Characteristics of Baroque Solid Space in the Perspectival Tabernacle of Bitonti and Borromini in Bologna

Giuseppe Amoruso

Abstract

The research presents an analysis of the tabernacle designed in Bologna by Giovanni Maria da Bitonto who, with Francesco Borromini, created the perspectival gallery for the Spada Palace in Rome. The tabernacle perspective works as a projective system which accelerates the natural perspective perception and modifies environmental and spatial features, of the built scenography. The construction technique is complex if applied to architectural space: Donato Bramante realized it, for the first time, in Milan, in the choir of Santa Maria at San Satiro. The spatial fruition of perspective, usually linked to central perspective or to psychological and perceptive phenomenon, became 'real'. The projective principle is the one known as 'relief-perspective', or designed to be used as a scenography or temporary installation. The survey of the tabernacle, in the church of San Paolo Maggiore in Bologna, reveals a small illusory space and also introduces a true protagonist of solid perspective applications, Giovanni Maria Bitonti. The research presents a graphic study of the perspective concept housed in the National Archive of Bologna and an accurate reconstruction of the solid perspective, using the most advanced techniques of digital documentation. The drawing examined has a graphic scale, in Bolognese feet; the drawing is of the model representing real architecture, making it comparable with the drawing of Spada Gallery conserved in the Albertina Library in Vienna.

Keywords: solid perspective, Giovanni Maria Bitonti, Francesco Borromini, solid homology, illusory space

Introduction

In 1666, the Bolognese Antonio Masini used, for the first time, the term "*quadrature*," in referring to a perspective application that had been successful in Bologna thanks to the works of Girolamo Curti, known as Dentone [1]. It was a new illusory and perspectival model which expanded interiors as spaces for scenography, and that artists used to call the '*di sotto in sù*' perspective. Cardinal Spada, Papal Legate in Bologna between 1627 and 1630, is remembered for having had a real obsession with perspective; Virgilio Spada, on the subject of the love for perspective of the Cardinal, his brother, wrote that "[he] turned the Cardinal Legate's palace upside-down, and adorned it with paintings and excellent perspectives. From the first day he entered the large palace he started to embellish it with sequences of doors, windows, perspectives, and similar things, which made it double" [Neppi 1975, p. 125]. In 1630, in the Palazzo Comunale, Girolamo Curti decorated the ceiling of the Sala Urbana, the hall dedicated to Maffeo Vincenzo Barberini, better known as Pope Urban VIII: Curti introduced coupled columns, loggias, and a greater architectural complexity of the recesses, as well as the use of circular shaped balustrades and a compositional austerity which made space perception a priority instead of depicting allegorical figures as used by other artists (fig. 1). In 1629, Cardinal Spada ordered decoration works for another hall, known as Sala Dentone: it is a *quadratura* painted on the vault and features a sophisticated architectural design that modifies the real space perception, so that the flat vault looks like a cylindrical vault.

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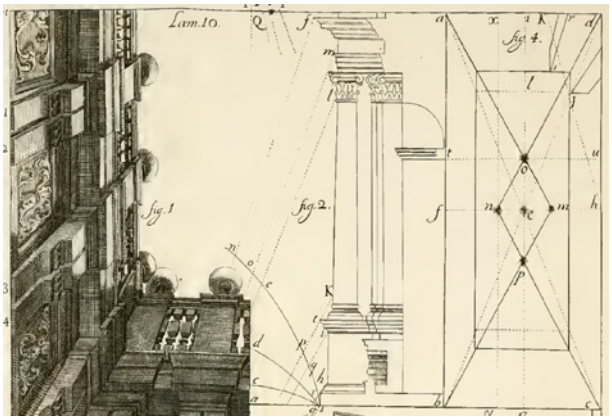
Fig. 1. Sala Urbana, Palazzo Comunale of Bologna, "di sotto in sù" perspective, G. Curti, 1630. Photogrammetric survey.

Fig. 2. Palomino 1715-1724; pp. 176-183, lamina 10 (detail).



