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Algorithmic Modeling for Complex Vaults in Vittone's Civil Architecture Between Archival Drawings and Realizations

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Abstract

The paper describes a work of geometric analysis, shape interpretation, and algorithmic modeling on the intradossal conformation of compound vaults inside Palazzo Grosso by Vittone. The tools of VPL allow to confront vocabularies and rules of three-dimensional homogeneous objects, to be applied to ideal models and built architecture.

Keywords Vaulted system · Archival drawings · Geometry · Visual Programming Language · Vittone

Introduction

The paper describes a work of geometric analysis, shape interpretation, and algorithmic modeling on the intradossal conformation of compound vaults inside Palazzo Grosso in Riva presso Chieri (TO), the work of Bernardo Antonio Vittone.

Evidenced by the presence of drawings of the building in his treatise works and a vast archive preserving the Palace's design documents, the study's approach was to start from one of the most characteristic rooms with the most documentation. The compound vault of the "Chinese" room allows the investigation to be conducted from the master's plan drawings to the completed work with data taken from the most current survey techniques.

The investigation of the geometric-formal understanding of these complex surfaces is translated through Visual Programming Language (VPL) to be able to compare the design drawings with the built reality, create constraints and parameters in algorithmic models that can be adapted to a repeatable and continuously developing methodology (Angjeliu et al. 2019; Vitali 2017) that can be used to study different complex vaulted systems.

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The Research

This study is placed in continuity with a more extensive research work that, for more than a decade, has been conducted on the analysis and relationship between geometry, form, and design of the complex vaulted systems built in Piedmontese civil architecture in the Baroque period (Spallone and Vitali 2017).

From the seventeenth and eighteenth centuries in Piedmont, compound vaults assumed great relevance within the typology of the aristocratic palace that was developing among the residences of the capital and in the origin cities of the families of the Savoy court. This unitary brick covering is first laid for the representative spaces but, once the construction technique is consolidated, also in secondary rooms, bringing that geometric complexity back to formal outcomes of great lightness and widely illuminated rooms thanks to the windows placed at the secondary vaults.

For this study, the architectural work referred to is Palazzo Grosso by Vittone, the nephew and apprentice of Gian Giacomo Plantery, a disciple of Filippo Juvarra and editor of Guarino Guarini's *Architettura Civile*. The redesign involving the palace is one of the architect's few attributions in the civil sector, to which he gives prominence through the inclusion of drawings of the building, for example, in one of his treatises: *Istruzioni elementari* (Vittone 1760: 86). The earliest drawings documenting this construction date from 1738 and are preserved and collected in the Riva presso Chieri Municipal Historical Archives (ASCRPC), which is based in the aforementioned building.

This important documentation makes it possible to analyze a part of the architect's compositional process, implementing the information on the subject of vaults that, in treatises, Vittone prefers to summarize and simplify (Vittone 1760: 501).

Among the more than 20 vaulted rooms of the palace, the one that presents the greatest characteristics of originality and that lends itself best to developments in the field of research is the "Chinese" room (a name due to the wall covered with painted Chinese paper, datable to the mid-eighteenth century) (Dalmasso 2008: 88–101). From this room, there is, among the original documents, a study drawing of the vault (Fig. 1a) in which, starting from the plan, the geometric constructions that constitute the composition constraints of the vault structure are

Fig. 1 Vault of the "Chinese" room in Palazzo Grosso at Riva presso Chieri: **a** Vittone, B. A., study plan for the "Chinese" room vault. ASCRPC, 3_21/78; **b** photograph of the vault (author's photo); **c** Top view of the point cloud (author's editing)

drawn. The comparison between the drawing and what was set in place (Fig. 1b) was made possible thanks to the point cloud (Fig. 1c) obtained from a survey carried out using the Leica BLK360 laser scanner; this step constitutes the first step of a methodology to be applied to the geometric reading of the forms under analysis.

The working methodology that follows involved the three-dimensional construction of parametric models through a single visual algorithm using Grasshopper software, a Rhinoceros plugin. The realization of this model aims to geometrically reinterpret the intradossal surface of the vault of the "Chinese" room from different sources, making up for the shortcomings of one source (such as the elevation drawing) with the most complete information inferred from the survey of the completed work.

