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Modélisation Informationnelle pour l'Architecture patrimoniale

Proceedings of the International Workshop

Informative Modelling for the Architectural heritage

Saint-Maximin la Sainte-Baume, 2006

CENTRE NATIONAL
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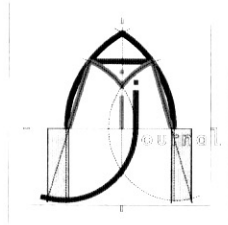
UMR CNRS/MCC 694 MAP
Modèles et simulations pour l'Architecture, l'urbanisme et le Paysage



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Between Design and Survey: Interpretative Problems in the Study of Drawings for Digital Modelling

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The aim of this study is to highlight some of the main problems concerning the interpretation of architectural projects – in the form of plans, models or collected data from survey – through the analysis of some case studies, and in relation to their digital modelling. The matters concerning the reconstruction of an architectural form, in fact, always require the knowledge of a number of aspects, which cannot be limited to the technical one.

We consider here some of the very remarkable works by Palladio [6]: many of his architectures are true interpretative puzzles, since there is a sharp difference between his drawings and realizations. As it has been often pointed out by Gioseffi [2] and Puppi [3] Palladio's drawings must be considered as "conceptual models", project abstractions showing an intention more than an actual geometrical-projective correspondence.

Another aspect we consider here concerns the perception of form: in many cases we have drawings looking like photographs of models and models (like the ones by Eisemann and Kawamata) made by deforming their morphology in order to look like drawings.

Besides such broad issues I shall consider a specific problem, namely the study of vaults – in particular the cross-vaults – reconstructed from drawings and data acquired during survey's operations. Also the employment of advanced laser relief methods can be ineffectual if they are not combined with a precise knowledge of the 3D structure of the architectural element that is analyzed.

Digital Representation, Modelling, Geometric Analysis, Numeric Survey, Virtual Reconstruction, Unbuilt Projects

SD I.3.5 – SD I.6.5 – SD F.2.2 - ** A.1 - * I.4.5**

1 - Introduction

The words "drawing", "model", "modeling", "construction" have become even more ambiguous since the introduction of digital technology. Even if the discipline of architecture requires a terminological codification, the ambiguity remains an essential component of it. However, in the field of architecture the ambiguity often derives from the fact that while a 3D digital model contains a great part of the information pertaining to architectural 2D contents, it is not always possible to reconstruct a 3D model starting from 2D data. Therefore the ambiguity is both theoretical and practical. How can we face the problem when we analyze data with the aim of a stereometric reconstruction of an architecture?

It is necessary to start a process of interpretation, which should aim not only to determine the scientific terminology to be adopted as the most appropriate one, but which should also above all diminish the "mass of ambiguity" contained in an operation of morphological description of a work of architecture. The inquiry into and the solution of some specific cases, by means of university studies and researches [1] [7] [8] allow us to define a strategy of intervention, and raise some new issues to be debated.

2 – "Drawing vs. moving"?

One of the first authors who raised the problem of the necessity of a specific terminology to adopt in the field of computer graphics was Ivan Sutherland, the author of 'Sketchpad', the first system of interactive design. In Sutherland's doctoral thesis on 'Sketchpad' [9] at the Massachussets Institute of Technology (MIT), we find a paragraph entitled "Drawing versus moving", where he states that: "An idea that was difficult for the author to grasp was that there is no state of the system that can be called 'drawing'. Conventionally, of course drawing is an active process which leaves a trail of carbon on the paper. With a computer sketch, however, any line segment is straight and can be relocated by moving one or both of its end points". As we know the system by Sutherland was originally a 2D one, even if only after few months the 3D application was developed, and the term "model" was soon introduced. Although the digital and analogical models have several characteristics in common, the main difference concerns what Sutherland himself was pointing out. The digital model is in fact a dynamic, changing one, and unlike the traditional one, it can be deformed, sectioned.

A remarkable example of the employment of the geometrical deformation in the field of architectural representation has been realized by a university research at the IUAV of Venice, directed by Camillo Trevisan [4]. It concerned the deformation of complex models of the perspective that Francesco Borromini realized in the mid-XVI century at Palazzo Spada in Rome (Fig. 1a). The aim of the research was the comprehension of the rules of the perspective

