

Beyond the Limits of the Constrained View: Interactive Digital Spaces for the Perspective *Quadratura* of the Royal Palace of Portici

Alessandra Pagliano, Barbara Ansaldi

Abstract

Between the 17th and the 18th century, quadraturism established itself as a technical and conceptual device capable of altering the perception of the architectural space: by means of linear and aerial perspective –sometimes rigorous, at other times departing from geometrical principles to create deliberate artifices– the quadratura creates the illusion of a depth that dematerializes the wall surface, expanding the space behind its physical boundaries. This results in alternatives and fictional spaces of unlimited depth, interacting with the real structure, enriching its spatiality to the point that it becomes impossible for it to maintain an independent and autonomous identity. Thus, a tension is established between what is real and what is represented through the use –for illusory purposes– of perspective drawing: this tension is what makes the Sala delle Guardie of the Royal Palace of Portici (Naples) an emblematic case of ‘revealed structure’ through drawing, the latter intended as an act of knowledge, interpretation and organization of visible space. By means of digital photogrammetric survey and perspective restitution of painted architectures, research intended to critically reinterpret the rules and derogations adopted by the artist-scenographer in designing his ‘augmented’ space in terms of spatial perception, offering a three-dimensional reconstruction of the painted architectures in order to allow their exploration from unrestricted viewpoints through Augmented Reality and Virtual Reality.

Keywords: quadraturism, reverse perspective, Augmented Reality, royal Palace of Portici.

Introduction

Quadraturism is a style of pictorial decoration which emerged mainly during the 17th and the 18th century and is characterized by the perspective representation of painted architectures that merge with the actual space in an illusionistic way, simulating a spatial continuity between the two. The quality of the psychological and emotional experience of such spaces, ‘enhanced’ by the painted perspectives, lies in the recognition and conscious enjoyment of their illusory value: similarly to what happens when observing a theatrical scene, the viewer is more deeply engaged in the experience of illusory spaces right when the artistic value of the representation is appreciated through an understanding of the geometric complexity of the projective processes that generated it. It was

no coincidence that Charles of Bourbon commissioned stage designer Vincenzo Re to fresco the most representative spaces of the Royal Palace of Portici, where he applied his theatrical experience to the decoration of the Atrium, the Salone Reale, the antechamber on the first floor, and the Sala delle Guardie. The purpose of the *quadratura* was not to simply decorate the plastered surfaces, but rather to give greater grandeur to the spaces, whose dimensions appeared inadequate to the rank of a royal palace. Re, in collaboration with the figure painter Crescenzo Gamba, executed the architectural perspectives of the Sala delle Guardie and of the First and Second Antechambers between 1744 and 1746 [Visone 2019, p. 153]. He resorted to the representation of scenic

perspectives of false Baroque architectures which, breaking through the walls, would give the illusory sensation of the presence of other adjoining spaces. In compensating for the lack of real architectural structures, he staged the illusion of wide-ranging spaces, opening upwards toward the vision of allegorical representations. The research therefore offers a traditional interpretation of the geometric processes employed by Re and Gamba in creating the perspective *quadratura* of the Sala delle Guardie. It then aims to create a digital product for an interactive and conscious fruition of the painted illusory perspective spaces, contributing to a deeper understanding of the design mechanisms that give meaning to both the real and imagined architectural space.

Architecture as a frame for painted spaces: quadraturism and space beyond physical boundaries

At the heart of Baroque and late-Baroque artistic production, quadraturism emerges not merely as a decorative language, but as a technical and theoretical tool capable of influencing the perception of architectural space. It consists of “representations of architecture that, by exploiting at times linear perspective, at times aerial perspective and other devices, induce in the viewer a perception of depth that ‘breaks through’ the wall surface, expanding the space that contains them to the limits of sight” [Migliari 2014, p. 1]. Quadraturism has its roots in the illusionistic devices already present in the wall paintings of Roman *domus* [Mazzoleni, Pappalardo 2004; Cardone 2014; Migliari 2014] –in the so-called Second and Fourth Pompeian Styles– particularly in the *cubicula*, where the small chamber intended for rest appeared larger thanks to the illusory breaking through the wall’s physical boundary.

The perspectival device of quadraturism is based on the integration of two complementary perceptual modes: *perspectiva naturalis*, linked to the empirical perception of space by the observer, and *perspectiva artificialis*, constructed according to codified and controllable geometric rules. The *quadratura* expands and alters the logical structure of space, since the painted architectures –inserted within a rigorous perspectival framework– imply the intention to create a structure, or a set of structures, as a substitute for the real one or in close relationship with it [Pascariello 2005, p. 15]. In this sense, although originating from illusory needs, the *quadratura* is based on a rational and planned

system, configuring itself as true designed space whose perception depends on the choice of the viewpoint. It is capable of transforming real spaces with defined boundaries into architectural ‘breakthroughs’, imbued with new meanings and sensations: the observer is invited to enter and ideally traverse them with their gaze, in a whirlwind of dynamism that generally favors circular movement around the room [Aterini 2015, p. 428]. The illusory effectiveness of a *quadratura*, therefore, does not lie so much in pictorial realism, but in the ability to generate an *architectura picta* consistent with the static, geometric, and perspectival principles inherent to the real construction. This principle of internal coherence allows a dialogue between real architecture and painted architecture, where one credibly and functionally extends into the other. The quadraturist representation thus becomes a ‘unrevealing drawing’: it shows and makes visible a spatial structure that does not physically exist but is logically plausible, while simultaneously concealing the two-dimensional physical surface it occupies, overwriting it.

