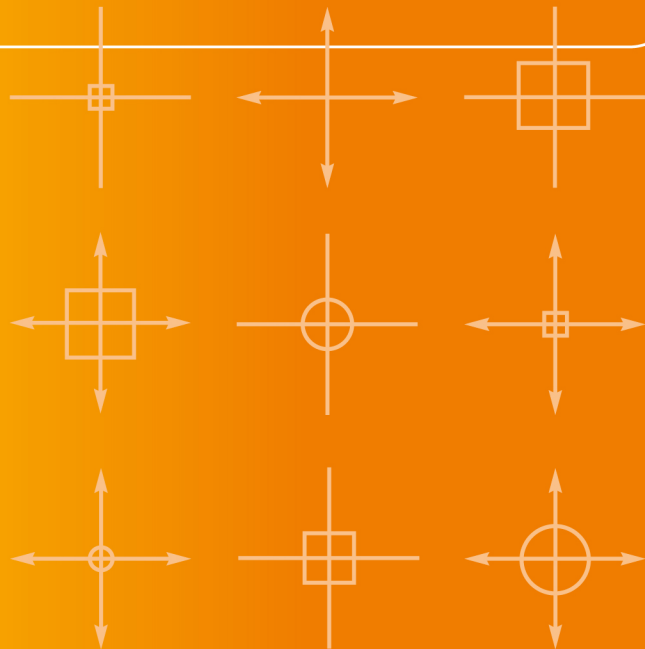


CHNT 20

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Reading the project and “reverse design”: An architectural approach to digital reconstruction

Giorgio VERDIANI

Dipartimento di Architettura, Florence University, Italy

Abstract: A lost architecture asks to the digital reconstructor to understand all the elements and to make logic and cultured matching with existing building and drawings, putting together all the possible, convenient and comparable samples. Any 3D modelling tools allow to reconstruct and to give strength to ideas and hypothesis, but they must be clearly aimed to a sort of reverse design process, a workflow oriented to find back the choices of ancient architects and constructors. Practical and technical choices were at the basis of the building development while consolidated procedures were adopted to solve construction situations. The knowledge of the ancient courtyard and the design logic in its contest become an important contribution in planning a digital reconstruction. The use of the measurement units of the time can be a first useful step in defining and reading the architectonic apparatus, while the construction of correct layout grid can give a better reading of the existing and can be extended to define a structure for the missing parts. In this presentation the process of reconstruction using “reverse design” interpretation will be developed with quick samples taken from five case studies: the “Campanile di Giotto” in the original Giotto’s project and of two of the “lost” ancient tower bells of “Santa Croce” in Florence; the rests of the *Cadi* bridge at the feet of the Alhambra hill in Granada; the St. Maria and St. Stefano church and the St. Donato cathedral in Arezzo, now simply poor remains of walls. For each sample the scheme of the workflows and the structure of the developing process will be described together with the most important references used for the digital reconstruction.

Keywords: Reverse Design; Built Heritage; Virtual Reconstruction; 3D Modeling; Architecture.

Introduction

The reconstruction of archaeological remains is a quite common operation in Cultural Heritage studies, it resolves a lot of undefined aspects to tourist and students visiting or studying a place, it allows to communicate the ancient condition, as well as the “possible/alternative” conditions, of a place. Most of the time it is supported by a multidisciplinary approach, mixing many scholars from different areas in the try to solve the puzzle created by remains, archives, traces, ancient witnesses, previous studies and all the possible evidences about the “how it was”. This process has many years of experiences testifying different way to face the reconstruction, from the “archaeological revival” to the modern multimedia uses, reconstructing a part of a town or a specific building has captured the abilities of many passionate scholars. In our days the digital and multimedia needs have asked for a complete rethinking of many previous reconstructions, the word “virtual” is appeared and it requires an accurate 3D modeling of many parts, the reconstruction is more and more made thinking to the global original building, not only to a single view. The access to the model is often a “multi-scale” one and this rises the level of knowledge about the details before needing an appropriate managing of

the details in themselves. Just to complete this quick tour about the environment in which all the people involved in reconstruction are used to move in, it is important to recall the strategic importance that this kind of solutions have assumed in the past twenty years: massive presence in media, significant presence in museums, important presence in scientific papers and ongoing research projects. The digital reconstruction is nowadays a part of the exhibition, it must be versatile, it must be correct, it must capture the attention but it must communicate its value, enriching the observers augmenting their knowledge. More than ever before the 3D model is the central part of the process, creating all the needed bases, from the creation of images to multimedia, to the creation of physical models, to the information linking, to the online dissemination and sharing. But all these considerations should not limit the way we intend the 3D reconstruction of ancient places, it is not strictly a final part of a process. It can be considered as "the" process. When the reconstructor gets involved in this work, most of the time it is a sort of "rebuilding" of the original structure, all the parts must work together, all the elements, doors, pillars, walls, columns, stairs and so on, must be checked and verified in their place and in their mix, they must comply to the original design will, expressed by its author/authors. The interpretation and comprehension of this will is most important for the understanding of the place than any other nice aspect in the reconstruction, it is a deep and accurate recreation of a creative process, something that may clarify the state of knowledge about a lost/transformed monument or simply help in formulating new hypothesis. In both the situations it is a robust contribution to the awareness about specific architectural heritage objects.