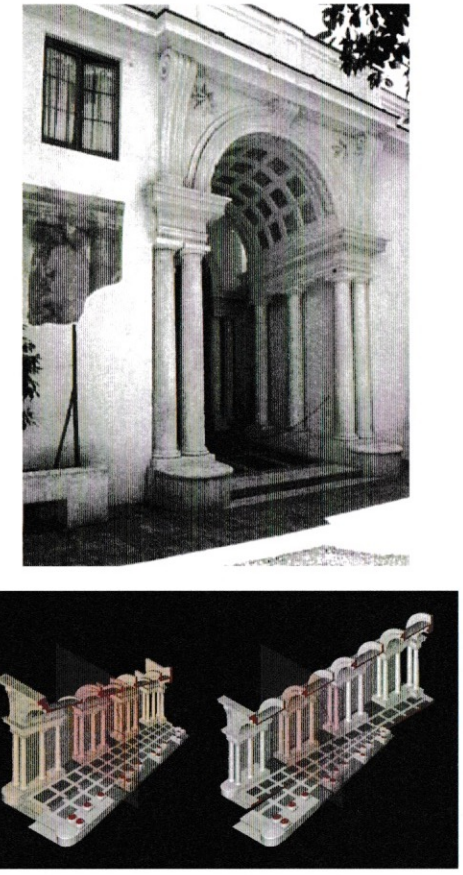


Fig. 1. The Perspective Gallery by F. Borromini in Rome: (a) – photographic image, (b) – deformed models [*aut. A. Sdegno, 1999; aut. A. Sdegno, E. Garbin, 1999*]

that Borromini applied in order to create the "solid perspective" of the colonnade (Fig. 1b). Even if we shall not consider now the whole complex study of projection, we can certainly highlight the algorithmic flexibility of the digital model of architecture.

3 - Palladian "drawings as models"

We all know that Andrea Palladio's works are central to the history of architecture. But it should also become clear that they are equally important for the history of representation and for digital modelling. The analysis of some case studies will enable us to see some of the reasons why they are so important. We shall not enter the field of the history of architecture, but we shall deal with matters of representation and modeling. Before doing that, however, I shall introduce the problem, as some scholars have described it.

In his introduction to the catalogue of an important exhibition in London, titled "Andrea Palladio. The portico and the farmyard" [10], Howard Burns wrote: "Palladio is the most familiar of Italian architects. His name at once calls to mind great porticoed country houses and façades articulated with classical orders. But the very familiarity of Palladio is an obstacle to seeing him clearly". As a matter of fact, if we observe any of his works, from the drawings contained in his treatise to the realized ones, we think that they are easily comprehensible and that all is ruled by the principles of symmetry and proportion, as a lexical application of the rules given by Vitruvius's treatise 15 centuries before. Actually, the complexity of Palladian morphology emerges from a careful analysis, and even more so if we proceed to a redrawing of his whole work, both on the basis of graphic elaborations from the "Four Books", and from the survey of the realized works which only partly correspond to his sketches.

Moreover, dealing with Palladio's architecture it is necessary to put into direct relation the terms "drawing" and "model", as some scholars have already done.

In particular, Decio Gioseffi as faced the topic of "drawing-model" in Palladio through a series of articles published on the Bollettino del Centro Internazionale di Studi di Architettura Andrea Palladio in Vicenza. Among them we should remember in particular the one [2] that deals with the origin of the term "model" (deriving from *modus*, meaning "measure", and *modulus*, meaning "unit of measurement") and arguing that it is necessary to consider the drawings by Palladio as abstract theoretical models, that is project experiments in progress. Gioseffi's essay was published some years after an important exhibition in Vicenza, showing the construction of some wood models, such as that of 'Palazzo Chiericati' (Fig. 2b), starting from the drawings published in the "Four Books" (Fig. 2a). In the catalogue [11] published in that occasion the photographs of those models were not inserted; they appeared few years later, in a volume edited by Renato Cevese [12]. Few years later Lionello Puppi [3] thought it very difficult to be

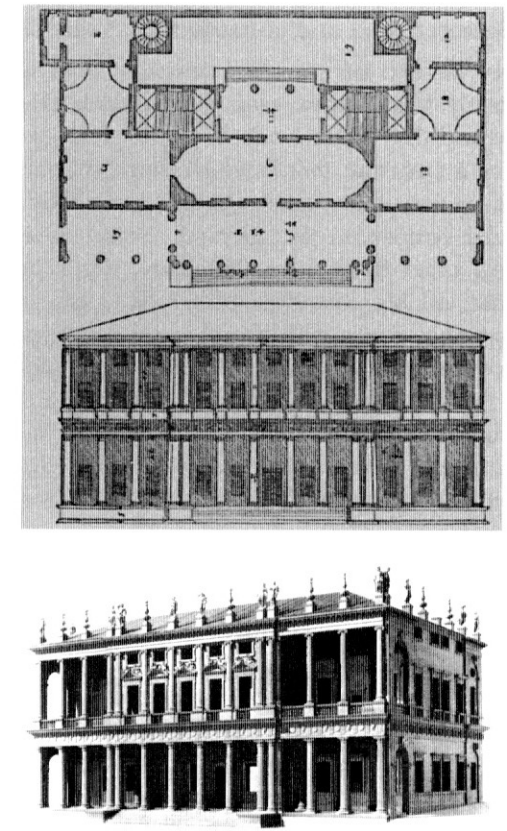


Fig. 2. 'Palazzo Chiericati' in Vicenza by A. Palladio: (a) – drawing, (b) – wood model [*A. Palladio, I Quattro Libri dell'Architettura, Dominico de' Franceschi, Venezia, 1570, II, p. 6; Centro Internazionale di Studi di Architettura Andrea Palladio, Vicenza*]

able to reconstruct the models starting from Palladio's drawings, exactly because a high degree of interpretation was required, which often risked of giving a wrong description of the original idea.