In the Sala delle Guardie of the Royal Palace of Portici, the painted architectural structures effectively carry out a true rewriting of the physical space: the wall, the vaulted surface, and the corner cease to be static boundaries and become thresholds that can be visually crossed, beyond which the painted image illusionistically multiplies the spaces. This is achieved also through a careful imitation of the architectural style of the real spaces, reproducing schemes of columns, pilasters, arches, capitals, pillars, impost lines, and proportions.

The observer is thus guided through an expanded spatial experience, in which the painted architectures appear as a necessary extension of the real walls: the intention is to imagine and represent the simulated space as an integral part of the real space that contains it, with the clear aim of reconstructing the illusory architecture and connect it to the actual one [Migliari 1999]. The illusory effect, in fact, becomes more effective the more structurally coherent it is –not a *trompe-l’œil* for its own sake, but a visual construction that entails a compositional intelligence grounded in shared architectural principles. In this sense, quadraturism presents itself as a revealing tool even before being an aesthetic one: through perspective drawing, painting unveils what architecture cannot physically achieve, disclosing a structural potential ‘beyond’ the walls. The perspective grid, invisible yet rigorous, acts as the generative framework of the painted space –a structure that does not

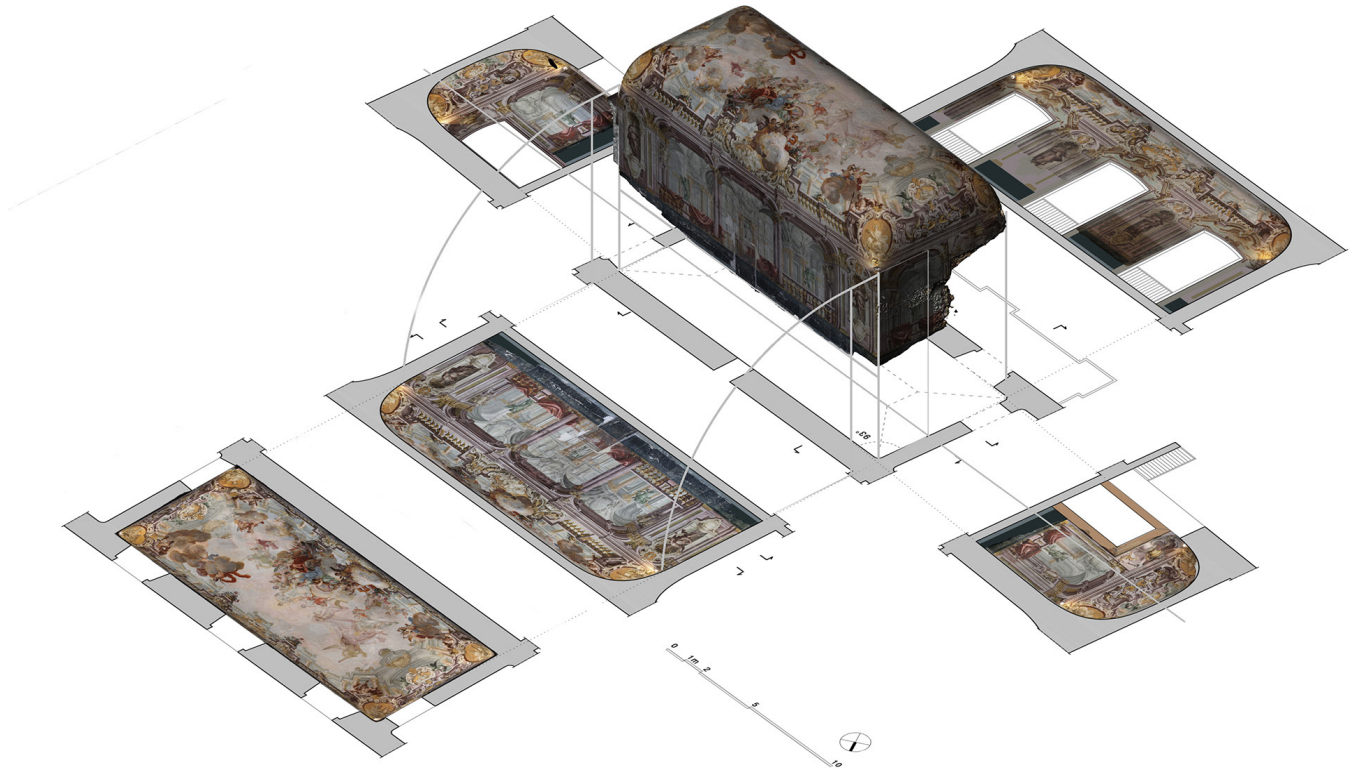


Fig. 1. Monge projections obtained from the mesh model with high-definition textures (graphic elaboration by the authors).

