# ARCHITECTURAL SURVEY OF THE VAULTS OF SANGALLO'S HOUSE IN FLORENCE

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## ABSTRACT

Many technologies have been used in cultural heritage conservation and documentation in recent years. One of these techniques, laser scanning which is increasingly becoming popular in late years is used for various purposes like surveying, modelling, archiving and visualization in the field of cultural heritage. Plenty of works have been done in heritage documentation with laser scanning technique allowing the user to achieve different information from a 3D model and helping to investigate the shape and components of heritage. This paper deals with how a 3D model can be used to identify the construction technique of heritage and the application of laser scanning for the generation of 3D models of the vaults in Sangallo's House in Firenze. The aim of this study is to compare the shape and the constructive techniques of surveyed vaults. To achieve this aim, we needed to obtain the thickness and the morphology of the vaults, and this information was provided by laser scanner survey. The paper presents applied technology and instruments used, steps of graphical evaluation and 3D, comparisons between the vaults. In order to make comparison, detailed surface modelling was needed to understand them and to be able to see the differences between construction techniques of the vaults. Leica HDS 6000 laser scanner was used for the generation of 3D model of the vaults. Then point clouds were registered in Cyclone. After that, cross sections were extracted from 3D model to understand vault thickness, shape and to have an idea about how they were built. The results will be displayed and evaluations will be made as conclusion.

**Key words:** Constructive Techniques, 3D Scanning, 3D modelling, Vaults, Sangallo

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## 1. THE SANGALLO'S HOUSE IN FLORENCE

The house that Giuliano and Antonio da Sangallo built for them in Borgo Pinti, Florence, is now known as Palazzo Ximenes-Panciatichi and it has never been studied systematically. In 1902 Cornelius von Fabriczy (von Fabriczy 1902) published some documents on it, but since that moment no other further research has been carried out on the history of the building or its material structure. Recent document researches and detail recordings concerning some rooms allow shining a new light on the history of the house and the techniques used to build it.