Reverse Design: Concept

The architects have a long story behind their working practice, longer than other scholars. This is not a matter of establishing a primacy in front of other disciplines, while in the use of archaeological digital reconstruction almost all the kind of operators have a similar legacy and duration of the experience. The point is another, the ancient constructors and architects operated their work using a logic and a language quite distant from the current approach. Sometimes it happens to get some astonishment when looking to monument reconstructed for real during the past two centuries, we consider all the ruins and all the ancient elements as precious fragments of the past, whenever possible they are preserved, kept in place and correctly restored and protected. In the past this was not an expression of the architectural logic, nor was it for the general building process. Reconstructing real parts, bringing back a building to its Medieval, Roman, "original" aspect, or at least to the "idea" of original in the mind of the restorer was a quite common phenomenon. In this sense the architects from the past centuries were used to think in a sort of continuity with their ancestors, the logic of reuse, demolition, reconstruction was brought on continuing an old behaviour. The sense of preservation, of musealization, took a short time to be developed in front of this and it is still an ongoing process. But we are in it and operate with it, we have a strong believing in our contemporary approach and that's correct. But at the same time we are in need of an abstraction, or at least a "level of abstraction" capable to bring who is involved in digital reconstruction towards a better reading of the project behind the remains or the actual appearance of the site/building. This process of "reverse design" should start from the state of the place to move gradually to the interpretation of the project, this should be done considering the cultural tendencies of that peculiar time, influences, metric units in use to dimension elements and establish proportions, formal relationships with other

buildings, influences from other authors, the building process of that time and all the "intangible" cultural elements defining the project environment in its time. Images, like paintings and drawings may help, but when it is a matter of medieval or even more ancient buildings, their representation can be more figurative than connected to the real. The representation, especially when it is made by artists, can be based on previous views, sometimes lost, sometimes still existing, so a correct and complete investigation about the way the subject of the reconstruction is represented is often worth the effort. It is quite clear that there are no regular and fully recurrent procedures, each archaeology/architecture has its own specific case and need assessment of its developing lines to help the definition of a reconstruction process.

Case study zero: The Giotto's tower bell in Florence

This is the “zero” case study because it has no 3D modelling, but shows clearly how an "reverse design" procedure may work in helping interpretation of the original project. As it is well known, the tower bell of the Florentine cathedral was a work from *Giotto di Bondone*, an important artist, here working as an architect. Giotto died while the tower bell was just at its beginning, with a large part of the basement completed (CISOTTO NALON 2000), but far from fully rising from the ground. The courtyard was then brought on by *Andrea Pisano*, who probably continued following Giotto's ideas for this building until 1348. Later the very completion of the tower was conducted by *Francesco Talenti*, his direction brought the courtyard to the roof in the 1359. So the tower we see in Florence is named Giotto's Tower Bell, but most of what appear in the skyline are planning choices from Francesco Talenti (VERDON, 1994). During the XIX century, the discovery of an ancient drawing from the XIII century, representing caused a wide discussion. The drawing, named "Pergamena di Siena" (Parchment from Siena) with its representation of a tower bell very compliant with the Giotto's tower bell was indicated as his original project. The completion of the top part of the building, represented with a Gothic pitched roof, appears very far from the realized work. Later the attribution changed and the various hypothesis from the XIX century about "restoring" the tower bell according to the Giotto's idea were left. But even if the ancient drawing is not about the main religious tower bell in Florence, it gives a suggestion and pushes a reflection about the design ideas from Giotto. Looking at the base of the tower it is clear the sequence of sculptures (CARLOTTI 2001): the origin and activities of humanity, the work of men, then the prophets and the sibyls. These sequences seem to indicate a sort of ascension, a progressive movement toward God from the origin of humanity and then up. It is possible to imagine a sequence of lines and geometrical figures underlining this, probably not far from the work of Francesco Talenti, but when coming to the upper parts, when the need to represent God in a geometrical shape, the idea to create a strong vanishing point using a pitched roof seems a good choice and correct with the figurative premise (Fig. 1).