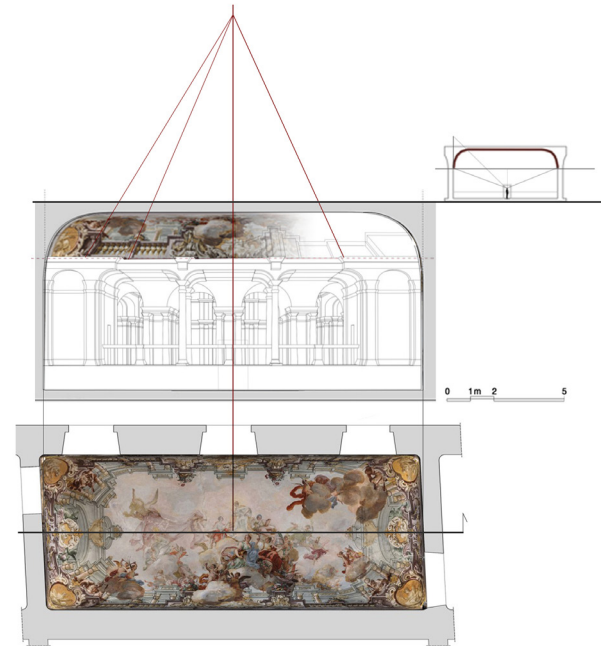
bear weight but imposes order, sustaining the coherence of the architectural image and guiding its perception. This tension between the built and the represented architecture is what makes the Sala delle Guardie an emblematic example of 'revealed structure', not in the technical sense of load-bearing capacity, but in the deeper one of drawing as an act of knowledge, interpretation, and organization of visible space. In this context, perspective drawing is not a mere mimetic tool, but a mediator between idea and perception, capable of revealing the invisible order that governs and sustains architectural appearance.

Drawing as structure of the illusory space

The relationship between painted spaces and real architecture is based on drawing as a means of expanding spatial experience through perception. Drawing is, in fact, the latent structure of the two liminal spaces: the painted one, which draws from the form of the real one those hidden laws and geometric relationships that rule the illusory project aimed at the verisimilitude. Perspective drawing, however, becomes an autonomous language because it is capable of generating architectural shapes that are completely non-existent in physical reality but perfectly coherent in the world of appearance. In this sense, drawing has been a design tool for the set designer Vincenzo Re in the Sala delle Guardie and a sort of 'revelation' for the scholar who wants to understand the compositional rules, but also the inevitable exceptions, of an 'other' space, investigated through the geometry that retraces the illusionistic construction of its configuration. The fundamental tools of this ancient practice of investigating painted architecture are primarily the linear conical perspective, in its reverse process that goes from the image to the true shape of the space through central projections, but also the in-depth analysis and knowledge of the architectural stylistic features of real space, which inspire the painted ones to achieve the perception of a unique architectural whole, with overall formal harmony, but with an amplified effect of depth.

The recognizability of the formal qualities of the painted space is one of the factors that determines the observer's voluntary fall into illusion. There is no doubt that the absence of static and structural problems grants freedom to the design of painted spaces, in which perspective drawing is the structure of the represented space, to

Fig. 2. Bottom orthographic projection of the pavilion vault and section, with identification of the privileged viewpoint (graphic elaboration by the authors).



be derogated according to pictorial and compositional principles without altering the overall scheme.

In the case of the perception of an architectural *quadratura*, it is essential to refer to the distinction Immanuel Kant makes between the terms 'illusion' and 'deception' in relation to sensory and transcendental appearances.

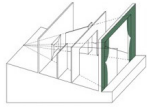
Cassandra Basile states that the term 'illusion' is associated with an awareness by the subject who evaluates an object or situation [Basile 2018, p. 416].

Once any sensory appearance is discovered, Kant refers to it as an 'illusion' in order to highlight its harmlessness for the subject perceiving it, who is aware and therefore able to judge the observed object correctly.

The correct judgment does not make the appearance disappear, but it remains as an illusion [Basile 2018, p. 416], emphasizing the game that involves the observer in appreciating the sensory illusion even when he understands that the presumed object is not real. The question, therefore, of the architectural consistency of the painted



PRIMO PIANO PROSPETTICO - FIRST DEPTH PLAN



SECONDO PIANO PROSPETTICO - SECOND DEPTH PLAN



PRINCIPALE - MAIN SCENIC PORTAL



ULTIMO PIANO PROSPETTICO - LAST DEPTH PLAN



FONDALE - BACKDROP

Fig. 3. Identification of depth planes (graphic elaboration by the authors).

Fig. 4. Identification of the center of projection through simulation of the cone of vision in the three-dimensional space of the model (graphic elaboration by the authors).

