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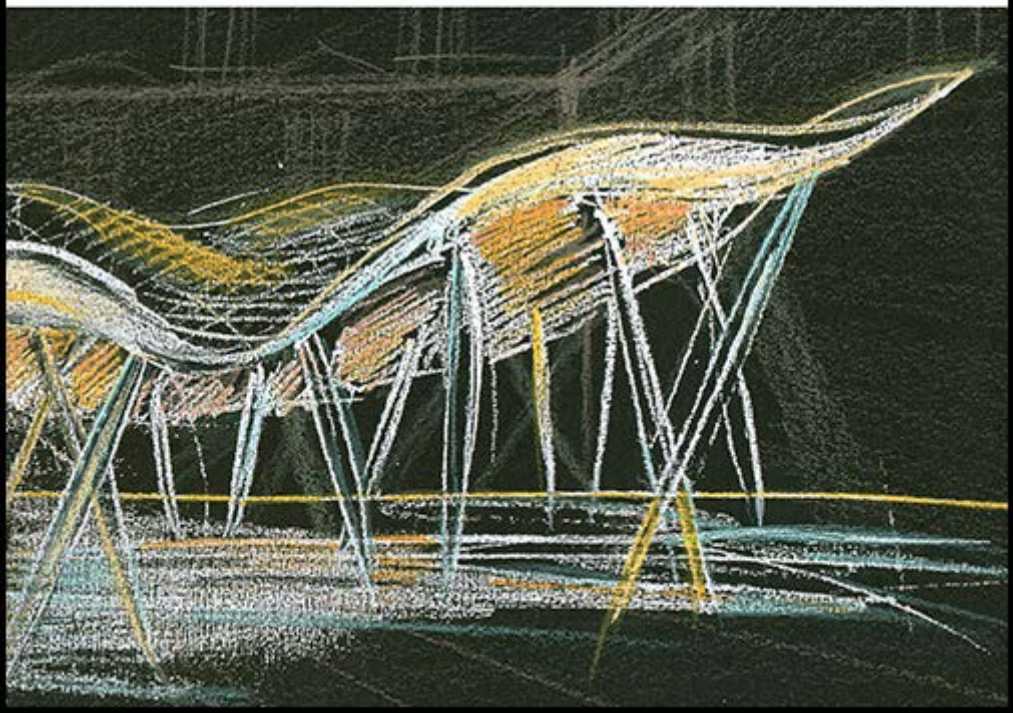


Dissemination Models for Communication of Cultural Heritage: '*di sotto in su*' Perspective Domes in Andrea Pozzo's Work

Leonardo Baglioni, Marta Salvatore

Abstract

This research deals with the communication and enhancement of cultural heritage through the construction of physical models that reproduce abstract theoretical processes making them accessible through visual interactive experience. This type of experimentation concerns perspective, in particular, the perspectives of fake hemispherical domes defined 'di sotto in su' *(from below) painted by Andrea Pozzo between the Seventeenth and Eighteenth centuries. The present essay explores the relationship between the true form of the dome and its perspective, with particular reference to the case of St. Ignatius, through the development of a theory that leads the different perspective images of the dome to a single ideal design model. This hypothesis has been analytically verified by measuring the invariance of the cross-ratio between the principal elements of the architectural order that articulate the tambour of the dome. This experimentation has been reproduced in an installation that relates the physical model of the true form of the dome with its perspective images and with the observer. The installation, which shows and demonstrates perspective through the perspective itself, has two distinct aims: the experimental validation of the formulated hypotheses and their subsequent sharing.*

Keywords: Andrea Pozzo, Perspective, Illusory Architectures, Fake Domes, Prototyping.

Introduction

Today, the communication of heritage is a central issue when it comes to the valorization of cultural assets. The concept of value loses its economic meaning to assume that of knowledge and its dissemination that, together, contribute to the enhancement of the asset. The flow of knowledge moves through two different levels of sharing: one relating to the dissemination of content within a scientific community in order to increase knowledge, the other relating to the sharing of content with the community, for explanatory purposes.
The term 'cultural asset' is generally understood to mean all the material and immaterial testimonies that have acquired a certain historical value over time. According to this broad meaning, cultural heritage can also include treatises and historical texts, witnesses of knowledge through the written communication of abstract principles and theories. The approach to an ancient text is generally reserved to the members of certain scientific communities, who are provided with the necessary tools to fully understand its meaning. This research aims to explain some of these theories, particularly those related to the projective principles underlying perspective representation, and to make them accessible through the tools of digital representation. The field of representation appears to be privileged in this sense, because it conveys theoretical content in visual form, through the construction of graphical, digital or physical models.
The interest in perspective is justified by the topicality of this method. Today, as in the past, the perspective transversally permeates a realistic representation of reality. This occurs

Fig. 1. Three models of the dome of the Collegio Romano; from the left the painted canvas, the sketch and the treatise (graphic elaboration by the authors).

in its analogical, graphical or physical form, but also in its contemporary digital forms, ranging from the construction of a virtual image or a rendered sequence, to photography, immersive photography or to the most recent applications of virtual and augmented reality. But not only that. The projective theories at the basis of perspective generalize the totality of methods of representation. All the methods of representation can be ascribed to perspective, taken in its most general form, namely relief perspective, as the studies conducted by Fiedler [Fiedler 1874] around the middle of the Nineteenth century show and we believe that this generalization is still valid today.
In this experimentation, the explanation of the projective principles underlying the functioning of the perspective machine concerns the fake hemispherical domes in perspective '*di sotto in su*', painted by Andrea Pozzo between the Seventeenth and Eighteenth centuries, with particular reference to the Collegio Romano's dome.
The research was articulated in two main phases: a first phase of analysis of the graphical models of the domes in relation to the true form of the design model, which led to the development of a perspective theory at the basis of their realization; a second phase devoted to the dissemination of the results. During the first phase, the use of virtual models allowed the experimental verification and validation of the formulated hypotheses; instead, in the second phase, the same models were the subject of an installation with which to convey the results achieved through direct interaction with the perspective machine.

