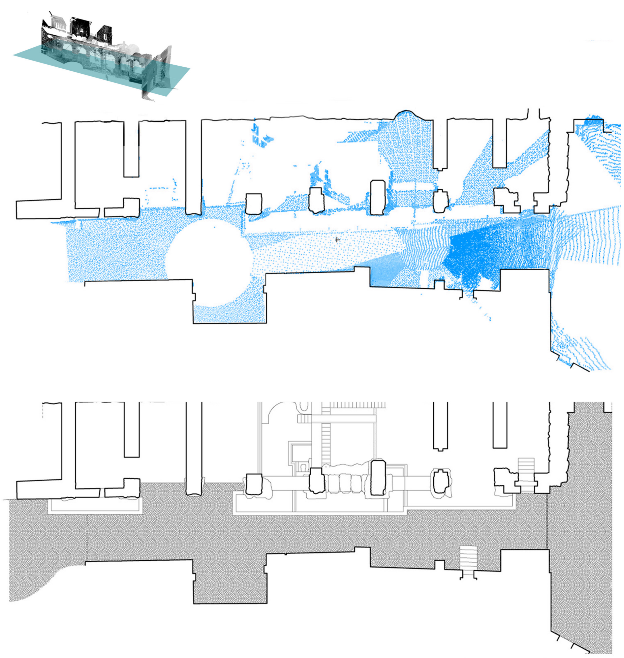

Fig. 10: From point cloud to 2D models. Horizontal section

The second procedure assumed the use of Dense Stereo Marching technology. 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.

The photograms were done with the reflex NIKON D300 camera with CMOS sensor of 12 megapixels. The procedure followed a scheme that guaranteed that the whole object be covered and each photograph overlapped with the successive one in at least 60-70 %.

Data elaboration was effected by software Agisoft Photoscan with the aim of calculating uncertainty and the geometric deviation diagnosed in the model obtained from elaborating the point cloud created by laser scanning.

Prior to effecting metric verification – done with the Blender 3D modeling – 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. 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

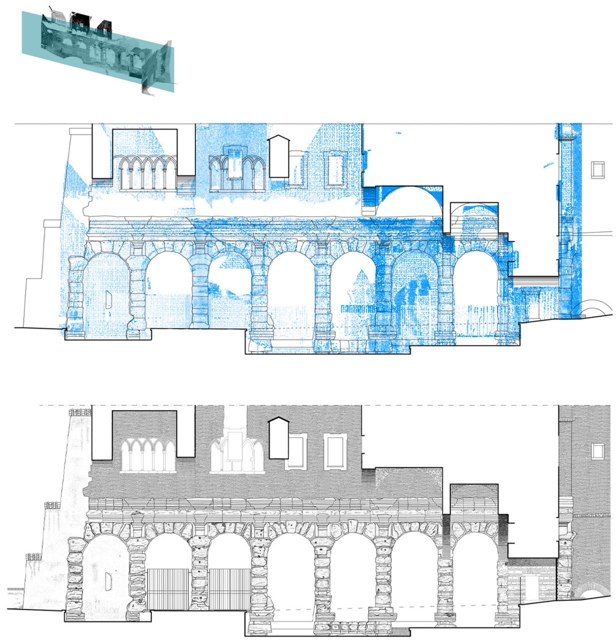

Fig. 11: From point cloud to 2D models. Vertical section

preventively at 1:100, the difference would amount to 2 mm, a value perfectly acceptable because it falls within the graphics error. Extra confirmation has been obtained by calculating the deviance value with CloudCompare , 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-dimensionalplane, proves to fall within millimeters.

The methodology applied demonstrates how in the case under analysis DSM technologies ensured a result comparable, in metric/proportion terms, to that obtained by laser scanning, which makes the technique in question suitable for gathering information that will serve the purpose of defining the matrix underlying the design of the archaeological organism examined. Emphasis must be placed on the fact that even though the comparison with this site were conducted at the 1:100 scale, other experiments have demonstrated that the methodology can be used to define models with a high level of detail, particularly when the uncertainty is controlled by methods ensuring a higher precision level[14].

