

THE VIRTUAL RECONSTRUCTION OF TEMPLE B IN SELINUNTE EXCAVATION SITE

G. Carra, S. D'Amelio, B. Villa

Representation Department, University of Palermo, Viale delle Scienze, 90128 Palermo, Italy - bevilla@unipa.it

Commission V, WG V/2

KEY WORDS: Cultural Heritage, Laser Scanning, Archaeology, Vision, Reconstruction, Building Model

ABSTRACT:

This paper proposes a study on the virtual reconstruction of temple B in Selinunte. It is the smallest of Selinunte's temples yet, despite its size, it has been the subject of great interest and debate by scholars since its discovery in 1823. The studies carried out throughout the XIX century and the first half of the XX century provided different renderings, especially as to the organization of the elevation. The goal of this work is the virtual anastylosis of temple B, through the study of all available historical sources, the survey of fragments preserved today at the "A.Salinas" Regional Archaeology Museum in Palermo, and the survey of the finds at Selinunte's site. The virtual reconstruction of a partly destroyed artefact is a complex operation requiring the collaboration of many human and cultural resources, as well as the use of various technologies. The work was focused on three main aspects: high accuracy in data acquisition, communication and exchange of information among the various professionals experts taking part in the project, production of 'open' papers, to discuss problems in data interpretation and in possible reconstruction hypotheses. This paper intends to give a contribution to favour the knowledge and exchange of information through the use of all available resources. It also intends to represent a case study for understanding all the problems relevant to the reconstruction process of a partly destroyed artefact. The work intends to be in line with the main international guidelines about the highly detailed virtual reconstruction of cultural heritage.

1. INTRODUCTION

During the past decades, the interest towards the rich historical-artistic heritage has been ever-increasing. Therefore, it is of paramount importance to enhance and preserve the Cultural Heritage at best, starting from its accurate documentation, which is the necessary assumption for its knowledge, for the preservation and restoration works, and for its virtual reconstruction. The goal of this paper is to report the methodological pathway followed during the surveying stages and during the development stages of a virtual reconstruction model. Particular attention was paid to the surveying process, meant as an accurate recording of all operations leading to the final product: the model of the architecture studied.

Temple B is characterized by the remarkable formal complexity of the fragments and by the limited number of finds. This provides a useful investigation field in order to assess the potentials and possible limits of modern surveying techniques, as well as the modelling possibilities of IT systems.

In Selinunte, only the ruins of the basement are still present, together with some courses of ashlar of the cella's wall (figure 1). Actually, the most interesting part for studying temples' architecture in the Hellenistic age, including polychromy, consists in the fragments of the temple's elevation, preserved at the "A.Salinas" Regional Archaeology Museum in Palermo, in the so-called Methopes' hall (figure 2).

The work described has been articulated as follows:

1. analysis of historical sources, in order to consider the main studies carried out on temple B and get to know the building and have a graphical basis to create 3D models of reconstruction hypotheses, to be compared;

2. execution and processing of 3D surveys of fragments of the elevation of temple B with the use of laser-scanning techniques;
3. execution and processing of surveys with topographic and photogrammetric techniques aimed at documenting the ruins of the basement and of the cella in Selinunte.



Figure 1. The ruins of the basement of temple B in Selinunte



Figure 2. Some fragments of temple B preserved at "A.Salinas" Regional Archaeology Museum in Palermo

2. TEMPLE B IN SELINUNTE

The archaeological area of Selinunte is among the largest and most important in the Western Mediterranean. In the past three centuries the city, built around 650 BC, has been the favourite destination of travellers and archaeologists from all parts of the world. The set of architectures present inside Selinunte archaeological park can be subdivided in three groups: the Eastern hill, the Acropolis, and the Gaggera hill (figure 3).