A design model for fake hemispherical domes

The idea of model has always permeated the activity of the designer for whom it is the instrument of control, analysis and communication of an ideal form. The model is therefore the representation of an idea, describing its specific part or aspect. Only as a whole and in their integration, the different models contribute to the definition of an ideal model, able to convey the overall idea of the form [Migliari 2004].
The theme of Andrea Pozzo's fake domes, which developed towards the end of his artistic activity and sanctioned his international success, highlights the transversal character of different forms of graphical and pictorial representation used by the artist in different phases of the design process. From the relationships that can be established between the different models it is possible, on the one hand, to explain Pozzo's *modus operandi* and, on the other hand, to demonstrate (by means of analytical tests) the convergence of representations towards the idea of a single architectural form.
In the case of the fake dome of the St. Ignatius Church in Rome, inaugurated in 1685 as a real prototype of the vast production of domes realized 'from below' in succeeding years, three models have come down to us, each of them for a

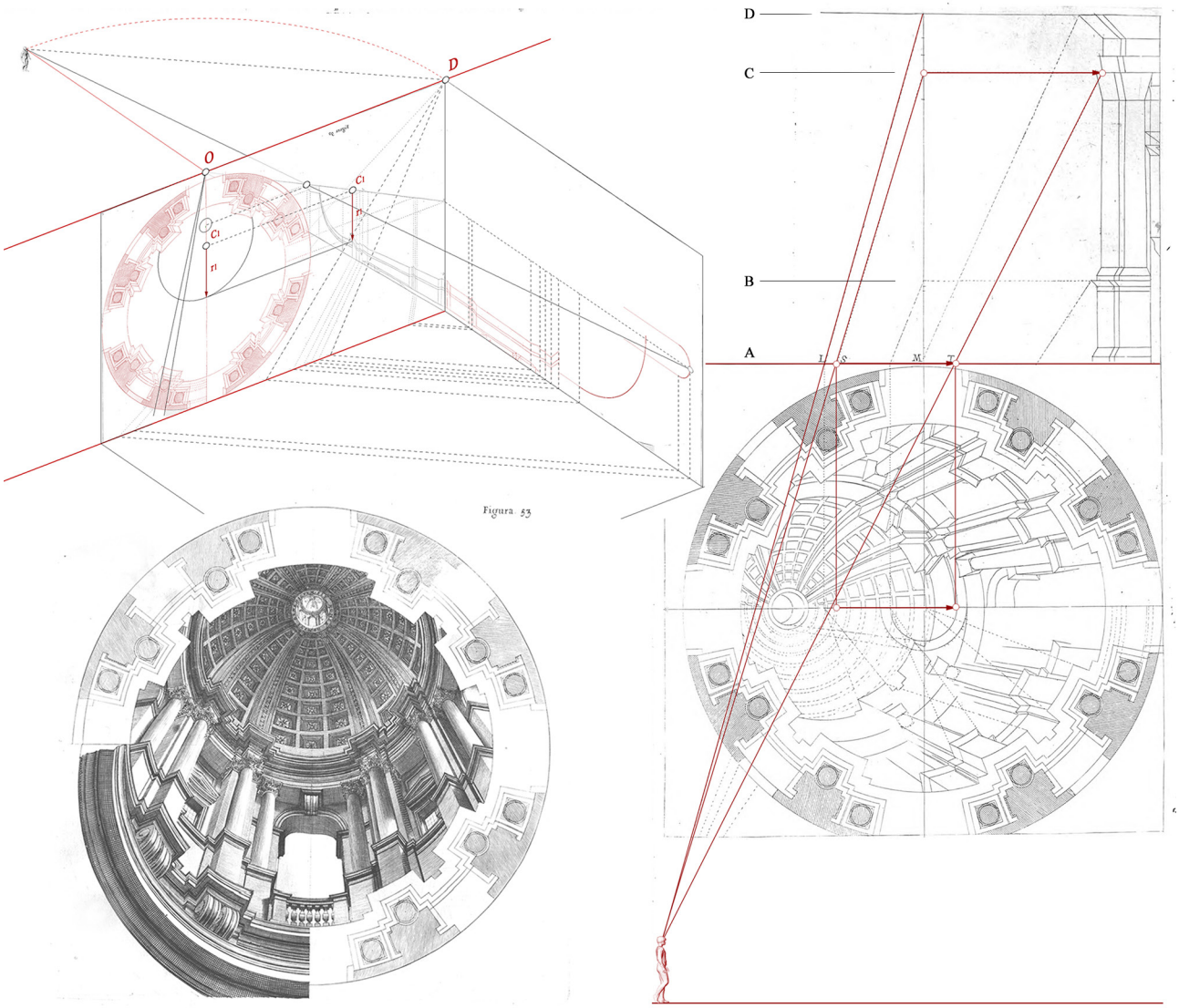
specific use: a sketch, which is preserved at the gallery of the Corsini Museum in Palazzo Barberini in Rome, the engravings of the graphic model of the dome that enrich the pages of the two volumes of the treatise on perspective and, finally, the painted canvas still visible today in the church of St. Ignatius [1]. The sketch is the first of the graphical models created by Pozzo. It is a square canvas measuring about 100 cm on each side and painted in oil that prefigures, presumably for the client, the perspective image of what will be the fake dome. The canvas, a faithful scale reproduction, which reduces the real size by about sixteen times, preserves, compared to the canvas in the church, the same perspective and a similar light and shade treatment. This is characterized by very dark tones, as if to simulate, or maybe amplify, the poorly illuminating effect of candles on the illusory intrados. The comparative analysis carried out on high-resolution photogrammetric surveys of the canvas and the sketch, reduced to the same size for means of comparison, shows the perspective coherence between these two models [2] (fig. 1) On the other hand, the main differences concern some morphological elements relating to the ornamental apparatus and the ceiling coffers in the dome. The sketch was followed by the realization of the canvas. The fake dome of St. Ignatius was an extraordinary success, which made this model a reference for several reproductions to follow, such as the church of Jesus in Frascati, the Abbey in Arezzo and the church of Jesus in Vienna, the only one to be painted on a surface with a double curvature, all made in the early Eighteenth century (fig. 2).