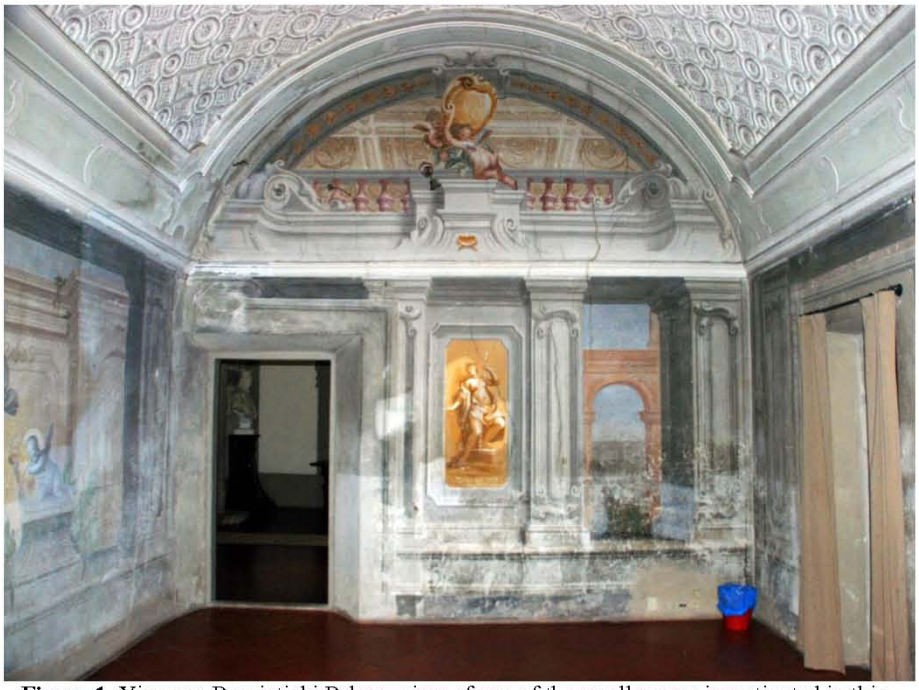

**Figure 1.** Ximenes-Panciatichi Palace, view of one of the small rooms investigated in this study.

The land was purchased by Giuliano and Antonio between 1490 and 1491, but the progress of the building works was slow. When the two brothers wrote their last wills, the building was still unfinished. After Giuliano's death in 1516 and Antonio's death in 1534, the property of the house passed from one member of the family to the other, and in 1603 it was sold to Sebastiano Ximenes, a Portuguese merchant linked to the Grand Duke's court. He restored the building and started its enlargement. Further enlargements and modifications were made during the 17$^{th}$ century and above all the 18$^{th}$ and 19$^{th}$ century (Belli 2012). These work campaigns transformed the original building - enclosed in a square area with a side of 40 *braccia fiorentine* (a unit of measurement equal to approx. 58 cm, that means a side

of approx. 23 m) and built up on just two floors – into a wide stately palace, enriched with a big garden and built up on four main floors.

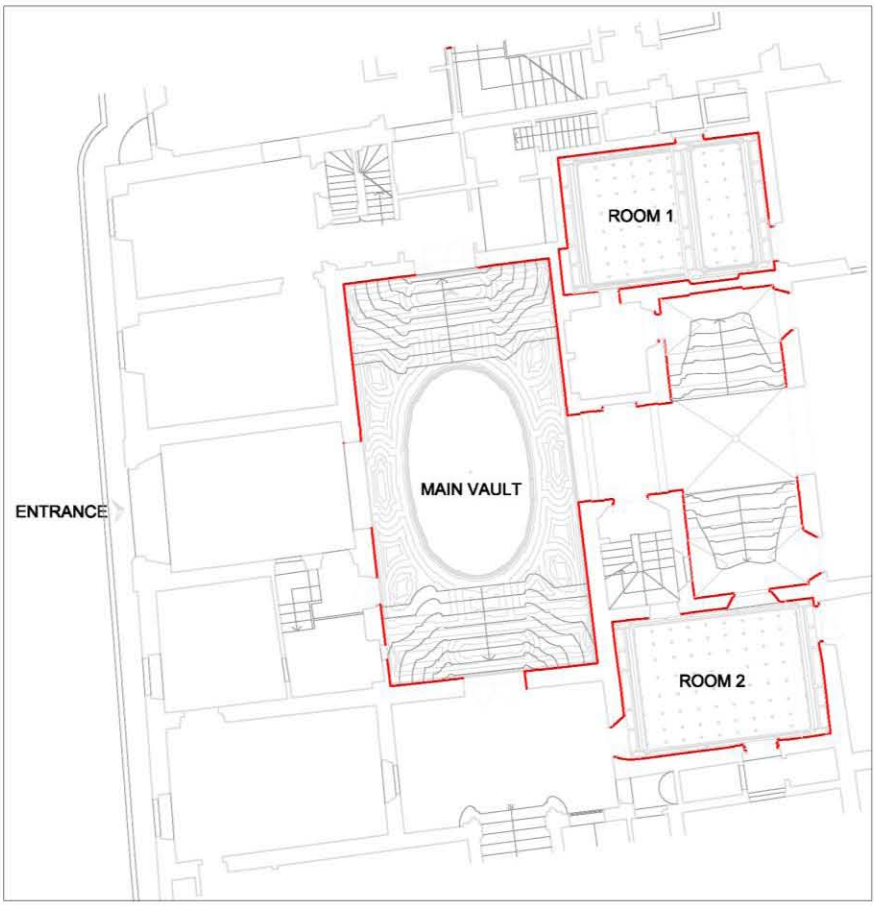


**Figure 2.** Plan of the original nucleus of the Sangallo's House in Florence. In red you can see the rooms subject to the survey campaign with laser scanner described in this report, while the representation of the adjacent rooms has been inferred by a previous survey (by Arch. Ilaria Filippini).

