

# Hand Made 3d Modelling for the Reconstructive Study of Temple C in Selinunte: Preliminary Results

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## Abstract

*This paper illustrates the preliminary results of the virtual reconstruction of temple C in Selinunte. The reconstruction was undertaken as part of the Land-Lab Project launched by the University of Lecce in 2003 for the promotion and appropriate exploitation of the cultural, historic, artistic and archaeological heritage of two Italian regions, Puglia and Sicily, using advanced technologies. The reconstruction of temple C was launched with the help of numerous experts in the field of surveying and representation, as well as art historians, archaeologists and architects, following a fully multidisciplinary approach. The reconstructive study was conducted in a 3D environment mainly using NURBS modelling, Subdivision Surfaces and sub-polygonal displacement. Our reconstructive approach, which might be defined numerical, makes it possible to recompose, at least in the initial phases of the work, all the surveyed architectural elements in accordance with a procedure based on digital anastylosis. The reconstruction of the monument represents a contribution to the study of Doric architecture in southern Italy conducted with the help of modern technologies.*

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics] Three-Dimensional Graphics and Realism

*«And it is now time for us to move on to the second phase of the study; from descriptive archaeology we must pass on to reconstructive archaeology»*

E. Gabrici, *Per la storia dell'architettura dorica in Sicilia*, 1935

## 1. The Land-Lab Project

This paper was written under the auspices of the Land-Lab Project (Multimedia Laboratory for archaeological research, training and communication), launched by the University of Lecce in February 2003, co-financed by the European Union in the ambit of the 2000-2006 National Operative Programme entitled “Scientific Research, Technological Development, Quality Training”. The Land-Lab Project is coordinated by Prof. F. D'Andria, of the University of Lecce and its goal is the promotion and appropriate exploitation of the cultural, historic, artistic and archaeological heritage of two Italian regions, Puglia and Sicily, using advanced technologies.

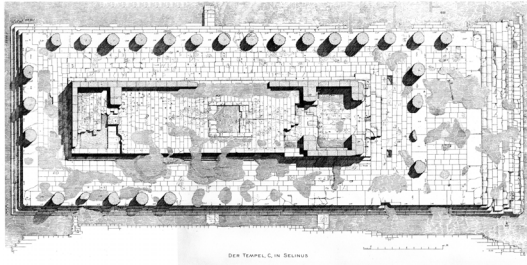


**Figure 1:** Temple C today. Fourteen columns on the North side, still in the position where they fell, were raised in 1925-1927 together with part of the trabeation.

Under the auspices of this project, a reconstructive study of Temple C of Selinunte was begun in 2005, with the aim of using innovative technologies in order to make a specific contribution to the study of Doric architecture in Sicily, but at the same time to use the results of the research to create multimedia products designed for the general population. This double objective was fulfilled by using rigorous methods of study, with a view to obtaining the most reliable reconstruction possible with the quantity and quality of data currently available.

## 2. Characteristics of the monument

Temple C is a peripteral Doric hexastyle with seventeen columns along its sides, with a pronaos, cella and adyton. It is located on the highest point of the Acropolis, with the stylobate at 30.40 metres above sea level. Fourteen columns on the North side, still in the position where they fell, were raised in 1925-1927 together with part of the trabeation (Figure 1). The temple is 23.90 by 63.70 m at the stylobate. The terrain on which the temple is constructed slopes downwards towards the West and the North. Above this base rises the crepidoma, made up of two steps of which the upper one is flush with the stylobate (Figure 2). The eastern side may be accessed by a broad flight of seven steps, exactly half the height of those of the crepidoma present on the long sides. As well as this flight of steps on the eastern side, access to the pteron was facilitated on the North and South sides by smaller flights of steps, traces of which may still be observed on the ground. The flooring is composed of rectangular slabs of irregular dimensions. In the pteron and in the pronaos, the slabs are oriented along the length of the building, while in the front pteron, in the cella and in the adyton they are perpendicular.



