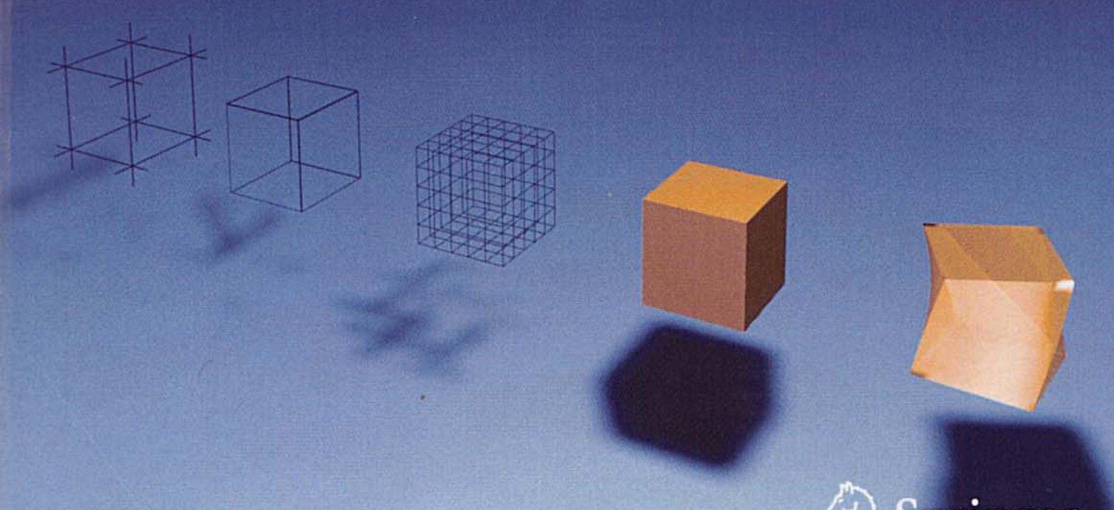
Computer Aided Architectural Design

Futures 2005

Bob Martens
André Brown



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From Architectural Intent to Physical Model

Representing the Chiostro della Carità *by Andrea Palladio with New Technologies*

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Keywords: laser scanner, digital modelling, rapid prototyping, 3D representation

Abstract: The research presented here addresses the subject of the analysis of partially executed architecture. Information for such analyses has been gathered with the use of laser instruments. The paper aims to show a method for processing the laser-surveyed data using geometric modelling software to construct the physical model of the structure through the use of prototypes created with a variety of materials. The laser technology is is interpreted using an additive system (*referred to as physical polymerization*).

1 INTRODUCTION

The aim of our research has been to analyze the possibility of transforming the data acquired during an instrumental survey of an historical building into a physical model. During the phase of data acquisition we have employed both traditional, photogrammetric techniques and a 3D laser scanner. The points and the surfaces in the digital model have been post-processed so that they could be utilized for the automatic construction of the model. Laser technology is always employed in the process.

The focus is an architectural structure designed by Andrea Palladio, located in Venice where the present day *Museo delle Gallerie dell'Accademia* resides. It deals with the *Convento della Carità*, which possesses several base materials and which presents itself as a work of great interest. Also of interest is that it is the author's sole work to redesign a *Casa degli antichi* – a Roman Domus – even though dictated by the needs of a religious community.

Among materials available for consideration, we have, first of all, the designs presented in Palladio's treatise (Palladio 1570) – in which the author makes explicit reference to his site, Venice. Secondly there are the well conserved executed sections of three designed sites: the façade of the interior courtyard, the *tablinum*, where the ancients displayed images of their ancestors – and the oval staircase. The latter is an extraordinary helicoidal staircase, which is of significant importance as it is the first Renaissance staircase of its kind. Due to this fact, it will be not be

B. Martens and A. Brown (eds.), Computer Aided Architectural Design Futures 2005, 83-92.

discussed in detail here. In addition to the Palladian designs and the constructed sections aforementioned, we have some other sources of information. These include a few graphic sources O. Bertotti Scamozzi's designs, F. Muttoni etchings, G. Leoni's interpretations and a few textual materials, such as those conserved in the Archives of the State of Venice. Moreover, Canal, said Canaletto, created an interesting painting in the mid 1700's that depicts the cloister in question. This painting has already been investigated and studied (Sdgeno 2004).