Figure 3. Selinunte's Archaeological Park

Temple B is located in the area of the Acropolis and it is the smallest of Selinunte's temples. Its dating still remains hard to determine, even though all scholars agree in considering it a temple belonging to the Hellenistic age. Recent studies have confirmed the dating to the first quarter of the 3rd century BC (300-275 BC). Despite its small size, this building has always aroused great interest among scholars and it has been the subject of a lively debate centred on the different reconstruction hypotheses advanced during the years, and on the use of colours by the Greeks. Temple B was discovered in 1823 by J.I.Hittorff, who made it famous with a text wholly devoted to the analysis of the finds and ruins of temple B, to a reconstruction hypothesis, and to the study of polychromy with the Greeks.

Subsequently, the studies of reconstruction hypotheses by scholars such as Cavallari and Lo Faso, Koldewey and Puchstein, Fougeres and Hulot, followed.

The fragments hosted in the museum allow to partly understand how the front was made. The basement in Selinunte, instead, gives us its planimetric size. On the basis of the archaeological finds, it results still impossible today to determine the precise planimetric topology and the architectural order, as well as the height of the temple's columns. Studies carried out in the past centuries have tried to make hypotheses of reconstruction by complementing the finds, according to analogies with other likely architectures or of the same period. The hypotheses advanced are mainly three: the first, by D. Lo Faso, proposes a temple in antis with Doric columns; the second, by J.I. Hittorf, proposes a tetrastyle prostyle temple with Ionic columns; the third hypothesis, by R. Koldewey and G. Fougeres, assumes a prostyle tetrastyle temple with Doric columns. Although we do not have any final evidence, the most likely hypothesis appears to be the one by Serradifalco, Dinsmoor, with temple B as a "distyle in antis".

3. LASER SURVEY

3.1 Equipment used

Due to the formal complexity of temple's B fragments, it was decided to use a scanner based on the principal of laser triangulation, *Minolta Vivid 9i*, because of the high performance as to accuracy provided by this class of devices (sub-millimetric precision) necessary for a correct and suitable description of the surface of the fragments of temple B (figure 4). It is a laser scanner with a 1m range, and an accuracy (x,y,z) of 0.05 mm.

The surveying operation made it possible to obtain an accurate 3D reconstruction of the fragments, and the drawing of detailed architectural patterns. The findings present characteristics that permit to fully apply and develop the potentials of the 3D surveying equipment, i.e.: fragility, complex morphology and the presence of gaps.



Figure 4. Phases of data acquisition at the "A.Salinas" Museum in Palermo

3.2 Data acquisition

About thirty hours net of work were necessary for the data acquisition operations, totalling almost 50 million points (table 1).

fragm	description	amount of points surveyed
A	Angular portion of the architrave	9,949,521
B	Angular triglyph	8,897,735
C	Sima, geison with mutules	7,831,118
D	Tympanum angular fragment	15,421,804
E	Sima with lion protome	7,388,977
F	Anta's capital	1,785,079

Table 1. Amount of points surveyed for each fragment

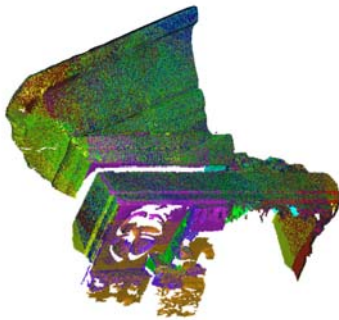


Figure 5. Example of the different scans required to describe a fragment's surface

In order to survey the fragments it was necessary to perform several partial scans (the number depends on the size of the item to be surveyed and on the relative distance between the device and the fragment), which were made from different positions and angles (figure 5). In this case study, for each single fragment, we performed from a minimum of 60 scans for the smallest fragments, to 90 scans for the biggest and morphologically most complex fragment (fragment D).

3.3 Data processing

Point cloud registration was performed using the Geomagic Studio 8 software. Initially, manual registration for homologous points were made (figure 6) and then a refinement was made with the global registration of all point clouds of each single fragment. All the foreign points of the surface (outliers, disconnected components) were filtered using the Geomagic Studio 8 software (table 2). Then the point clouds were decimated, cutting the total amount of points down to 50% of the original datum, in order to process the datum more easily. Lastly, with the merging, the surfaces were made seamless by point triangulation.