The importance of the St. Ignatius dome project led Pozzo to include its construction in both volumes of his treatise on perspective, to compare the effectiveness of the two perspective procedures that are therein respectively described [Pozzo 1693; Pozzo 1700]. In both volumes, the construction of the perspective passes through the representation in plan and elevation [3] (fig. 3). This *modus operandi*, common to all the case studies described in the treatise and therefore transversal, highlights the markedly design character of Pozzo's work, in which the perspective representation of the form derives from a precise architectural project which, as Pozzo himself observes, inevitably precedes it [Mancini, Fasolo 2018]. "whence you may perceive, that for designing things of this kind, the Painter ought to have no less skill in architecture, than is required for the execution of solid works" [Pozzo 1707, The Sixty-eight Figure].

The model published in the treatise is the most recent one. Although it explicitly reproduces the Collegio Romano's dome with the declared aim of preserving its future me-

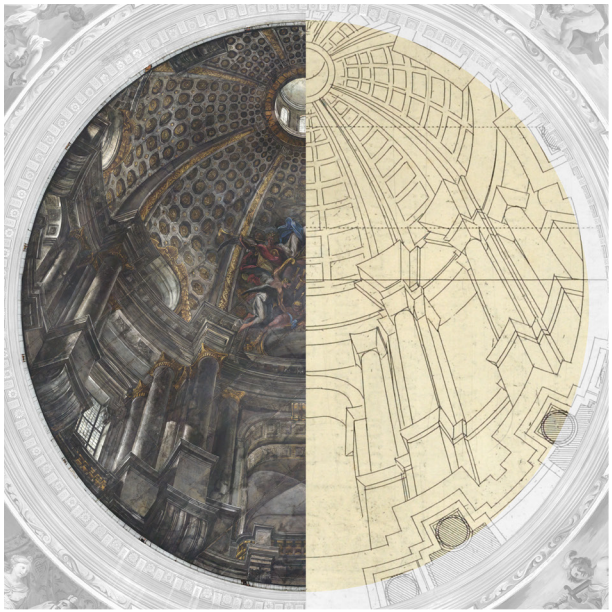
Fig. 2. Fake domes of the Abbey of SS. Flora and Lucilla in Arezzo (on the top) and of the Church of Jesus in Vienna (photographs by authors).

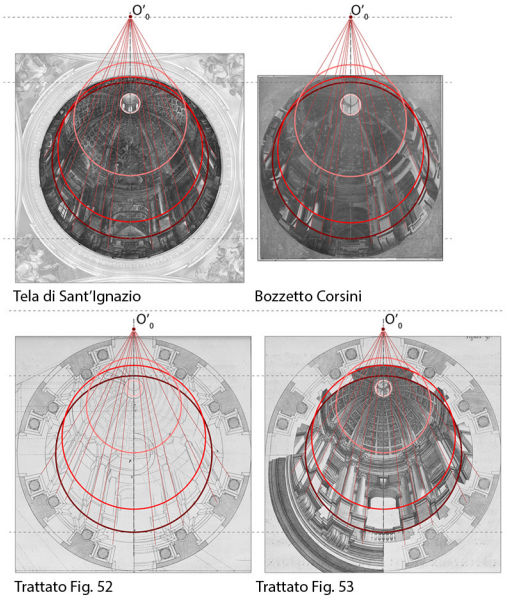
Fig. 3. Construction of the perspective of the dome with the rules of the treatise (graphic elaboration by the authors).