The enquiry demonstrates the way in which the object of study is situated within the Roman tradition of constructing edifices. Metrological and proportion analyses make clear the geometric definition of spaces by finding correspondences that refer to construction principles of Roman culture and of Roman architectural tradition. Survey proves to be an indispensable tool for analyses, documentation and critical interpretation of archaeological artifacts on large, medium and small scale. At the same time, the joint contribution of architects and archaeologists and the application of innovative technologies guarantee high quality of final product elaboration and makes for an interchange of objective data open to later interpretations (Fig. 10, Fig. 11).

New inquiries into the analysis of form, geometry and proportions have been operatively converted into a research of the underlying constructive/proportional module with the view to confirming or rejecting the idea of the complex having been constructed on the basis of a geometric matrix and a module of reference (Fig. 12, Fig. 13). A close study of the whole structure indicates that it is based on a barycentric rectangle formally structured by a longitudinal axis and a transverse one 34,50 m long and 11,56 m wide and the facade composed of six arches varying in hight from 5,96 m to 6,91. However, metric indications alone proved to be useless if not accompanied by a careful metrological and proportion study. Such a study has been conducted correctly by preparing a survey campaign using high precision tools.

The results of the campaign - which included the whole structure turned out to be significant: the proportions between the length and the width of the main space were found to be exactly 1:3. Moreover, each part contains exactly 19 times the main module, identified on the composition level in the section of the pilasters. Thus, there emerges the unity of the design basis of the architectonic complex, which enables the constructors to establish the dimensions of various parts of the temple. The height of the lower part equals 12 modules, the span between the aisles equals 6 modules while the capital of the lower order of the structure is one module high. The proportions of the arches correspond to two circumferences of 5,5 modules of the diameter intersecting at half the total height of the span. Likewise the design of the hypogeum corroborated the application of the same module. Although lower than the superior space, its height equals more or less 8 modules while the height of the arches is one and a half of the circumference of 5,5 modules which define the height of the arches of the main front. The successive stage of the study focused on trying to establish the unity of measure as the factor regulating the whole architectonic complex by studying the scheme of proportions. The dimension of the module proves to be exactly the double of the Roman foot (29, 6 cm) and understandably corresponds to that of other architectural structures erected in the neighborhood, such as the Porta Maggiore, the arches of the Vergine aqueduct in Campio Marzio or the portico of the Portico di Claudio. As soon as the proportions and the underlying rules that the proportions and the underlying rules that define the architectonic structure had been verified, it was possible to work out its representation by characterizing the surface of its elements. Texture mapping has been performed on the mathematical 3D model that provide information on the characteristic appearance of materials as well as on their state of conservation.

[14](Cipriani & Fantini, 2015).

The enquiry demonstrates the way in which Roman tradition of constructing edifices.

Metrological and proportion analyses (Fig. 14). Make clear the geometry correspondences that