In the field of the logical-morphological analysis of some of Palladio's works we will remember the studies of William Michell [13] above all, which face the problem from the semantic point of view and develop some previous researches [5] [14].

3.1. Between idea and construction: Villa Capra

Now we have to analyze some works by Palladio to clarify the aspects listed over. One of them is certainly Villa Capra, said "La Rotonda (Fig. 3a). In this building the four pronaos were created and they present a building of great symbolic value. In fact, there is no main view, but we have a structure that faces all four cardinal axes equally. Another Palladian invention was that of the use of elements of sacred and public architectures, within private villas, like the upper triangular tympanum that gives the structure an unusual magnificence for a private house. A question arises from this architecture: was it created as Palladio wanted, or is it only a partial outcome of his intended plans? We ask ourselves this question when we compare a photographic image with the drawing that appears in his treatise of architecture [6]. The four pronaos are present, while the covering is quite different: in the published version we have a dome (another element taken from sacred art) that emerges from the building, while in the constructed version the dome is built into the stonework, so much so that it does not look like a hemisphere at all from the outside. The spherical form – quite extravagant for a private home – was hypothesized by Palladio. But this dome is an *unbuilt* element.

With digital instruments we can reconstruct the dome and carry out an overlapping of the two solutions (Fig. 3b) (see note 1.). We can hypothesize that, if Palladio had had our digital elaboration techniques available to him, he would have published this image in his treatise, as it shows the intention and realization in one sole figuration. In this case also, the comparison between the two ideas is possible and it allows for verification of the difference between them through two physical models. Besides this, we have to remind that the treatise is dated 1570 and was realized after the completion of the "Rotonda", even though using another project. This encourages us to consider his treatise as a work of idealization of projects, presentations of solutions and ideas, a repertoire of possible developments and conceptions (see note 2.).

Note 1. The reconstruction was done during my didactic activity at IUAV University of Venice in 2002.

Note 2. One must also remember that Palladio's treatise [6] is the first book of architecture that conteins designs by the author himself.

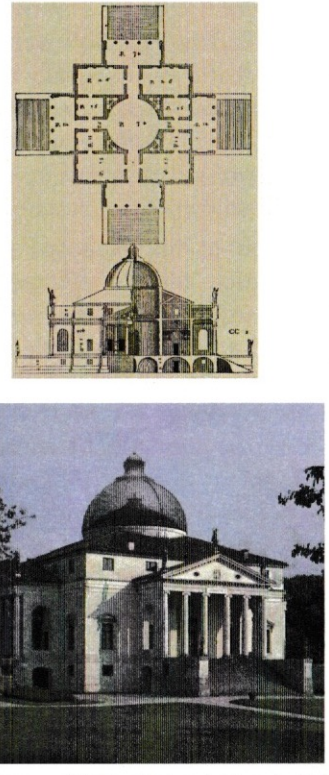
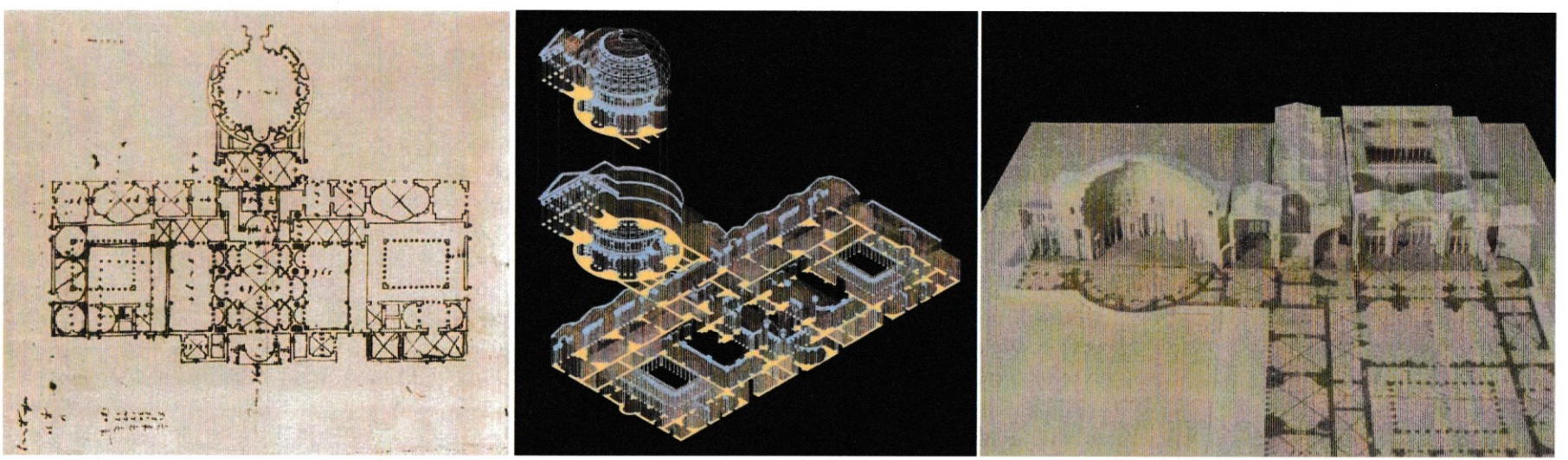


