Foreword

FROM ARCHITECTURE AND ARCHAEOLOGY SURVEYING TOWARDS 3D VIRTUAL MODELS – THE ROLE OF 3D MODELS FOR PRESERVING AND VALORIZING ARCHITECTURE AND ARCHAEOLOGY

My activity as professor started in the distant year 1962 and precisely at that time, I took a keen interest in the domain of drawing, initially as professor in drawing from reality. Then my attention gradually shifted and focused on the field of architecture surveying in all its varieties. Hence I was able to participate personally in the profound transformations that developed in this field of endeavor in the span of almost fifty years. The first of these activities matured in the form of the publication at the beginning of the 80ies after twenty years of experience (Docci & Maestri, 1984).

The fact of having started my research activity at the beginning of the 60ies, made it possible for me to participate personally in a whole series of epoch making changes that resulted in a series of new surveying methodologies to finally arrive at experiments with 3D virtual models of today. Therefore, I deem it useful to sketch out a brief synthesis of these transformations.

At the beginning of the sixties some Departments of Architecture, especially at Italian universities, offered to their students a course in surveying based mainly on direct surveying that continued its traditional role as an instrument of cognizing historical structures, following the Italian Renaissance tradition introduced and developed by great masters like Brunelleschi, Sangallo, Palladio, and many other important architects who practiced this method to get to know works antiquity closer. It was especially in the school of Rome that the formative course in architecture was based on the teachings of Gustavo Giovannoni which put in the foreground knowledge of history through surveying and mastery of the discipline of restoration.

In the very same period took place the first experiments with the application of aero photogrammetry to architecture surveying. This gave rise to the so called “close range photogrammetry”.

Many of us took part in these experiments personally, supported also by a favorable international climate, researchers being interested in saving and preserving historical site¹. The ex RADAAR Department of University of Rome Sapienza² could not remain indifferent to the challenge and thanks to the contribution of many of our colleagues numerous surveying campaigns were conducted (Docci, 2001) with digital photogrammetry, applying innovative procedures with the view to interpreting the historical fabric (structure) in more detail and to gaining a really profound knowledge of the object surveyed. There is no need to enumerate all the research efforts in this regard. Suffice it to mention the huge surveying campaign on the Colosseum (Il Colosseo. Studi e Ricerche, 1999; Docci, 1999).
It can be said that research activity in the field of photogrammetry started to decrease in intensity and interest. Nevertheless, at the same time – thanks to the advent of informatics which had already revolutionized photogrammetry enabling a transition from analogue to digital photogrammetry – it initiated a new adventure through integrating laser scanner technology with informatics. What I mean is that in the mid-seventies there appeared first laser scanners used for surveying architecture by scanning its surfaces. The methodology made it possible for the researcher to acquire very fast the coordinates of millions of points from surfaces to be surveyed. Our Department played a strategic role in the development of the new surveying methodology, employing resources and researchers to try out the new instruments and conduct experiments with them.

Before describing these research experiences, I wish to underline that I have always maintained – since the appearance of photogrammetry that preceded those methodologies – that neither direct nor topographical surveying should be abandoned. Rather they ought to be integrated with the new ones in order to be able to take advantage of different potentialities of each of them.

It must be underlined that as concerns the relation with the morphology of the work to be surveyed, certain methodologies turn out to be more adequate that others. Obviously, this concerns also the work of architecture in relation to its various component parts. These remarks are even more pertinent as regards architectural surveying which has to confront various typologies of remnants and masonry works often severely damaged or collapsed.

As far as this phenomenon is concerned, I remember that at that time I was coordinator on national scale of some Prin projects whose aim was to integrate various surveying methodologies with the view to optimizing the performance of diverse methodologies (Metodologie innovative integrate per il rilevamento dell’architettura e dell’ambiente, 2005; Metodi e tecniche integrate di rilevamento per la realizzazione di modelli virtuali dell’architettura della città, 2007; Docci, 2007b; Metodologie integrate per il rilievo, il disegno, la modellazione dell’architettura e della città, 2011).