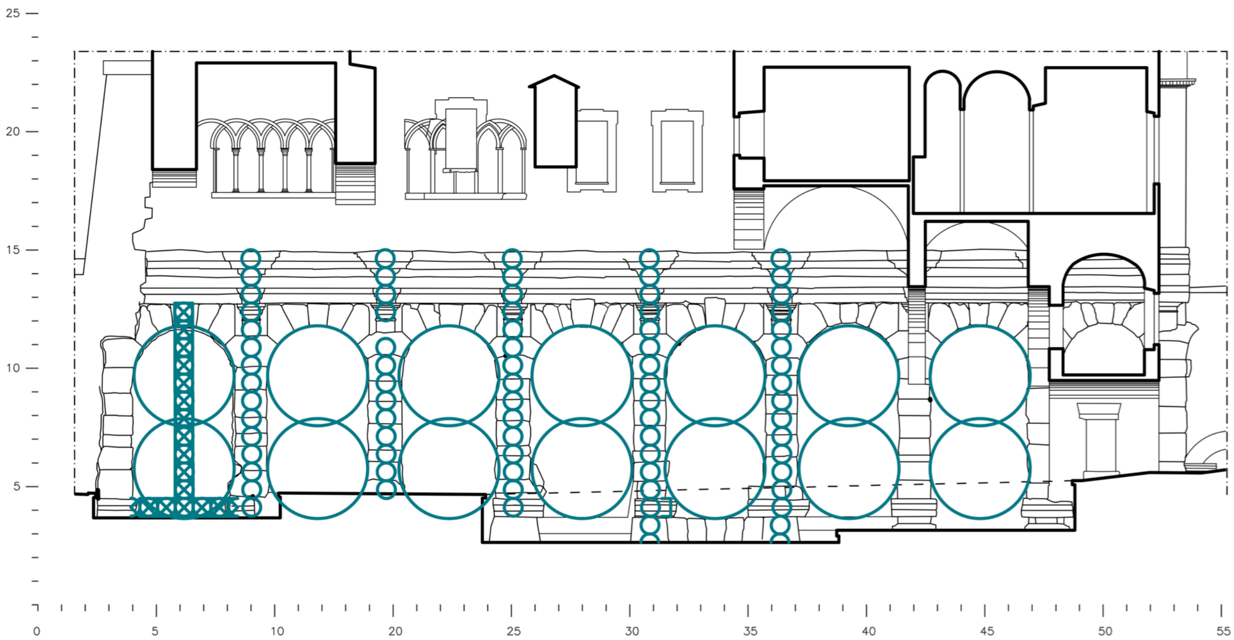

Fig. 12: Metrological analysis

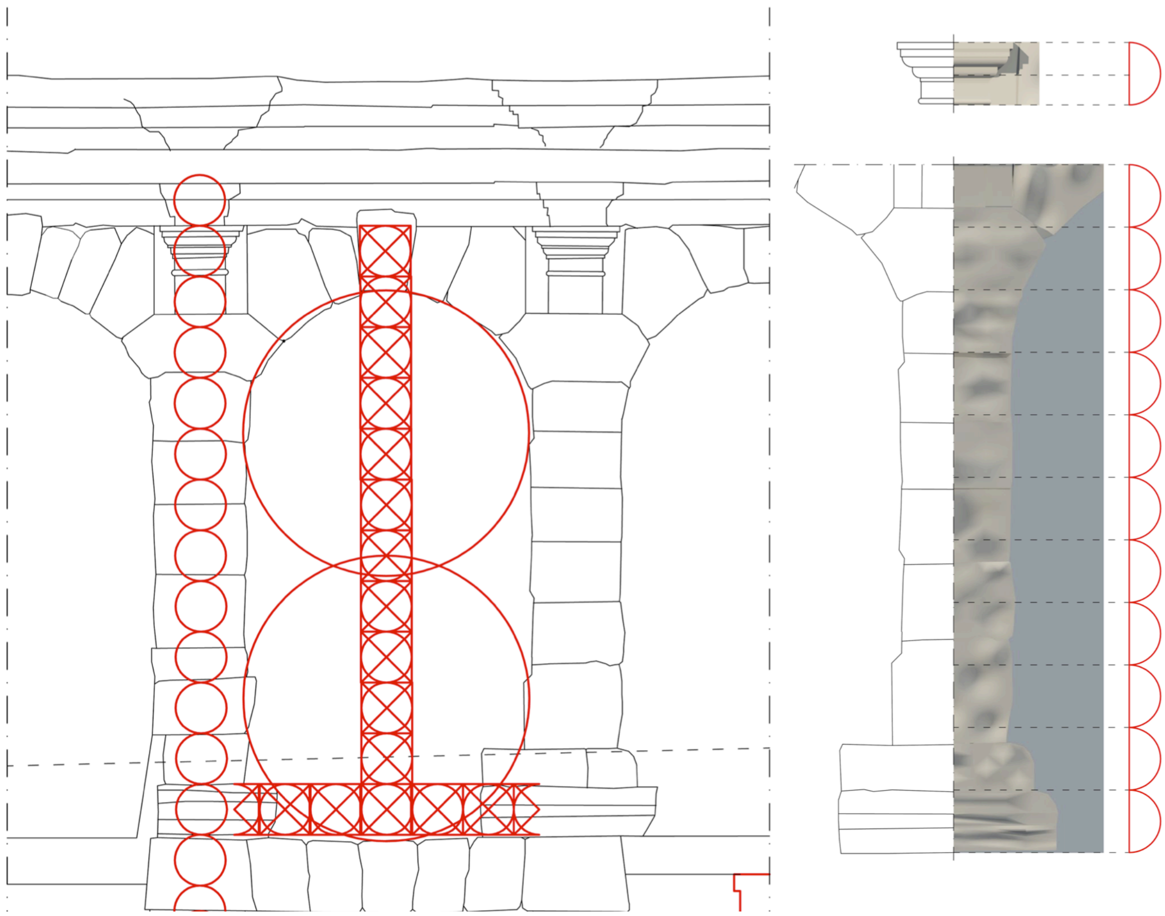

Fig. 13: Metrological analysis

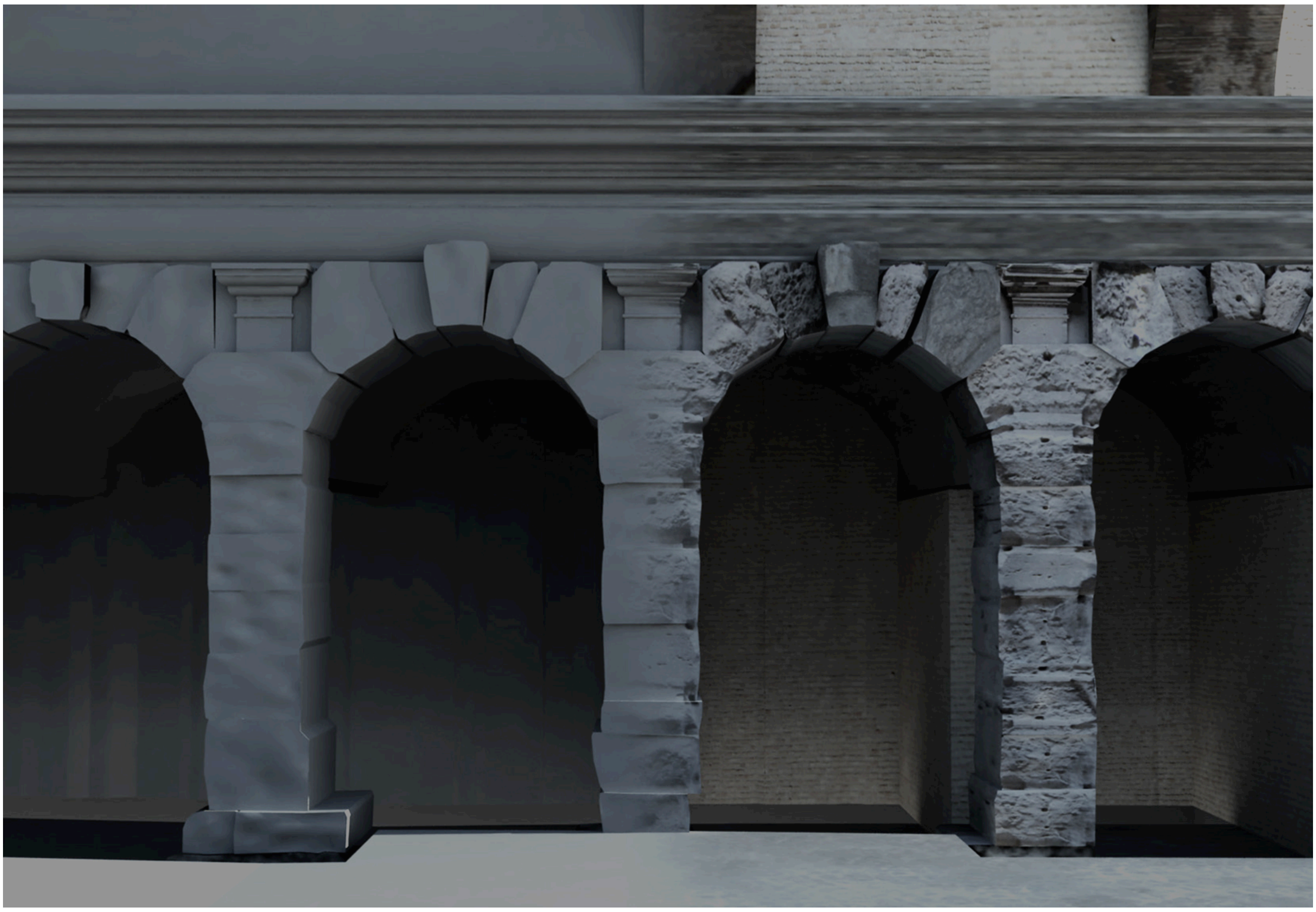

Fig. 14: 3d model, integration of techniques for representation

refer to construction of space by finding principles of Roman culture and of Roman architectural tradition.