The vault is built with four curved surfaces and a flat ceiling in the middle where painters used to depict allegories or, more frequently, the sky. The *quadratura* is enriched by a big serliana opening and the perspective projection is characterized by a prevalent vanishing point. The *quadratura* projection is not based on the one-point perspective, as in the Sala Urbana and according to Vignola and Tibaldi; Curti proposed an innovation, 4 vanishing points to harmonize the real space with the illusory space; this technique was exported to Spain and subsequently described by Palomino [Palomino 1715-1724, lamina 10, pp. 176-183] (fig. 2).
This practical construction technique is used for those rooms that deviate from the ideal square indicated by treatises (in the case of a square room artists used the one vanishing point perspective) as the proportion is one to two (9 per 18 *braccia*); in the rectangular rooms, perspective perception is eccentric; because of the doors' positions, observation was always from a side, and therefore it was necessary to modify perspective projection as the practice suggested by Viola Zanini [Viola Zanini 1629].
The *quadratura* of the Sala Dentone is contemporary to the ceiling decoration of the Sala Urbana; it was painted 45 years before the fresco that Colonna, after his stay at the Royal Court in Madrid, designed for the Senate gallery of the Palazzo Comunale in 1677. The overall height of the perceived environment is equal to twice the height of the room measured from the floor to the vault.

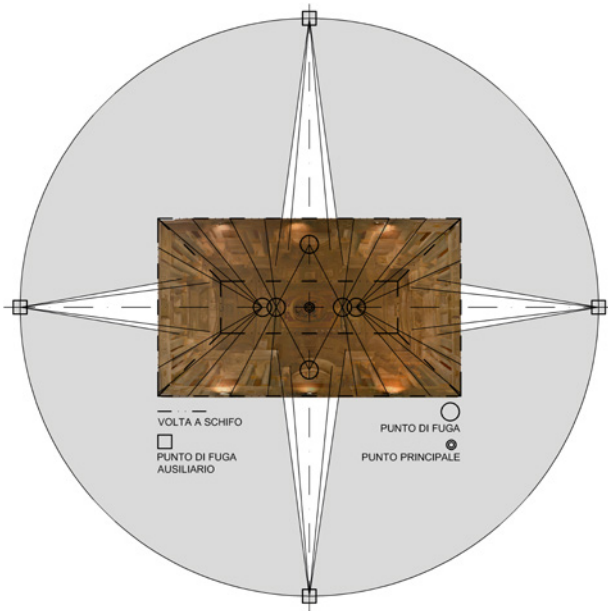
This proportion is obtained by placing the spectator's viewpoint at the center of the gallery at a height of 5 Bolognese feet from the floor and taking visual rays from the observer [2]. The room is assumed to be proportionally composed by 2 squares whose sides are 9 *braccia* in length, and the gallery volume generates 4 squares according to a harmonic classical proportional ratio. The distance between columns creates a compositional effect; the *quadratura* is designed with an intercolumniation of 3 and 5 diameters, named systyle and araeostyle.
The continuous parapet is part of the architectural order, replacing the more classic pedestal; it also works as a regulator system as it compensates the irregularities of the room (fig. 3).
The study of the illusory frescoes of the Palazzo Comunale in Bologna, at the time seat of the local Senate and housing the Pontifical Legate apartments, presented graphical outcomes and highlighted the projective parameters of the illusory space; construction techniques influenced the real perception of *quadratura* and solid scenic space of sacred objects, environment and architecture.