**Figure 2:** *Plan of Temple C. Koldewey and Puchstein, 1899, fig. 12, op. cit.*

The peristyle is composed of Doric columns: six along the facade and seventeen along the sides. There is a second row of columns on the eastern side, resulting in a double span in front of the pronaos, with a depth of four intercolumni. The structure of the columns of the peristyle is not homogeneous: the shafts of the six columns along the front and the first eight columns of the South side are monolithic, while the others are made up of drums of varying heights, and thus number. The irregularities in the structure of the columns are matched by those in the finish: most of the columns have sixteen flutes, but there are also columns with twenty flutes. The columns are slightly conical, but there is no entasis. The connection between column and capital shows clear signs of subsequent modification. Originally the flutes terminated in a moulding below the echinus; subsequently they were extended in plaster up to the hypotrachelion, eliminating the moulding.

The monument owes much of its fame to the discovery of the large metopes, decorated with reliefs and present only on the eastern side.

As for the tympanum, all the fragments discovered indicate that the roof sloped at 23° along its entire length and width. The tympanum, together with the horizontal geison of the entire perimeter, was covered with large architectural terracottas, partly conserved and now visible in the museum of Palermo (Figure 3).

The chronology of temple C is a matter of some debate. Little is known of the hypothetical predecessor to the current building, but many scholars agree that its construction began in about 540-530 BC. It is to this period that the reconstruction proposed in this paper refers.

### 3. Study methods and the multidisciplinary approach

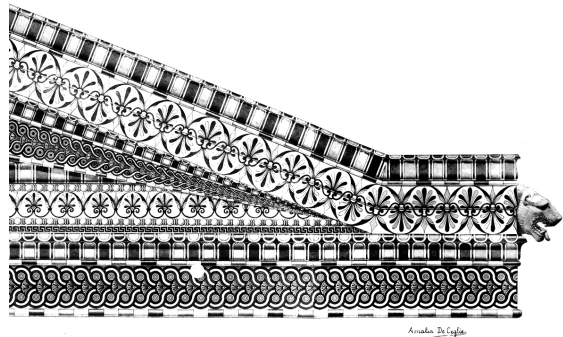
It is now beyond dispute that in the future archaeology will become increasingly oriented to the processing of data and simulation. It is many years now since descriptive archaeology opened its doors to interpretative and reconstructive archaeology, in an attempt to imagine and represent with great verisimilitude ever more extensive portions of past civilisations. The reconstruction of Temple C in Selinunte, before becoming a digital image and the tangible expression of the possibilities offered by the new technologies, represents an attempt to tackle a highly complex and hotly debated theme via the only route possible today: the multidisciplinary approach. I believe that the issue of the reconstruction of Temple C has never



**Figure 3:** *Terracottas conserved and now visible in the museum of Palermo*

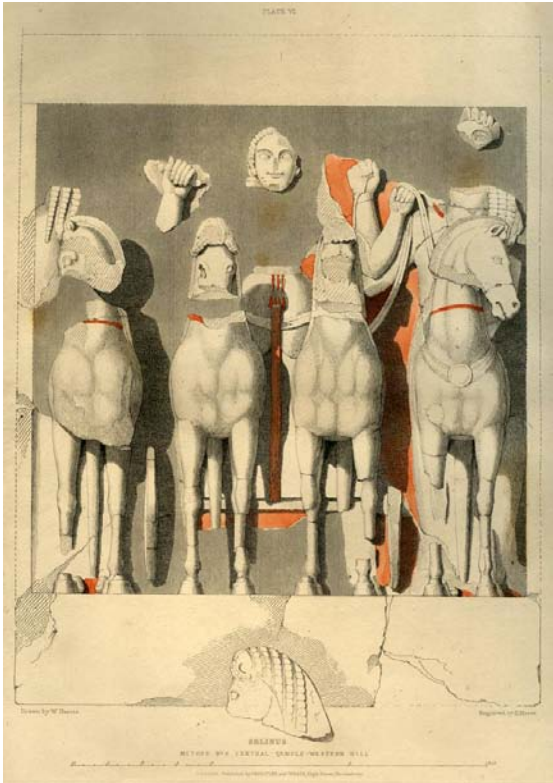
before been tackled from such a premise. The reconstructions that we propose here represent the result of an integrated and synergetic effort carried out by a heterogeneous team of scholars in the field of surveying and representation, art historians, archaeologists and architects. The reconstruction of "C" represents not so much the response to the problem of reconstructing a single monument, but a proposal for a fully three-dimensional view of a sixth century Doric temple, showing all the elements of which it was composed with the most fascinating of Visual Computing technologies: three-dimensional digital graphics.