4. *Conclusions*

An approach open on various disciplines makes it possible to be critical of stratified contexts so characteristic of the field of archaeology, extracting from it information that allow us to understand and analyze them. . Defining an open system based on the integration of specific and heterogeneous competences involved in the study of archaeological heritage provides the point of departure for structuring out a process whose objective is cognition (knowledge or cognition and knowledge). Survey and representation become indispensable for analyzing, interpreting and documenting cultural heritage effort of architects and archaeologists guarantees quality of elaborating the final Product. Moreover, the application of all the more innovative technologies ensures the possibility to exchange objective data open to further interpretations. Every project that aims at the and parcel of a virtualization of archaeological elements is part process which comes to be articulated in the knowledge of the current state and in putting forward interpretative hypotheses upon past moments in the existence of the artifact. The methodological stage as well as the practices that lead to the construction of models and database creation rest upon objective highly interdisciplinary operations. This latter feature is of determining value not only for reconstruction, which is the domain of virtual archaeology, but also for public administration, engineering companies and events organized within the sector of cultural tourism.

The structure of any computerized system places at our disposal detailed and complete documentation and makes it possible to diffuse the results obtained from survey operations and three-dimensional model construction shaping them in various modalities, accessible to various, generic or specialized users according to their

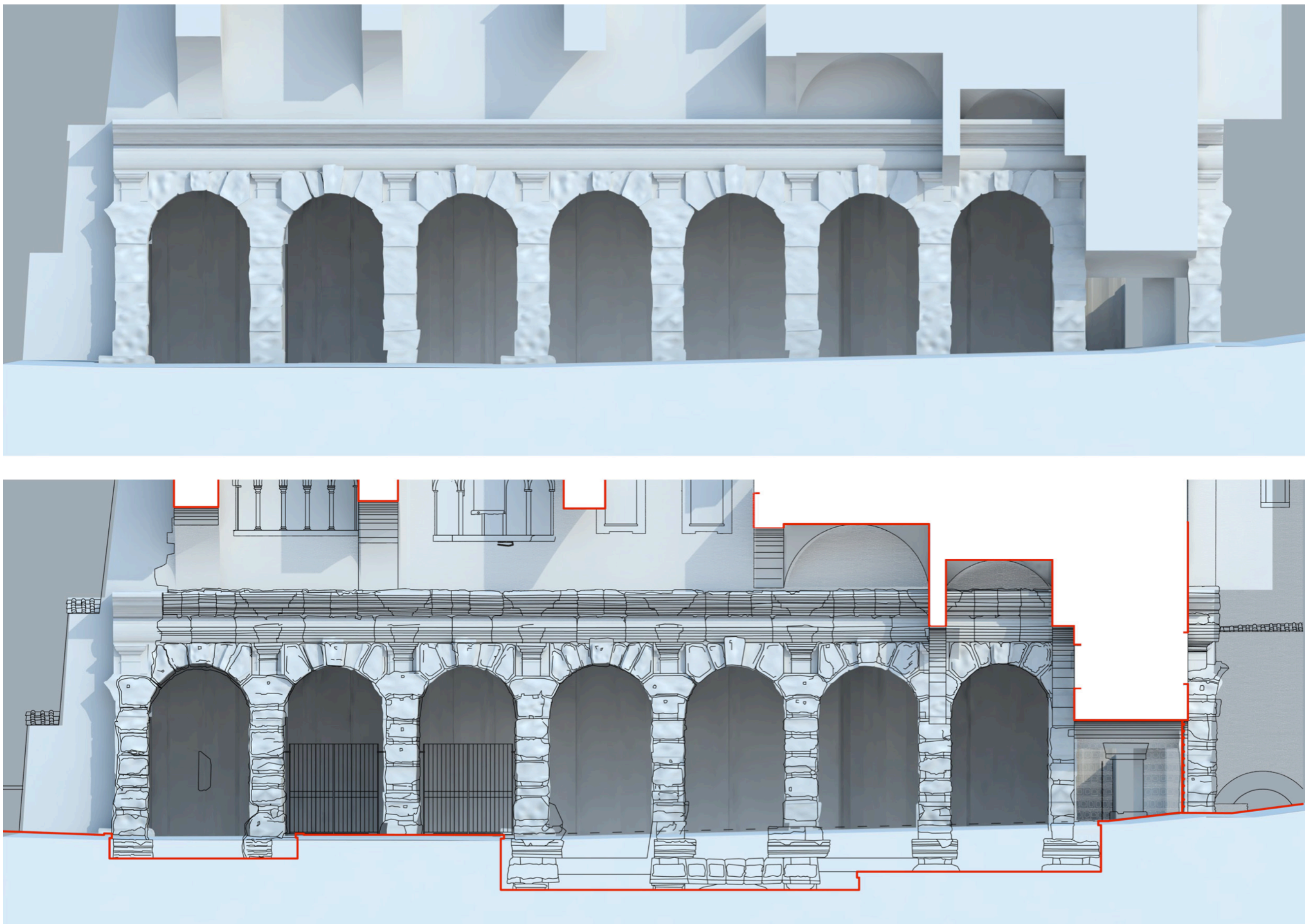

Fig. 15: 3d/2d model, integration of techniques for representation

needs (Fig. 15). Digital instruments open up the possibility to establish a continuous relation between iconicity and visualization of the object surveyed, formalized through models that provide various possibilities linked to the use through various scales of representation (from 1;1 to 1:∞), different interpretation levels, for purposes that swing lead to knowledge, its diffusion and research. In this way, a system is structured out – rigid, but dynamic and complete in its contents, based on the transitive use of various models. Thanks to a high similarity level in relation to the real object, the constructed models have been used as instruments for understanding and communicating the object under analysis. Models were