Case study one: The original tower bell of the St. Croce church in Florence

The first tower bell in St. Croce in Florence fell over the church in 1521 (CAPALBO 2001). Now a day no significant remains are in place to testify its presence, the fragments of walls (for a long time reused to host some bells) were completely removed in the early half of the XIX century when the new tower bell from *Gaetano Baccani* was erected (VERDIANI 2005). It is not possible to give back a clear shape to this lost Architecture, but it is possible to make a try materializing it interpolating between paintings, traces in the walls

(giving a partial indication about the size of at least one side of the tower) (Fig. 2) and hazarding to recognize a representation of this tower in the fresco from Spinello Aretino in the St. Croce sacristy, realized a long time before the disaster and representing "Jerusalem" but with a clear reference to Florence (Fig. 3). In this way the tower painted at the right side of the fresco may be considered compliant with the one drawn in the "Carta della Catena" especially in the "Petrini Brothers" copy. Starting from this idea, the interpolation with other similar tower bell, even from different ages, can help in giving shape to what is lost. In this way a lot of elements can find a way to be clearly represented, except the precise connection of the tower with the church walls.

Case study two: The Sangallo's tower bell of the St. Croce church in Florence

After the disaster of the original tower bell, the St. Croce church and convent found some resources to realize a new one. The work was taken by Francesco da Sangallo, but after a quick start in 1549, with the making of the basement, the money stopped and the rising of the tower arrested. The massive basement, completed, but far from being a "tower" remains for centuries at the side of the church façade, getting the nickname of "the stone of St. Croce" (Fig. 5). This unlucky courtyard is a quite complex puzzle; the main rule seems linked to "losing" elements allowing a memory of this architecture. Its remains were demolished in the XIX century, but the architects from that age took a survey of it before destructing it, so wrong the original drawings have been lost during the XX century. Also the medal with the original representation of the finished tower bell is now missing, maybe sooner or later in the future these evidences will come out again, but right now it is possible to work only on pictures from archives (Fig. 6). The process of digital reconstruction here starts from the digitalization and then the 3D model making of the realized basement. Then a geometric scheme is extracted from a picture of the medal, the main lines of the project are easily identified, creating a layout base to be considered as a guideline for further developments. At this point a complex network of relationships is established between similar architectures and other works from the Sangallo's Family. A significant contribution comes from the tower bell of church of St. Biagio in Montepulciano, near Siena (CLAUSSE 1902), a work from the same period, designed by Antonio da Sangallo the Elder. The combination of all this suggestion allows a gradual and progressive construction of the resulting hypothesis (Fig. 7). In this case it is not a destroyed architecture, it is an ideal materialization of a never realized building, an impossible building, not passed through historical event, but directly created from the project, or at least from a logical reconstruction from the pale traces left from that work.

Case study three: The Cadí gate at the Alhambra hill in Granada

Granada, in Spain, is well known all over the world for the beauty of its Muslim downtown called *Albayzín* and of the Alhambra. At the feet of the hill where the Alhambra rises, along the Darro river, it is possible to see the so-called "Cadí Bridge". It is a Moorish arch portion from the XI Century. The research about this fragment has been established on the analysis and investigation of the actual state of this ruin, using S.f.M. Photogrammetry to create a base for reconstruction (RODRIGUEZ-NAVARRO 2012). The ruins of the Cadi (Fig. 8) now rise with a very transformed contest, where sections, paths, levels, buildings have a quite different condition in front of the time of this element construction. So the best thing is to start from the more "solid" evidences