Fig. 3. Villa Capra, said "La Rotonda" by A. Palladio: (a) – drawing, (b) – digital photomontage, [*A. Palladio, I Quattro Libri dell'Architettura, Dominico de' Franceschi, Venezia, 1570, II, p. 19; aut. student D. De Santis, 2002*]

3.2. The reconsctruction of the *Terme di Agrippa*

Another interesting architecture is the *Terme di Agrippa* in Rome, as a unique case in which the author would design the "Antico". This case was recently studied at IUAV University of Venice (see note 3.). The *Terme di Agrippa* are a singular example of innovative planning executed in the Roman period. It was a building where Romans met not only to have thermal baths at different temperatures, but also to do sports, to talk to friends, to discuss business and to feast. The *Terme di Agrippa* are the first thermal baths of antiquity and sprung from the center of Rome. But, in 1540, when Palladio was in Rome they were in a state of complete destruction. Only one building was left, the Pantheon, which is, even today, one of the most important ancient buildings in Rome. It served as an entrance hall. Palladio then began to make some hypothetical plans. We can imagine how this building, which no longer exists, could have been like. There are several beautiful sketches by Palladio (Fig. 4a) in the RIBA (see note 4.) archive in London that hypothesize some design solutions, first published in Zorzi [15].

Note 3. The reconstruction was made by Chiara Stefani during her thesis at IUAV University of Venice, and was partially published in: C. Stefani, *Les Thermes d'Agrippa à Rome*, in Sdegno [8], pp. 47-61.
Note 4. Royal Institute of British Architect.



This can be seen relatively clearly in some plans, in which, within the symmetrical framework, we find two different solutions: the square courtyard on one side and the rectangular one on the

Fig. 4. *Terme di Agrippa* by A. Palladio: (a) – drawing, (b) – digital reconstruction, (c) – physical nylon model [*RIBA, London, Vol. VII, fol. 1; aut. C. Stefani, 2004; aut. Protoservice, 2005*]

other side. It is therefore an operation of invention, a design hypothesis of a structure that did not exist.

Therefore, we have to ask ourselves: why did Palladio dedicate his time in planning a work that he would never execute? Owing to the characteristics of the project – the big size and the specific function – we can hardly imagine that it would be ever realized. So then why did Palladio re-plan it? Moreover, the care with which he draws it is amazing, a detail of admirable graphics. Thanks to the care taken by the author, it was possible to analyze the plan. It was possible to make all the singular elements of the work coincide in such a way as to transform these Palladian designs into a digital model (Fig. 4b), one model that synthesizes Palladio's operations, even though this was done with very traditional methods. Those who use Computer Aided Design techniques know well that when one enters hand-drawn plans in the computer's memory, many of the details are likely to be lost. It is often necessary to approximate measurements because CAD drawing is much more precise than pencil drawing, but in this case the correspondence is perfect. There is great accuracy in the tracing of the lines, as if it were a drawing that was destined for the construction site, to be used for the creation of the work. It was so precise that it was possible to reconstruct the physical model, using rapid prototyping techniques (Fig. 4c).

3.3. Re-designing an Acropolic Temple

During the same period that Palladio designs the *Terme di Agrippa* he is also interested in another structure. The drawings are what are left of this structure. They are kept at the RIBA archive (Fig. 5), and they were studied at IUAV, as the preceding case (see note 5.). Historians are not sure of the location of this structure. It could also be a pure planning exercise, without context. Either it may deal with the Temple of Ercole Vincitore in Tivoli, or it may be the Temple of the Fortuna Primigenia in Preneste. Both of them are small cities near Rome. We are interested in analyzing it, because it is an *unbuilt project*, not realized. We should say that it is very interesting, because there are two different versions with different types of drawings.