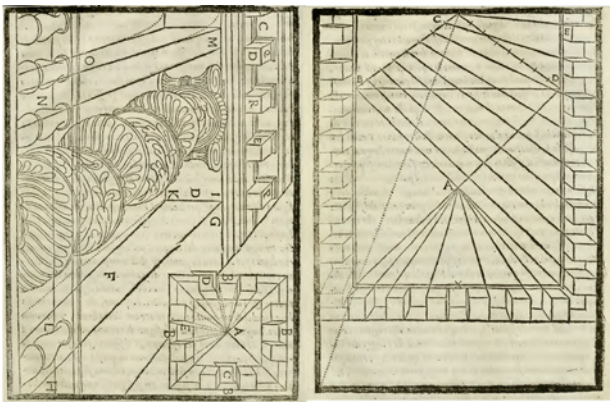
The perspective of solid space

Construction technique was particularly sophisticated when it was applied to the architectural space; optical corrections, as well as other illusory effects or perspective applications, are already present in the first half of the twelfth century [3]. During the Renaissance, the concept of architectural space is directly associated with the central perspective or with the development of psychological and perceptive phenomenon. This means proposing a mathematical artifice to provoke a sense of wonder [Fano 1979]. This is the field of study that the American psychologist James Jerome Gibson called "picture perception" [Gibson 1950]. Furthermore it is interesting to recall the psychology of perspective, that is, the link between the operative tool and the concepts that it allows to be transmitted to its users; in this transformation process artists had the role of setting up specific processes of perception and experience of works creating a conflict between the experience derived from observation of the painting, with that derived from the observation of the environment in which the work was inserted.
Experimental researches in cognitive psychology have shown precisely the 'strength of the illusion' concept,

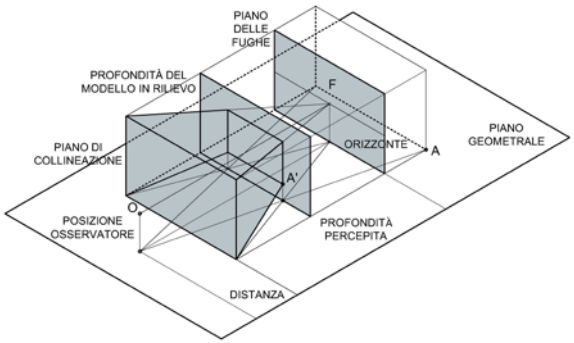
Fig. 3. Vault of the Sala Dentone, Palazzo Comunale of Bologna, Girolamo Curti with Francesco Castelli and Angelo Michele Colonna, 1627-1630 circa. Parameters of the perspective projection.

Fig. 4. Viola Zanini, 1629, p.30. Projection methods of "di sotto in sù" perspective, as painted on ceilings and vaults.





a question already pointed out by Leonardo about the reason why perspective representations do not appear deformed and unexpectedly retain their spatial coherence, even if they are observed from different and far points of view not standing in the geometrically fixed eye-point, the unique observation parameter used for their construction [Kubovy 1986]. Perspective, despite being a tool for the representation of reality, especially for its ability to improve the perception of the third dimension, cannot be taken as a mere product of visual perception. It "contributes only to create the evocative illusion of infinite spaces resumed in the synthesis of the correct geometric construction that can be performed on the plane (linear perspective) and in space (scenographical perspective)" [Fano 1979, p. 18].
In the design practice, in different ages, examples are documented in which, constructively, a three-dimensional effect was used according to perception needs; after the initial state of wonder, the spectator can recognize the signs of accelerated or delayed perspective convergence compared to that which occurs, naturally, in visual perception. This projective application is known as 'relief-perspective', otherwise known as solid perspective, built in the form of a permanent stage or as a scenography and a temporary installation, this being the most popular field of adoption (fig. 4).



Figs. 5, 6. Tabernacle model from photogrammetric survey. 67-image mosaic processed with SFM software.

Fig. 7. The projection system of relief-perspective: the real space deformation generates a scenic space that supports the material representation.