mory, it presents some differences with respect to the canvas and the Corsini sketch.
"The cupola in this plate will in all likelihood be of longer duration, than that which I painted on a very large table, for the flat ceiling of the church of S. Ignatius of the Roman College, anno 1685. For if that suffers by any accident, with the help of this its place may be supply'd by a better" [Pozzo 1707, The Ninety-first figure]
These differences especially refer to the position of the principal point and the depth of the tambour. In all the drawings the principal point is aligned according to the direction that the axis of the dome would have had if it had been represented in perspective. Therefore, in the treatise engravings, it is closer to the center of the impost circumference. Instead, the depth of the tambour is greater in the treatise engravings compared to the canvas and the sketch Corsini (fig. 4).
Considering the rigorous morphological coherence between the parts of the architectural order that structure the dome in all three graphic models, we wondered about the possible true form of the illusory space represented, researching a formal coherence between the theoretical model of design and the graphic models in question [4]. If perspective expands and contracts the same represented space, we ask ourselves what are the relationships that exist between the different models of perspective domes, and if it is possible to hypothesize the existence of a single architectural model to which all these perspective images allude. To this end, the true shape of the dome has been reconstructed, choosing the Corsini sketch from all the perspectives received, because it is authentic and because, as already mentioned, it is a prototype of the models to follow. Other reasons for choosing the sketch instead of the canvas are due to the various manipulations over time through much restoration [Pascoli 1736, pp. 245-276; Baldinucci 1975, pp. 315-326; Carta 1996].
The geometric restitution of a perspective requires the reverse reconstruction of the process that generated the perspective image and the spatial definition of the forms represented in it. It is an indeterminate problem that can find different solutions because of the hypotheses formulated on the basis of interpretations of an architectural nature.
In the general case of architectural perspectives, it is not always possible to return a plausible form to the represen-

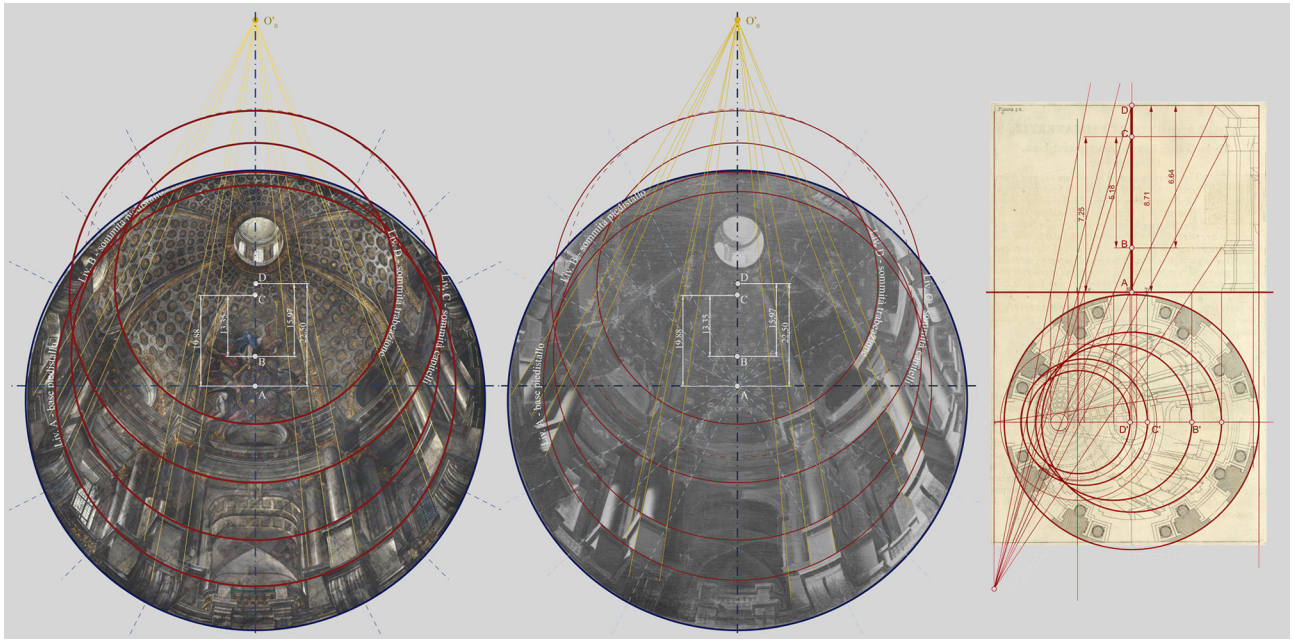
Fig. 4. Perspective analysis of the three models of the dome. At left the comparison between canvas and treatise (graphic elaboration by the authors).





ted space because often the pictorial work is conceived in a perspective and non-architectural key. Thus, the perspective restitution of the painted spaces often alters the proportions of the objects represented with results that are inconsistent with the physical reality expected [Baglioni, Fasolo, Migliari 2016]. In our opinion, however, the case of Pozzo goes beyond these considerations. The markedly projectural nature that strongly permeates the pages of the treatise legitimizes the venturing within the reconstructive hypotheses of true form, in search of the original design idea.
In a perspective from below, the picture plane is horizontal and perspective restitution becomes a complex problem because the elements that are normally used as a reference for the reconstruction of the distance points, such as the square bases of the columns, are missing. In the cases in question, the problem is amplified by the impossibility of reading the impost circumference of the vault, occluded, in all the perspective models, by the protruding frame of the projecting shelves.
In order to reconstruct the true shape of the dome, it is assumed that it would conform to the drawings of the elevation published in the treatise engravings. On these drawings, the proportions of the elements of the architectural order of the dome tambour, relating to the base, the column and the entablature, have been verified, with the intention of proving their invariance in the different perspective models. The verification can be executed because, in a perspective with a horizontal picture plane, it is possible to reconstruct the centers of the circles that remain in true form, on the perspective of the revolution axis at different heights corresponding to the elements of the architectural order.
There is a particular type of ratio between the lengths of three aligned segments that remain constant after one or more projective operations: the cross-ratio. The perspective of three aligned and contiguous segments, AB, BC and CD, alters the objective lengths and the relationships derived from the comparison of one segment with another. The cross-ratio, which is measured by the ratio between the simple ratios (AC/BC)/(AD/BD), is a projective invariance, therefore it remains constant regardless of the type and number of projective transformations that are applied. The invariance values of the cross-ratio, which measures about