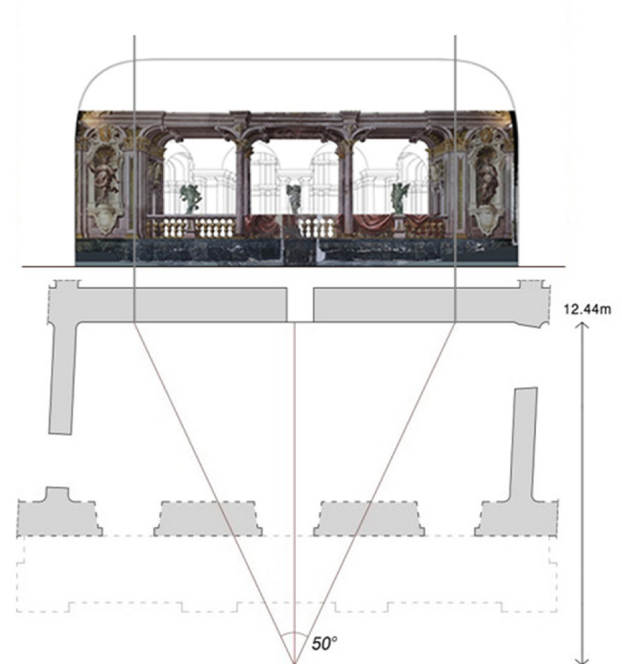
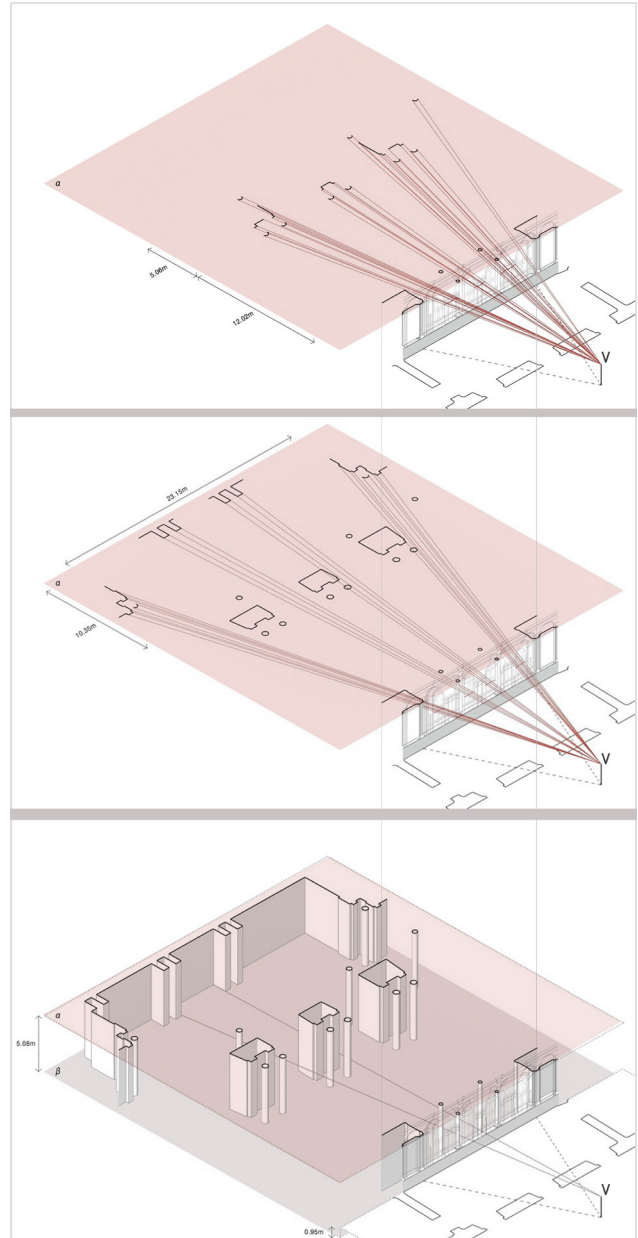
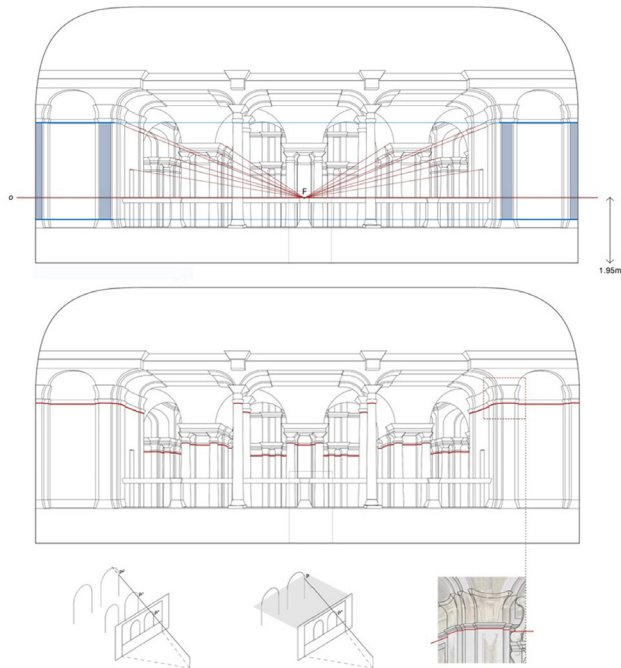


Fig. 5. Identification of the horizon line, the pilasters aligned with the perspective frame, and the horizontal elements intended to be placed at the same level (graphic elaboration by the authors).

