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# The vault with intertwined arches in Castle of Racconigi: 3D digital reconstruction

Fabrizio Natta<sup>1</sup>

<sup>1</sup> Dept. of Architecture and Design, Politecnico di Torino, Viale Mattioli 39, Torino, Italy  
fabrizio.natta@polito.it

**Abstract.** The complex approach of Guarini to each discipline (Geometry, Architecture, Philosophy, Astronomy) finds important development in his method of implementing vaulted systems.

The importance of this architectural element, which Guarini reminds as “the main part of the buildings”, is reflected in the new taste of the civil architecture of the period.

The design by Guarini for the vault in the Hall of Honor in Racconigi Castle is documented in a single drawing representing the hall’s cross-section. Guarini devotes particular attention to the drawing, both from the geometric and the representative point of view.

Based on this drawing we want to propose, through the most recent digital modeling and visualization methods, a three-dimensional reconstruction of this unrealized work.

The analysis method involves an in-depth examination of: Guarini’s theory and his systematic approach to vaulted structures, linking Architecture and Geometry, the problems of design the artifacts, the comparison with similar shapes designed by the architect.

Through a method of representation based on geometrical principles, the aim of this paper is to give evidence – and a three-dimensional visualization – of a case study documented by an archival source, already analyzed by historians.

**Keywords:** Guarino Guarini, Architectural drawing, Vaulted systems, 3D digital reconstruction.

## 1 “On the vaults, and various modes of making them”

The complex approach of Guarini to each discipline (Geometry, Architecture, Philosophy, Astronomy) finds important development in his method of implementing vaulted systems.

The importance of this architectural element, which Guarini reminds as “the main part of the buildings”<sup>1</sup>, is reflected in the new taste of the civil architecture of the period. The discourse about the vaulted systems is articulated by Guarini through three texts: *Euclides adauctus* (1671), *Modo di misurare le fabbriche* (1674) and *Architettura Civile* (published posthumously in 1737) [1].

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<sup>1</sup> Guarini, G.: *Architettura Civile*. Treat. III, Cap. XXVI, «Delle Volte, e varj modi di farle». Mairesse, Turin (1737).

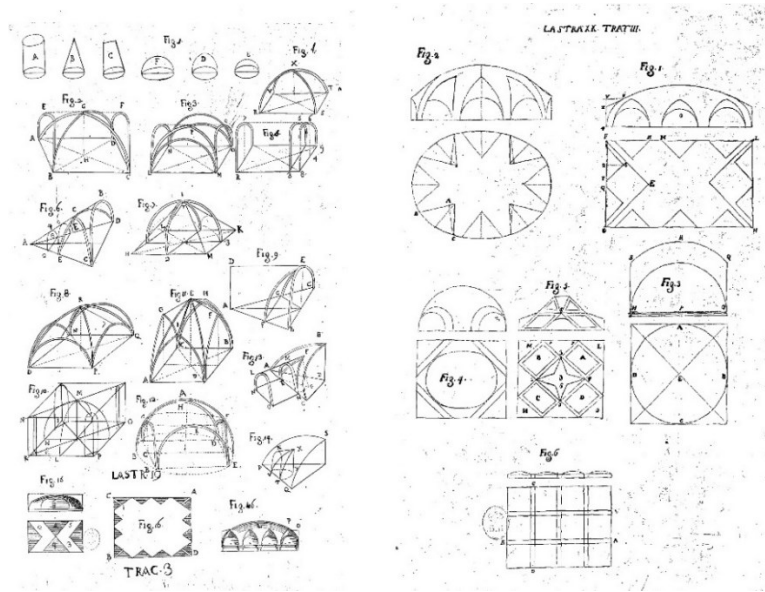
In these writings are developed reasoning on the invention, construction, and calculation of surfaces and volumes of these shapes [2].

In the *Architettura Civile*, he dedicates a chapter on vaults and organized in “Observations”, with continuous references to the *Euclides* in which he exposes the scientific demonstration of such contents. Guarini articulates through the observations with the numerous variables he found and those of his invention. The identification of “six round bodies”<sup>2</sup> (cylinder, cone, sphere, ellipsoid/oval rotation, ellipsoid/oval scalene), allow the generation of different types of vault, described and illustrated (see Fig. 1) by Guarini constituting a vocabulary on which to investigate and understand the coeval morphological and constructive issues.