In the effort to define a replicable and implementable methodology, the survey data were analyzed and evaluated to recreate the ideal geometry, searching where possible for parallelisms and perpendicularity, symmetries, implementing a controlled simplification of the geometric generatrices and the identification of ideal reference surfaces.

During the creation phase of the visual algorithm, solid construction was preferred (as opposed to the surface) to model the intradossal 'void', obtaining the negative of the vaulted surface as it develops from the vault impost plane; this was done to facilitate later stages of communication with other software with which it will be easier to operate on the modeling elements either by subtraction of solids or through thickening of surfaces.

The first phase of work involved the analysis and creation of the main vault surface of this room, a cloister on a rectangular base of 7.27 × 6.76 m and a rise equal to 2.10 m. The analysis of the point cloud of the sections of the main vault portions allows us to prefer, both for adherence to the cloud, a geometric construction from ellipse arcs as opposed to polycentric arcs with three centers, with a final result more controllable and manageable during the construction phase of the visual algorithm (Lanzara et al. 2019) (Fig. 2). The three-dimensional operations of extrusion (*_Extr*), closure of plane holes (*_Cap*), and intersection of solids (*_SInt*) finally allow for the completion of the cloister vault (replacing *_SInt* with *_SUnion* would have realized the elements for the groin vault).

The construction of the secondary vaults is generated from the plan projection of their intersections with the main vault: the vertical development of this projection acts as a cut plane on the main surface. It is precisely on these elements that the main differences between the design drawing and the survey point cloud are noted: differences that are less pronounced in the development of the axial vaults data comparison, otherwise very evident for the corner vaults.

Axial vaults have a simple plan drawing: as can be recognized by the marks on the archival drawing (compass point, construction lines) formed by a triangle that can be defined in its vertices as the intersection of two different circumferences (with center at the intersection of the room's main axes with the room's perimeter) with the perimeter and axes. The sides of the triangle incident on the axis are subsequently connected with a circumferential arc, which takes on different radius values on the archival drawing and the horizontal projection of the cloud.

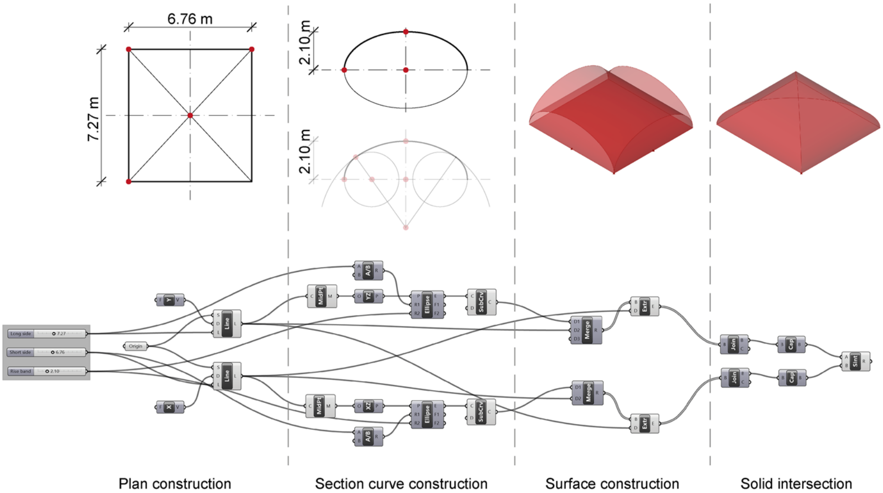

Fig. 2 Graphical and algorithmic construction of the main cloister vault with the selection of section curve (author's modeling and editing)

Three-dimensionally, this type of vault (from the surface generated by sections) is constructively dependent on the cut of the main vault. To model the surface of this vault, the minimal geometries necessary to construct a network of curves were identified (*_NetSurf*): the intersection curve of the main vault and the connected cut planes (*_Project*); the parabolic curve on the ambit wall, with defined tangency constraints (*_BzSpan*); the polycentric arc running along the axis of symmetry (*_ArcSED*); and a curve dependent on the previous elements (*_Arc3Pt*) placed in the junction, as an additional constraint for construction. For the solid creation of this component, from the elements just listed, surfaces are made and joined into a single closed polysurface (*_BVol*).