Fig. 6. Projection of the painted elements onto the horizontal plane to define their spatial placement (graphic elaboration by the authors).



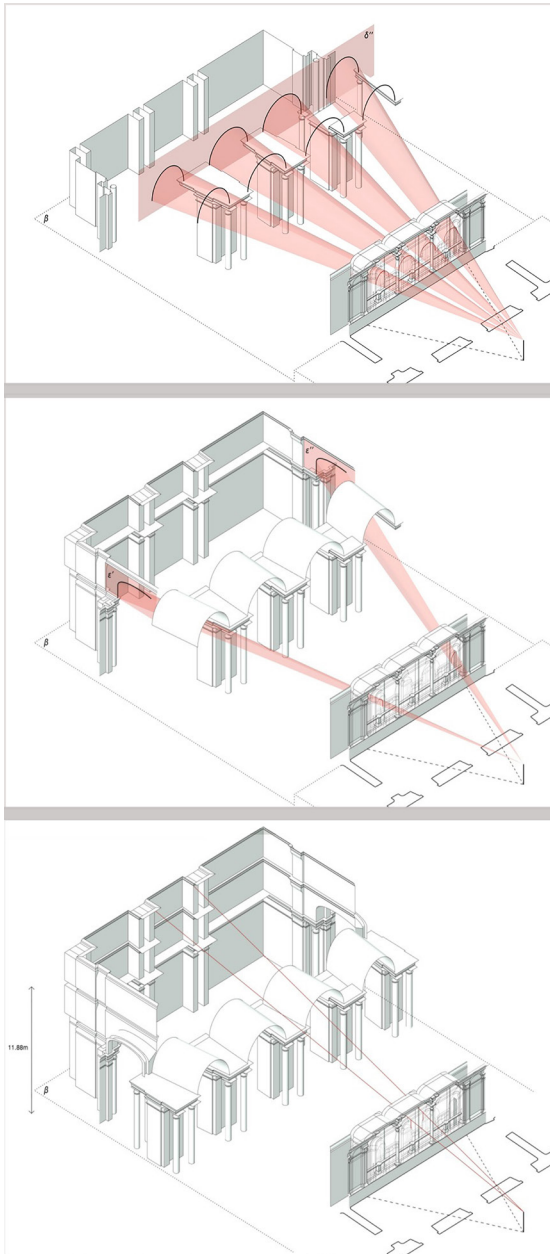


Fig. 7. Perspective reconstruction of additional painted architectural elements through the perspective alignments between the projection center, the perspective image, and the spatial position consistent with the previously reconstructed architectural elements (graphic elaboration by the authors).

space with the real one of the architecture that frames it was the fundamental critical-interpretative position of our approach in defining those painted elements that could be recognized in a spatial relationship with their counterparts in the physical space.

In order to obtain a three-dimensional model recording both the shape and spatial positioning of the real physical elements and of the perspective painted ones, a digital photogrammetric survey was carried out in the room (165 photos taken with a Canon EOS 250 D camera, with 70% partial overlap, then processed using *Metashape* software and scaled according to the direct survey data). A textured polygonal mesh model was thus prepared on which to work, in reverse perspective rendering method, i.e., by applying the same projective processes that led to the painted architectural image but spatializing these processes in the three-dimensionality of the digital model. Once the plants, sections, and the reflected ceiling plan of the vaulted surface had been obtained by the 3D model, it was possible to work on the true shape of each painted wall (fig. 1).

The presence of a frescoed vaulted ceiling with an illusory zenithal perspective prompted us to place its projection center in the middle of the room, at a height of 150 cm from the floor; from this position, the illusory decorations projected onto the vaulted ceiling, which simulate a break-through of the covering surface, give the observer the perception that the height of the vertical walls is more than the actual height of the room.

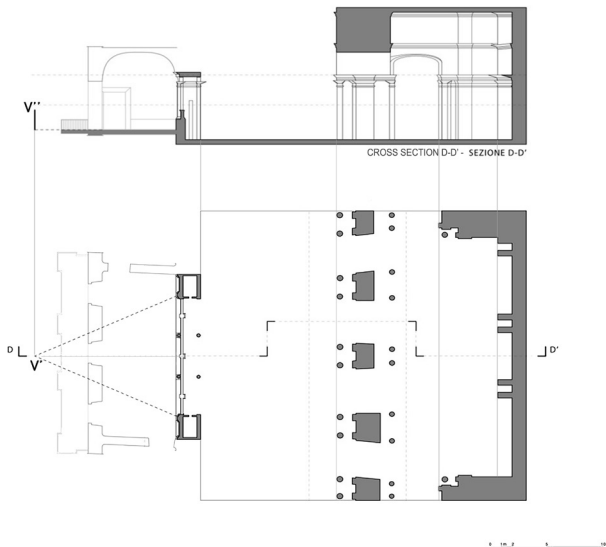
With respect to the viewpoint thus determined, the perspective painted on the pavilion vault presents a bilateral symmetry, thus validating the chosen position for the projective center/observer, which is, moreover, the one traditionally most used by quadraturist painters (fig. 2).