## 2. THE VAULTS STUDIED

Despite the alterations, the most ancient nucleus of the palace is even today easy to be detected. It is characterised by a perfectly symmetric U structure, which develops around a wide cross double-height room. On the back, on the sides of the loggia facing the garden, there are two equal rooms, covered by stuccoed barrel vaults. The kind of decoration and the technique used are typical of Sangallo, and in fact these

vaults have always been considered as the few original elements that survived transformations. Instead, not enough attention has been paid to the big barrel vault covering the central room.

### 2.1. The vault of the central room

Altered by 18th-century banded decorations, the vault has been considered as an intervention occurring later than the first building phase (Marchini 1942). But the strict analogies between the plan of the house in Borgo Pinti and the plan of the villa in Poggio a Caiano, designed by Giuliano da Sangallo for Lorenzo de' Medici in the same years, lead us to believe that the vault had always been there. In Poggio a Caiano too, in fact, the most important room is made up of a big transverse room, covered by an impressive barrel vault. The Sangallo origin of the vault in Borgo Pinti is supported also by another evidence. In the *Life* of Giuliano da Sangallo, in fact, Vasari included an anecdote according to which to convince Lorenzo to build a big barrel vault in the room of Poggio a Caiano, the architect built a similar vault in his own house (Vasari 1878-1881). So, when Vasari wrote the *Lives* (published for the first time in 1550), the vault should have already been built and noticed by him, as he surely knew the Sangallo's house being a friend of Francesco, Giuliano's son.

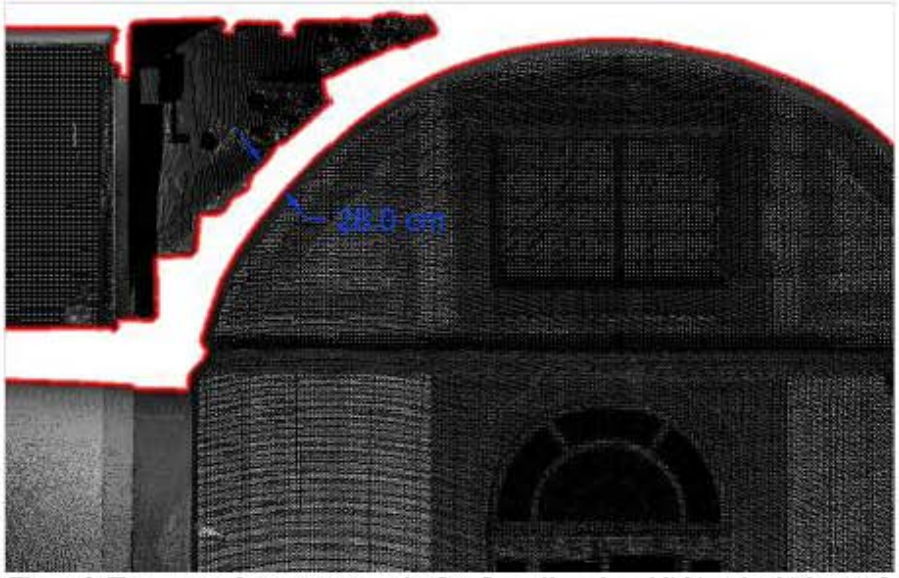


**Figure 3.** The survey of some rooms on the first floor allowed establishing the thickness of the vault of the big access area: approx. 28 cm.

The vault is smaller in size, but it can be compared to the one in Poggio a Caiano (approx. 13.50 x 6.90 m against 19.80 x 10. 50 m), and additionally they seem to have been built through a single concrete casting, as you can see by inspecting the extrados. It is an ancient technique, which has been brought from Rome to Florence by Giuliano da Sangallo, according to Vasari (Vasari 1878-1881).