constructed with two objectives in view, which imposed the necessity to distinguish figurative models from those prepared for scientific purposes. The aim of figurative models is the research into mimesis: their objective is to provide documentation similar to reality for purely educational purposes. Similarity to the real object has its source in geometric recognizability of individual parts and in the application of texture, integrating formal information with material and chromatic features establishing a relation with reality from the point of view of perception. Models created for scientific purposes, on the other hand, are characterized by well defined geometries and a high level of metric precision strongly connected with the definition of scale reference.

Survey proves to be an indispensable tool for analyses, documentation and critical interpretation of archaeological artifacts on large, medium and small scale. At the same time, the joint contribution of architects and archaeologists and the application of innovative technologies guarantee high quality of final product elaboration and makes for an interchange of objective data open to later interpretations. Elaboration of models for static and dynamic representations of objects as well as creating database for interactive use online constitute a model for managing archaeological heritage with the following objectives in view: cataloguing and valorizing cultural heritage, creating scientific educational documentation, diffusion of information in a structured and interactive manner. The latter idea is strictly connected with the problems involved in public interchange and diffusion of data with formats of extensive diffusion through data banks more and more accessible, complete, applicable and usable from a distance precisely because they have been digitalized.

REFERENCES

Apollonio, F. I., Gaiani M., & Zheng, S. (2013). Characterization of Uncertainty and Approximation in Digital Reconstruction of CH Artifacts. In *Le vie dei Mercanti XI Forum Internazionale di Studi* (pp. 860-869). Naple, IT: La scuola di Pitagora editrice.

Apollonio, F.I., Gaiani, M., & Baldissini, S. (2011). Construction, Management and Visualization of 3D Models for Cultural Heritage GIS Systems. In *Digital Media and its Application in Cultural Heritage* (pp. 283- 299). Amman: CSAAR Press.

Apollonio, F. I., Gaiani, M., & Zheng, S. (2013). 3D modeling and data enrichment in digital reconstruction of Architectural Heritage. In *XXIV International CIPA Symposium, ISPRS, 2013* (pp. 43-48). Strasbourg: France.

Baker, D., Denard, M. H., & Bentkowska-Kafel, M. A. (2012). *Paradata and Transparency in Virtual Heritage*. UK: Ashgate Publishing.