Also in the field of archaeology our work was based on the same criteria adopted for the integration of different methodologies within the Firb project of 2003 under the title “Nuove metodologie e tecnologie integrate per la documentazione e restauro dei complessi archeologici e monumentali mediterranei” (New Integrated Methodologies and Technologies for Documenting and Restoring Archaeological and Monumental Mediterranean Complexes) demonstrating that integration of different methodologies becomes a powerful tool to improve the operative quality of surveying, which – in turn – furthers a more profound knowledge of the artifact. So, on the one hand surveying with the help of laser scanning opened up new horizons, but on the other hand research activities were conducted which clearly demonstrated that the so called “point cloud” was only a numerical model which as such could not represent architecture without an elaboration that would transform it into a continuous, geometrical or mathematical model, whichever term one prefers to adopt (Docci, Gaiani & Migliari, 2001). This problem gave rise to many misunderstandings as scanning does not guarantee that the coordinates of points characteristic for the work surveyed will certainly be picked up. That is why the numeric model has to be transformed into a continuous one with the aim of the researcher having at his disposal the whole surface of the object in a way that ensures the presence of qualifying points which identify the object surveyed. The fact that on the market there were professionals who did not work scrupulously enough resulted in the uncertainty among clients and years of work in order to eliminate these misinterpretations.

In the first decades of the XXI century the methodology of laser scanner surveying reached its full development and numerous initial mistakes were overcome, even though until today there still appear publications whose authors maintain that the view of an edifice can be obtained through simple orientation
and the projection of the point cloud on the plane of representation, forgetting the fact that laser survey does not guarantee that all the points which characterize the object will be surveyed if laser scanning is not integrated with other elaborations. On the other hand there appeared numerous publications, which brought out the different problems and – particularly – demonstrated methodological differences between traditional and laser scanner surveying to such an extent that one can now talk about new theories of architectonic surveying.

The fact that it is impossible to scan all characteristic point clouds of the object surveyed with a laser scanner imposes the application of the procedure that ensures the transformation of the point cloud into a continuous geometric model through the mesh or NURBS, in order to obtain a 3D continuous model of the work of architecture surveyed from which one can acquire 2D orthogonal projections with the certainty of having included the characteristic points of the object (Docci, Bianchini & Ippolito, 2011; Docci, 2012).

The survey of the Colosseum was a test of serious experiments in close range photogrammetry. Laser scanner surveying led our Department into international European projects that resulted in the scanning of the internal part of Hagia Sophia in Istanbul (Docci, 2003) and several Roman theaters, like that of Mérida, of Gerasa and of Petra (Bianchini, 2013; more specifically on the theater in Mérida: Docci, 2013b).

Figure 1. Façade of the Church of San Girolamo degli Schiavoni; elaboration from a photogrammetric survey
(elaborated by Department ex RADAAr)
In the field of architectonic surveying of particular importance was the collaboration with our Spanish colleagues archaeologists thanks to which we acquired a direct knowledge of the Arco di Giano in Rome.

As I have already written above enquiries into laser surveying resulted in the development of research of 3D digital models, which took into consideration the necessity of transforming discontinuous numerical models into continuous geometrical ones.

Elaboration of such models also proved that by superimposing on these models high definition photographs of the object surveyed we could obtain 3D digital models with so clearly characterized surfaces that they enabled the researchers to explore such models in more precise way in comparison with the direct view of the structure.

At the same time, however, thanks to the development of software which became more and more reliable, a new surveying methodology was born, the so called photo modeling. Through this methodology, it is also possible to obtain high definition 3D models with a high reliability level from the metrological point of view. With only a few dozen images, which show each point of the work surveyed, it is possible...
to obtain a 3D digital model and extract from it all the 2D representations necessary for its documentation (Docci, 2013a).

Various experiments conducted especially in the domain of archaeology allowed us to compare the survey of an object done with the laser scanner with that obtained through photo modeling. In this way we could single out a number differences between these two methodologies, calculated with the precision to a few millimeters relative to the average of measurements. This can be seen in the survey of a vase form a tomb in the archaeological zone of Crustumerium (Lazio) elaborated by the Ph.D. Thesis of Francesco Borgogni3.