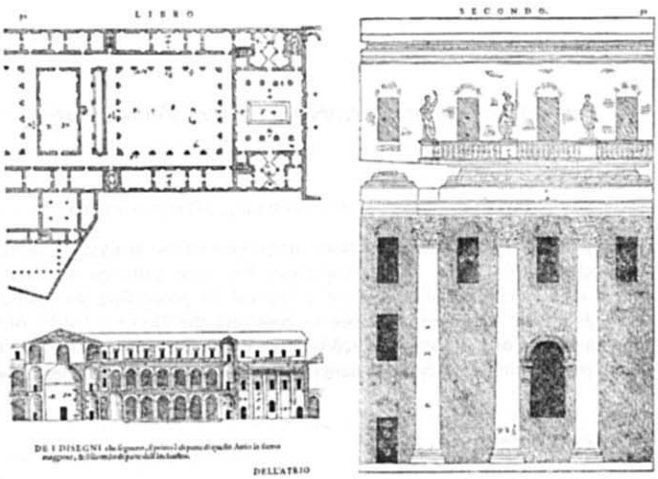


Figure 1-2 Palladian drawings from the 'Quattro Libri dell'Architettura'

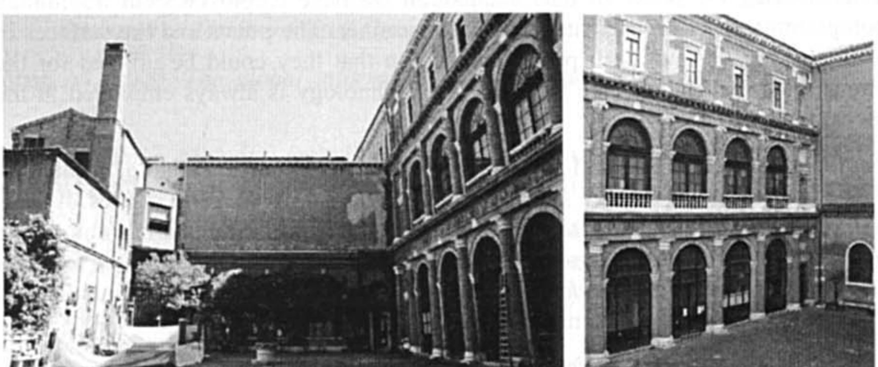


Figure 3-4 Photographs of the 'Chiostro della Carità' in Venice

The work is structured around a central cloister on which a vitruvian elevation appears that is subdivided in three orders: Doric, Ionic, and Corinthian. The central cloister is the true focus of this investigation. The executed elevation corresponds almost perfectly to the Palladian design, with variations in the dimensions of the orders. To the side of this, the *atrium* was planned and constructed, while in 1630 was destroyed by fire and never rebuilt. Then, the *tablina* – two small vaulted spaces, symmetrical with respect to the longitudinal axis of the structure – were planned for, but only one of these was realized. Finally a series of stairs lead to the upper levels, one of which is the oval set mentioned previously.

2 LASER SCANNING

In addition to the initial investigation of documentary sources consisting of Palladian texts and designs, a 3D laser scan was executed using a 3D Laser Scanner (Mensi GS 200). The main scanning was done from a position in the centre of the courtyard, placing markers on significant architectural points in order to mount two secondary scans. This work was supported by an agreement between the Faculty of Architecture at the IUAV University of Venice and the Gamsau centre of research in Marseille.