These studies are also fundamental for understanding Guarini’s method of graphic representation, which emphasizes the difficulty of “put in drawing”<sup>3</sup> these artifacts.

The analysis of Guarini’s drawings and the recognizing of geometric rules at the basis of his design is a fundamental part of this study, which aims to find a three-dimensional visual solution to its shapes remained on paper.

The possibility of consulting Guarini’s drawings, provided by the archival catalogue by Augusta Lange on the occasion of the Congress (concluded in 1670 with the publication of the proceedings) dedicated to the figure of Guarini [3], is an essential source for this type of research.



**Fig. 1.** Plate XIX and XX. In: Guarini, G.: *Architettura Civile*, Mairesse, Turin (1737).

<sup>2</sup> Guarini, G.: *Architettura Civile*. Treat. III, Cap. XXVI, Obs. I. «Delle Volte, e varj modi di farle». Mairesse, Turin (1737).

<sup>3</sup> Guarini, G.: *Architettura Civile*. Treat. III, Cap. XXVI, «Delle Volte, e varj modi di farle». Mairesse, Turin (1737).

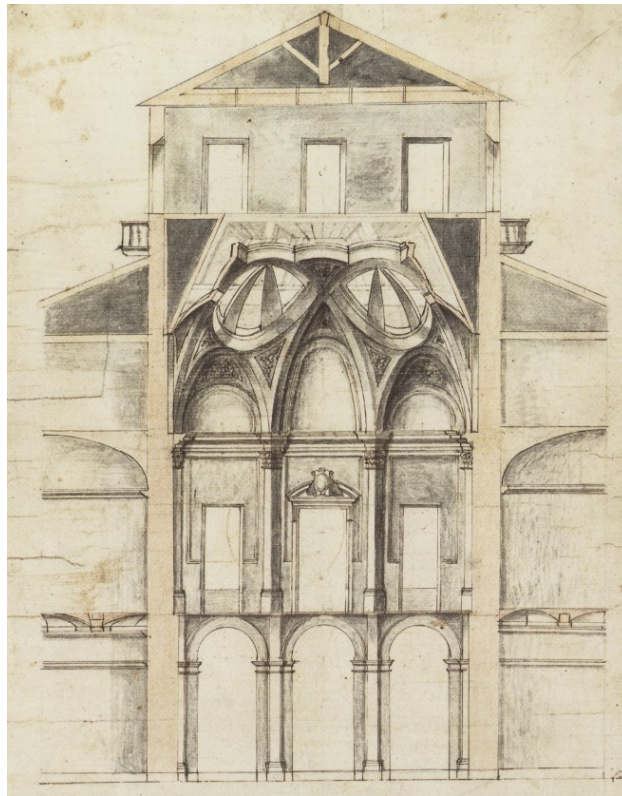
## 2 Guarini's design for the Castle of Racconigi

Lange's work [4] allows us to view many drawings for Racconigi Castle by Guarini and his assistants from 1677 onwards.

The desire to transform the late medieval castle into an updated palace adapted to the popular French models of the time dates back at least to 1664, but the castle needed substantial modifications to become a new location to the Savoia-Carignano court [5].

Guarini's project is based on volumes designed in plan by his predecessors. He proposes a hall, located in the second floor level, within the walls of the inner courtyard of the old castle on which a spectacular vault with intertwined arches is set up. It is indirectly illuminated by the upper windows which natural light is filtered by an intermediate structure.

This intervention can be appreciated from the only drawing related to this project: the cross-section of the Hall of the Castle (see Fig. 2). The drawing is focused on the central part of the building, with half of the lateral rooms on three levels and not taking into consideration the underground level of the prisons.



**Fig. 2.** Guarini, G.: Section of the hall of the Castle of Racconigi with the perforated vaulted structure. Approx. 1677. In: Turin, Archivio di Stato, Corte, Archivio Savoia-Carignano, cat. 95, mazzo 2, fasc. 121, n. 6.