THE ROLE OF 3D SURVEYING IN PROJECTING OF CAMPAIGNS FOR VALORIZING AND PRESERVING OF ARCHITECTURE AND ARCHAEOLOGY

As we have presented above, thanks to laser surveying and photo modeling it is possible to construct high definition 3D digital models of works of architecture and archaeology with the objective to preserve or valorize them. Such models can be used in a variety of ways: from the traditional one for obtaining
traditional representation, through 2D drawings (plans, views, and sections) that documents the current state of the work, to the one which allows the architect or restorer to design his task, operating directly on the 3D model. Moreover, the model makes it possible to explore the object in question accurately, also at close range. Apart from this aspect of cognizing the artifact, the methodology presented allows one to map out all the surfaces tracing the perimeters. It is even possible to trace the outlines of homogeneous zones, survey various critical points, find out whether there are still surfaces to reinforce, etc. Having completed this first stage of cognizing the artifact, it is possible to work directly on the 3D model to elaborate the intervention project and then, if deemed necessary, to return to bi-dimensional representation and send it to the building site. In other words, the cognitive and intervention operation performed on the 3D virtual model can be projected onto two orthogonal planes of representation to obtain 2D representations which will support the stage of actualizing the intervention. One can also import the model into the BIM (Building Information Modeling) with which it is possible to elaborate the project with the BIM methodology that – as is well known – allows one to manage the project but
above all ensures a coordinated management of the site and provides a system of continuous monitoring that is less costly and more efficacious in actualizing the project. Understandably, in order to work with this methodology the project designer must be able to address the projecting task in a way different from...
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Figure 6. Geometric and architectonical plan and elevation of Mérida theatre’s scene
(elaboration: Mario Doci, Luca J. Senatore)

the traditional one. Such a methodology turns out to be more efficacious allowing the project designer to visualize the suggested interventions in the 3D space. Consequently, he has the spatial aspect of the project under control. Thus, surveying acquires a new dimension and especially a new way of relating to the project. But first of all it is now evident that the project designer can control the results of his
interventions on the spatial aspect of his own project, particularly in cases of modifying interventions, like for example introducing new elements into the structure.

The new methodology has already been put to practice. In a recently undertaken surveying campaign for the restoration of the Caserma Cascino in Cagliari with the collaboration of Prof. Tatiana Kirova, the virtual model of the surfaces of external volumetry was applied to design the restoration working directly on the 3D model. The results were of considerable interest.

Analogous operations can be conducted at archaeological sites to realize high definition 3D models on which it will be possible to develop various solutions pertaining to the interventions that lead to valorizing and preserving the artifacts. The experimental case I personally participated in was related to the roofing of the excavation of Villa dei Volusii at Lucus Feroniae, where we managed to establish the spatial relation between the new wooden roofing with particularly sensible parts of the archaeological finding, like the floor mosaics of the villa⁵.

*Figure 7. Janus Arch, Rome. 2D elevation with different mapping overlay (elaboration: Carlo Bianchini, Francesco Borgogni, Carlo Inglese, Alfonso Ippolito, Luca J. Senatore)*
To conclude, it behooves to say that in the case of historical buildings and archeological discoveries the marriage of surveying with innovative technologies (laser scanner and photo modeling) and BIM not only renders it possible to construct 3D models very fast but also to reach a remarkable degree of metric reliability – if the survey operation is based directly on laser scanning, provided that the point clouds can be directly loaded into BIM programs.
Figure 9. Edicola della Musa, Villa Borghese, Rome. Elaboration of 3D model from Structure from Motion (elaboration: Martina Atteni, Cristiana Bartolomei, Eliana Capiato, Alfonso Ippolito)
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Figure 10. Edicola della Musa, Villa Borghese, Rome. From Mesh model to texturized model (elaboration: Martina Atteni, Cristiana Bartolomei, Eliana Capiato, Alfonso Ippolito)

I think that the relationship between surveying and designing will acquire a more and more important role provided that the possibilities offered to the designer to operate directly in the 3D dimension can improve the quality of interventions for the sake of gaining more knowledge that he can have directly at the designing stage.

THE ROLE OF SURVEYING IN THE ACQUISITION OF KNOWLEDGE OF ARCHAEOLOGY AND NON-CONSTRUCTED ARCHITECTURE

It has already been demonstrated that digital 3D models can be constructed on the basis of a point cloud obtained through laser scanning. Laser scanning can also be applied to archaeological sites where artifacts partially preserved had been excavated. These artifacts can be scanned in order to create 3D models of the parts, which had survived. What is more, such a model can be then integrated into the missing parts
Figure 11. Edicola della Musa, Villa Borghese, Rome. From 3D to 2D models
(elaboration: Martina Atteni, Cristiana Bartolomei, Eliana Capiato, Alfonso Ippolito)
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*Figure 12. Edicola della Musa, Villa Borghese, Rome. From 3D to 2D models (elaboration: Martina Atteni, Cristiana Bartolomei, Eliana Capiato, Alfonso Ippolito)*
Figure 13. Archaeological site of Crustumerium, Lazio. Tomb: comparison between 3D data from laser scanner and Structure from Motion. Oinochoe: 3D data comparison between models. Maximum deviation 10 mm; medium deviation: 1.5 mm
(elaboration: Francesco Borgogni)
using the metric information encoded in the object and integrating it into other pieces of our knowledge, for example the way of constructing buildings. Naturally, all this concerns knowledge that is not arbitrary but applicable to further the knowledge of the objects from the past.