### 2.1. The vaults of the minor rooms

The direct surveys on the vault covering the minor room at south, which were carried out inside a hole in decoration, proved that this structure too is made of concrete and the material used to built it is similar to the one of the bigger vault. The vault seems to bear no load, as over the casting (whose keystone is 11 cm thick) we noticed a wooden element, probably the joist of a slab. Instead, it was not possible to carry out a similar inspection on the vault of the room at north, as the decoration there has no holes and it is impossible to access the extrados (unlike the previous case). However, we can reasonably assume that in this case too the same technique has been used.

## 3. THE NEED FOR A HIGH RESOLUTION SURVEY

To have further data on the two smaller vaults and on the one in the central room we thought about carrying out their survey with suitable tools to ensure extremely precise results. We needed some information on the exact geometry of the vaults to confirm the hypothetical building techniques. We also considered it appropriate to compare some particular sections of the two small vaults, as well as their profile with the one of the bigger vault. In the first case, the aim was checking the possibility that the same rib had been used for both structures, while in the second case the aim was understanding if the shape and the structure of the big vault reproduce on a bigger scale those of the minor vaults, to further support the hypothesis that the coverage of the central space too dates back to the first (Sangallo-style) phase of the works. Finally, we analysed the stucco decoration of the two minor vaults. On their intrados we always noticed a decoration module made up of a circular crown containing four small figures, which is crossed by four smaller circles. This motif was made by impressing in succession a square mould (maybe of wood) with a side of one *braccio* (approx. 58.6 cm) onto a very thin layer of gypsum mortar. The particularly detailed 3D survey of the intrados available suggested the possibility of comparing (by overlapping them) a couple of modules extracted from the two vaults, in order to check whether the same mould was used and thus have another useful element to date these structures.

### 3.1. 3D scanning systems

To survey the rooms we used the 3D scanner Leica HDS6000 of the GeCo Laboratory (University of Florence).
A 3D scanner is a tool that can automatically record 3D coordinates of points evenly distributed on a portion of the surface of an object. The surveyed points have a high resolution.
The choice of using 3D scanning systems is related to their ability to make higher sampling of the space compared to traditional topographic instruments. After some data processing, a complete database of geometric information is provided and it is possible to display a full 3D model, which can be explored in real time.

### 3.2. Topographic survey

Each range map is initially formulated within a reference system built in the scanner. Common reference points were needed to link all the data acquired from different positions: for this purpose we used points of known coordinates in a single reference system, materialized by means of specific targets, which were measured topographically starting from the vertexes of a topographic framework. The design of this framework was carried out to meet the specific needs of the project, i.e. defining the correct mutual position of rooms that are not directly connected. In particular, we needed to connect the rooms on the first floor with the ground floor to assess the thickness of the vault covering it and to position the minor room at north (room 1), whose access door from the loggia has been infilled. The topographic connection was thus made by carrying out measurements through a small window and by positioning a vertex in the small adjacent room.

### 3.3. Quantification of the data acquired through 3D scanning

The number of 3D acquisitions required depends on the range of 3D scanners and on the complexity of the object being surveyed. In this case we carried out 6 scans for the minor rooms, 4 scans in the big room, 2 scans for the portion of extrados on the upper floor and 4 scans in the connecting rooms, for a total of 14 scanpositions. The scanning was carried out with a field of view of 360 degrees horizontally and 155 degrees vertically (excluding only the shadow cone projected by the tripod), with resolutions defined according to the level of detail of the surfaces surveyed. To document the stucco decorations of the minor rooms we used the "highest resolution" (that means about 3 mm spacing between points at a range of 10 m), while for the adjacent rooms a "medium resolution" was sufficient (that means about 1 cm spacing between points at a range of 10 m). In total we acquired over 740 million points.