Baker, D., Bentkowska-Kafel, A., & Denard, H. (Eds.) (2010). *Paradata*. Londres: Ashgate. Retrieved from http://www.digitalhumanities.org/view/Adho/DigRes

Batley, S. (2005). *Classification in Theory and Practice.* Oxford: Chandos

Bianchini, C., Borgogni, F., Ippolito, A., & Senatore, L.J. (2014) Rilevare e rappresentare l'archeologia: verso una sistematizzazione. In P. Clini (Ed.), *Vitruvio e L'archeologia* (pp.147-172). Venezia: Marsilio.

Bianchini, C., Borgogni, F., Ippolito, A., & Senatore, L.J. (2014). The Surveying and Representation Process Applied to Archaeology: A Quest for Invariants in a Highly Variable Context. In P. Di Giamberardino, D. Iacoviello, N. Renato, J. Manuel, R.S. Tavares, *Computational Modeling of Objects Presented in Images Fundamentals, Methods and Applications* (pp. 1-29). Berlino: Springer International Publishing.

Bianchini, C. (2012). *La documentazione dei teatri antichi del mediterraneo. Le attività del progetto Athena a Mèrida*. Roma: Gangemi.

Bianchini, C. (2012). Rilievo e metodo scientifico. In L. Carlevaris, M. Filippa (a cura di) *Elogio della Teoria. Identità delle discipline del Disegno e del Rilievo* (pp.391-400). Roma: Gangemi Editore.

Callieri, M., Dellepiane, M., & Scopigno, R. (2015). Remote visualization and navigation of 3D models of archeological sites. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XL (5/W4), 147-154.

Chiavoni, E. & Filippa, M. (2011). *Metodologie integrate per il rilievo, il disegno, la modellazione dell'architettura e della città*, Roma: Gangemi.

Cipriani, L., & Fantini, F. (2015). Modelli digitali da *Structure From Motion* per la costruzione di un sistema conoscitivo dei portici di Bologna. *Disegnare Idee Immagini*, 50, 70-81.

De Luca, L. (2011). *La Fotomodellazione architettonica*. Palermo: Flaccovio Editore.

Docci, M. (1989). Disegno e rilievo: quale didattica? In *Disegnare idee immagini*, n. 0, Roma, p.38

Gaiani, M., Benedetti, B., & Apollonio, F.I. (2011). Teorie per rappresentare e comunicare i siti archeologici attraverso modelli critici. In *SCIRES-IT SCientific RESearch and Information Technology. Ricerca Scientifica e Tecnologie dell'Informazione,* 2, pp. 33-70. Retrieved from http://caspur-ciberpublishing.it/index.php/scires-it/article/viewFile/9549/8918.

Gaiani M., Benedetti B., & Remondino, F. (2009). *Modelli digitali 3D in archeologia: il caso di Pompei*. Pisa: Edizioni della Normale.

Guidi, G., Russo, M., & Angheleddu, D. (2013). Digital reconstruction of an archaeological site based on the integration of 3D data and historical sources. In *Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 40(5/W1), 99-105.

Ippolito, A. (2015). Analisi e documentazione digitale del patrimonio archeologico. Un approccio multidisciplinare. In F. Anichini, G. Gattiglia, M.L. Gualandi *Mappa Data Book 1. I dati dell'archeologia urbana italiana* (pp.72-88). Roma: Ed. Nuova Cultura.

Ippolito A. (2009). L'analisi delle superfici murarie del Tempio del Divo Claudio. *Disegnare Idee Immagini*, 38, 76-85.

Remondino, F. & Campana, S. (2014). 3D Recording and Modelling in Archaeology and Cultural Heritage - Theory and Best Practices. Oxford: Information Press.

Siotto, E., Callieri, M., Pingi, P., Scopigno, R., Benassi, L., Parri, A., La Monica & D., Ferrara, A. (2014). From the archival documentation to standardised web database and 3D models: the case study of the Camaldolese Abbey in Volterra (Italy). In *Proceedings* of *CHNT 18 - 18th International Conference on Cultural Heritage and New Technologies* (pp.1-9). Wien, Austria: Museen der Stadt Wien.

Scopigno, R., Callieri, M., Cignoni, P., Corsini, M., Dellepiane, M., Ponchio, F. & Ranzuglia, G. (2011). 3D models for Cultural Heritage: beyond plain visualization. In *IEEE Computer*, 44 (7), 48-55