All Guarini's efforts seem to be dedicated to the representation of this impressive vaulted structure. Watercolor colors are applied according to the principles indicated by him<sup>4</sup> and shading allows the understanding the spatiality of the complex structure.

As we can only refer to the section drawing to understand the spatial conformation of the hall, we have to complete its knowledge referring to other plans drawn up during the project phase by him and others architects.

Analyzing the drawings for the first noble floor it can be deduced that Guarini searched in the plan a ratio three by five, reducing the width to support the walls of the long sides of the hall in vertical continuity with the walls of the atrium [6].

The Hall is divided by half-pillars diagonal to the walls, thus dividing the short side into three bays, where large rectangular openings access the other rooms.

Through the relevant survey drawings by Giovanni Battista Borra, dated mid-fifties of the eighteenth century<sup>5</sup>, it can be inferred that even the walls of the long side had to be divided into three larger areas.

Above the cornice it develops the vaulted structure made of intertwined arches, sails and eyes-shaped arranged around the large central opening with a total height similar to the order. The walls of the hall are raised in order to place an additional superimposed structure with the function of a light chamber – through a system of reflecting surfaces – and to mediate the presence of the sixteen large windows on the top level.

## 2.1 Comparison with other Guarini's work

The solution proposed by Guarini for the Castle of Racconigi finds many references in other architectures built or only designed by him.

The system of intertwined arches is taken from its domes for churches with a central plan, mainly in the example of the church of San Lorenzo in Turin (see Fig. 3). This interweaving of arches is generated by the intersection of vertical planes on a polygonal plan with a surface of revolution. Geometry allows the system to be adopted to different solutions. In the designs for Palazzo Madama and Palazzo Carignano, instead, we find similar solutions related to the natural lighting system (see Fig. 3).

The need to have a large lighting inside the main hall leads the architect to think of a solution with a double ceiling; the first with the main vaulted structure, the second with a lightweight structure that allows to hide and filter the light from the large openings on the top level.

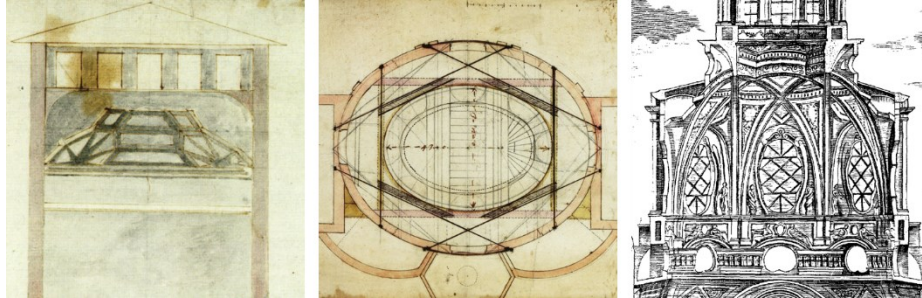
The project for Racconigi contains many of his concepts for “buildings with domes”<sup>6</sup>, in a totally innovative way for the civil buildings of the time and where the hall represents the climax of the ceremonial path [7].

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<sup>4</sup> Guarini, G.: *Architettura Civile*. Treat. I, Cap. VI, «Degl'Instrumenti dell'Architettura». Mairesse, Turin (1737).

<sup>5</sup> Turin, Archivio di Stato di Torino, Archivio Savoia-Carignano, cat. 43, mazzo 1, fasc. 6, n. 22.

<sup>6</sup> Dardanelli, G.: *Le idee di Guarini per il palazzo con cupola di Racconigi*, pp. 425-439. In: Dardanelli, G., Klaiber, S., Millon, H. A. (eds.): *Guarino Guarini*. Allemandi. Turin (2006).