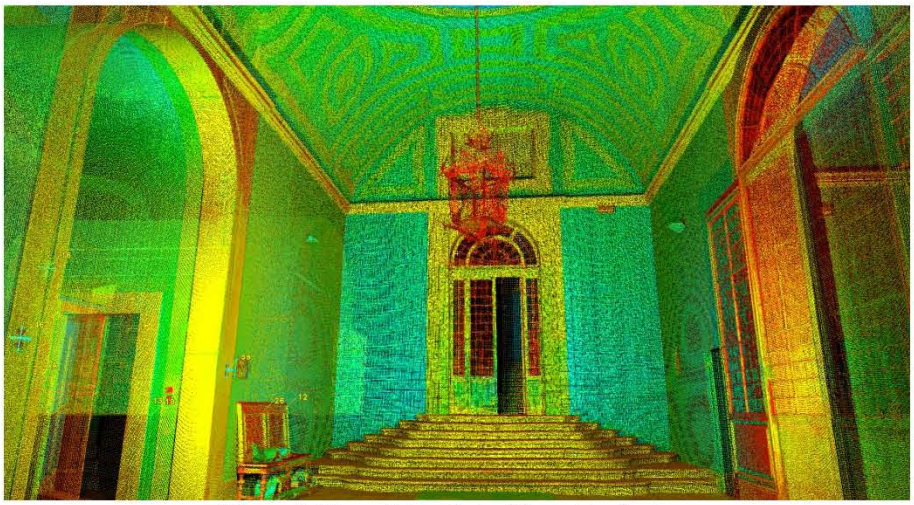

**Figure 4.** View of the whole 3D model of points

## 4. GRAPHICAL ELABORATIONS ON ACQUIRED DATA

The database is the starting point from which it is possible to extract different kinds of information required for documenting the building: raster (orthoimages), vectorial representations and three-dimensional models.
The representation of the plans, views and section profiles has been performed through the geometric interpretation of the subtle lines of the clouds of points. All the graphic representations are two dimensional, but they keep their referential three dimensional homogeneity: every processing belongs to a plane where both the position and the lying position in the defined space of the adopted reference system are known.

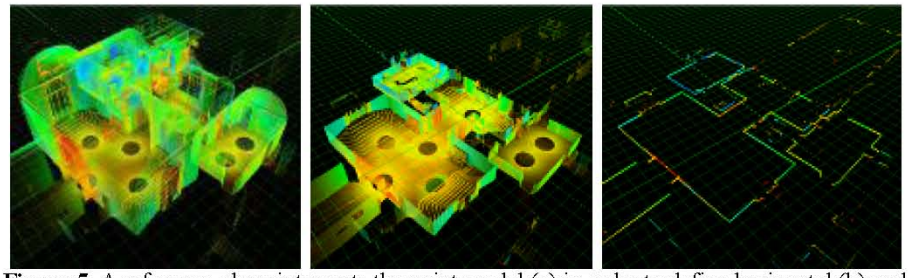

**Figure 5.** A reference plane intersects the point model (a) in order to define horizontal (b) and vertical sections; a "slice" of the point model (c) is the base for vector drawings.