The horizon line was identified by the convergence of lines that are the perspective image of the perpendiculars to the frame; point V_0 falls, as expected, along the vertical midline of the wall, at the intersection with the upper line of the balustrade.

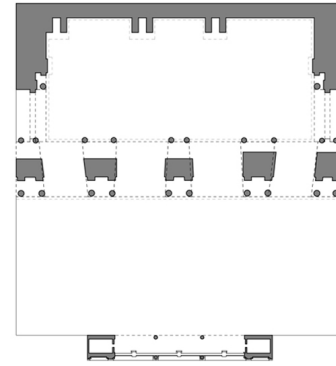
Drawing thus becomes structure, in the wider sense of the term, as the set of elements that constitutes an organic system thanks to their mutual relationships

Fig. 8. Plan and section of the painted space reconstructed from the wall in a frontal position relative to the windows of the room (graphic elaboration by the authors).

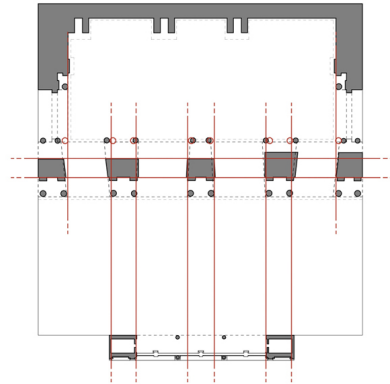
Fig. 9. Comparison between the reconstructed plan and the philologically reconstructed plan, elaborated based on hypotheses concerning the spatial logic underlying the artist's perspective design (graphic elaboration by the authors).



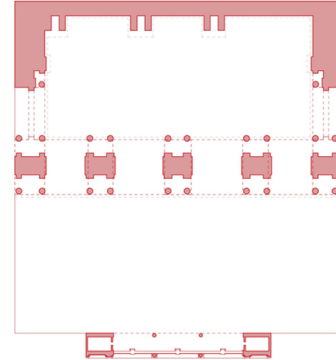
PLAN OBTAINED THROUGH PERSPECTIVE RESTITUTION



HYPOTHESES ON ALIGNMENTS



PHILOLOGICAL RECONSTRUCTION



of dependence. If structure is therefore the organized complex of the parts of an organism, a construction, or a system, considered in their mutual relationships, the perspective drawing of the *Quadratura* becomes the structure of two topologically different but apparently connected and uniform spaces. The various planes of depth along which the rows of columns and arches are arranged have been discretized, thanks to an interpretation inspired by the principles of contemporary theatrical scenography (fig. 3), according to layers of depth parallel to the perspective frame, thus retracing the rich tradition of 17th and 18th century sketches, with which the scenographer Vincenzo Re was deeply familiar and from which he certainly drew inspiration.

The first necessary step in the restitution of the true shape of the painted architecture was to complete the identification of the internal orientation of the perspective reference and, therefore, the position of viewpoint *V*, which coincides with the center of projection. We noticed that an observer standing in the center of the room, the ideal position for the aforementioned zenithal perspective along the vaulted ceiling, would not have been able to see at a glance the entire wall corresponding to the long side of the room, as a consequence of the

physiological limits of the visual cone, established in literature as maximum 60°.

According to the scenography main rules established by Serlio [Serlio 1545], as well as by many other later treatisers, the ideal viewpoint of a stage setting, or the privileged observer (which coincides with the center of projection of the entire perspective system), is frequently placed outside the physical space of the theatre building, thereby reducing the effect of perspective distortions for less privileged observers who are positioned to the side. Similarly, Vincenzo Re placed his projection center beyond the boundary of the room, in the contiguous space. The position was identified considering that the entire wall falls within the 60° visual cone and that the painted second plane of depth is contained within a 50° visual angle. The hypothesis was verified by placing a digital camera in the 3D model of the room (fig. 4). Again, according to an interpretation based on the illusionistic stage design principles, it was noted that the perspective floor plan coincides with the horizon line. This choice comes from the stage setting tradition, described by Ferdinando Galli Bibiena in his 1732 treatise, *Direzioni della prospettiva teorica corrispondenti a quelle dell'architettura, istruzione a' giovani studenti di pittura, e architettura nell'Accademia clementina dell'Instituto delle Scienze*, table No. 49, useful for adapting architectural perspectives to the two-dimensionality of the painted canvas that rests on the stage with a straight base [Pagliano 2016]. Since there are no physical elements protruding sculpturally from the wall, such as pilasters, moldings, or capitals, we chose to place the image plane in coincidence with the pilasters in the foreground (fig. 5), which are thus considered to be in their true form and size.