Thanks to digital and the work carried out in CG (*Computer Graphics*) it has been possible to gather all the data from the CAD surveys conducted by C.M. Amici of the University of Lecce and bring them together in the 3D modelling software, with the aim of studying the monument not only in two-dimensional views, but in its



**Figure 4:** *E. Gabrici, reconstruction of the tympanum corner, op. cit., fig. XXV*

fully three-dimensional aspects; not merely seen as in plans of the layout or the facade, but from all possible points of view. E. Gabrici, one of the most important scholars of temple C, wrote in 1935: «Such a solution would have already been achieved if the work of the digger had been integrated with that of the illustrator [...] if a terracotta is described from just one point of view and without a cross-section, it has a rather limited value in terms of a reconstruction of the whole». Our reconstructive approach, which we might call numeric, makes it possible to recompose, at least in the initial phases, all the surveyed architectural elements in accordance with a procedure



**Figure 5:** *Angell and Harris, metope C6*

based on digital anastylosis. It aims to juxtapose the original elements, following the lines along which the individual pieces fit together and resolving the problem of the missing parts by continuously cross-checking against the construction techniques of the period and the laws of statics. The digital anastylosis can achieve a high level of reliability at least up to the height of the trabeation, given that fortunately much of the stone structure lies where it collapsed or is kept in the Salinas museum in Palermo. This methodological approach to a large extent overcomes the limits of a reconstructive procedure based on purely analogical criteria, i.e. comparisons and stylistic analogies with other monuments of the period, especially if one considers the many unique features of the monument. The slope of the roof, the monolithic columns next to columns made up of a number of drums, columns with 16 flutes next to columns with 20 flutes, architectural terracottas, and chromatic characteristics are only some of the elements that demonstrate the level of experimentation reached by the architects of Selinunte in the construction of this temple, but they also make the building a great and original piece of architecture.

It is also true however that not all the elements necessary for a faithful and reliable reconstruction are in our possession. There is also some uncertainty as to the reconstruction of the corners, the connections between the architectural terracottas, the sculptural or decorative elements of the temple, and the quantity and type of ex votos present around the temple, of which little or nothing has remained. For these problems it was necessary to use analogies with solutions or elements that are well-known

and documented, which are suitable in this case in that they are chronologically and stylistically similar. In the reconstruction the priority objective was thus to demonstrate the scientific nature and the rigour of the methodological approach, and to propose a complete reconstruction of the original appearance of the monument, containing every architectural element compatible with the style of the epoch and its constructional features.

To this end it was necessary to include in this paper a descriptive plate showing all the elements that were proposed with recourse to analogical criteria, all the original elements that were created by means of digital anastylosis and the parts needed for completion proposed because they connected logically with those elements about which there was no uncertainty (completion of the epistyle, of the trabeation, the walls of the cella, etc.).

