

# FROM THE SURVEY TO THE 3D ANIMATION: THE SANTA MARIA IN SOLARIO CHAPEL IN BRESCIA (Italy)

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## ABSTRACT

The main task of this work is the digital 3D reconstruction of the Santa Maria in Solario chapel that is part of the Santa Giulia monastery, founded in the year 753.

The use of these new technologies to the cultural heritage, has the aim to become a working tool for the researchers and a tool also for the tourists. The work started from the topographic survey from a net materialised in the Chapel; using these data it was possible to reconstruct the main structure.

For the 3D modelling of the surfaces it was necessary to use a digital photogrammetric approach.

Two hundreds taken of the painted inside walls was carried on, using Rollei 6008 metric camera. Several points were chosen on the painting walls. For the digital restitution the software CDW from Rollei was used. Finally the 3D reconstruction was moved in 3D STUDIO MAX, in the way to obtain a 3D raster-vector image of the architectural building. Is still in run the realization of an animation that will allows to visit the chapel from unusual points of view, with the realism of a faithful reconstruction.

## 1. BRIEF HISTORICAL DESCRIPTION

Before describe the job in the detail it's opportune to give a brief historical description of the environment and of the building object of analysis.

The area on which the monastery rises was inhabited since the iron age, densely and luxuriously built in Roman epoch, center of modest residences in the V and VI centuries. The first archaeological searches has in fact brought to light, from the foundations of the monastery, a vast building complex. Recently has been hypothesized that the area had occupied from a "domus" wide 120 meters and long 60 meters (such dimensions would make it the bigger "domus" between those found in northern Italy). Used for 4 centuries, from the half of the I century to the half of the V century, the "domus" had a series of transformations that show the beginning of the degrade. In fact, in the years of the crisis of the Roman empire, Brescia, invaded from the Visigoti (402) and ransacked from the army of Attila, was involved in the process of impoverishment and decadence that happened in the territories of the empire until his fall (476). This process went on in the period of the Ostrogothic domination (493-526) and in the first times of the Longobard occupation (since 569). There are signs of the degrades and of the destruction also in the archaeological finds of the "domus" of Saint Julia where were found signs of a violent fire that around the half of the VI century struck the already compromised buildings structures of Roman age. In the first years of the Longobard occupation had built huts of small proportions, that used partly of the masonries remained of the "domus" and for the rest used poor materials, clay, wood and dry walls. In the VII century the huts were replaced with constructions of superior quality, as a church. In the 753, for want of Desiderio before he became the Longobards' king, were founded the monastery and the church of Saint Salvatore. At the monastery was attributed the name of Saint Julia in memory of the Cathaginian virgin Saint Julia who, according to the legend, died as a martyr in Corsica and whose relics were brought in the monastery in year 762: since then, the monastery had the double denomination of Saint Salvatore – Saint Julia.

The complex of Saint Salvatore – Saint Julia, from the extension of around 4350 [mq], has constituted from many different buildings, structures and of open spaces connected between them: the churches of Saint Salvatore, Saint Maria in Solario and Saint Julia, the three cloisters, the adjacent local of work and residence of the nuns, the undergrounds and the vegetable – garden.

The monastery had an important economic and politics position and represented a center of religious formation: a college for the principal imperial princesses Europeans destined to have a political important role in the varied short of the Christianity. In the XIII century because of the grow weak of the regal protection and of the peculation of noble local families, the monastery lost much of his power and of his prestige. In the year 1798 a Napoleonic edict destined the buildings of the monastery to barracks and military hospital: gone on to the military property the stable lived in a state of complete abandonment. Only after a century, in the year 1882, was prepared the museum of the Christian age in the desecrated church of Saint Julia, definitely settled in the year 1949: this museum gathers works and artistic evidences of the III and the XVII century.

Actually the monastic complex presents itself in Renaissance forms prevalently. The works completed between the second half of the Four hundred and the end of the Five hundred have restructured the building overall. Only the restructure of the churches of Saint Savior and of Saint Maria in Solario dates back to the epoches former the Renaissance period.

The basilica of **Saint. Salvatore** that now could be seen is not the original one founded from Desiderio, on the contrary a slower construction, dates back to the first years of the IX century and placed on the real church founded from Desiderio: this last one was erected on the ruins of a big Roman building. The Roman building, dates back to the I century, known like the house of the nymphaeum because of the presence of numerous plumbings and tubs, was destroyed at the beginnings of the V century. On these ruins Desiderio made build the first basilica of St. Salvatore, with an aisle, three apses and a dome. In the year 815, above the first basilica was built a second basilica, that still visible.