Starting from these elements, we placed one horizontal plane at the height of the collar of these pillars in the foreground, onto which we projected, from point *V* all the other painted collars at a different depth plane, assuming that they were at the same height, in accordance with the architectural consistency of the painted space (fig. 6).

According to this hypothesis, the perspective restitution was carried out by running in reverse order the conical projections that have been necessary to Vincenzo Re for the construction of the perspective image, thus spatializing in a digital 3D model those geometric processes typically drawn in 2D, through the descriptive geometry's methods (fig. 7). Using a similar process, the true shape of the painted spaces on the other walls of the room has been

Fig. 10. Comparison between the perspective image painted on the room wall and the corresponding view of the 3D model, obtained from the philological reconstruction and observed from the same viewpoint (graphic elaboration by the authors).



reconstructed. Each wall has its own projection center, but they are all the same height, as can be seen from the horizon lines on each wall, which are all at the same height from the floor. This geometric expedient has a highly effective illusory effect, as the observer perceives the painted space as a single, coherent architectural system (fig. 8), an external space concentric to that of the Guard Room, which appears to surround the room on all four sides, being visible through the filter of the arches painted in the foreground.

The revealed space and its augmented fruition

Extended Reality (XR) technologies are increasingly emerging as tools of primary scientific and applicative relevance in the field of Cultural Heritage communication. They are now widely implemented in museums as well as in historical and archaeological sites worldwide [Innocente et al. 2023], with the purpose of providing visitors with interactive and immersive experiences [Casale 2018]. Among these technologies, AR (Augmented Reality) and VR (Virtual Reality) represent two of the most significant developments, functioning as privileged instruments not only for the enhancement and fruition of Cultural Heritage in a broad sense, but also for the analysis and interpretation of painted architectures, as exemplified by the case of *quadratura*. The advantages of interactive digital visualization range from cultural and physical accessibility to interpretation, engagement, and inclusive communication [Pagliano 2023]. Indeed, the interaction with virtual spaces and objects contributes to the promotion of cultural heritage and enhances understanding of the site, fostering critical feedback and increasing awareness [Innocente et al. 2023].

The construction of the three-dimensional model derived from the perspective restitution of the painted architectures in the Sala delle Guardie represents the starting point for a broader reflection on the interaction between illusionistic space and digital technologies. One of the most significant aspects that emerged during the modeling process concerns the necessity of reconstructing, beyond the architectural frames delimiting the scene, a continuous and coherent space. Indeed, the painted architecture is conceived in continuity with the real architecture of the Royal Palace, echoing its style, architectural layout, and proportions, while also respecting the height

of the springing line of the vaults. It should be noted, however, that a careful philological reconstruction of the drawings obtained through perspective restitution was required in order to correct a series of spatial inconsistencies. In some cases, the reconstructed plan deviated from what would be architecturally plausible: for instance, a trapezoidal section of the pillar plan, rather than a rectangular one, contradicted the spatial logic that the painter had in all likelihood conceived according to coherent canons and stylistic principles. For this reason, the space was 'rectified' in those areas where only minor discrepancies and geometric inconsistencies were detected—conditions that would have been incompatible with a functional and feasible architectural structure (figs. 9, 10). This operation proved necessary because the *quadratura*, although appearing perfectly regular from a perspectival point of view, would inevitably reveal, when observed from other viewpoints, optical adjustments and distortions devised to serve the pictorial illusion—yet impossible to translate into a three-dimensional structure governed by logical consistency. The adoption of AR and VR technologies, which allow users to freely vary their point of view and to 'enter' the space, makes it essential to employ a model free from structural inconsistencies. Otherwise, the user would perceive distortions which, although legitimate on the painted surface, would appear disturbing and misleading within the immersive experience.

By positioning virtual cameras, it becomes possible to inhabit the model as if it were a real space (fig. 11), thereby simulating the experience of the historical viewer and even surpassing it by detaching oneself from the privileged viewpoint. The virtual dimension allows "to investigate the space of the hypothetical, going beyond the single and finite point of view of perspectival representation" [Pascariello 2005, p. 20]. The freedom to vary the position of the observer required, in fact, an additional interpretative effort aimed at achieving a philological reconstruction of those portions not visible from the main viewpoint and therefore not directly recoverable. It is precisely in these 'perceptual overflows'—only visible from viewpoints not originally envisaged by the artist—that the possibility of exploring the virtual three-dimensional model becomes a critical rather than merely experiential tool, revealing the design complexity underlying the pictorial illusion.

The three-dimensional model can be experienced through two different modes of interaction: AR, which allows virtual elements to be superimposed onto the real environment,

Fig. 11. Plan of the 3D model derived from the philological reconstruction, integrated with parts not visible in the painting and reconstructed based on interpretative hypotheses of the spatial logic (graphic elaboration by the authors).