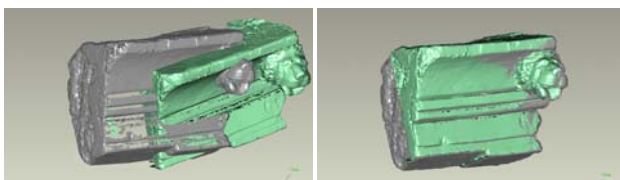


Figure 6. Manual registration among point clouds

fragm	Amount of points eliminated	% of the total
A	368,378	3.70%
B	354,069	3.95%
C	247,442	3.15%
D	522,955	3.40%
E	481,822	6.50%
F	368,696	20.65%

Table 2. Amount of points filtered per each fragment surveyed

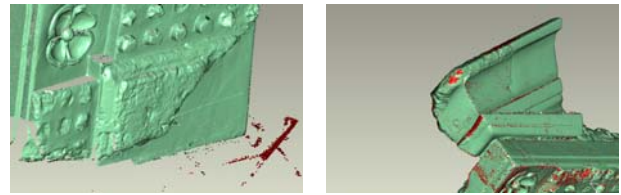


Figure 7. Disposal of foreign points on the surface of the object

3.4 Digital archive

The most evident result of the 3D survey is the setting up of a digital archive of the most significant fragments of temple B. The data of the survey, once processed, represent a useful means of documentation as to various aspects of preservation, enjoyment and study on finds (figures 8-13). Such an archive presents some benefits and advantages:

- i. It is a 3D and highly detailed method of reporting finds;
- ii. It represents the evidence of the actual state of finds at the moment of the survey;
- iii. It is much easier to look through. Indeed, the computerized 3D data can be looked through anywhere and any time;
- iv. It can be used to make copies, by prototyping processes, and results extremely useful when replacing the original with a replica;
- v. It is interactive. The 3D surveys allow displaying the find in the round on a PC in order to analyze it as if it were in front of you.



Figure 8. Fragment A, architrave

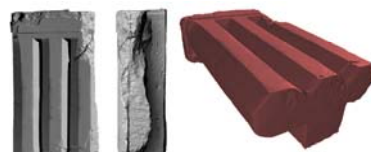


Figure 9. Fragment B, triglyph



Figure 10. Fragment C, tympanum



Figure 11. Fragment D, tympanum



Figure 12. Fragment E, lateral sima with lion protome



Figure 13. Fragment F, capital of the anta

4. TOPOGRAPHIC AND PHOTOGRAMMETRIC SURVEY

The state of the temple's remains was reported by means of surveys performed with topography and digital photogrammetry techniques. Then, after surveying the site and processing the data obtained, the graphic representations were developed of the actual state of the ruins of temple B in Selinunte (plan, facades, sections) on a 1:50 scale. These surveys represent a valid tool for the documentation and for an in-depth knowledge of the building.

The methodological pattern consists of the following stages:

1. setting up a planaltimetric network;
2. topographic surveying of the detail points necessary to define the geometrics of the building;
3. surveying of the photogrammetric support point;
4. photogrammetric taking for fronts definition.

4.1 Topographic survey

In order to perform the topographic survey, a Leica TCR 1105 total station was used characterized by a 5" nominal precision for the angular measurements, and by 2mm + 2ppm nominal precision for distance measurements. From each vertex of the network the following points were surveyed (figure 14):

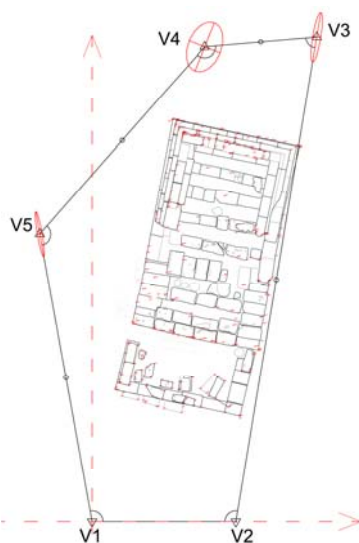


Figure 14. Scheme of the topographic network

1. the detail points of the temple's elements (quoins' edges and vertices) useful to determine the shape and size of temple B (all in all, 234 detail points);
2. the photogrammetric support points, such points are needed to obtain orthoimages through the photogrammetric rectification procedures (all in all, 93 photogrammetric support points).