The church of St. Salvatore has now a longitudinal plant, with three aisles, divided by two lines of columns. The plant of the basilica is inspired by models of Ravenna. The columns and the capitals in stone and in plaster belong to different epochs: from the Roman age to the VIII century. On the walls of the central aisle, above the arcs, are visible traces of frescos of Carolingian age. Along the northern aisle should be seen three chapels added in the XIV century, decorated with frescos of different epoches. The three apses and the wooden roof to trusses belong to the restaurations performed in the 1958.

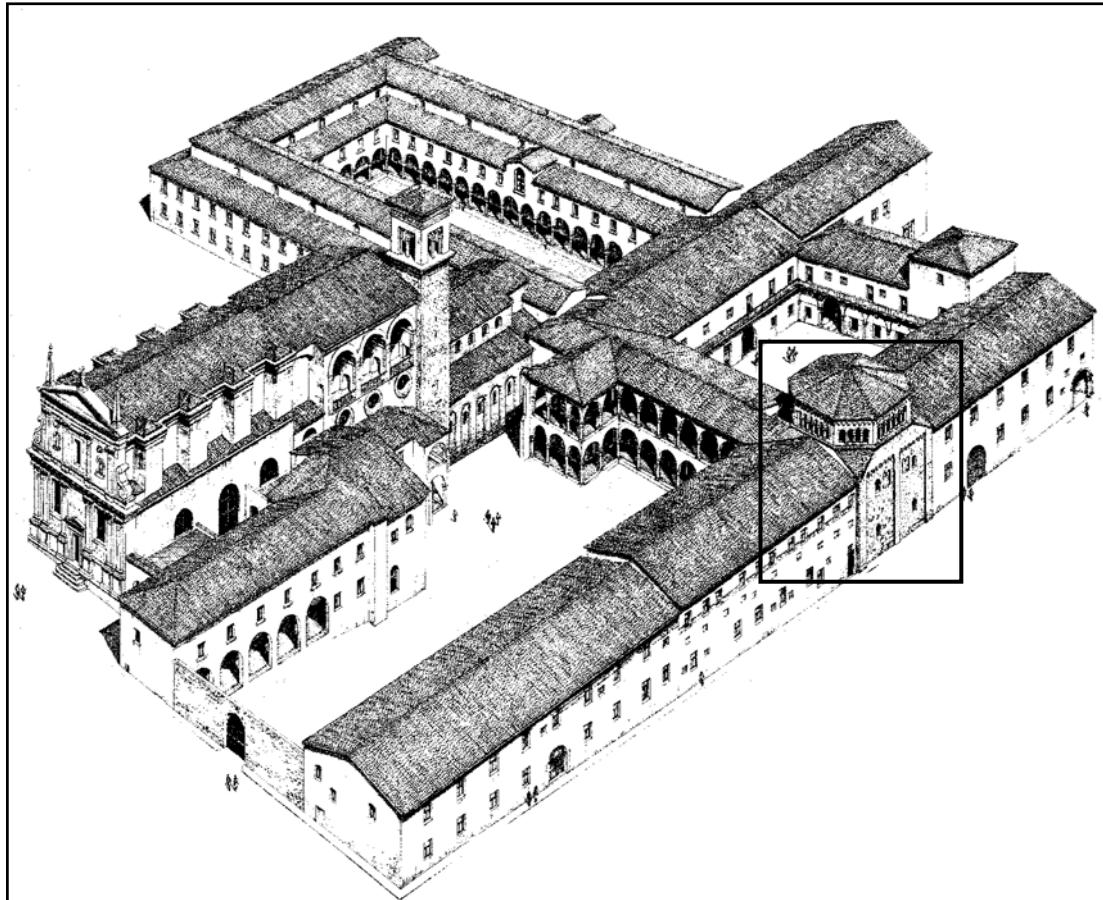
The sacellum (oratory) of **Saint Maria in Solario** built toward the half of the XII century and incorporated in the following amplifications of the monastery, it's like a small fort instead a sacred building. The building of square plant, externally conformed almost to tower, was probably situated in angle to the original monastery. The building structure composed with tanned of local stone (medolo) well square and disposed on horizontal courses, included fragments of Roman headstones. The wall which turns to south is animated from three pilaster strip and decorated in the superior part from simple arcs. The building has an octagonal lantern with a small loggia composed by little arcs on little pillars and mullions. The mullions and the capitals belong to the VIII and IX centuries. The building has two storeys. The ground floor has illuminated from two hold windows and covered with four cross vaults that lean on arcs inserted along the walls and on a Roman altar to the center, used as a pillar.