Fig. 5. Calculation of the cross-ratio in perspectives of the canvas, the sketch and the treatise (graphic elaboration by the authors).



1,064 in the case of the Corsini sketch, 1,066 in the case of the treatise and finally 1,072 in the case of the canvas [5], have shown the same proportioning of the elements of the architectural order (fig. 5). The hypothesis according to which the architectural perspectives of the dome are the images of the same architectural model seen from different projection centers is therefore legitimate. Then, the difference is in the perspective view, namely in the position of the center of projection, determined by the principal point and the principal distance.
The analysis of the invariance of the cross-ratio was also applied to the case of the fake dome of the canvas in Arezzo, resulting in support of the expressed hypothesis. Based on projective invariance, the proposed method has general validity and can also be applied to cases of false domes on a polygonal plant or painted on surfaces with a double curvature, such as the dome of Jesus of Vienna [6].
The analytical verification of the invariance of the cross-ratio has therefore shown the existence of an ideal model of reference, proportionate according to the architectural order, consistent with the representations in true form of the treatise dome, to which the three models can be connected. With the intention of verifying this theory from a projective point of view, a virtual restitution of the perspective relationships that exist between the ideal model of the dome, its perspective representations and the position of the ob-

Fig. 6. Restitution of the ideal model of dome (graphic elaboration by the authors).