In the *Histoire de la Perspective ancienne et moderne*, Poudra defines perspective as the "*science des l'apparences*" in continuity with the tradition of scientific studies on optics that was resumed in the popular medieval text *De Aspectibus* attributed to the Arab scholar Ibn al-Haytham, known in the West as Alhazen [Poudra 1864].
The research project identifies the illusory design parameters in relation to the use of perspective drawing and its material reproduction, from the sketch to the perspective tools for achieving perceptual effects and architectural space experience. We can scientifically determine methods from the analysis of the appearance and subsequently verify their reproducibility and variations, and also the most appropriate operational and conceptual features.
Starting from the *stiacciato* technique, popular in the field of sculpture, Bramante developed an architectural application called solid or relief perspective, from the established term in use in the artistic production of bas-reliefs. According to Poudra, "relief-perspective is an extension of the perspective plane, or rather the linear perspective is a special case of relief-perspective" [Poudra 1860, p. 1].
In his treatise Poudra speaks about a new application of descriptive geometry; he also argues that finally architects will get tools to advantageously change the interior or exterior appearance of buildings; design application has a specific practical aim but also a geometrical reason which lies in the projective process which, by means of the rules of perspective, transforms objects of the space according to a collineation process; it creates a solid homology between the real space and the space that undergoes transformation and perspective contraction.
The half-space behind the plane of traces is transformed into the space between the front plane and a parallel plane of converging lines. The infinite half-space is transformed in a finite space; briefly the projective concept of the perspective transformation of a plane is applied to a spatial object or to a half-space [Leopold 2014, p. 964]. According to this system, the two processes of image generation, the classic one according to descriptive geometry and the one of computer representation (mathematical), coincide [Migliari 2009]. This homology constitutes the perspective of figures on the 'objective space,' projected on a second space superimposed on the first. The projective geometric procedure of graphic correspondence is based on considerations relating to the correspondence of points, lines and planes according to the solid homology whose center is represented by the point of view; therefore, the

Fig. 8. Tabernacle model from photogrammetric survey. 67-image mosaic processed with SFM software.

construction of the three-dimensional perspectival image starts from the axis-plane, on which the proportional scale is the one of reality, and it is developed in the space between this axis-plane and the so-called limit-plane, locus of points at infinity of objective straight lines belonging to the above mentioned space.
This methodology of representation of three-dimensional space was necessary to build scenographic systems that had to be reduced to the limited size of a theater stage; the projective-graphics system was developed to build the scenic space into the theatrical stage to give the illusion of a great depth in a much smaller space (fig. 7). What characterizes the deformation of objects is the product of a particular position of the viewer and the figure that must produce a perfect illusion, with the model of which it will show the appearance, relations of position and shape that satisfy the following two conditions: visual rays conducted from viewpoint to the different points of the model pass through the corresponding points of the relief; all the points

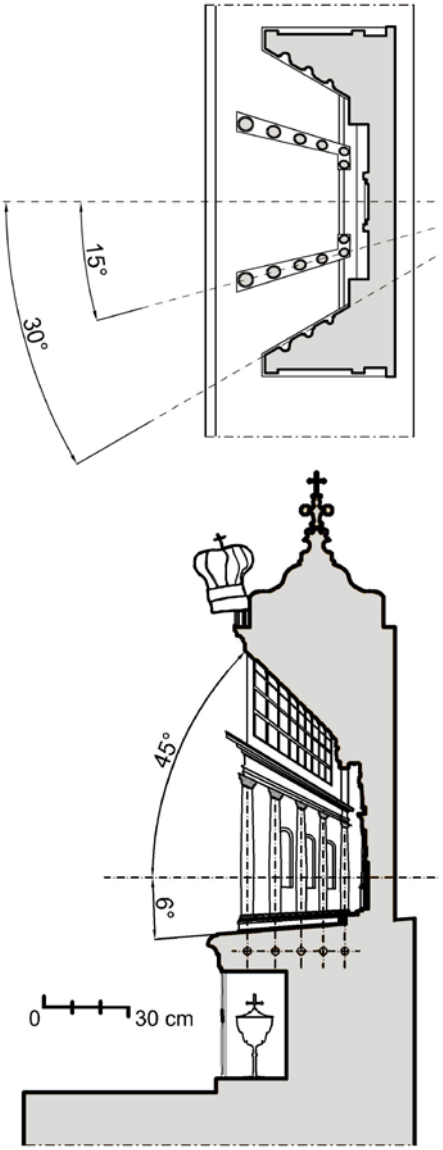
that lie on a straight line in the model are thus found on a straight line in the relief and, therefore, to the two points of the model on the same plane correspond the points of the relief also located on the same plane.
These conditions may be reduced to one fundamental result, that all planar elements of the model correspond, on the relief-perspective, other parties equally planar, which are the perspectives of the first one on many and different planes and they are referred to the same position of the eye. The relief-perspective is a projective contraction of the real space that generates a space that can be described as scenographic and that supports the representation [Migliari 2009].
In this field of application, the two superimposed spaces of the relief-perspective projective transformation are both represented: the isotropic space, and the anisotropic, scenographic space.
The depth of the space that appears to be transformed in relief, the space between the plane of traces or'collineation plane' and the plane of convergent lines produces the relief-perspective, containing it within. The relief depth, the space layer between front plane and the plane of vanishing points, determines substantially the relief-perspective. If the relief depth is zero, we deal with the conventional perspective" [Leopold 2014].
Camerota describes these achievements as "material" perspective that marks the transition from pre-Baroque space, in which the projective methods are used to "correct the deceptions of vision to save the proportional order of the architectural elements," to a new concept of space where the design addresses a "deception research by creating imaginary spaces that go beyond the physical limit of the built environment" [Camerota 2006, p. 34].
In this cultural framework Caramuel De Lobkowitz presented his theory of "*architectura obliqua*" as an application of geometric transformations that generate ellipses from circles and ovals bodies from the globes, when the orthogonality conditions that commonly affect ordinary architecture, named '*recta*,' and the construction of the architectural order are not practicable.
When the ground plane is inclined or when the geometry of a façade is curvilinear, as in circular or elliptical plan layouts, the order must undergo a transformation, thus creating an oblique space [De Lobkowitz 1678].
This construction technique became very useful and frequent in scenic perspective and Bitonti also used it for his works.