The upper floor (solarium) of Saint Maria in Solario has a squared plant with three small semicircular niches obtained from the Oriental wall, is covered with a semispheric dome which is connected to the walls with pendentives. In the northern wall a small door introduces staircase, obtained in the thickness of the masonry, that connects the two storeys: a fragment of Roman epoch acts from lintel to the door of the staircase that conducts to the room of the ground floor. At the upper floor there is a second door, today not practicable, which connected this storey of Saint Maria in Solario with the environments of the convent.

The walls are entirely decorated with frescos of different epoches. The best part of the paintings have performed between the second and the third decade of the Five hundred, from Floriano Ferramola. The subjects of the paintings describe the history of the monasticism, the devotions traditionally practiced in the monastery and the struggle against the heresy.

Inside the solarium there is the cross of the Desiderio King that represents an important jewellery work of the end of the VIII century. The cross is in metallic league on wooden structure, has characterized from many of smooth stones, incised or impressed and of glassy transparent cameos of Carolingian epoch.

The architectural form of the building of Saint Maria in Solario finds a justification both in the different use of the two storeys (treasury and church) as from the religious point of view: the inferior square plant, as square it is the representative sign of the earth, raises toward a circular dome, like circular it is the sign of the kingdom of God.



**Figure 1. The view of Santa Giulia monastery. Inside the rectangle you can see the external shape of the chapel.**

## 2. TOPOGRAPHIC SURVEY

The topographic survey made with traditional tools was used to survey the complex architecture geometry and the acquisition of the control points to the goals of the photogrammetric study.

This work has required a long will during the acquisition and elaboration of the informations and during the reconstruction of the geometries. The articulated geometry of the inside architecture has required the survey of many points, imposing the management of a numerous drafts of the varied architectural elements and the schematic position of the points to describe the geometry.

### 2.1 NET SURVEY

The first step was to trace inside the chapel a small net of arrangement, which then has allowed to bring back all the following phases of the survey to an only one system of reference. Therefore is evident how is fundamental guarantee an elevated precision of the work performed in this phase; possible errors would finish in fact to be reflected directly on the measure of points surveyed from it. Because of the limited dimensions of the chapel, the detail regular plant and the presence of a reliquary in which is preserved the cross of King Desiderio, and that represented an imposing visual obstacle, was considered reasonable to proceed with the tracing of a net composed only by four vertexes, arranged to form approximately a square.

Their location was choiced after have appraised with care the complete visibility of the place beginning from them and the possibility to collimate the points of the building surface keeping the instrument at a distance that allows favorable operational conditions and doesn't involve errors due to a too tilted view.

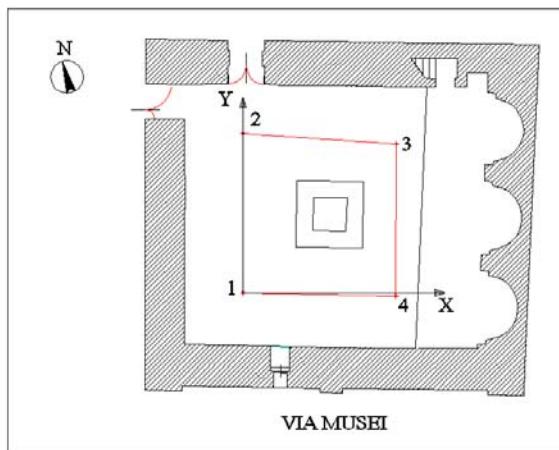


Figure 2. The vertexes net position.

To materialize the vertexes inside the place, was chosen to use small brass nails and fix them in the small cracks which were between the ample stone plates of the flooring. That has avoided damages to the place and at the same time has guaranteed an express and sure recovery of the vertexes in the following operations of measure. In fact it's important to remember that the topographical survey was made in the arc of many months, and during this period the chapel was open to the public.