#### 4. Past reconstructions

The study of temple C and the history of its reconstruction begins with the drawings and the reports by Angell and Harris in 1823 (Figure 5). Decisive progress in the research was made thanks to the systematic excavations by Cavallari in 1868. This work prepared the way for the research of W. Dörpfeld and his followers, and R. Koldewey and O. Puchstein, who carried out the systematic survey of the remains and the discussion of the building, making a contribution that is still fundamental today. The study of the cladding and the fictile decoration dominated



**Figure 6:** *Hulot and Fougère, view of the ancient city. In the circle temple C*

the scientific work of Gabrici, whose studies contain discussions of various problems linked to the reconstruction of the tympanum and the partial constructive solutions proposed for the roof (Figure 4). Highly interesting and of considerable impact are the reconstructions by the French scientists G. Fougères and J. Hulot (Figure 6), who succeeded in providing a representation of the entire city of Selinunte with views from above and from the sea. In the necessary study of the documentation provided by the above-mentioned authors, the difficulty clearly emerges of finding a univocal solution to the question of the building's original aspect, as seen in the differences in the shape of the tympanum and the details of the architectural terracottas. The studies on temple C clearly show the contradictions and the

incompleteness of the data available in the past, but at the same time confirm the interest and the ferment among the great scholars of ancient architecture regarding the important question of its reconstruction. There is even thinly veiled criticism of the activities of those who, at the beginning of the twentieth century, sought to provide answers to the difficult problem of the architectural terracottas; thus E. Gabrici: «*But since a true and proper definitive report on the precious material discovered was lacking, the scientific enquiry had to limit itself for more than half a century to the studies that certain foreign archaeologists managed to perform, not without a degree of haste, on temple C [...] as if I could, in just a few years, remedy the inertia of the past, by publishing in superficial manner, and with little regard for my own reputation, accounts of the terracottas of temple C without the necessary long preparation that an argument of such weight requires*».

sense of wonder and respect for the grandeur of ancient architecture.

### 5. The hand made 3D modelling

The process of reconstruction by digital anastylosis is followed by the three-dimensional modelling of the individual architectural and sculptural elements that comprise temple C, in accordance with the classic inductive method, which moves from the particular to the general. Each of these elements was re-worked in two dimensions using NURBS modelling (*Non Uniform Rational Beta Spline*) and *Subdivision Surfaces*, starting with the detailed two-dimensional survey drawings produced by the team coordinated by C. Marconi (Columbia University, New York). The fragmentary nature of the surviving pieces, and in some cases the total absence of the originals, made it impossible to use alternative



**Figure 7:** The final 3d reconstruction model without texture maps. Radiosity algorithms. More than 9 Mill. poly

Gabrici himself, however, proposes two different solutions for the corners at the base of the tympanum, and cautiously avoids drawing up a unified proposal that includes the entire prospect. However, it is to him that we owe the first reliable reconstructions of numerous architectural elements, which have been useful for our reconstruction, but whose accuracy has been only partly confirmed by the most recent studies. Concerning the drawings by Hulot and Fougères, we should stress again their ability to recreate the monuments of the entire acropolis in complex environments, with the buildings immersed in scenes of daily life. Their drawings clearly show the desire to emphasise the monumentality of the temples, enhancing their proportions with the aim of inspiring in the observer a

technologies, but did however demonstrate the validity of the techniques proposed, even for the purposes of the Land-Lab Project. Each component of the temple will be inserted in interactive multimedia applications, with stereoscopic visualization, for virtual navigation. It will be possible to search and explore each element following the by now well-established *Augmented Reality* approach. The exploration of temple C can however also take place in more traditional and passive ways, and for this a stereoscopic movie is in preparation that will enable the general public to discover the distinctive features of the monument without necessarily having to interact with it. For these different requirements high resolution models (Figure 7) are needed, with highly detailed textures, in large part created using digital painting performed directly on the models. Many maps have been created by manipulating photographs taken in the museum of Palermo