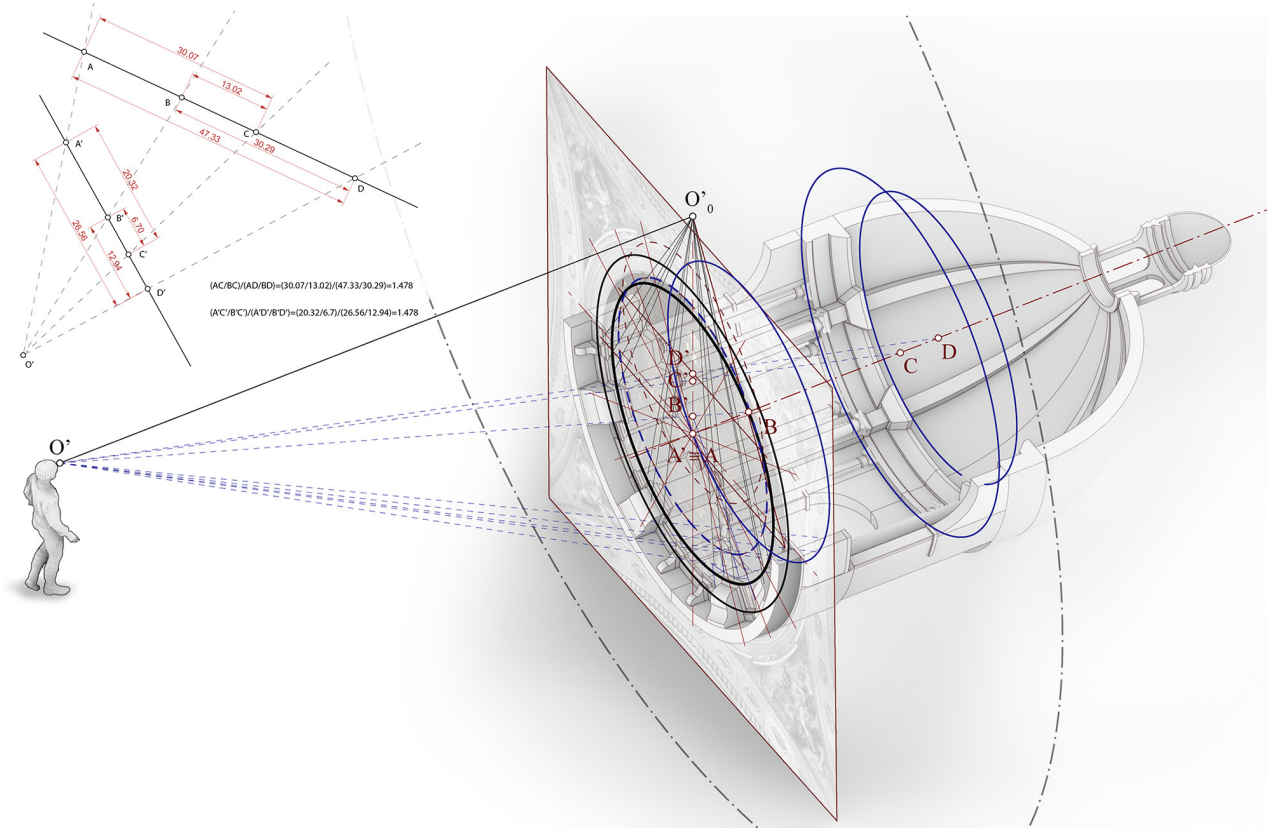
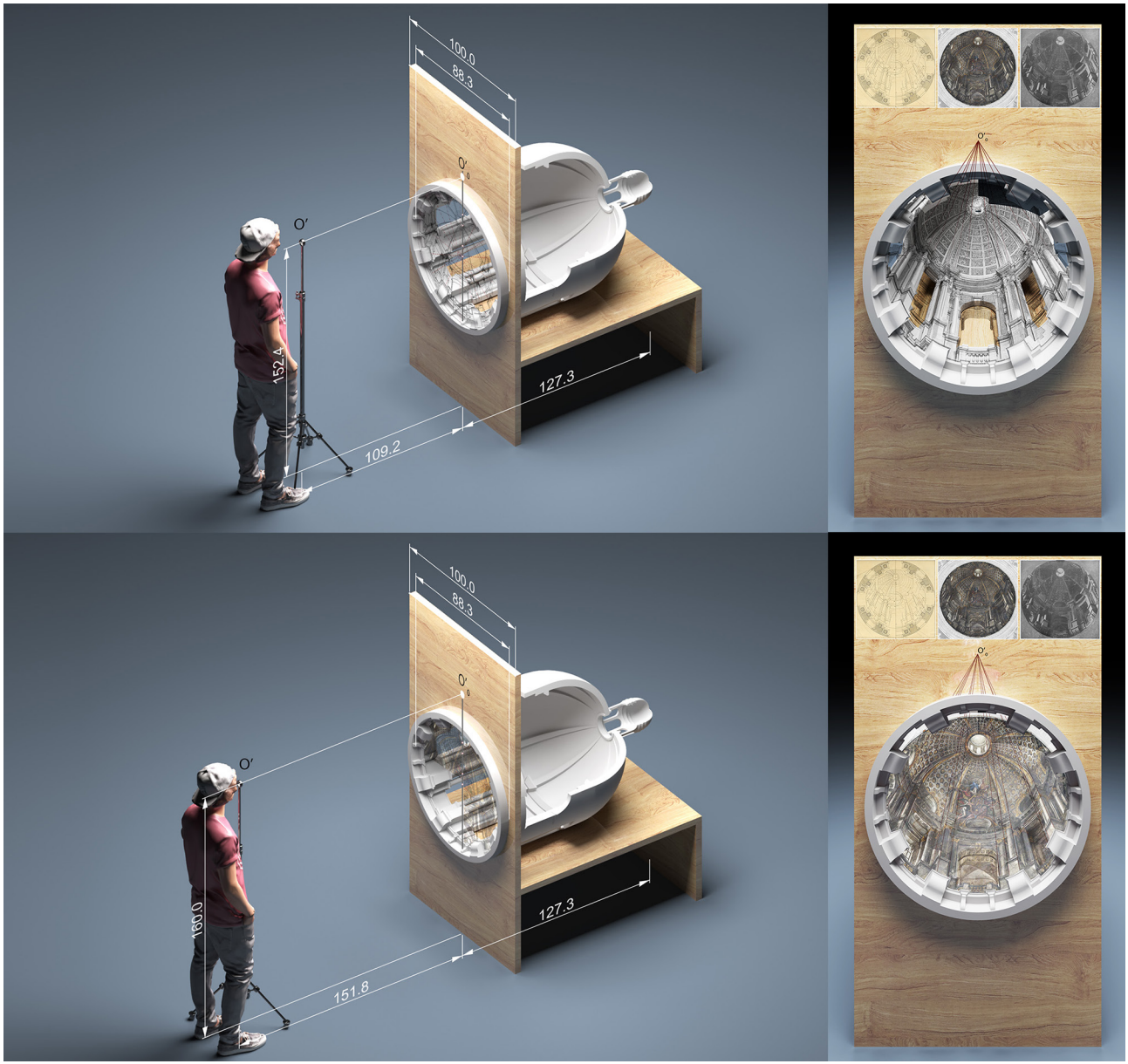


Fig. 7. Project for installation of the perspective machine (graphic elaboration by the authors).