The plan definition of the corner vaults is constructed, in the archival drawing, by lines orthogonal to the perimeter of the room, connected by a large circumference radius (Fig. 3a); the point cloud gives back a different constructed reality, in which the same lines are inclined compared to the perimeter of the room and connected by a smaller radius circumference arc (Fig. 3b).

The algorithm for defining these vaults in plan exploits the centers of circumference found in the archival drawing: the intersection points of circumferences and projections in the plan of the pavilion (*_CCX*) and the perpendicular projections of the same points along the perimeter (*_CrvCP*).

On a three-dimensional level, this corner vault is defined with a sail surface independent of the main vault; having identified the axis of rotation perpendicular to the impost plane at the intersection of the diagonals of the lunette, solid intersection operations are made between: the extrusion of the area of the corner lunette and a sphere passing through the points defined in the plan drawing and the keystone on the rotation axis (*_Sph4Pt*) located at an elevation slightly below the keystone of the main vault.

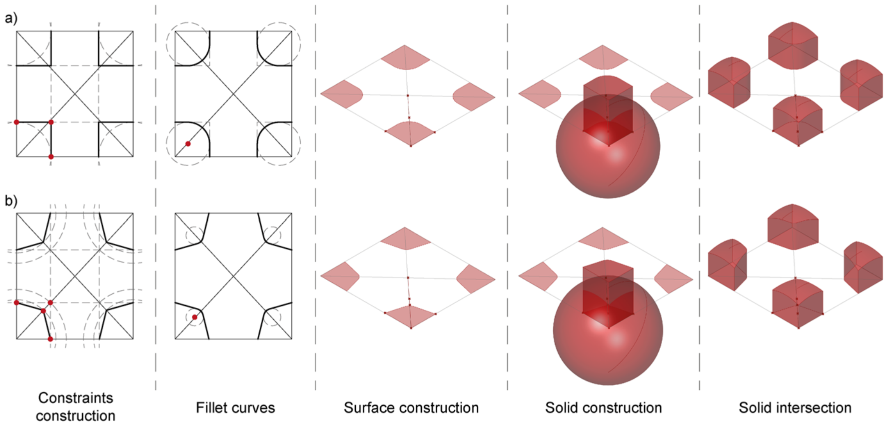

Fig. 3 Corner lunettes construction: **a** by original drawings; **b** by realized project (author's modeling and editing)

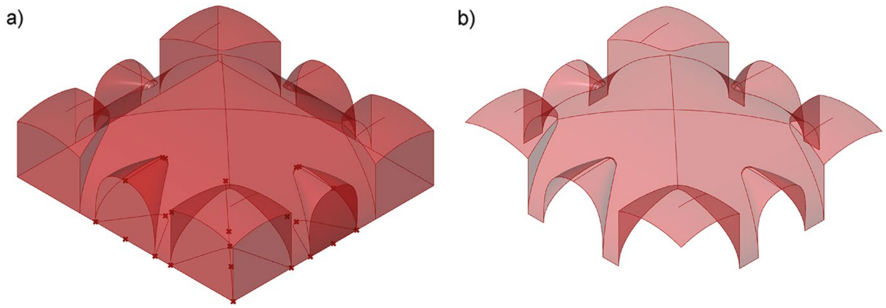

Fig. 4 Solid and surface model of the intradosal vault generated by algorithms (author's modeling and editing)

Having defined by algorithmic modeling the main and secondary geometries (axial and corner) the last steps required to complete the model involve only the joining of the components (Fig. 4): the result thus constructed will always be modifiable and applicable to other similar studies objects, present, in this case, even in Vittone's building.

Conclusion

This research represents a contribution in a parametric key to the thread of study on the geometric interpretation of complex vaulted systems developed through the experimentation and refinement of a method that incorporates into the workflow the tools useful for comparing ideal models, built architecture, the study of the main treatise sources and, especially in this application, archival materials.

The tools of algorithmic modeling allow this work to confront an ever-developing scene (Bagnolo et al. 2022; Bolognesi and Stancato 2021; López-Mozo et al. 2022) and to facilitate the search for vocabularies and rules of three-dimensional form in the study of classes of homogeneous objects, to be applied to ideal models and built architecture.

The generated models thus become tools for supporting analysis and verifying the results obtained, having control over the fixed and variable characteristics of the parameters assigned during the creation of the visual algorithm.

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Data Availability Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

Declarations

Conflict of interest The author declares that he has no conflicts of interest.

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