The perspectival tabernacle by Bitonti

"Under minimum size, one observes a huge portico; in a small space a long path can be seen. The more distant they are, the greater appear the small objects placed in their proper places." With these words Bernardino Spada described the emotion aroused in observing the perspective gallery he commissioned to Borromini and Bitonti, completed in 1653 (Bib. Vat., Barb.Lat. 1005, 102) [Neppi 1975, p. 280]. Presenting below the graphic documentation of the perspectival tabernacle in Bologna, an illusory space of very small size, this description will fit the case of this object of sacred art designed and built by Bitonti and commissioned by Spada.
When Bernardino Spada returned to Rome, the Capodiferro Palace became the concrete testimony of the ideal residence of Bernardino, interiors and façades enriched by illusory architectures, Borromini's perspectival gallery, but also rooms decorated with illusory frescoes commissioned to Dentone and Colonna.
The real protagonist of solid perspective applications, however, was Father Giovanni Maria, born in Bitonto (Bari) in 1586 and therefore known as Bitonti.
In 1647 Bitonti–mathematician, expert of perspective, scenographer and Bernardino's personal advisor–was commissioned to design a perspectival tabernacle in Bologna for the church of San Paolo Maggiore [Sinisgalli 1998]. Bernardino also entrusted him with the construction of the colonnade at the Spada Palace, the best-known perspectival space of this century of wonders that was built in 1652, in partnership with Borromini, who was the advisor of Bernardino's brother, Virgilio Spada.
On the occasion of the enlargement of the palace, Cardinal Spada decided to build the perspectival gallery in Spada Palace: a perspectival telescope, a long alley perpendicular to the walls for about eight meters and forty-eight centimeters; its sides are very convergent, so that the architectural motif of the arch with columns built in a regular scale, which delimits the entrance, whose height is four meters and ten centimeters and width two meters ninety-five centimeters, at the end of the gallery is diminished until it reaches two meters and forty-five centimeters in height and one meter in width [Paris 2016].
The construction technique is of a theatrical type: an inclined plane with a slope of about 7% (Sinisgalli speaks of 5.5° [Sinisgalli 1998]) and a theoretical vanishing point placed behind the background.