These 3D models can play different roles depending whether they are used for studying the artifact or for informing visitors about it. They can also be applied to realize a hypothesis that can be confirmed or modified with the gradual acquisition of new information on the object analyzed.

In her Ph.D. thesis, Giulia Pettoello put this intervention methodology into practice. She applied the photo modeling methodology to the survey of the base part of and the terrain around the grand Temple of Vulci. Starting with the pedestal she reconstructed the upper part of the temple relying on the data provided by the most current studies of Etruscan archaeology on the construction of buildings of this particular typology. As we know, they were built of masonry, wood and terracotta. As can be gathered from the images. The temple is linked to the orography of the terrain and the base serves as the generating element of the space above it. The three dimensional form of the grand Temple of Vulci can be explored interactively and provides the user with a well calibrated idea of the resolution of space of the original edifice.

The application of this methodology to non-constructed architecture seems to be of particular interest. One can study this proposal in detail tracing the construction of a 3D digital model of Antonio da Sangallo the Younger’s design of the new St. Peter’s Basilica.

In this case there were two possibilities: one to create a digital model on the basis of drawings housed at the Uffizi Gallery in Florence, the other one one – to use Sangallo’s wooden model preserved and housed at the Simon Mago chamber at the Vatican (Docci 2007a; Bianchini 2007; Ippolito 2007). Assuming that the proportions and quality of the wooden model is reliable, the researchers chose the latter and proceeded to scan it. As can be gauged from the 3D model, the quality of the scansion made it possible to interpret Sangallo’s original design accurately and discovered new elements for pondering the work especially with the objective of achieving a more adequate historical and critical analysis.

As can be seen the application of 3D virtual models opens up new horizons also for research in the domain of history of architecture. These observations make me believe that in the years to come constructing 3D models can become one of the fields of major scientific research effort in the discipline of drawing. The possibility to improve the quality of 3D virtual models not only for their metric quality but also for an elevated image definition will certainly make it possible to operate with greater certainty already at the stage of developing the preservation project.

Mario Docci
Sapienza University of Rome, Italy
Figure 14. Great Temple, Vulci. Pedestal. Bibliographical data and 2D/3D models from Structure from Motion
(elaboration: Giulia Pettoello)
Figure 15. Interactive App for smartphones. Steps for virtual reconstruction of 3D model (elaboration: Giulia Pettoello)
Figure 16. Virtual reconstruction of 3D model from bibliographical data. Software Rhinoceros (elaboration: Giulia Pettoello)
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Figure 17. Virtual reconstruction of 3D model. From Mesh to NURBS
(elaboration: Giulia Pettoello)
Figure 18. The section and the main façade of the virtual model by Antonio da Sangallo the Younger for the new St. Peter’s in the Vatican and rendered view of the dome (elaboration: Alfonso Ippolito, Luca J. Senatore)
Figure 19. Virtual replica of the wooden model by Antonio da Sangallo the Younger for the new St. Peter’s in the Vatican. Two-colour illustration of the main entrance (rendering)
(elaboration: Alfonso Ippolito, Luca J. Senatore)
Figure 20. Virtual replica of the wooden model by Antonio da Sangallo the Younger for the new St. Peter’s in the Vatican. Two-colour illustration of the main façade (rendering)
(elaboration: Alfonso Ippolito, Luca J. Senatore)
REFERENCES


Metodologie integrate per il rilievo, il disegno, la modellazione dell’architettura e della città. (2011). 

ENDNOTES

1. The contributions of ICOMOS and CIPA (International Committee for Documentation of Cultural Heritage) should be mentioned in this context.

2. The Department ex RADAAR has been instituted by University “La Sapienza” of Rome in 1982. In the last 20 years it has achieved important results both in the field of theory and practice concerning the analysis and the graphic representation of architectural patrimony as well as in surveying Cultural Heritage Patrimony assets. Among the numerous research must be mentioned the surveys and analyses of the Colosseum, of the Dome of St. Peter’s Basilica, of Castel Sant’Angelo in Rome, the Reggia Caserta in Naples. On the international level, surveys and studies were conducted of Biblos (Lebanon), the archaeological complex of the Theater and Amphitheater at Mérida (Spain), the theatres of Jerash, of Petra in Jordan and the Hagia Sophia Basilica Istanbul.


4. BIM is a multidimensional design system that can manage a project and the building site in a different way involving all the actors participating in the process.

5. The valorization project of the Villa dei Volusii was elaborated between 1996 and 1998 by Mario Docci and Gaetano Miarelli Marini on behalf of the Società Autostrade S.p.A.