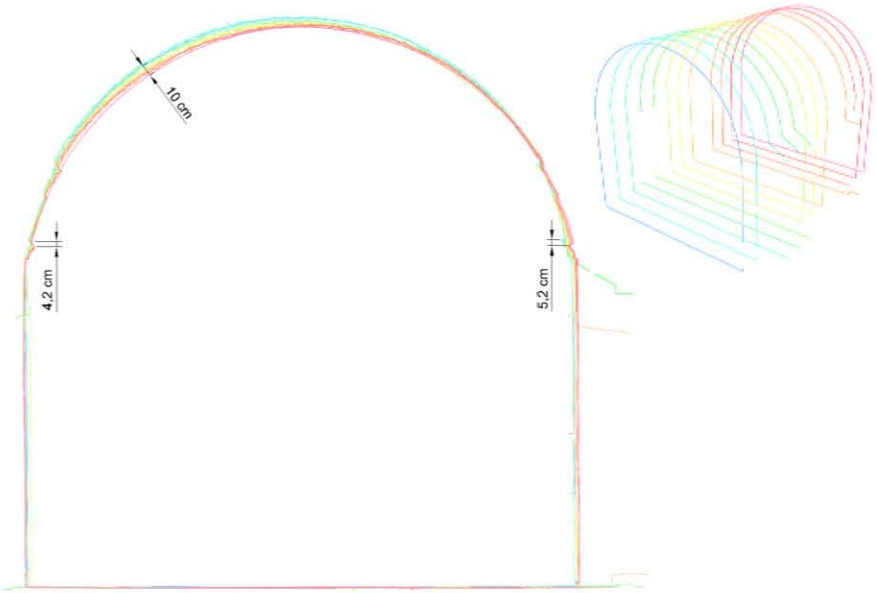


**Figure 6.** A series of cross sections of room 2, with a distance of 50 cm (the reference plane fits one of the short walls). They allow quantifying the deformation of the structure.

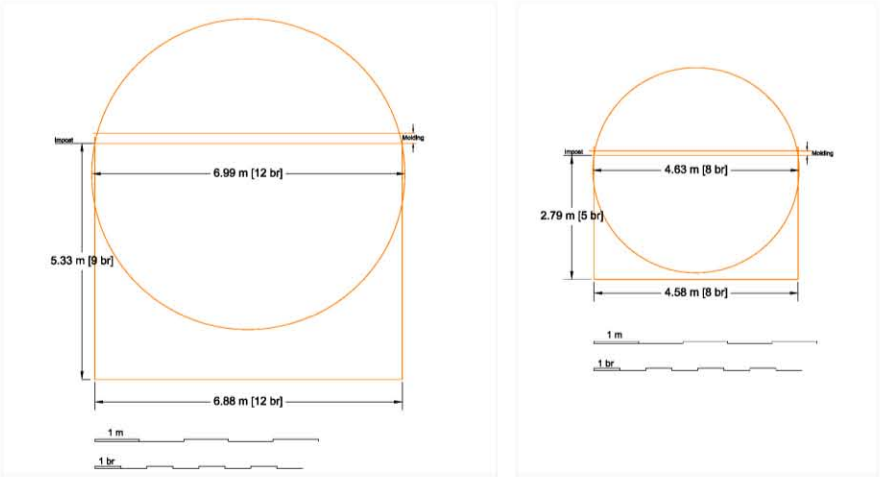


**Figure 7.** The sections of the vaults in the big room and of the minor vaults are formed by round arches and they are all connected to the wall through a vertical tangent, except for minimum deviations, which cannot be perceived directly as it is hidden by cornices.

The high resolution adopted during the acquisition phase allows obtaining some ortho images of the point model: these are raster data in which the metric value is ensured by the definition of an orthogonal viewpoint and a prefixed plane, and the chromatic information comes from the intensity with which the laser signal is

reflected by the surface hit. Starting from these drawings it is therefore possible to represent the elements in sight, such as the projection of the vault decorations.