The position of the collimated points from the vertexes of this net, was related to a Cartesian system with the origin in the point 1 and Y axle directs along the side of the net that unites the vertexes 1 and 2. Following have brought, in the Table 1, the coordinates of the vertexes and the quadratic middle discards gotten at the end of the compensation of the measures by least squares adjustment.

Finally, for each vertex has been realized a monograph that describes their principal characteristics, in particular:

- The identification number
- The coordinates and the quadratic middle discard
- The type of used materialization
- A photographic image that frames the vertex position
- A map of the place where is shown the position of the vertex in comparison with some elements easily identifiable inside the chapel.

The tools used during the topographical survey was a total station Leica TPS 1103 that has assured a precision equal to 2mm + 2ppm in the measure of the distances and of 3" for the angles.

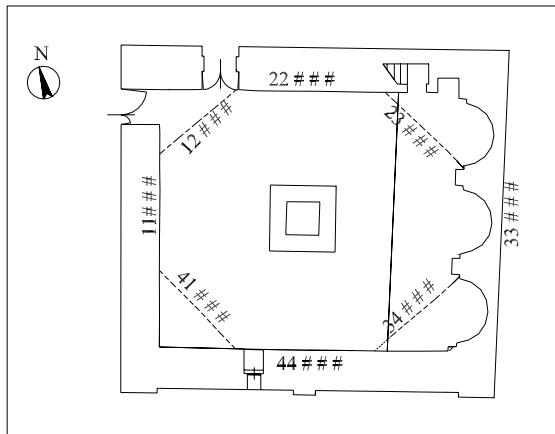
Vertice	X (meters)	Y (meters)	Z (meters)	q.m.d X (mm)	q.m.d Y (mm)	q.m.d Z (mm)
1	100,000	100,000	100,000	0,0	0,0	0,0
2	100,000	105,714	100,046	0,0	0,5	0,1
3	105,487	105,331	100,053	0,5	0,5	0,1
4	105,468	99,887	100,007	0,5	0,1	0,1

**Table 1. Vertices coordinate and relative quadratic middle discard (q.m.d).**

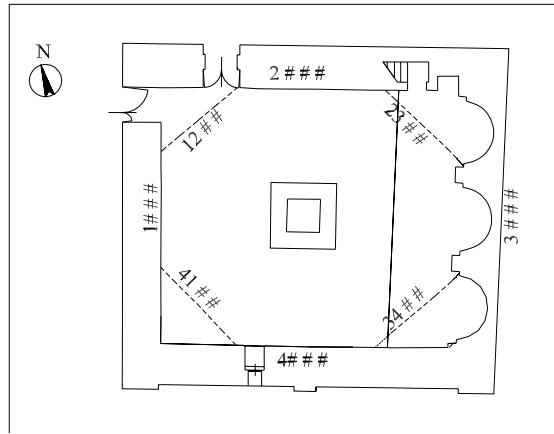
## 2.2 GEOMETRIES SURVEY

Because of the articulated architectural composition of the place, the survey of the geometries was made using an orderly and rational method considering each time surfaces well definite. Therefore the chapel was decomposed in the four sides walls, in the four plumes and in the dome, associating each ones to a different denomination to allow an easy identification. Particular to the wall west, disposed along the side 1-2 of the net, has been assigned the name of "WALL 1," naming the other walls in an increasing way in a clockwise direction. Following the same criterion the plumes have been numbered, to which were assigned the indexes of the two adjacent walls as the first two identified figures.

Because of the many measured points, the demand has risen of assign a number of identification to each. The numeration was made to allow to bring back, immediately and with univocity, each point to the respective architectural element. This procedure was adopted also in the following phase dedicated to the survey of the control points used during the photogrammetric process. For these points a different code of identification has been adopted so to easily realize their difference as regards the previous ones. Following two images describe two different numerations. The # characters symbolize the progressive number code of point.