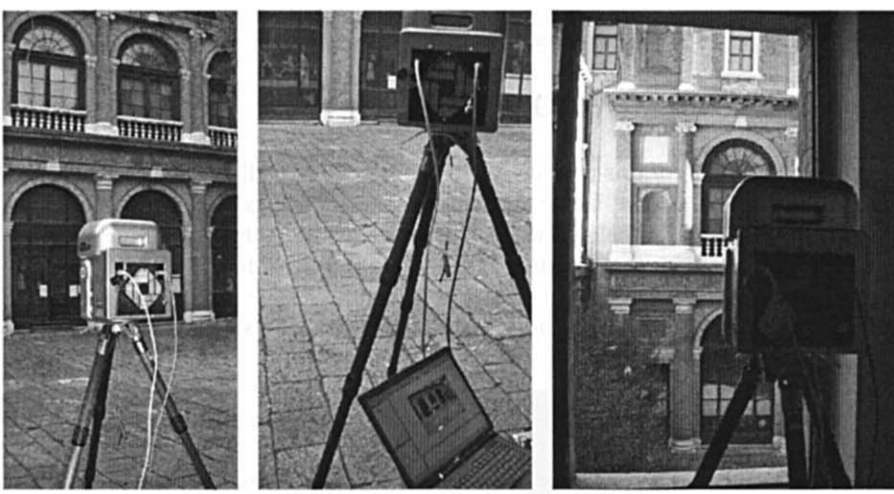
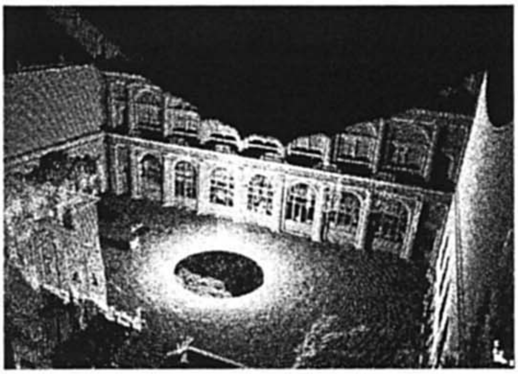


Figure 5-7 3D Laser scanning

In order to compensate for the areas that were not covered by the principal scans, two partial scans were added to the main one. Moreover, other scans taken at a superior height were made so that further detailed information on the architectural orders, and a greater amount of reference points, would be available for consideration. The second phase of the work dealt with the treatment of the points cloud so as to be able to select profiles necessary for the geometric reconstruction of the elements. The cloud has 4.273.839 points and was made in one day (8 hours) with a group of four users. The vertical section of the points cloud took place on the axis of the first order on the left, while the horizontal ones took place at varying levels. In particular, the dimensions of reference were 1, 2, 3, 4, 5 meters. From the sections we proceeded to the geometric modelling of surfaces. The handling of the points cloud occurred using *RealWorks Survey* software. Specific software for the treatment of 3D numerical data is being developed under the direction of the Gamsau centre.



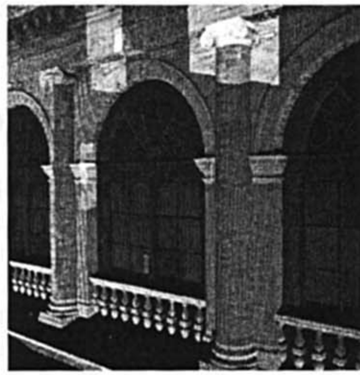


Figure 8-9 Points' clouds of the 'Chiostro della Carità'

3 GEOMETRIC MODELING

The most delicate part of this project was the geometric modelling of surfaces and of volumes. In particular, the Doric order was constructed as a surface of simple extrusion in the case of the plinth, as an angular extrusion in the case of the superior abacus, and as a surface of revolution for the *tora* and the inferior *scotia*, the shaft, the superior *echinus* and the lower cinctures. In any case, the arch and the cornices can be built either as simple extrusions or as extrusions along shaped directrixes.