4.2 Photogrammetric survey, orthoimages and restitution

For the photogrammetric survey, a non-metric Canon EOS-1Ds mark II camera, digital reflex, professional use, equipped with a full-format 16.7 effective megapixel CMOS sensor was used. The sensor's size is 36 mm × 24 mm. The finest images' size is 4992 pixel × 3328 pixel and they can be stored both in RAW format and in JPG format. The camera was used with a Canon EF 50 mm f/1.4 USM fixed focus lens.

The rectification of photograms was performed with the *MSR Rollei Metric* software, in order to obtain the orthoimages of the fronts of temple B and of the cella's and basement's plan by mosaicing the rectificated images.



Figure 15. Restitution of the elevations with the orthoimages

The orthoimages allowed to restitute both the morphology of each single quoin, the projections, and the conditions of the surfaces, enabling to produce a high-quality relief. Therefore orthoimages were useful, in the relief restitution operations, to streamline the topographic surveying process, greatly reducing the number of detail points to be surveyed.

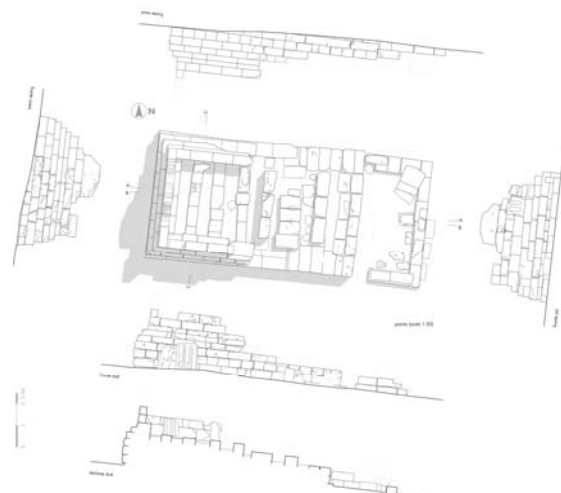


Figure 16. Restitution drawings

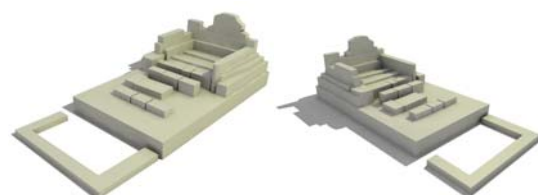


Figure 17. 3D views of the ruins of temple B in situ

5. THE VIRTUAL RECONSTRUCTION OF TEMPLE B

The virtual reconstruction of temple B was achieved in two stages. In the first stage, all the fragments acquired with the 3D laser scanner were mounted. In the second stage, a high number of sections were automatically extracted from the 3D models, in order to determine all the geometric matrices of the building, and proceed to a NURBS surface reconstruction. We believe that the virtual model of an artefact should not provide a univocal and dogmatic reconstruction as opposed to other hypotheses advanced but, on the contrary, it should be an advanced tool of debate and control for the experts in the sector, besides being an added value for the enjoyment of the asset by the public. The rendering of the temple's virtual model results of all the data acquisition operations made during the two surveying campaigns, of their analysis and interpretation, of the historical investigation, and of a study of the treatises on temple classical architecture. Indeed the research is based on the integration of information coming from different fields, such as the metric and historical study.