**Figure 3. Numeration of geometric points.**



**Figure 4. Numeration of control points.**

## 2.3 WIREFRAME MODEL CONSTRUCTION

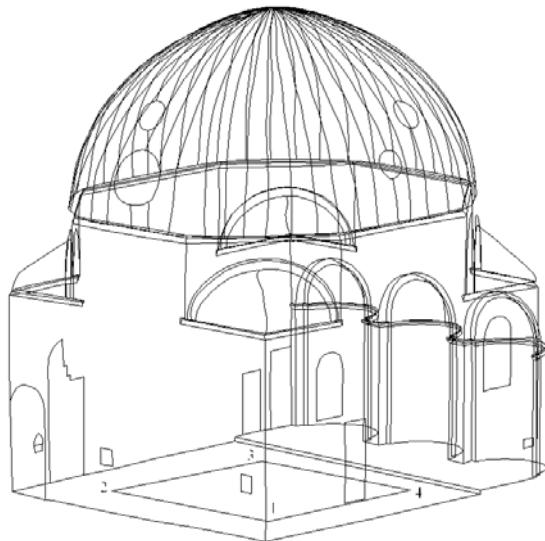
The points coordinates, fixed in the used reference system, were imported in the Autocad software where, using of the spiline command, has been possible to build a three-dimensional wireframe model of the whole local.

This operation, was conducted verifying the exact reconstruction of the geometries as soon as comparing them with the drafts traced during the survey. Because of the presence of a jut out cornice, in the lower part of tambour of the dome wasn't possible to collimate meaningful points. This and other hidden parts from the cone of shade of the element in projection, were therefore rebuilt through a geometric approximation, legitimated from the limited uncertainty.

The following step, always through the Autocad software, was the construction of the surfaces that have allowed to complete the reconstruction from a vectorial point of view and for about geometries of the model. The model used for the surfaces, has called "COON SURFACES" and has characterized from a rectangular meshes that has given proof to approximate in the best way the real surface. Despite that each wall was fragmentized in more portions, so to reduce the approximation and to make the digital reconstruction as near as possible to the real course. This wish is perceivable above all in the reconstruction detailed of frames and pilaster strips.

A particular attention was required from the modeling of the semispheric dome that positioned itself on the four walls according to an octagonal base. To limit the approximation of the reconstruction within acceptable limits, the surface of the semispheric dome has

been divided in 49 parts. That has been possible also thanks to the elevated number of points, around 600, localized in according to the stars painted on the dome that describes approximately the meridians.



**Figure 5. A view of the wireframe model.**

### 3. PHOTOGRAMMETRIC SURVEY

In order to the the photogrammetric survey has been a basic importance the model created at the end of the traditional topographical survey. This has represented a precious tool for the planning of the photographic work in particular way to respect the percentage of overlap and to optimize the operations.

The photogrammetric survey has been used not for the reconstruction of the geometries but for give useful informations in order to map the surfaces richly painted and decorated. So was used the application of the straighten technique for those surfaces that they with good approximation could be considered plain, while for the curved surfaces was used the stereoscopy that has allowed to reconstruct the external orientation of the camera. In both the cases, the photogrammetric survey has required the two following phases of work.

#### - taking the photographic images

The photogrammetric used camera is the Rollei semimetric 6008 with the film size 60mm x 60mm and 3x3 resau. Next, all the photographic images have been scanned with a resolution equal to 600 dpi. Even if the application of the stereoscopy was provided only in correspondence of the curved surfaces, also the ample painted and plain walls has been used a cover for images that guarantee the necessary overlap to the application of this technique (longitudinal overlap= 70% transversal overlap= 30%).

This is essentially due to the wish to create a rich database of images also usable for deepens and detailed elaborations of the chapel. That has carried to create a collection of images composed by about 200 photos, each one identified with a code number. A special study was made to search the right film for the environment in which the work was made.

In fact should be remember that inside the chapel there is dim light because the light penetrates into the room only through the small apertures which are at the base of the dome. This is due to the wish of recreate an atmosphere of the middle age and for the necessity to preserve the integrity of the frescos.

After a series of proofs that have allowed to try more films and different conditions of illumination, the film Kodak Ektachrome 160T has been considered the most suitable film for reproduce the valuable frescos at the best.

#### - control points survey

The survey of the control points has been conduced with the same instruments used during the geometry inquiry .

The choice of the points to use during the operations of digital photogrammetry, has made because the necessity to distinguish the point on the image with clarity. With regard to this necessity, in more situation have been found many problems connected with the difficulties to find elements univocally identifiable like points on the painted surface.

This difficulty is connected also with the impossibility to apply opportune spot that could have damaged the fragile frescos. For what concern the dome, the operations were simpler thanks to the presence of a series of stars disposed along the meridians of the dome; that has allowed to consider the same points measured during the reconstruction of the model as control points.