It is known that there is an area in which it is possible to recognize the ruins of the Tempio di Ercole Vincitore, and another one that shows the architectural complex of Tempio della Fortuna Primigenia in Preneste. All the palladian drawings have been analyzed and transformed in diagrams so that one can clearly see how many elements were used by Palladio to try to design this acropolic structure.

There are two kinds of drawings: in one case we have geometrical drawings with a very clean, clear mark, "in pulito" of two projections, the frontal view and the side view, while the plan that could immediately clarify the three-dimensional morphology of the project is missing; in the

Note 5. The reconstruction was made by Viviana Magnarin during her thesis at IUAV University of Venice, and was partially published in: V. Magnarin, *Un temple acropolique*, in Sdegno [8], pp. 63-73.

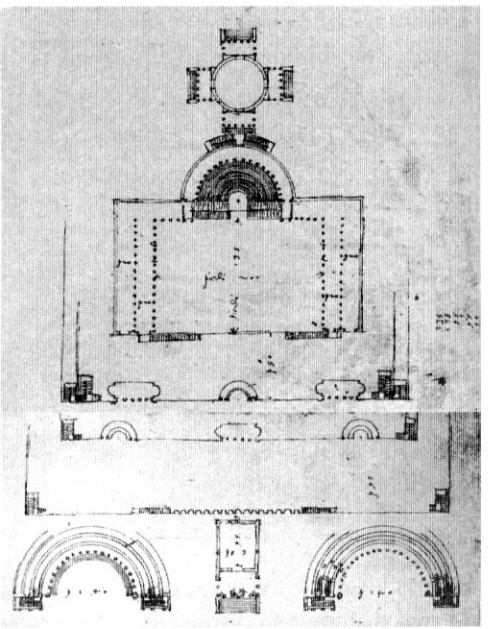


Fig. 5. Drawing for an Acropolic Temple by A. Palladio [*RIBA, London, Vol. IX, Fol. 7*]

other case, there are drawings in the forms of sketches of a plan and of a frontal view. They are difficult to decipher because they are a slightly blurred in the outline, even though very clear in the spatial configuration of the architectural structure.

It is very probable that it is not a drawing of an existing structure, but that it is an ideal plan, a hypothesis that was not meant to be realized. Maybe, as we would say today, we can consider it as an "academic" exercise, which only wants to experiment a montage of architectonic elements that can lead to a possible solution using the graphics technique. We must suppose that he had considered it an integral part of his curriculum necessary for the formation of an architect, the equivalent to a university thesis to obtain his degree and to be able to have access to the profession.

If we study these drawings, we will see that in the first case the structure ends at the summit of a small circular temple similar to the Temple of Vesta, proceeding down towards the lower part with a hemicycle, a portico-like structure, a large step system, to the central Temple with two other hemicycles on the sides and a portico structure below that defines three courtyards.

In the second case, however, there is a strange small temple with four pronaos at the summit, while all the other elements are located in similar positions – the upper hemicycles, the lower hemicycles, the temple, ect. – but they vary in dimension and morphology with respect to the preceding solution.

Some important characteristics can be identified in the two projects: in the first case we were able to reconstruct the geometry by recreating the plan that, as was mentioned, was missing. This was done by intersection. The perfect correspondence between the two existing vertical sections confirmed the hypothesis that Palladio surely had a plan as a first drawing and that, later, that drawing had been lost. In fact, we know that the Vicentine architect considered the plan of an architectural structure as the generator of the design, the instrument that one begins with, to proceed to successive architectural planning and developing. It is therefore an important result that has not been considered until this point. So we have all the main elements for the representation in order to construct the 3D model of the each part of the structure: the Tempio di Vesta, the hemicycles, the theatre, the main temple, the portico, and it is possible to render the whole structure with simulation software (Fig. 6a).

We can apply the same procedure to the second temple, from plan and elevation to obtain the third projection, the section. As in the preceding case, now we can create the 3D model of the structure. We can see that some elements change their morphology: the hemicycle is the same, also the temple, the theatre, some stairs, but on the upper level we have a structure with four pronaos.

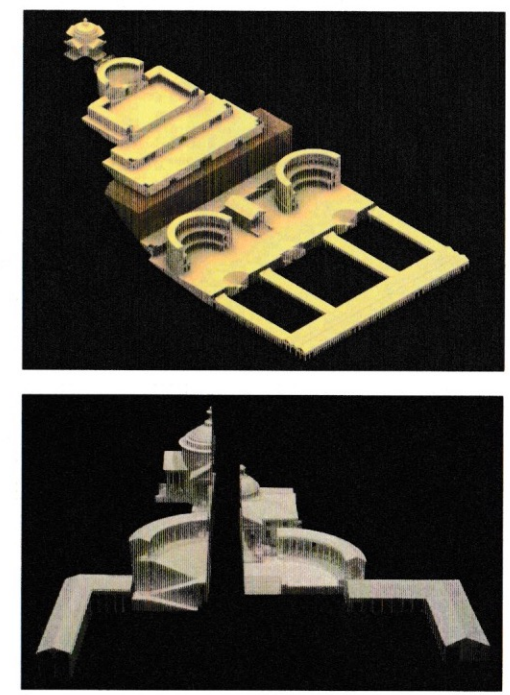


Fig. 6. Design for an Acropolic Temple by A. Palladio : (a) – digital reconstruction, (b) – physical nylon model, [*aut. V. Magnarin, 2004; aut. Protoservice, 2005*]