coming from the architecture element in itself. The first process must take care about the main arch, trying to find back the main lines of the missing part of the Cadi. The first reconstruction process was done using 2D drawings (Fig. 9). The tracing of the arch was focused on the best fitting of the curvature and checking it back to the “ideal” Moorish arch construction. The result is a horseshoe arch according to the definition given to the arches whose design corresponds to a circle segment having a length greater than half circumference, like in example: ultra-semicircular arc, resulting in a shape similar to a real horseshoe (*herradura* in Spanish) (SÁNCHEZ 2011). This allows also to find a symmetry axes. There are no guaranties about the fact that the Cadi was a symmetric structure, but studying about the architecture of that period it came out clear an important preference for symmetric solutions, last but not least, mirroring the Cadi on the found axis will create a more stable structure, with all the loads coming from the arch to be well supported by the structure of the resulting building. As it is logical for a Moorish architecture, the design of the original fortification was not planned in meters but using the typical measurement system of that culture: the cubit (VALLVÉ BERMEJO 1976). In the Hispano-Arabic metrology. Considering the “Common” Cubit the resulting grid comes out with lighter reference to the angles of the construction, but the arch came out to be exactly 10 Cubit large, quite a robust result for such a building. Extending the grid, it is possible to imagine the original aspect of the tower and starting to develop reconstructed hypothesis. The overall process of reconstruction was based on 10 steps: 1) the curvature of the arch is found starting from the traces along its remains in the ruins, this was done using a simple three points arch, identifying a single curvature, in this way it was found a first axis crossing the centre of the arch. All the lines generated by the lengthening of each single stone are then projected to the axis. 2) Discretization based on the interpolation of the lines coming from the stones, optimization of the curvature according to the new centre and the arch ruin profile. 3) Definition of a mirrored set of lines and curves, tracing of the second arch. 4) Check of some measurements according to cubit units. 5) Optimization of the suggested reconstruction according to the cubit units. 6) First definition of the theoretic model of the symmetric Cadi. 7) Comparison with the actual section crossing the banks. 8) Integration and completion of the theoretic model. 9) Cubit unit grid aligned on the theoretic model. 10) Final adjustments and optimization of the proposed model according to the cubit grid. One of the most meaningful result in the geometrical reconstruction is the fact that the second tower enters and overruns the actual river bank, entering the area close to the buildings (Fig. 10). The bank has seen various changes in time and now it is not possible to consider it a meaningful sign in front of its condition at the time of the Cadi, but imaging the second tower close to the town pushes the attention to the relationships between the buildings and the defensive walls and gates. Studying the aerial images from the area it is possible to notice a system of ancient walls connecting the Cadi structure to the main Alhambra fortress (VERDIANI 2012).

Case study four: The church of St. Mary and St. Stefano at the Pionta hillock in Arezzo

The hillock named "Pionta", in Arezzo, Italy, was once a walled citadel, which was politically aligned with the Pope. In 1561 it was destroyed (TAFI 1995). The rediscovery of this area started in the 1960s (FATUCCHI 1998). In 2014 after an accurate digital survey of the whole area, the research group I was coordinating started the reading of the architectural traces, the interpretation of the original architectural projects, brought the basis for hypothesizing a map of the next possible excavations. Inside this work a significant task has been

brought on about digital reconstruction of two meaningful churches, the St. Mary and Stefano and the St. Donato. Both have the rule of cathedral, both have been destroyed with the ancient citadel. The virtual reconstruction started from the main evidence of the site: The Church of St. Mary and Stefano (Fig. 11). The remains of the crypt, the walls, and the previous archaeological investigations (MELUCCO VACCARO 1991) and studies offered the base for an architectural reflection of this building. The plan of the church was compared with other similar ones like St. Salvatore in Agna, Pistoia and St. Eugenia in Bagnoro, Arezzo. These two churches are in well-preserved conditions and useful to better understand the general aspect of the elevations and sections of the ruined church. The study of the geometrical layout, based on the units of that time, the Florentine "braccia", was done starting from the remains. This work was very beneficial in defining a spatial grid, able to be extended, and allowing a better understanding of the proportions of each part. To test the virtual project, the mosaics found during the excavation in the 1960s (TRISTANO 2005) and now conserved in St. Stefano Church were virtually brought back into place and extended in their pattern to fill the whole space. This was a successful test; the new hypothetical plot showed to be perfectly compliant with this operation (Fig. 12).

Case study five: The cathedral of St. Donato at the Pionta hillock in Arezzo

This important church is a great mystery, demolished with all the other building on the Pionta hillock, it left absolutely no trace of its structure for a minimal reading. It is known that it was a rich and important church, that its architect was named *Maginardo*, but no physical traces of it exist anymore.

Thus, a drawing from Giorgio Vasari the Younger (STEFANELLI 1970), various paints and some sculpted representation allow a certain definition of the original building (Fig. 13). The ancient drawing is a fundamental piece, while it allows to put in scale and orient the plan view. The complex process of digital reconstruction of this building is fully described in another article (by G. Verdiani, M. Pucci, M. Mariottini) in this same ebook, in the proceedings of the session "New Realities". The process of reconstruction put a first, intense, question: why, in the total destruction of the Citadel on the Pionta hillock, only the basement of the St. Mary and Stefano remains in place, no other constructions are there any more, no trace of large basements, neither the ancient walls closing the citadel left any trace. A possible answer may come from placing this first drawing over the ruins of the St. Mary and Stefano church. They look compliant, so it is possible to suppose the St. Donato as built over the previous church, a renewal of the Cathedral. No other evidences can support this idea, but this is something happened in other towns in those centuries, the old church leave space for the new one, the ancient basement remains beneath the new building. This hypothesis should explain why there are remains of the St. Mary and Stefano, they were underground at the time of the demolition and so they remained. Obviously there is no way to demonstrate this, but in the lack of any archaeological finds this can take place in the various number of ideas about this place. The definition of the digital reconstruction was here operated using directly a 3D modelling process, starting from the inside and then going to the apses, then back to the interior and in the end completing the external sides. For the interior a *matroneo* (women's gallery) has been thought to match the St. Vitale in Ravenna structure, this Romanesque masterpiece is considered a direct reference for the work of Maginardo by many previous studies (PIZZI 1995). Thus it is quite clear that this is not a central plant church, it is a particular, almost experimental solution. It seems that there are no other

buildings with similar layout available for a direct match. It is possible to find similar plants only from very later construction, with different architectural aspects. The development of the model confirms the complex and rich characteristic of this architecture, confirming it as one of the most peculiar lost building from that age (Fig. 14).