### 3.1 PLANAR SURFACES

As told before, for the surfaces that with good approximation could be considered plain, has been used the technique of straighten. Particularly in this way have been reconstructed the images of the four ample walls, for each one have been straightened and merged about 25 images. The result obtained at the end of this elaboration has required a small intervention of photograph-retouch to eliminate sudden changes of contrast or illumination between the images.

The software used for the operations of straighten is the Rollei MSR. The final result has satisfied completely the expectations, bringing to light many frescos that aren't in general clear visible to the usual visitor because the low illumination.

### 3.2 CURVED SURFACES

For the surfaces of the niches, of the plumes and the dome is been instead applied the stereoscopy. That has foreseen the use of a special CDW software of the Rollei that has allowed, beginning from the photographic images and from a series of points of support, to reconstruct the camera orientation at the moment of release, during a photogrammetric bundle adjustment. The result of this operation wasn't as for the plain surfaces a straightened image, but numerical informations used in the following phase of mapping.

## 4. 3D MODELLING

After have created the model through the AUTOCAD software and have gotten the results of the photogrammetric elaboration, these informations were inputed in a software that can allow to integrate them, in order to respect the precisions required as work objective and to obtain the valuable results also from the point of view of the quality of the graphic restitution. For this purpose has considered as the ideal tool the software 3D STUDIO MAX.

### 4.1 SURFACES MAPPING

The phase of mapping of the images upon the 3D model, created on the base of the geometries measured during the topographical survey, was completely realized through the software 3D STUDIO MAX.

The methods used were different according to the surface that were to be mapping. Particularly a different procedure was used for the dome which has required a specific study. On the base of the photographic cover and in order of the semispheric geometry, was considered reasonable, also according with the precisions to obtain, to divide the calotte surface into 12 segments. With the informations obtained through the application of the CDW software, each single segment was mapping, verifying for each ones the congruence in the position of the numerous painted stars, that define the meridians of the dome. The gotten results have been satisfying and consistent with the objectives imposed.

An analogous procedure was used for the niches and the plumes: in fact it has been sufficient use the 3D model as a screen and project the corresponding image using raytracing techniques. The "Digital Projectors" use the same interior and exterior orientation as related cameras, obtained from bundle adjustment. This has been possible thanks also to the potentialities offered from the software 3D STUDIO that has allowed to set the parameters in a correct way. An other big advantage of this software is the complete compatibility with the AUTOCAD software, used for the reconstruction of the geometric model.

Simpler was instead resulted the mapping of the images previously elaborated through the MSR software, for which has been sufficient to project directly the image upon the corresponding surface through a plane parallel to the same surface. The image gotten at the end of straighten and merge phases is in fact an orthogonal projection of the photographed surface.

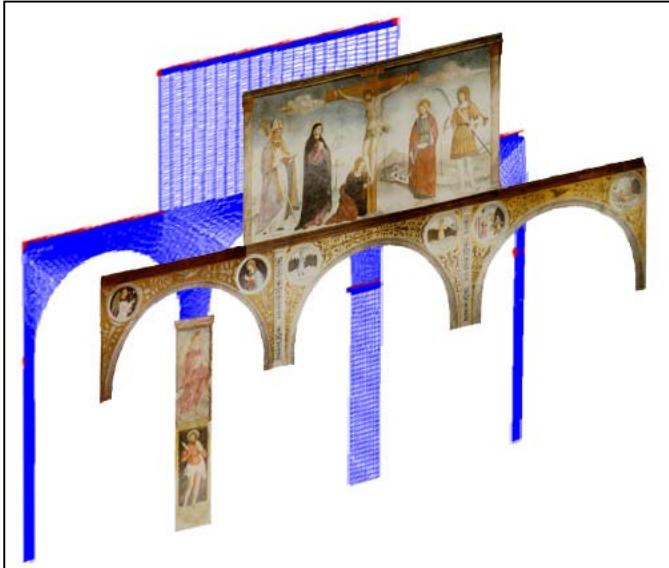


Figure 6. The mapping plane in this case is parallel to the surface.