**Figure 8:** *The Kalypter Hegemon. NURBS model with UVW mapping*

or directly at the site of Selinunte, and others were derived from the reconstructive watercolour paintings created by A. La Porta especially for this project. In all cases, the most important aspect proved to be the respect for the original chromatic characteristics. In the case of the *Kalypter Hegemon*, for example, inaccuracies were noticed in all the older reconstructions we looked at. The 3D approach, together with a careful re-examination of the finds, enabled a more accurate study of both the external geometry and the pictorial motifs, leading to a solution that was new and highly impressive. The second, but no less important aspect is the continuous process of verification of the structural consistency between the architectural terracottas and the stone structure of the building. Very often in the past the interdependence between these two elements was neglected. The considerable loads resulting from the weight of the load-bearing stone structure, combined with the significant weight of the architectural terracottas, cannot be ignored, and make verification of the statics of the building essential. This verification showed that the solution proposed by Gabrici to the question of the fit between the terracottas in the corners of the tympanum – the Chinese-style roof that had also been suggested by Koldewey and Puchstein – is unfeasible. The proposal that we present here resolves the issue of the corners and shows the tympanum as a simple triangle whose sides are inclined at a fixed angle of  $23^\circ$ , in accordance with the stone elements scrupulously surveyed by C.M. Amici, but also with the surviving fragments of the architectural terracottas.

The technological innovations of the last few years have also provided a valid solution for the modelling of the metopes originally present on the eastern side. Of the ten metopes that adorned the temple, only three have been restored and are visible in the museum of Palermo. The other fragments however enabled Prof. C. Marconi to produce some outline drawings of the entire sequence. Their manipulation using image editing software made it possible to use *sub-polygonal displacement*, an evolution of the normal-map, to obtain a simulation of the reliefs valid for the medium-distance camera views. This technique makes it possible to obtain high levels of detail in the relief simply by using a greyscale map which the software uses only in the rendering phase. The same technique was successfully used in the modelling of the six-panel entrance gate, of which no elements survive

except the elaborate mechanism that may be deduced from the metal rails on the floor. In the solution presented here, the central panels are composed of an open grille and the lateral panels are decorated with rosettes.

Of the gorgoneion, which originally took up a large part of the tympanum, a few pieces are currently conserved and observable today in a reconstruction created in the Gabrici room of the museum of Palermo. Thanks to the hand made modelling obtained with the *Subdivision Surfaces* and the *sub-polygonal displacement*, the study of the colour and a careful re-examination of the finds kept in the museum has provided an image that completes the figurative and plastic features of the monument, further enriched with the complex chromatics that characterize the roof.

The rigorous study conducted on the temple – based on the analysis of the sources, the virtual anastylosis of the stone elements surveyed, the photographic documentation, the sampling of the colour and the *hand made* modelling – is



**Figure 9:** *The gorgoneion. Modelled using subdivision surfaces and sub-polygonal displacement*



**Figure 10:** *Study of the warrior's armour*



**Figure 11:** *The first rendering of the complete scene with a test study of ex-votos*

accompanied by the study of the photographic realism of the overall result. The images that we show here were processed with *Radiosity* algorithms, with direct light set in accordance with the latitude and longitude of the site. Much attention was paid to the human beings used to show the scale of the building to help the observer to measure the building correctly and to enrich the scene with further information concerning clothing and religious ritual. Every virtual person is complete with rigging with Inverse Kinematics settings for movements and state-of-the-art cloth simulation.



**Figure 12:** *Bird's eye view of the roof with its original colors*

The study of the monument conducted so far will soon be extended to the area around it, with a view to gaining a larger and more complex vision of the context that needs to take account of the possible relations between the different buildings present within the temenos (the sacred area around the temple). Attention will thus be focused on a broader understanding of the monumental layout of the acropolis.

The reconstruction of temple C clearly cannot be considered concluded, given the number of elements still open to discussion, but many problems have also been resolved; the difficult work carried out so far has laid the foundation for future studies and new debate on the reconstruction of this great example of Doric architecture in Italy.

### Acknowledgments

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- The archaeological survey was conducted by C.M. Amici of the University of Lecce.
- The two-dimensional drawings of the terracottas were made by A. La Porta.
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Figure 13: Sacrifice ritual in a natural setting

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