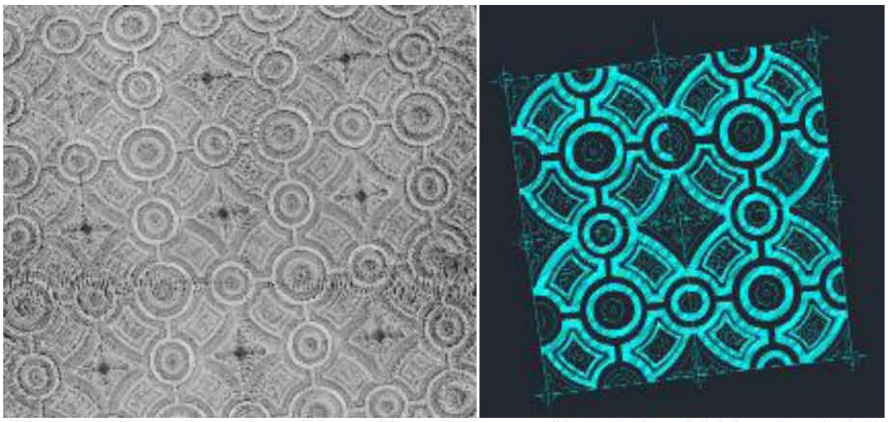

**Figure 8.** Stucco decoration of the vaults: orthoimage of the point model (a) and vectorial representation (b).

The point model surveyed through scanning represents an extremely detailed (even though discrete) description of the surfaces of the object. To reconstruct their continuity we need to calculate a mesh, i.e. a continuous surface made up of triangular faces sharing an adjacent side. Further processing is thus required to optimize the mesh, close any possible hole, and simplify it with the aim of improving its usability.