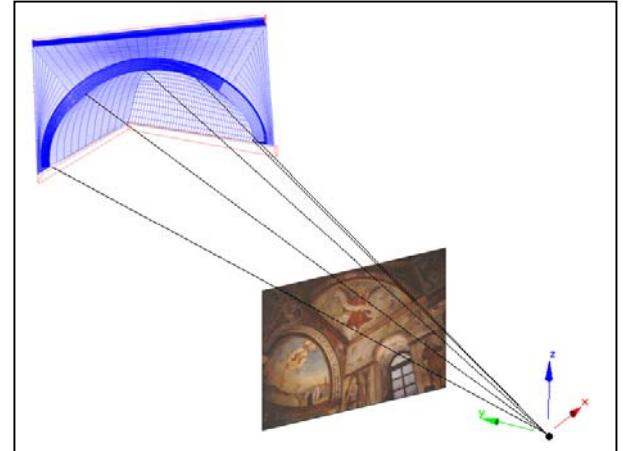


Figure 7. The surface model has been used as a projection screen.

## 5. CONCLUSIONS

The principal meaning of this work is in the study of the traditional and advances techniques of survey, in order to individualize a methodology of approach to the faithful reconstruction of the digital model of an architectural building.

The obtained results, can and must be valued according to different points of view, represented, not only from their quality, but also from the financial investment demanded for an intervention of this kind and from the necessary times to his realization.

In fact to elaborate the gathered informations have been necessary long hours of work with a powerful stations of calculus.

Also the various finality of this work can't be neglecting: in fact doesn't take the place of a real visit to the architectural building, but wants to allow the visitors a personalized and complete fruition of the heritage, offering a completeness of informations that make this tool an important means of divulgation. In fact is important to remember that different compression formats of the digital video allow to limit the dimensions in terms of memory and therefore to carry to a better facility of diffusion of the multimedia product.

Moreover is important to underline how the digital reconstruction is founded strictly on a topographical principles and is connected with a survey for which have used technologies that guarantee a degree of accuracy that makes it an important cognitive tool also for scientific studies.

Just the versatility of the obtained result has been one of the principal objectives that the explained work wanted to hit, allowing also during the same survey, the creation of a precious database composed by images and geometries.

## 6. REFERENCES

- BEZOARI G., GUZZETTI F., *Impianto generale di un rilievo architettonico*, in «Recuperare», 2, 1992.
- CROSILLA F., VISINTINI D., *Controllo di qualità del raddrizzamento digitale per il rilievo dell'architettura*, in «Bollettino della S.I.F.E.T.», 2, 1994.
- COLOMBO L., *Dalla rappresentazione fotogrammetrica classica ai modelli raster tridimensionali*, in «Bollettino della S.I.F.E.T.», 4, 1994.
- CUNDARI C., *Rilievo architettonico e fotogrammetria*, Napoli, 1979.
- KRAUS K., *Fotogrammetria, Volume 1: Teoria e applicazioni*, Levrotto & Bella, Torino, 1994.
- MALINVERNI E.S., *Applicazioni di fotogrammetria digitale nel rilievo di architetture*, in «Bollettino della S.I.F.E.T.», 1, 1996.
- MONTI C., *Per una conoscenza metrica dell'Architettura*, in «TEMA rivista trimestrale di restauro. Dossier: «Un rilievo per il restauro?»», 3-4, 1996.
- RANELLUCCI S., *Ricerche ed esperienze sulla restituzione grafica per la conservazione*, in «TEMA rivista trimestrale di restauro», 3, 1995.
- SELVINI A., *Elementi di fotogrammetria*, Città Studi, Milano, 1994.
- VASSENA G. ARENGHI A., *The use of topographic and photogrammetric surveys as input for 3D virtual reality tours, the survey data storage using HTML*, in: Cultural Heritage Networks Hypermedia, “2<sup>nd</sup> International Conference, Milan, 13-16 September 1997.
- VASSENA G. ARENGHI A., *Archivio di Stato di Mantova. Operazioni di progetto, misura e compensazione della rete topografica generale di Inquadramento. Certificazione delle operazioni di rilievo fotogrammetrico*, in: relazione tecnica, Brescia.
- VASSENA G., DELLA TORRE S., FERRARI F., RIINA G., “Il rilevamento finalizzato al progetto di conservazione. Il caso della torre dell'antica rocca di Serignana”, Stampato in proprio ai sensi della legge 22/1939 n.374 e obblighi previsti dall'art. 1 del D.L. luogotenenziale 31.08.1945 n.660, Brescia, maggio 2000.