The floor, as in stage sets, is inclined towards the small courtyard that concludes the gallery; the point of view was ideally positioned at the center of the main courtyard of the building, allowing the observer to perceive an environment of increased depth of up to forty meters.
Sinisgalli, as a result of a detailed geometric survey, verified that the gallery does not possess both the characteristics of a solid perspective, according to the projective concept which subsequently has been defined, for example by the treatise of Poudra [Poudra 1860]. The first fundamental rule, that of the convergence of orthogonal straight lines to the pictorial plane towards a single point, has been verified, while the progressive placement and foreshortening of the objects according to the distance from the point of view was not followed; the arrangement of the 12 different columns has a different and specific layout and such 'proportional alterations' follow a geometric series [Trevisan 2001, p. 19].
Before the construction of the gallery in Rome, Bitonti was commissioned to design the tabernacle in the Spada Chapel in the Church of San Paolo Maggiore in Bologna; this perspectival architecture was built in 1648 and placed on the altar one year later (figs. 5, 6).
Illustrations present an unpublished graphic study on archival documents, an accurate survey with advanced techniques of digital documentation, extracting dense point clouds from images through SFM photogrammetry and also a comparison with the perspective of Spada Gallery in Rome.
Lighting conditions and translucent, metallic and gilded materials, influenced operations of image acquisition.
The tabernacle by Bitonti addresses an architectural space with three modules, covered by a round arch and with two rectangular fronts on the sides; the '*serliana*' window is surmounted by a Baroque entablature. It is symmetrically flanked by two rectangular openings surmounted by a lintel above the attic floor and a balustrade; between the arch and the two openings two columns are placed framing the space. The central arch makes efficient both the static as well as the compositional solution breaking the uniformity and rigidity of the continual horizontal entablature.
The arch introduces the spectator to the gallery enclosed in a barrel vault characterized by lacunars (a 9 x 9 subdivision of the conical surface), as common in basilicas and bringing the attention towards the focal point, at the physical end of the colonnade, a vestibule and a portal with columns and pediments, which probably leads to a second

Fig. 9. Architectural survey of the tabernacle. Sections show angular references, making construction simple.



gallery built in sequence: columns, built in agate with capitals and bases in gilded bronze, are in total 12, 6 per side, with an explicit allusion to the apostles. In the side walls of the tabernacle a theory of pillars is punctuated by three niches (figs. 8, 9).
The depth of the altar, designed by Borromini, was one of the constraints and parameters which Bitonti had to consider for developing the perspectival model; to complete the residence of the Eucharist, the gallery above allowed display of the sacrament and was equipped with an indispensable accessory which compensated and reduced the inclination of the relief to a horizontal plane. In accordance with the rules of solid perspective, the ground plane is built inclined in order to improve the depth perception and accelerate the perspective.
The sketch of the tabernacle [4] shows a graphic scale of ten Bolognese feet, which means that the drawing is actually the representative model of a real architecture rather than describing a small object, part of the array of a sacred altar; the research points out, for the first time, its projective issues by comparison with the Spada Gallery drawing found at the Albertina Library of Vienna [Amoruso, Sdegno, Riavis 2016]. In the sketch, the foreground column does not fit the perspective projection and the drawing has several distance points referred to the viewpoint, the position in which the observer is assumed to be, that is, at 2.80 meters (figs. 10, 11).
There are further features supporting the thesis that the project has a spatial, architectural and symbolic function: a statue is depicted over the top of the attic floor [5]; its height, according to the graphic scale, is about 5 feet, where a Bolognese foot measures 0.380098 meters, and is divided into 12 ounces, as also mentioned by Serlio [Serlio 1551]; the architectural order is composite (and not Corinthian, as erroneously reported on the drawing), often used in the architecture of Borromini, and Bitonti himself painted columns of the same order in 1631 in the perspectival gallery of the altarpiece for the Church of the Annunciation in Bitonto [6].
On the 3D point cloud, the inclination of the ground floor measured approximately 6 degrees, thus the same as the Spada Gallery. The inclination of the tapered-conical vault is 45 degrees, a very practical building rule; the spectator's perception is of 1 meter in depth, while the tabernacle is 0.58 meter in length. The tabernacle plan is given by angles, making the construction simple; if the central line is taken as a reference, the lateral aisles are inclined at 45 degrees, while columns are rotated by 15 degrees and form a 30-degree angle. Therefore, homology is given by planes set at intervals of multiples of 15 degrees (fig. 9).

Fig. 10. Perspective drawing of the tabernacle, signed by L. Franzini; graphic scale in Bolognese feet (Bologna, State Archive, envelope 87/4979, f. 130). The analysis highlights several distance points, depicted with different colors.