**Fig. 3.** Guarini, G.: Section for the vault of the hall of Palazzo Madama in Turin. Approx. 1675-1677. In: Turin, Archivio di Stato, Corte, Archivio Savoia-Carignano, cat. 43, mazzo 1, fasc. 3, n. 4; Guarini, G.: Study for the double vault of the hall of Palazzo Carignano in Turin. Approx. 1682. In: Turin, Archivio di Stato, Corte, Archivio Savoia-Carignano, cat. 95, mazzo 2, fasc. 39, n. 39); «Facies interna S. Laurentii Taurini», detail of the cross-arched structure. In: Guarini, G.: *Dissegni d'architettura civile et ecclesiastica*, Eredi Giannelli, Turin (1686).

### 3 Geometric approach for shape understanding

Guarini in the *Architettura Civile*<sup>7</sup> underlines the importance of the plan in his design methods [8]. The same attention is reserved in this study, so in the operations of graphic analysis and three-dimensional modeling, we wanted to investigate the construction of the plan and then make any considerations at the level of the sections.

Due to the limits in modeling of complex surfaces (especially double curvature) of the software used, the room plan, which, as mentioned above, has a rectangular shape of ratios 3 by 5 had to be initially assumed as square. On this square plan was built the model of the vault that, finally, was modified to adapt it to the real shape of the plan.

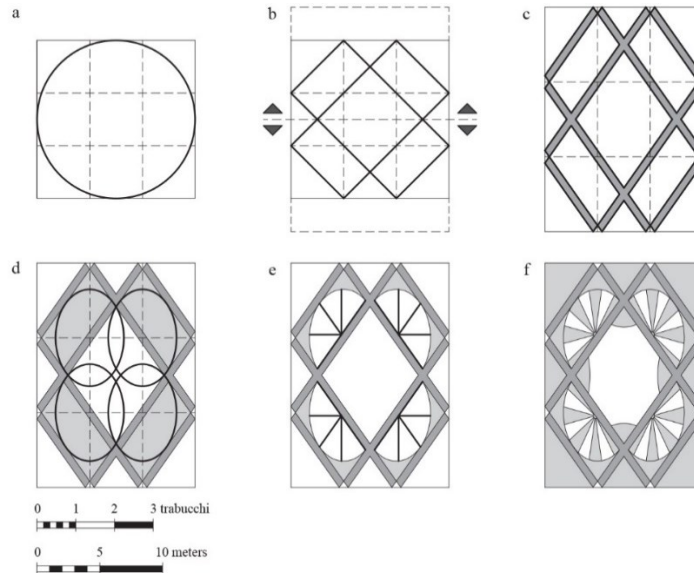
For this reason, the construction starts from a square plan of side of about 12,6 m. (equal to 4 trabucchi<sup>8</sup>) in which a circumference is inscribed (see Fig. 4a). The tripartition of all sides is used to identify through diagonal lines the position of the intertwined arches (see Fig. 4b). Later the thickness of these arches (equal to about 0,50 m. or one piede liprando) has been established (see Fig. 4c). To complete the plan of the covering of the remaining fields are used ellipses tangent to the angular arches (see Fig. 4d). The remaining arcs of ellipses are radially divided (see Fig. 6e). Finally, the central opening plan is defined by circle portions (see Fig. 5f).

The section of the Racconigi hall was already been object of study in its three-dimensional model since 2002<sup>9</sup>. The results have led to the construction of an analytical model of the arched structure and the possible overall conformation in projection in plan.

<sup>7</sup> Guarini, G.: *Architettura Civile*. Treat. II, Cap. VII. «Del modo in generale di disegnare le Pianta». Mairesse, Turin (1737).

<sup>8</sup> Ancient measure of length adopted in Piedmont equivalent to 3,086 meters. The trabucco could be divided into 6 *piedi liprandi* (equivalent to 0.513 m).

<sup>9</sup> The research has been conducted by M. Boetti and A. Raschieri edited by G. Dardanella and G. Cappelletti with the consultancy H. A. Millon. It led to the elaboration of two possible models



**Fig. 4.** Schematic plan drawing of the hall of the Castle of Racconigi.

The present work focus on the geometric interpretation and choose a representation in orthogonal axonometry. The assessment of the shape tries to identified sequences and typical developments of Guarini's *modus operandi*.