A reflection on the methods: systematization

Each reconstruction asks for a very specific approach, it is not that simple to define a systematization for the operators or for certain kind of structures, thus it is possible to define a generic set of conditions that are quite common in the digital reconstruction of an architecture. First of all: does the subject existing anymore? Was it built? When was it destroyed? If the architecture object of the survey is still (even partially) in place, that's a very important factor. The reconstructor will be able to expand his ideas starting from some remains, it will be possible to complete and trace the geometry of the partial elements, to make a sure compare with other building. If the architecture was destroyed or it it was never built, the first step will be to find all the possible witnesses of the missing building. Then the further step will be to ask themselves how much reliable are the ancient drawings, which level of abstraction they have, which one is a copy of the other, which kind of relationship (if any) there is between each representation. For example, a drawing from a certain age can be reproduced in various and altered ways, maybe it has been used as the reference of a fresco, but nor the original one, nor the following versions may be fully reliable. An accurate reflection must be brought on by the operators, thinking about the “weight” of each element in the old representation and about the ancient way of drawing and painting architecture and urban space, the rules of perspective are a late arrival in the history of representation. If the lost/altered architecture belong to recent time, the possibility of finding old or recent pictures changes everything, up to the point of making the process of “reverse design” quite secondary, in this case the reconstruction will be more direct and will need only partially a complex process of understanding, it will be more near to a process of direct reproduction from drawings/photography. If any remains of the lost/altered architecture still exist in place: make a digital survey of them, and then compare the survey of any previous traditional survey and or technical drawings, it will help in understanding if in the past there were any misunderstanding or wrong interpretation of the real shape of the item you are going to study. Then the survey will be the basic point from which start an accurate reconstruction. Secondly: find and study the measurement units from the original time of the lost/altered building, this is a fundamental passage, it will make possible to understand the basic plot and proportions of the architecture, it will give you all the needed suggestion about how to complete that missing wall or that crushed part of a front. Thirdly: compare the first results coming in your mind and the survey of the remains with as many as possible architectures from the same author, the same historical period, the same kind of building, this will be a great help in all the major abstractions you will be called to make for all the missing parts. A further step from this point can be an intense investigation to find where all the missing parts are gone: they are on the ground? They are stolen as construction materials? They were used as decorations for other buildings? If any of these conditions are present, the operator will immediately become a hound and start searching, measuring and creating digital version of all the possible discovered pieces, just to bring them back to the starting point of the missing architecture. Most of the time these first steps in the reconstruction bring to a first “materialization” of the idea, creating well working bases for further refining. They can be largely enhanced by an interdisciplinary collaboration with scholars and

experts about that subject, that author, that place, but the first results from a reconstruction are always a great base for starting debates and bringing on knowledge.

An evaluation of the methods

For any reconstruction the final result is a focal point at the end of a long process, thus, it is fundamental to keep in mind that it is not important how good is the quality of the rendering or the dynamic of an animation, the main subject should be how correct is the process and how well resolved are all the parts in need for a reconstruction purely based on deduction. If the process is traced with correct procedures, if the operators choose the right approach, the final proposal will be not simply a “3D model” but an intuitive proposal about the original aspect of a place. Then all the further steps in data treatment will be logical and will take their place. It is important to trace the evolution of the 3D model, if all the key choices are documented even with few images, it will be easier to transmit to other the process and enrich the understanding of what has been done. It is a part of the work, and old solutions, even when abandoned, can still give some interesting chances in finding new paths and to restart the reasoning from certain crucial points.

Conclusions

The “Reverse Design” ask to the reconstructor a clear comprehension of the architectural language, of the technical issues, but most of all of the architect’s way of thinking the project. A significant abstraction is needed to reach and catch the thoughts and the philosophy of a distant age. But a creative approach and a certain need of lucky intuitions may help. The journey to rediscovering can ask for well organized group of competences, but it also needs the capacity to set to zero all the influences and rethink from zero the reason of the project, finding back the issues and the ideas that moved the planning choices.