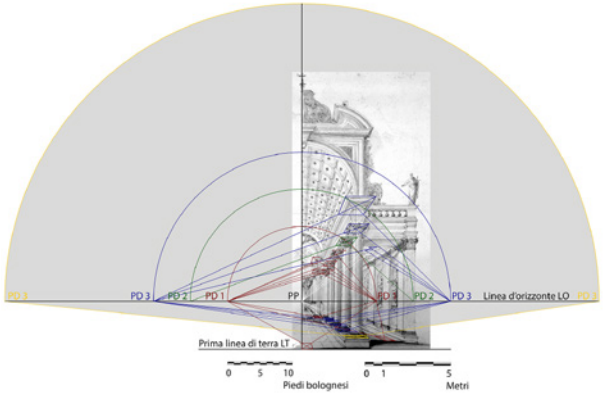
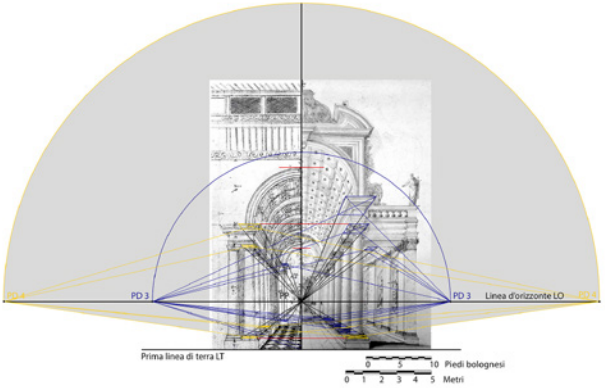


Fig. 11. Comparison between the drawing of the tabernacle (graphic scale in Bolognese feet) and the drawing of Galleria Spada (proportionally scaled).



Bitonti, in designing the tabernacle, practices Caramuel's oblique architecture taking a strong position in the controversy which also involved Bernini.

Conclusions

In 1642, the French Jesuit Jean Du Breil published the *Perspective Pratique* presenting, for the first time, the new field of scenographic design, reduced to a two-dimensional support. His *scaena ductilis* summarizes perspective and theatrical knowledge as well as scientific and empirical spatial issues and its graphic expression. The representation of scenes and their construction techniques therefore provided to architecture the place to experiment illusory effects and their relationship with real space; this widespread practical culture will enable Bernini, Bitonti and Borromini to introduce the dynamism of the observer within the space, and the acceleration of spatial perception in their relief-perspectives. The research presented several outcomes, since very often parallels and feedback are common to the works of Bramante, Bitonti and Borromini; further studies, by comparison with written sources such as the Poudra treatise, support the graphical analysis.
In the study of the documental sources and of the applications, particular emphasis was given to the graphic instruments for the representation of illusory space, through the analysis of the solid perspective of the tabernacle, described for the first time in its characteristics, and in the comparison of the projectivity of the archived drawing and of the constructed perspective.
As a future direction of research, the author will investigate the presence of a regular ideal model that originated the tabernacle, or if Bitonti followed a set of rigorous relief-perspective rules. Representation is useful and effective in the understanding and perception of space; this task is more compelling if knowledge and practical solutions from old sources of perspective and descriptive geometry are rediscovered. The reproduction of these methods, through simulation, augmented reality fruition and 3D replicas opens new scenarios for research concerning representation [7].

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Note

[1] On the Bolognese school, see Giuliani 2007.

[2] Approximately 190 cm.

[3] Previous to the introduction of the study of Optics in the West.

[4] The drawing is signed by Ludovico Franzini and it is currently conserved at the State Archive of Bologna, envelope 87/4979.

[5] The statue, never realized, holds a sword, as a tribute to Paolo Spada ('*Spada*' means sword), family founder and patron of the chapel.

[6] The altarpiece is currently conserved at the Pinacoteca 'Mons. Aurelio Marena' of the Museo Diocesano, Bitonto.

[7] This research was part of the 2010-2011 PRIN *Prospettive Architettoniche: conservazione digitale, divulgazione e studio coordinated* by R. Migliari, Sapienza University of Rome; the author participated in the Polytechnic University of Milan research team coordinated by M. Rossi.

Autore

Giuseppe Amoruso, Department of Design, Polytechnic University of Milan, giuseppe.amoruso@polimi.it

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