So, the second case, clarifies several work methods that Palladio used in architectural planning. In fact, some solutions were surely employed as base material for the executive planning of his other works, the ones that were actually realized. There is a figurative resemblance between the second version of the plan of the acropolic temple and the design for Villa Capra or Villa Trissino in Meledo, both of them published in Palladio (1570), though there are differences between drawings and buildings (in the first house the dome was not realized, and in the second one only a terminal fragment of the barchessa wing was realized).

The structure is the same, as we can transform the two projects – one into the other – with a few simple vertical and horizontal operations. The model is divided into two, the hemicycle change position, from up to down, and the main temple is inserted inside the two wings (Fig. 6b).

4 – The Representation Hinge: Touching and Seeing

Besides the problems concerning the morphology of an architecture, when one deals with representation, it is necessary also to inquire into the problems of modelling and visualization. If, as already stated, in some cases the graphic figuration gives the illusion to the observer to be in front of a real scene (as an example, see the panoramic drawing of the 'Three million inhabitant Town' by Le Corbusier) (Fig. 7), in other cases the model provides a representation of the drawing, solving some projective problems.

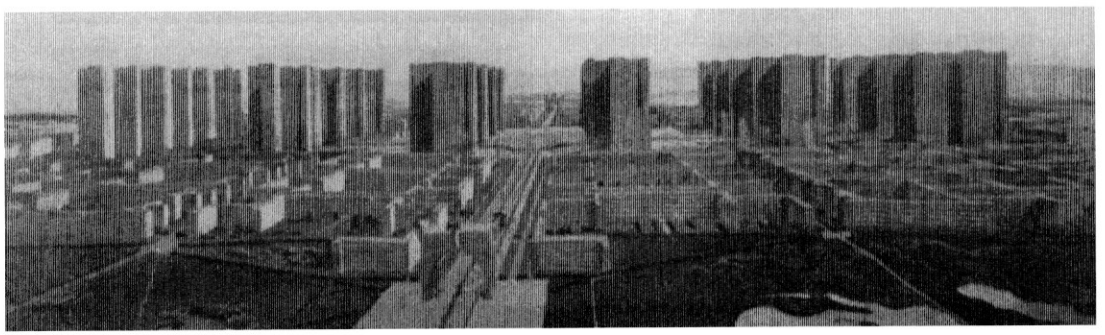
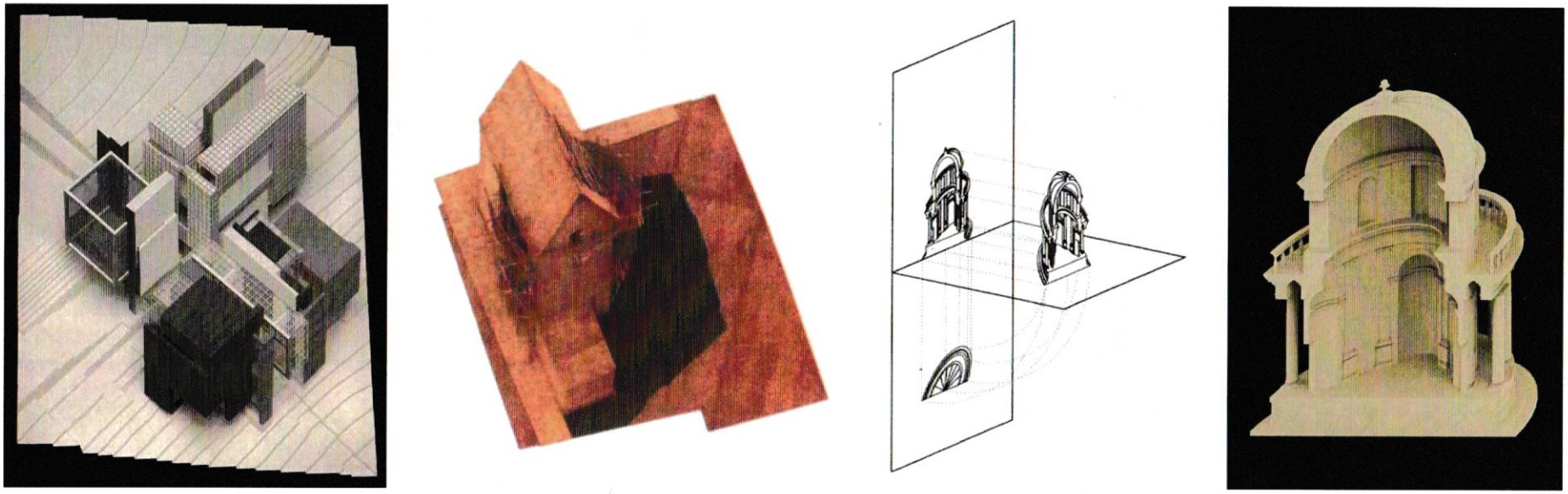