Figure 10 The treatment of points' cloud from profiles

The entablature was realized as a simple linear extrusion, on which an automatic triangularisation of a few particulars was superimposed, such as the *bucrania* and round bas-reliefs. In fact, bas-relief elements are directly managed by the software that provides creation of the mesh.

With the exception of the capital, the superior level was executed implementing the same method as was used for the Doric order. Moreover, the Ionic volute – an object rather complex to construct – demanded a different approach. As a point of departure, it was decided to verify the *voluta*'s stereometry using the classical geometric construction, provided in the two-dimensional drawing of the spiral that generates the form. Therefore, the channel would be constructed as an extrusion of a significant section along a spiraliform directrix. The 3D volute was nevertheless executed via mathematics and was compared with the numeric one. The latter had been derived from the points cloud, as the information was not sufficient enough for modelling.

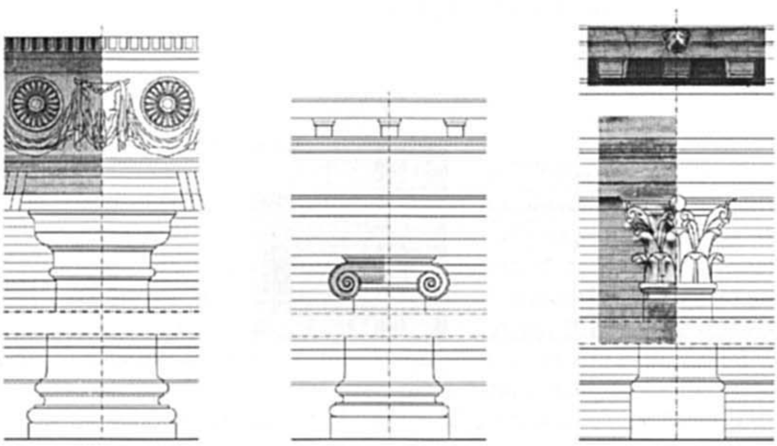


Figure 11 The construction of Doric, Ionic and Corinthian Orders

Finally, the last level showed the construction of the Corinthian pilaster and that of the cornices of the openings. In this case an ulterior problem occurred. In a way it is partly similar to the preceding one, with the difference that while the profile of the pilaster's shaft could be individuated rather well, the Corinthian capital was all but impossible to construct with the collected points. In this case, the density of the acanthus leaves, and the distance from the pick-up point, did not allow for the acquisition of a quantity of information sufficient for 3D modelling. In spite of this, we proceeded by acquiring a series of photographic images, digitalizing them, and comparing them with the designs of the orders as they are presented in Palladio's treatise.

Subsequent altimetrical verification took place using photogrammetric procedures to acquire perspective restitution from photographs. The first order on the ground floor, in particular, was obtained from a vertically planed photograph. Noted is the planimetric form obtained thanks to direct acquisition using basic metric instruments. As for the superior orders, perspective restitution was taken from a photograph at an inclined plane, with individuation of three vanishing points towards which all lines concur. In order to obtain the best results it was decided to photograph the angle between Palladio's building and the existing brickwork side of the cloister.