**Figure 9.** Surface models of the vault in room 1 (a) and room 2 (b).

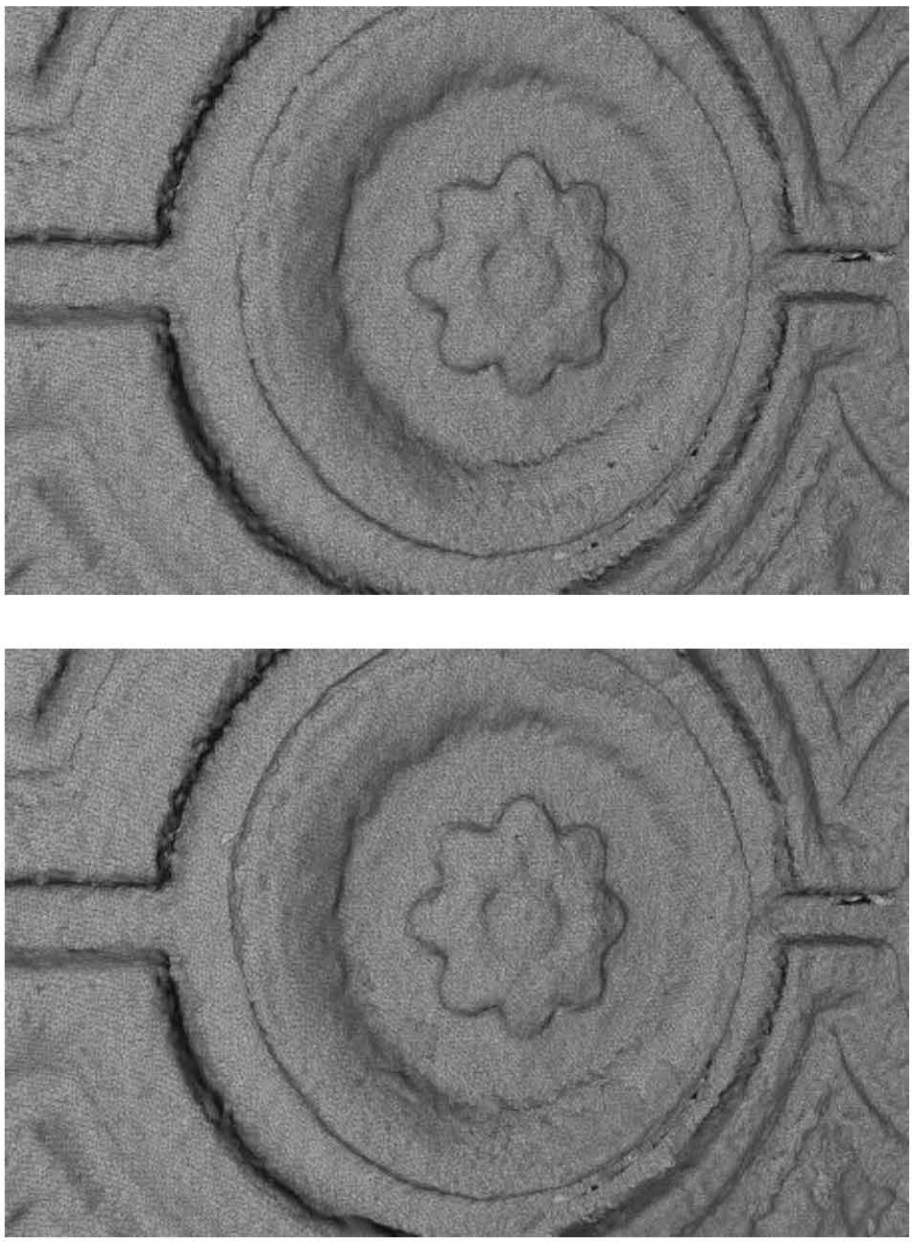

**Figure 10.** A very detailed view of the decoration of both vaults – wireframe model (a - room 1, and b - room 2).

## 5. CONCLUSIONS AND FUTURE POSSIBILITIES

The completeness and resolution of the data surveyed in the vaulted rooms allowed carrying out drawings useful to interpret historical-building aspects, as well as quantifying the size that characterises the vaults in terms of structure (span, curvature and thickness) and decoration.
To study the geometry of the vaults we needed to assess their size expressed in *braccia fiorentine da panno* (58.36 cm), i.e. the unit of measurement used at the time of their construction. Moreover, the aim of reconstructing their design geometry, which can be directly compared with what is described in coeval manuals, required space geometrization. The irregularities and deformations due to the building of the architecture have thus been neglected, paying more attention to an "ideal geometry" of the vaulted rooms. In particular, the following aspects have been neglected: out-of-plumb, out-of-line and bowing of the walls, the difference in height of the cornices on the opposite sides of the room, and the presence of stucco decorations. Thanks to the high resolution of the laser scanner survey we managed to compare the real building with its geometrization and thus quantify what we can call the "tolerance of the architecture". In the case of the surveyed rooms, this value is approximately 5 cm and it represents a limit to be taken into consideration while studying the geometries and their proportions.
The sections of the vaults in all the three rooms have a perfectly semicircular profile, with a diameter equal to 4.63 m (8 *braccia*) for the minor rooms and 6.99 m (12 *braccia*) for the central room, values that correspond to the design dimensions. In every room the vault springer is next to the lower level of the cornice.
The small dimensional differences between the vault diameter and the room width generate a slightly depressed arch.
The other drawings presented to describe the development of the cross section and the type of springer highlight the compliance among the three vaults analysed.
We can notice that the plan proportions of the rooms seem to be calculated according to the size of the ribs: for the bigger room the plan sides (13.50 m x 6.90 m) approximate a ratio of 1:2 (12 x 24 *braccia*), while for the two minor rooms (6.80 m x 4.60 m) they approximate a ratio of 2:3 (8 x 12 *braccia*).
For the larger vault it was also possible to determine the thickness of the reins, equal to approx. 28 cm. Thanks to the data obtained on the extrados, the thickness of the vault could be even throughout its whole width. These data confirm the direct observation of a small portion of accessible extrados and the fact that the vault was built entirely through casting and not with bricks. We can notice that the keystone thickness of the vault in one of the minor rooms, which has been directly verified, is proportionally lower compared to the one of the big vault (11 cm).
With the aim of hypothesizing a date for the two smaller rooms, we analysed the stucco decoration by means of surface models and high resolution. The analogy between the decorations shown in the figures above confirm the hypothetical reuse of the same mould, even if in one of the rooms small stucco pyramids have been added to the corners of the square tiles to mask the junction of the adjacent impressions. Even though it is not possible to date the construction or decoration of

the vaults, they can be considered as coeval or built within a relatively short period of time.
We have shown here the first results of a reserch that will continue with further processing of the data acquired to compare thoroughly the two minor rooms and further verify their building technique. Moreover, we wish to assess the possibility of an original continuation of the decoration impressed under the 18th-century bands currently present next to the springer of both smaller vaults, by using a digital model of the general conditions as the basis of a hypothetical virtual reconstruction of the look of the rooms at Sangallo's time.

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