Fig. 7. The panoramic representation of the 'Three Million Inhabitant Town' by Le Corbusier [*Fondation Le Corbusier*]

The most evident one concerns the kind of projection: the human, "photographic" eye observes in fact a scene with a conic projection (from a proper point of view), while the "graphic eye", has greater liberty since it can employ orthogonal projections, axonometries and perspectives. In

particular we shall try to analyze a kind of axonometry – the oblique one – which is very different from a perspective representation. In fact, if an orthogonal projection is figuratively close to a perspective, even if it is completely different from a projective point of view, an oblique axonometry is sharply different from a perspective.

If, for example, we observe Peter Eisenman project for the 'House X' (Fig. 8a) or the one by Tadashi Kawamata for 'The House of Squatters' (Fig. 8b) we notice that the two physical models have something in common. In both cases they are deformed along an axis, so that they seem to be squeezed upon themselves. But if we observe them – even photographically – from a privileged stand-point, we can see what was the sense of such an operation.



The most frequent cases of an oblique axonometry, in fact, enable us to obtain either the real plan or the real elevation, which cannot be obtained by any photographic camera.

In order to verify the possibility of using this procedure – from photograph to drawing – we have constructed a solid digital model of an architecture, enabling us to verify the exactness of projective properties as well as the efficacy of the working method. We decided to analyse the 'Tempietto' of St. Peter in Montorio by Donato Bramante, built in Rome in XVI century, whose

Fig. 8. Deformed architectural models: (a) – 'House X' by P. Eisenman, (b) – 'The House of Squatters' by T. Kawamata, (c) - diagram of the 'Tempietto' of St. Peter in Montorio, - (d) 'Tempietto' of St. Peter in Montorio [*A+U, 1980, n. 112, frontespice; London, Annely Juda Fine Art; aut. A. Sdegno, 2004; aut. A. Sdegno, 2004*]

specific elements – such as the doric order, the pilaster strip, the pediment – require a particular ability in the creation of the model, and in the descriptive projection of them, which is very difficult to realize with traditional techniques on paper.

When the model was realized, utilizing boolean interactive graphic tools, we began to deform it (Fig. 8c), vizualizing the result in orthogonal view (Fig. 8d), to control directly the correctness of the work.

At the end of the operation, it was necessary to control the analytic values generated by the method, in order to verify the results and compare the geometric forms obtained. Following the homology criterion, it was possibile to associate the oblique projections of the "Tempietto" with the orthogonal projection of the deformed model.

The initial stereometric configuration was perfectly superimposed to the one obtained after the manipulation, so that the hypothesis of an affinity between deformation and projection was proved.

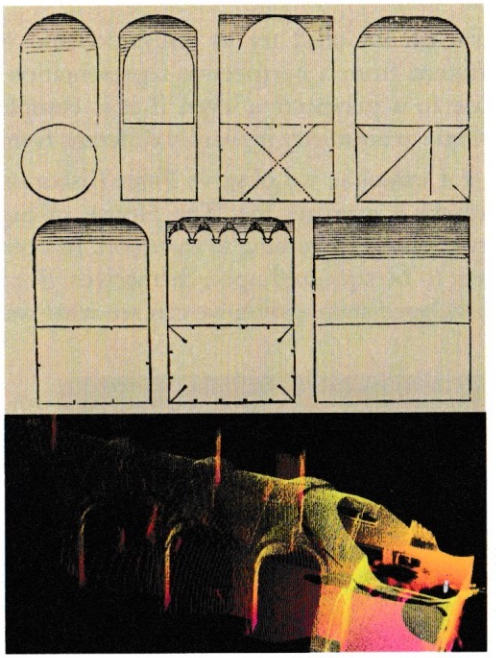
Deforming a model could be a useful way to understand the geometry of an architecture, and the laws that define the mechanism of projection.

5 – Between Design and Survey: some Geometric Reflections on the Construction of Vaults

The last aspect we shall consider is a specific case of architectural geometry, that is the vaults system. We know that there are many kinds of architectural vaults, and in order to have a simplified but representative cases of them it is useful to refer to Andrea Palladio's classification in his treatise. In one of his drawings he shows us the way in which these vaults are determined (Fig. 9a).