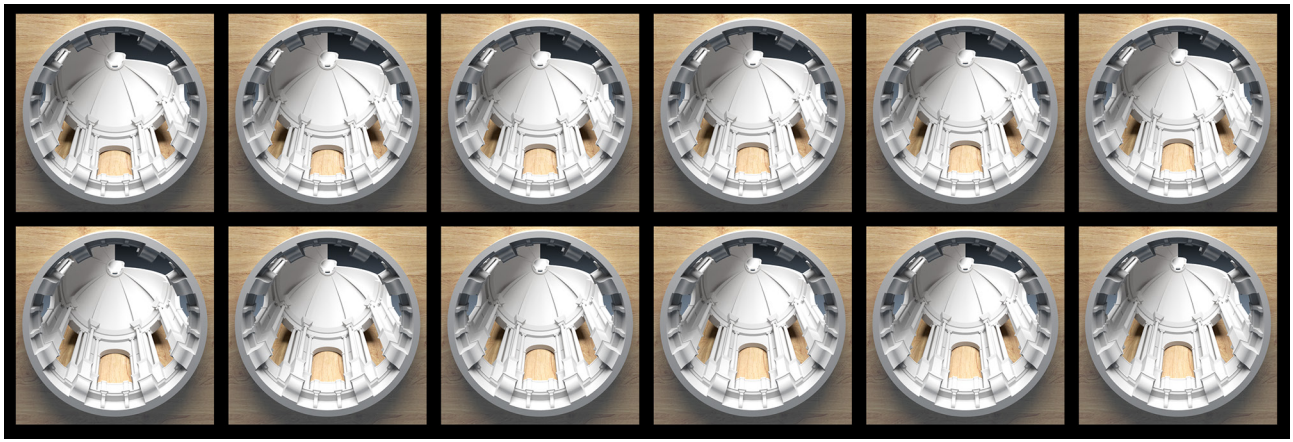


server has been carried out. The effectiveness of this simulation has led to the creation of an installation through which to experimentally validate this theory (fig. 6).

Exploration of the perspective machine

The model of the real form of the fake dome was the subject of a perspective installation conceived with two linked, but distinct, purposes. The first, devoted to validating and experimentally verifying the theory elaborated, was finalized to sharing the results within the scientific community; the second was aimed at communicating this theory to a wider and more inexperienced public, through an installation capable of describing the perspective through a physical model with which to interact in order to fully participate in the functioning of the perspective machine.
The installation reproduces the existing projective relationship between the theoretical design model of the ideal dome and the graphic models that constitute its different perspective images. Designed in large dimensions but, at the moment, realized with low-cost techniques of rapid prototyping, this installation reproduces the ideal model of dome design arranged horizontally so that it can be observed without necessarily having to look up. At the level of the dome impost plane, the perspectives of the graphical models of the painted domes, imprinted on interchangeable transparent discs, are arranged. Each of these images corresponds to a specific point of view. Observation from the relative projection center of the different graphical models, shows the persistence of the illusion. In fact, it is possible to verify every time the coherence of the graphical model with the perspective image that is naturally produced by observing, from the same projection center, the physical design model of the dome (fig. 7).
Understanding its more general meaning, which explores the functioning of the perspective machine, the installation expresses the relationship between the real space represented by the physical model, and the particular case of the linear perspective that corresponds to it. To understand the projective relations that exist between real space and its perspective, it is useful to observe the perspective machine from two different points of view: that of the observer, who is inside the perspective and who fully appreciates the illusion of perspective; that of an external spectator who understands the reasons for the illusion. This double mode of observation allows us to experiment the parameters that define the foreshortening in perspective and that depend, as illustrated, on the principal distance and the position of the projection center. An external observation reveals these variations, which can be appreciated by the physical movements of the observer, while an internal observation allows us to explore the perspective effects of contraction and dilation which are characteristic of the projective space. Moving away from the painting, in fact, the perspective space reduces its depth, the angle of field decreases, as if

Fig. 8. Perspective effects of contraction and dilation of the projective space (graphic elaboration by the authors).



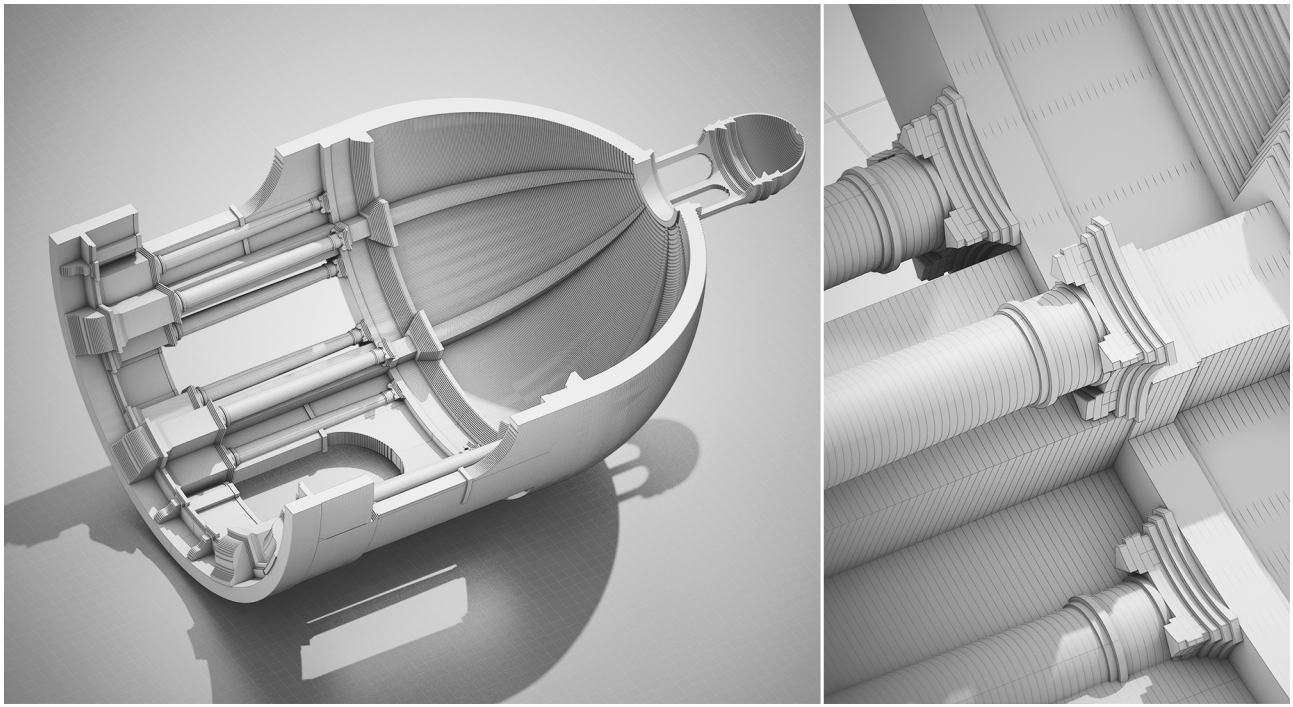


Fig. 9. Project for the prototyping model of the dome on a large scale with laser cutting techniques (graphic elaboration by the authors).