A very complex work where the use of contemporary digital tools is essential, but where an elastic and intelligent way of thinking architecture is at the base of any meaningful conquest.

Figures



Fig. 1 – From the left: the tower bell of Giotto in the urban context; the so called “Pergamena di Siena”; view and layout scheme of the East front of the tower bell.



Fig. 2 – From the left: the original St. Croce tower bell; the reuse of its ruins until the XIX century; the trace of the remains in our time.



Fig. 3 – Spinello Aretino: Fresco from the St. Croce sacristy, showing an ideal Florentine skyline



Fig. 4 – Hypothetical reconstruction of the very first St. Croce bell tower.

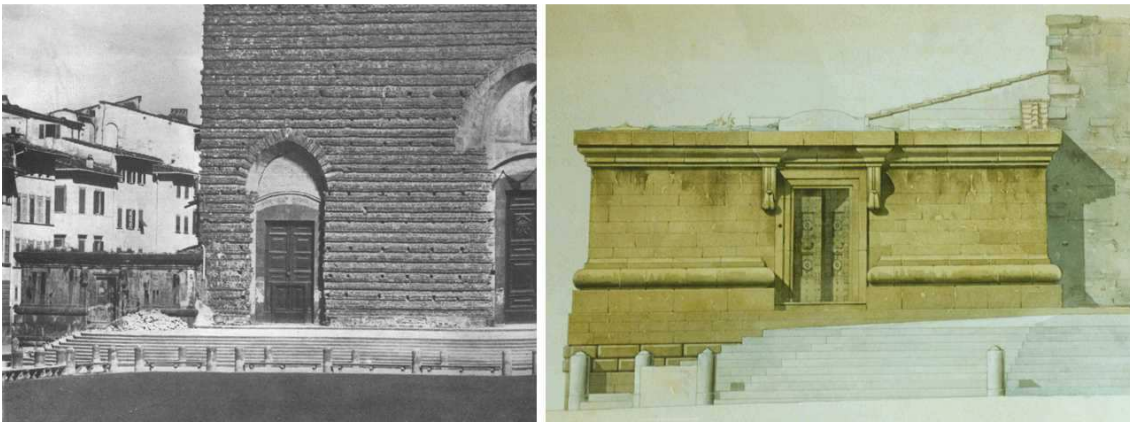


Fig. 5 – The basement of the St. Croce tower bell from Francesco da Sangallo, picture and survey from the XIX century.



Fig. 6 – The St. Croce tower bell from Francesco da Sangallo, original medal and schematic reconstruction.

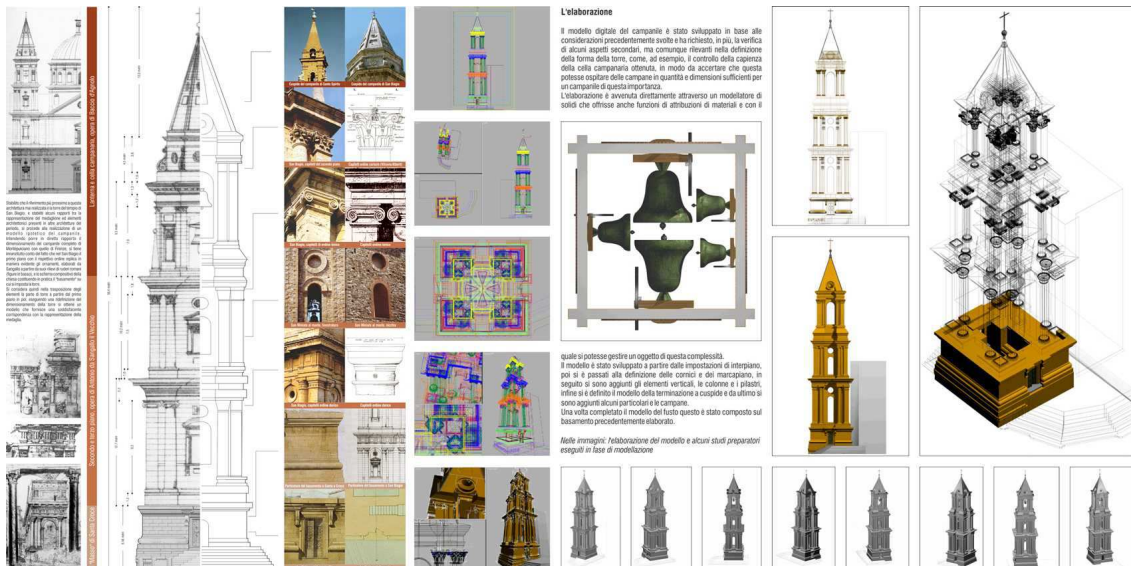


Fig. 7 – The St. Croce tower bell from Francesco da Sangallo, information interpolation for digital reconstruction.