Figure 18. Reconstruction of the elevation of temple B, main (left) and side (right) front

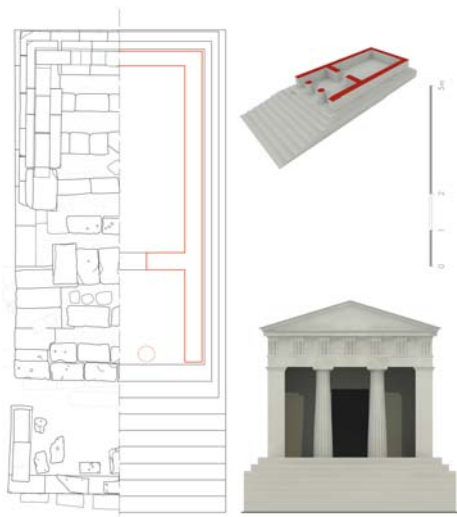


Figure 19. Virtual reconstruction of temple B, according to the distyle *in antis* typology of the Doric order

5.1 Three-dimensional modelling

The modelling of the architectural elements making up the elevation of temple B was made generating geometric models, on the basis of the numerical data of the laser-scanning survey carried out on the fragments. As the work went by, two methodological issues arose, to which we tried to give an answer by adopting an operative praxis based on methodological interpretation. They are:

- a. *Positioning*, it consists in the fact that fragments are positioned at random, they are positioned in a completely arbitrary manner. Consequently, it is necessary to identify (horizontal or vertical) plans of reference to make appropriate rototranslations.
- b. *Approximation*. This issue affects the shifting from the point cloud to the geometric model. The high number of data acquired by the survey needs to be cut down, selecting the strictly necessary information in order to create a reconstructive geometric model.

Those issues were faced making use of point clouds managing software, which can generate plans, cylinders, and other geometric primitives with the *best fit* method. All dimensional and geometric analyses were carried out using the *Rapidform 2006* and *Raindrop Geomagic Studio 8* softwares.

5.2 Processing stages and emerging methodological issues

Below we list the operational and methodological principles applied for reconstructing temple B in Selinunte, and namely the part of fragments surveyed with laser-scanning.

1. *Positioning of fragments in a single system of reference*. Through the interpolation of geometric primitives, we identified plans, cylinders and lines, needed to perform the rototranslations (figure 20);
2. *Approximation*. The high number of data acquired needs to be cut down. The model is constructed with the few sections that, extruded, approximate the real surfaces of the element (figure 21);
3. *Identification of the most indicative sections* among the different sections passing through parallel planes and with reduced step. Among them, we identified those useful to perform the dimensional analysis and to describe the geometry of the architectural elements of the fragments (figure 22);
4. *Metric and geometric check operations* of the architectural elements on the 3D model by 'direct' instantaneous measurements via software (figure 23);
5. *Construction of the ideal geometric model*, with NURBS surface modelling software (figure 24).

Having determined the sections and profiles, the modelling of the shape of temple B was performed with the help of commonly available 3D modelling programs (*Rhinoceros*).

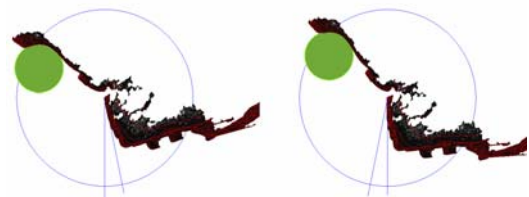


Figure 20. Example of rototranslation of fragments through the interpolation of the axes of reference.

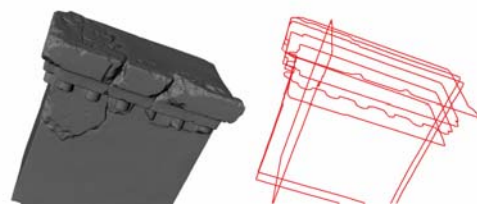


Figure 21. Extractions of sections from the numeric model

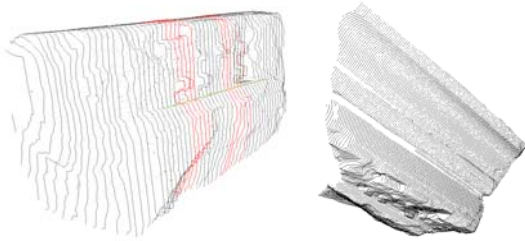


Figure 22. Identification of the most indicative sections from the numerical model