using a telephoto lens, making the perspective appear more flattened. One must imagine moving away until reaching an infinite distance from the picture plane, arriving at a limit condition in which the space projection becomes parallel. Impossible to reproduce in physical reality, this simulation is easily reflected in the dynamic virtual reproductions of the perspective machine (fig. 8).
In perspective, the larger the size of the installation, the more effective the interaction. For this reason, the project foresees its realization in dimensions that include the observer, thus amplifying the illusory power of perspective. To this purpose, the prototyping of the wooden model is currently in the design phase with laser cutting techniques that allow the construction of large models for the assembly of successive layers [7] (fig. 9). To measure the effects of the painted canvas in an optimal way, the model should be housed in the rooms of the church of St. Ignatius, in order to better appreciate, by comparison with the real painting, the effects produced by the variation of the foreshortening.
The prototype, made in small size, was tested in academic contexts, to support the verification of the proposed theory and was recently exhibited at the Maker Faire 2018 held in Rome (fig. 10), where it aroused special interest, stimulating a surprising curiosity and the active participation of a particularly young and heterogeneous audience.

Conclusions

The research aimed to propose a method of analysis and study of the domes '*di sotto in su*' based on the projective invariance of the cross-ratio to demonstrate the existence of a single design model with different architectural perspective images. The generality of the method allows its applica-

Fig. 10. Images from the recent Maker Faire 2018 in Rome (photographs by authors).

tion to other types of domes, currently under study, such as those on a polygonal plant or painted on surfaces with a double curvature.
The existence of an ideal model at the base of the domes viewed from below, reinforces the dual design character of Pozzo's theoretical and practical work. He imagines and describes the architectural models of the three-dimensional space through design drawings in plan and elevation, but at the same time designs in a scenic key, illusory architectures through perspective representations.
Characteristic of Pozzo's design activity, the idea of a model permeates the research in all its phases, from analysis to critical elaboration up to communication of the contents. This idea animates the definition of the geometries of the dome, in search of its ideal model starting from a critical reading of the relative graphic models. It characterizes the restitution phase by reproducing projective principles at the basis of the functioning of the perspective machine in a static and dynamic way. Finally, through the proposed installation, this idea expresses, in physical form, the relations that exist between the ideal model of the dome, its graphical model and the observer.
Today, digital representation allows us to operate with heterogeneous models, to relate them to each other, and to reproduce them continuously in their physical form. These different declinations of the ideal model show how this has been, and continues to be, a privileged tool for the transmission of knowledge, able to address even a heterogeneous public translating difficult to access projective theories into a simple and explicit language.
This is the main purpose of the proposed installation, aiming to demonstrate perspective through the language of perspective itself, proposing a fruition by an external spectator, who looks at the described procedures from the outside or by an internal observer, who is, instead, an integral part of the projective process.

Notes

[1] There is evidence of a second sketch, at present unavailable, about which Lina Montalto speaks in her studies on the subject and preserved for a long time in the sacristy of the S. Ignazio church [Montalto 1962].

[2] The painted canvas and the Corsini sketch were acquired through high-resolution photogrammetric panoramas, then straightened by means of control points acquired with topographic instruments.

[3] The first rule described by Pozzo teaches how to build perspective through the degradation of the plan and the elevation. These two images, degraded and associated in space on planes perpendicular to each other, allow the perspective construction by intersecting the lines passing through corresponding points. Instead, the second rule consists in projecting the plan and the elevation onto the picture plane, also represented in plan and elevation. For further information about the methods for perspective construction described by Pozzo, see a study by the authors entitled *Andrea Pozzo e la finta cupola di S. Ignazio in Roma* [Baglioni, Salvatore 2019].

[4] The three models of the dome of the Collegio Romano have the same articulation of the tambour, that are divided into eight parts, marked by twin columns interspersed with a column projecting on cantilevered shelves, framing a central arch and side windows that are different in each case.

[5] The uncertainty of the measurements is attributable to the different physical dimensions of the three models analyzed.

[6] In the case of the fake dome of the Church of Jesus in Vienna, the cross-ratio can be calculated directly from the perspective of the painting made by the projection center, using the centers of the ellipses to identify the segments aligned on the axis of revolution.

[7] This technique was used by Mario Botta in 1999, for the installation that reproduces in scale the church of San Carlo alle Quattro Fontane by Francesco Borromini on the shores of Lugano Lake, in Switzerland.

Authors

Leonardo Baglioni, Department of History, Representation and Restoration of Architecture, Sapienza University of Rome, leonardo.baglioni@uniroma1.it
Marta Salvatore, Department of History, Representation and Restoration of Architecture, Sapienza University of Rome, marta.salvatore@uniroma1.it

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