Fig. 8 – The ruins of the Cadi in Granada, at the feet of the Alhambra hill.

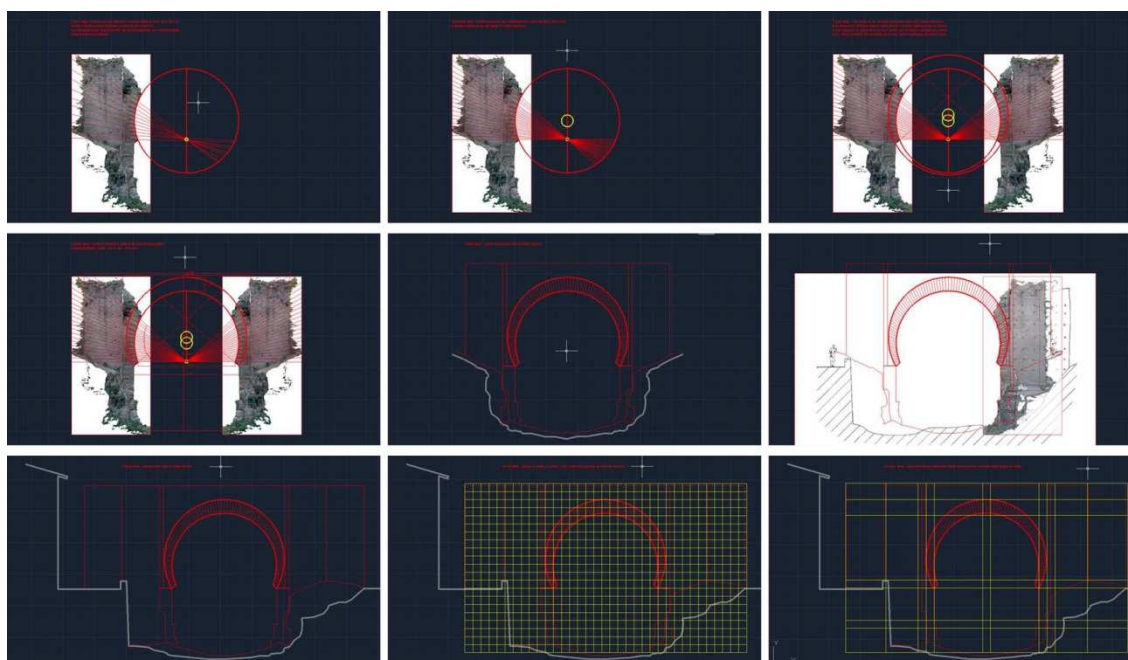


Fig. 9 – Geometrical reconstruction of the Cadi in Granada.



Fig. 10 – First reconstruction hypothesis for the Cadi in Granada (P. Formaglini, F. Giansanti).

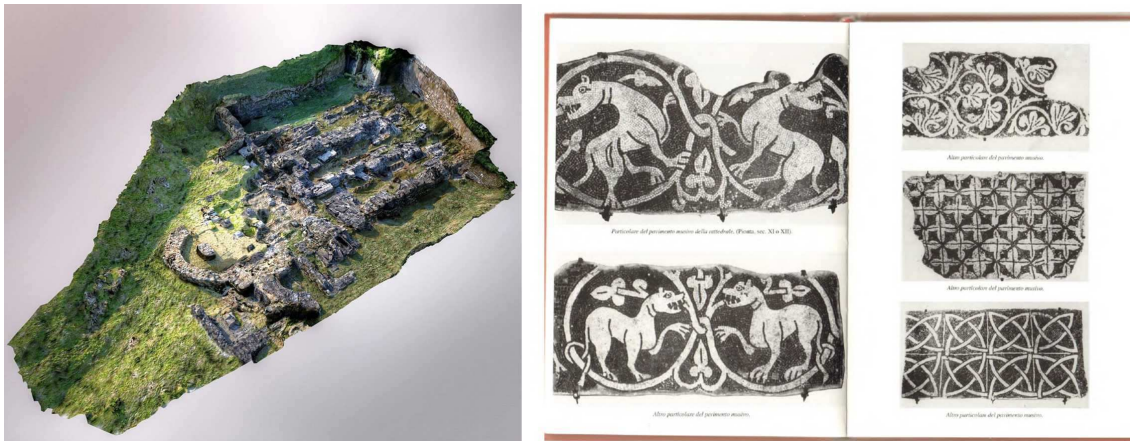


Fig. 11 – Arezzo, ruins of the St. Stefano and Mary church, view from the digital survey (M. Pucci) and remains of the original mosaics, removed during the first excavations.