Now if we consider the solution he adopted for the Convento della Carità, we shall find something odd. The rigour with which Palladio describes the vault systems – we should remember that Palladio devotes a chapter of his treatise to the "abuses" – clashes with the way he employs them in the courtyard. We would expect, in fact, to see a non vaulted system for the peristilium, since we have the trabeation in the façade which recalls the elementary structural system, and we have a simple a barrell vault. If we consider the solution adopted in other known porticoes, as for example the portico of the IUAV at the Tolentini (Fig. 9b), we might find ourselves in front of a series of a cross vaults, while Palladio employs this "strange" solution.

There is another place in the Convent where he uses the cross vault, and it is exactly in the tablinum, where there is a combination of a cross and lunette vaults (Fig. 9c). There is also a



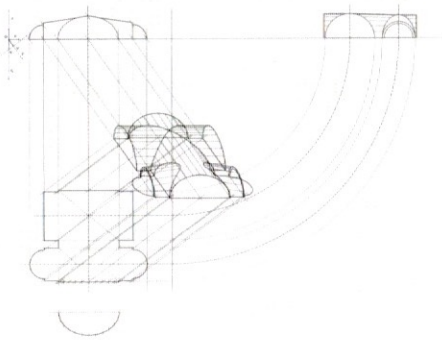


Fig. 9. Some examples of vaults : (a) – palladian vaults, (b) – points' cloud of the cross vault of the Tolentini (c) – geometric analysis of the cross vault of the tablinum in the *Convento della Carità*, [*A. Palladio, "I Quattro Libri dell'Architettura", Dominico De Franceschi, Venezia 1570, I, p. 54; aut. A. Sdegno and P. Vernier, 2006; aut. A. Sdegno, 2003*]

difference in the heights, showing how Palladio meant to express the leading idea of the treatise: a combination of an ancient element (the cross vault) with a modern one (the lunette vault), constituting a sophisticated and very personal solution.

It would be interesting to make a 3D scanning in order to understand if there are slight constructive differences unveiling some further aspect of the complex history of the Convent.

This has happened to the cloister of the Incurabili in Venice (Fig. 10a), where after a very accurate scanning (Fig. 10b) it became evident that the real configurative geometry of the cross vaults of the path was slightly different from the known one (Fig. 10c).

The realization often brings with it a modification of the morphology of the original drawing.

6 - Conclusion

These examples demonstrate the need of expanding this research into the relationship between drawings and digital models, including more case studies and integrating the knowledge of historic-documentary and geometric-configurative to the drawing and survey activities, in order to enlarge the study to other fields and above all to verify the starting data.

The themes concerning the modeling require the overcoming of the classical identification of the operation of digital form construction with the algorithmic procedure. We must combine this codified procedure with a knowledge of the methods of plan and space geometry which have determined the basic rules for the production of the algorithm.

Therefore the study of the theoretical apparatus concerning matter of morphology appears to be an essential subject to pursue. The issue is to establish the modes to make the web governing the relations among the different disciplinary units both compatible and comprehensible.

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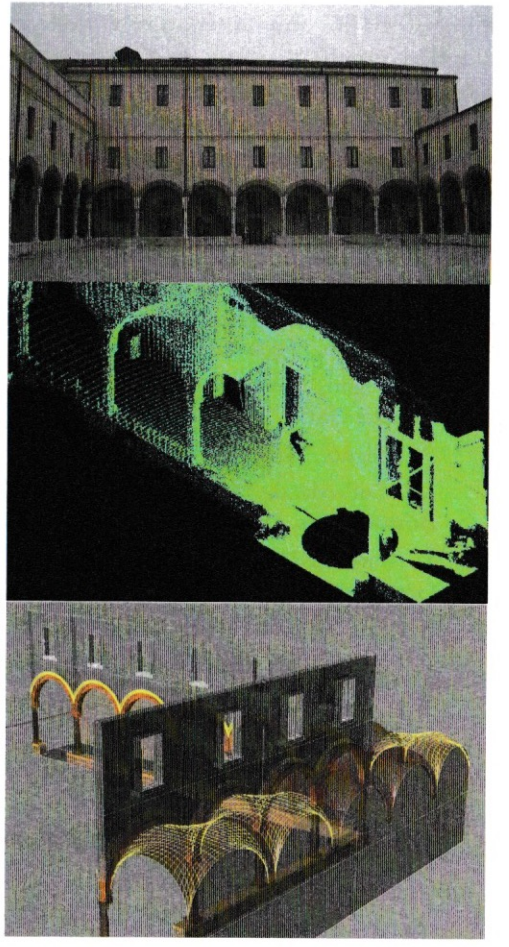

Fig. 10. The 'Incurabili' Cloister in Venicei: (a) – photographic image, (b) – points' cloud, (c)- digital reconstruction [*aut. A. Sdegno, 2006; aut. A. Sdegno and P. Vernier, 2006; aut. Student S. Terrana, 2006*]

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