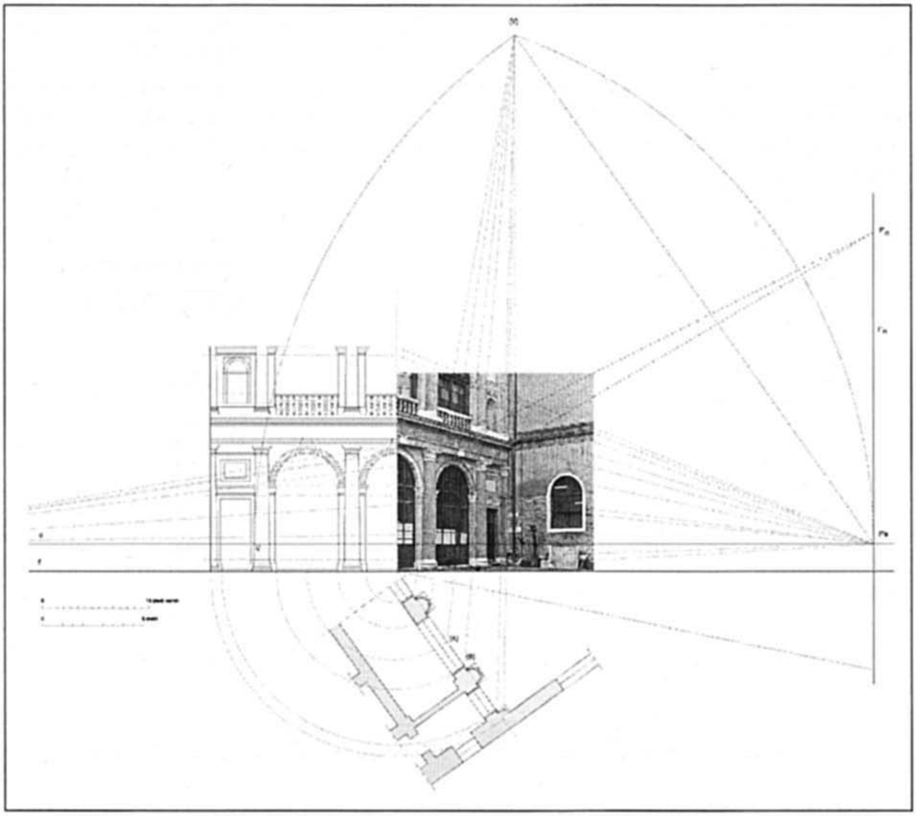


Figure 12 Perspective restitution from photograph

Palladio's designs, the points cloud, and traditional photogrammetric procedures have all aided in the construction of one 3D element. From this one solid model, a digital yet exact copy of the actual state of the convent was constructed. Using this model as a point of departure it was possible to analyze some of the convent's geometric structures. These include the barrel vaults on the *peristilium* pathway. Having constructed the main part of the façade, it was then possible to reconstruct the entire cloister, as it had been devised by Palladio, replicating the model on all four sides. The final model of the cloister has 1.254.832 faces, and we used 370 objects.

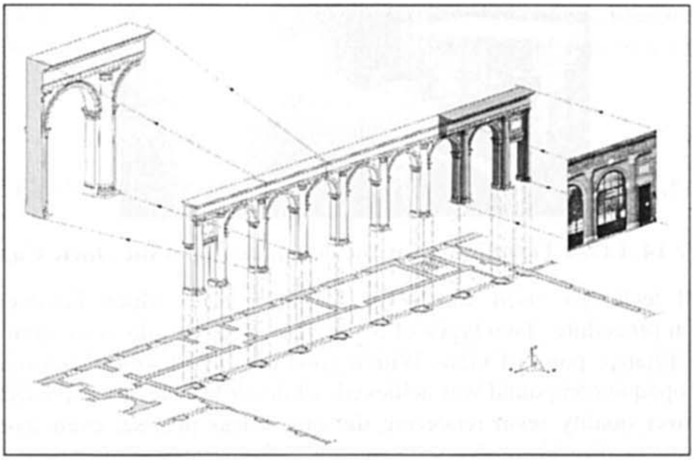


Figure 13 The digital model of the Doric colonnade

4 RAPID PROTOTYPING

The last stage of research was the execution of a physical prototype of the perceived façade, making use of electronic technology for the construction of models. Before executing the task of construction through numerical control, a selection of technology was made, analyzing various types of materials and techniques. A Palladian Doric capital was used as a model for this study. It was to be realized at a scale of 1:500 with respect to the actual capital of the *Convento della Carità*. It was also decided to reconstruct the entire stereometry rather than just half of it, as it is presented in the realized façade (in the form of a semi-column). Many different materials and techniques were used.