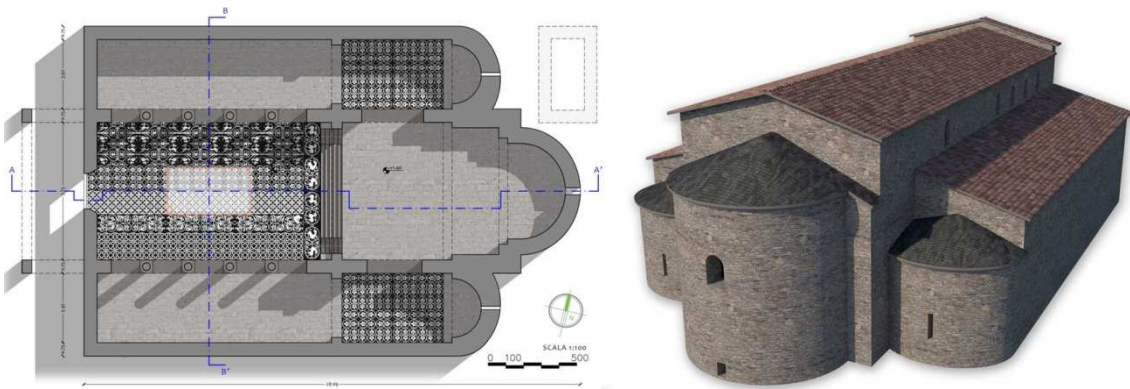


Fig. 12 – Arezzo, digital reconstruction of the St. Stefano and Mary church (I. Giannini).

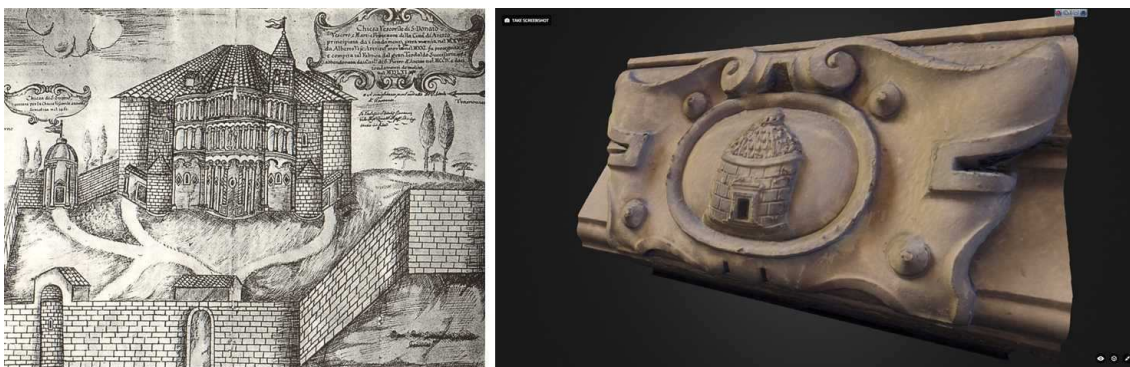


Fig. 13 – Arezzo, graphical fragments about the St. Donato cathedral.

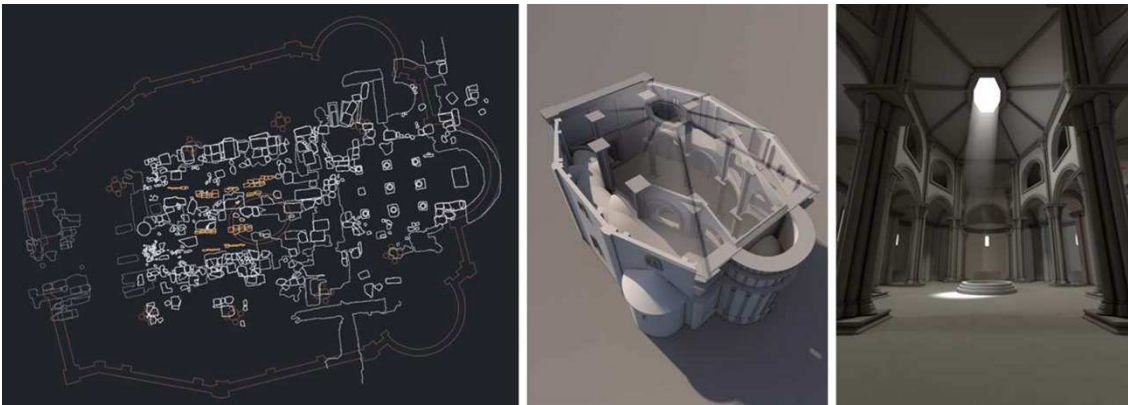


Fig. 14 – Arezzo, Digital reconstruction of the St. Donato cathedral (G. Verdiani and M. Pucci).

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