Starting from a dome, the operation has been done by cutting planes of the principal shape following the diagonals identified by the tripartition of the space (see Fig. 5a); these intersections determine the internal edge of the intertwined arches (see Fig. 5b). For the creation of the arches it should be noted that these elements are not generated by cuts of the principal shape, but they are generated by conoids, what Guarini defines as "*cono che finisce in una linea*"<sup>10</sup> (cones that end in a line), both for the main and secondary arches of the angular sectors (see Fig. 5c).

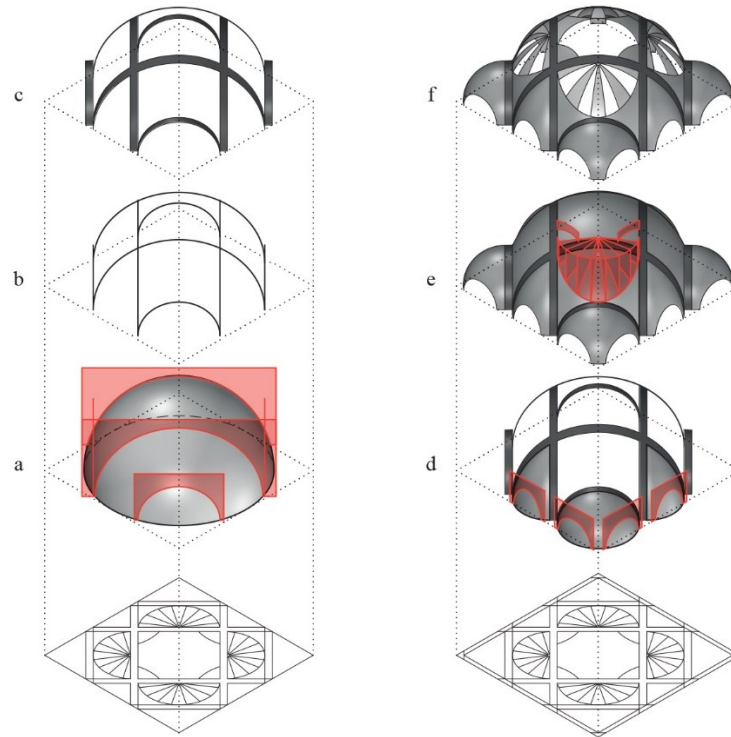
Once the main structure of arches has been identified, perimeter lunettes with a composition of sails are placed in continuity with it (see Fig. 5d). The remaining fields use the main dome to generate empty vaulted surfaces in order to recreate four large eye-glass shapes (see Fig. 5e) for the creation of spectacular lighting effects (see Fig. 5f).

With a geometrically composed vault in a three-dimensional space it is easy to proceed with the visualization of the object. By assigning thicknesses and including possible improvements of the three-dimensional space, it was possible to create a perspective view of the model (see Fig. 6). The creation of this visualization "without materials" aims to evaluate the how the relationship between geometry and architecture is evidenced by the particular light-effects that Guarini wanted to create.

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for the restitution of the vault, starting from the hypothesis of three or five supports for the arches on the long sides.

<sup>10</sup> Guarini, G.: *Architettura Civile*. Treat. II, Cap. XXVI, Obs. IV. «Delle Volte, che nascono dal cono, che finisce in una linea». Mairesse, Turin (1737).



**Fig. 5.** Graphic analysis and digital modeling of the vault in the Castle of Racconigi.



**Fig. 6.** Perspective view of the digital reconstruction of the vault in the Castle of Racconigi.



## 4 Conclusions

The research focus on a part of Guarini's thinking about vaults, looking for a method for a deep understanding of his work, starting from the geometric components. This aspect, that characterizes each of his creations, is therefore used by Guarini not only as a compositional tool but also as a medium of expression.

The drawing analyzed is part of an extensive archive. The aim is to study the architect's theoretical and construction work in order to better understand every single part of it. The interpretation method is structured with representative techniques in adherence to Guarini's compositional thought, with the possibility of operating in a three-dimensional space to better understand the theoretical models, the design drawings and the architectures realized.

Inserted as a meeting point between representation techniques from different eras, this work tries to find a critical filter between the discipline of representation and his relationship with history of architecture, with the awareness that this theme is fertile ground for further studies and in-depth study.

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