The first instrument implemented was the numerically controlled machine that permits a procedure known as *Laminated Object Manufacturing* (LOM). This technique allows for the construction of a volume beginning with very thin layers of thermo adhesive paper that are cut with a laser and glued automatically. These layers of paper are 0.066 mm thick. The model required finishing by hand, taking manually away the parts external to the central volume. The LOM technique was often used a few years ago, while rapid prototyping is now preferred. Rapid prototyping executes a single component much more quickly and is an automatic process that does not require refinishing on the part of the user. The appearance of the piece is of particular interest, since the presence of lines, similar to wood grain, gives it a woody quality. Even its consistency is woody, as compressed paper renders this final result. However, this technology was considered less appropriate since it can only be used for simple forms and curves, but not for complex surfaces such as acanthus leaves.

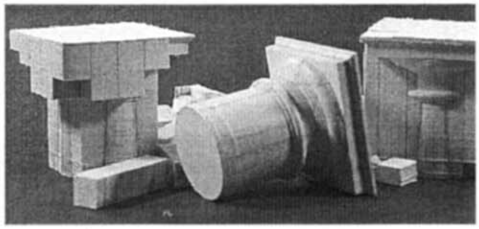


Figure 14 LOM Techniques for the construction of the Doric Capital

The second technique used was *resin polymerization*, which involves a laser solidification procedure. Two types of resin were used. Results were quite different from the qualitative point of view. With a good density of solidification a compact and almost opaque compound was achieved, while air bubbles were present with the use of a lower quality resin rendering the object less precise, even though more pleasing aesthetically. The colours of the materials can vary and the consistency is rubbery.

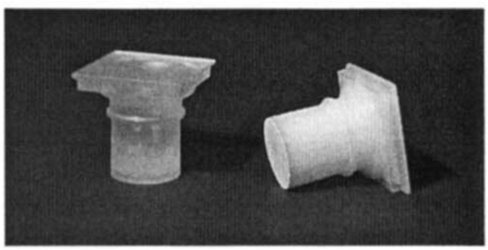


Figure 15 RP Techniques with resin for the construction of the Doric Capital

The third technique involved the implementation of *rapid prototyping* (RP) with the use of powders. Such a technique proved to be very interesting as production time was short, yet the precision of the final physical model was high. Furthermore, it was possible to use different materials. These included grey coloured aluminium powder, nylon and glass powders with each of the latter being white. Most recently attention has been turned to ceramic powder, which is especially useful in architecture because it gives a greater physical weight compared to nylon, not to mention a different chromatism. The use of this material is still in the experimental stage, and we have produced the entire project with it.

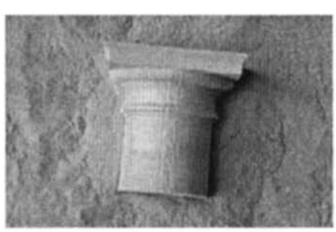


Figure 16 RP techniques with nylon powder for the Doric Capital

The scale of representation has been defined at 1:500. This three-dimensional model will help surpass the limitations of an exclusively virtual representation of the project.

5 CONCLUSIONS AND POSSIBLE DEVELOPMENTS

The findings in this paper demonstrate how advanced research institutes and private partners can work together effectively to study the representation of architecture using new computer instruments. Through the use of geometric data, point cloud information can be applied to the modelling of solids in such a way that execution can be achieved using new physical construction technologies (LOM, RP, etc.).

As far as possible developments regarding numerical input are concerned, the following are desirable: the improvement of acquiring points, particularly for defining architectonic details; the moderation of numerical data in line with the requirements of specific software, and the integration with other representation techniques, (photogrammetrical morphing, photomodelling, etc.). On the other hand, experiments for output technologies should necessarily deal with the problems faced in the use of new materials; for example, calcareous sand has already been investigated. Also, a useful area of investigation could be that of trying to use artificial compounds that integrate different materials, such as the technique required for the colouring of powders. However, verifying the durability and the physical behaviour of any new material is always required.

ACKNOWLEDGMENTS

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