Figure 23. Example of direct measurements on the digital model of the fragment

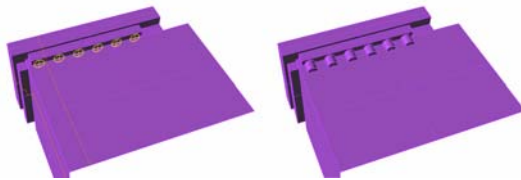


Figure 24. Example of extrusion of the sections obtained by the analysis of the fragments

6. CONCLUSIONS

The use of modern equipment and the adoption of modern surveying techniques have modified both the criteria of study and the results obtained in the field of the rendering of Cultural Heritage. This is mostly due to the high quality of modern tools used for surveying, to their possibility of integration, and to the expression possibilities linked to digital representation. Thus they also represent the ideal instrument for documenting archaeological and architectural artefact.

The 3D surveys of fragments proved to be suitable for an accurate morphological and metric analysis, allowing to obtain data which could hardly be identified with outdated techniques, such as the application of the profilometer, etc.

The metric analysis on the architectural element provided evidence about the potentials of critical investigation on the data from the survey. It highlighted the fact that it is not only a matter of obtaining a large amount of data, but also to provide instruments for the metrical and dimensional analysis, that allow to investigate the geometries in-depth, following the processing of a large amount of data. The set of possible analyses on acquired 3D data provides tools that permit to virtually reconstruct the artefact with an excellent degree of definition, also in order to understand the design ideas underlying it. The models' potentials of analysis are extremely useful because they allow to perform metric, proportional, and metrologic investigations, as well as to make comparisons that can be carried out by different people in different places.

Actually, the aspect of virtual reconstructions appears to be an excellent instrument for studying architectures, especially when they have many missing parts. Thanks to the potentials of modern computer-graphics, it is possible to provide in a very short time virtual scenarios of reconstruction hypotheses of buildings which, given their computerized format, also allow for rapid circulation and for an easy exchange of information.

The field of virtual reconstruction also involves different professionals and it allows, thanks to the synthetic nature of all the information and data acquired, an immediate comprehensibility. Lastly, the virtual reconstruction of a building, which intends to be a scientific tool of synthetic study of the acquired metric information and of the reconstruction hypotheses, can be used both as an analysis assessment tool by scholars, and for the diffusion, circulation and promotion of the heritage within museums, tourist areas, and areas characterized by cultural heritage, in order to enhance them.

REFERENCES

- Beraldin J., Blais F., 1997. *Active 3D sensing*. National Research Council Canada (NCR), Ottawa.
- Crosilla F., Dequal S., 2006. *Il laser scanning terrestre*. International Centre for Mechanical Sciences (CISM), Udine.
- Crosilla F., Galetto R., 2003. *La tecnica del laser scanning: teoria ed applicazioni*. International Centre for Mechanical Sciences (CISM), Udine.
- Fougeres G., Hulot J., 1910. *Selinonte: la ville, l'acropole et les temples*. Paris.
- Hittorff J.I., Zanth L., 1851. *Restitution du temple d'Empedocle à Sélinonte, ou l'Architecture polychrome chez les Grecs*. Paris.
- Koldewey R., Puchstein O., 1899. *Die Griechischen tempel in unteritalien und sicilien*. Berlin.
- Lo Faso D., 1834. *Antichità della Sicilia, esposte ed illustrate*, Vol.2, Palermo.
- Mueller P., Van Gool L., Vereenoghe T., Vergauwen M., Waelkens M., 2004. *Total recall: a plea for realism in models of the past*, XXth ISPRS Congress, Istanbul.
- Migliari R., 2001. *Frontiere del rilievo. Dalla matita alle scansioni 3D*. Roma.

ACKNOWLEDGEMENTS

This work has been performed using the equipment made available by the LABORATORIO DI ATENEIO in "Knowledge, management and enjoyment of cultural heritage with advanced IT" of the University of Palermo.

Moreover, we'd like to thank:

- The "A. Salinas" Regional Archaeology Museum in Palermo for enabling the study of the fragments of temple B.
- Cultural Heritage Regional Agency of Trapani.