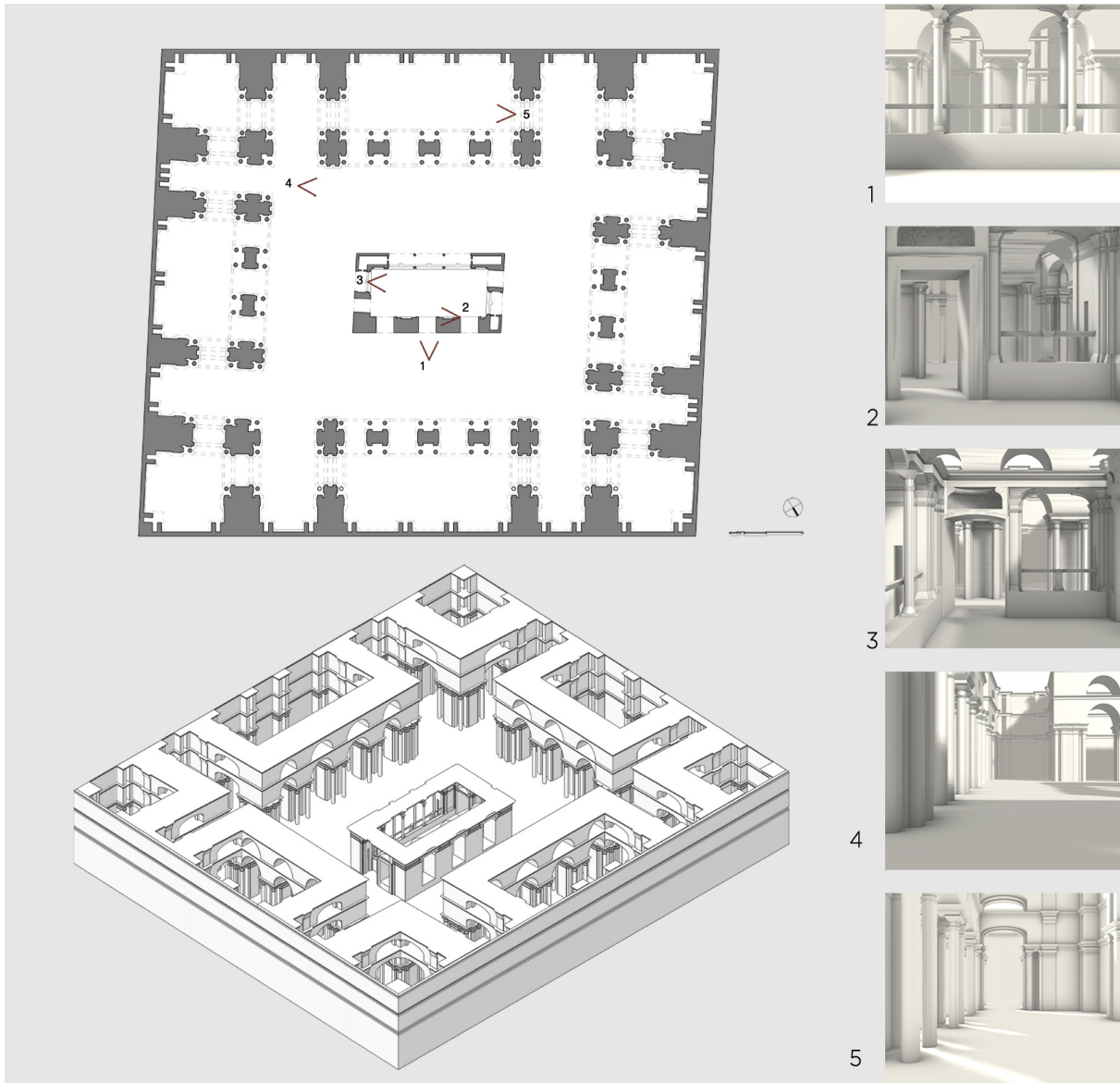


Fig. 12. Top, an example of Augmented Reality application using the quadratura itself as the target to activate digital content through the Artivive platform. Bottom, 360° panoramic image obtained from the three-dimensional model using Blender, employed to create an immersive VR video, available on YouTube (graphic elaboration by the authors).



thereby enriching its perception and experience; or VR, based on the use of a fully immersive environment, isolating the user from the physical world and 'immersing' them in a simulated space that can be explored in first person. Both modes of interaction enhance sensory perception by providing additional information beyond what can be directly perceived. Moreover, they enable a dynamic interaction with the heritage asset, fostering user engagement and immersiveness [Zhou et al. 2022], while also highlighting their role as privileged tools for the analysis and interpretation of space. In particular, the use of AR proves to be strategic in explicitly revealing the relationship between real and painted space, offering the observer instruments for critical and informed interpretation. AR makes it possible not only to explore the revealed pictorial space from different angles, but also to challenge the perceptual stability of the frontal vision traditionally imposed by the single viewpoint, allowing for the analysis and verification of spatial hypotheses and configurations (fig. 12) while standing before the painted work.

While AR provides only partially immersive interaction, VR is instead capable of ensuring the highest degree of immersiveness, embodying an advanced integration between technology and perception that deliver experiences transcending the boundaries of physical reality [Camagni 2024, p. 137]. Its main purpose is to reproduce a condition of virtual presence –that is, to generate in users the impression of actually being inside the digital environment and of experiencing it through their senses (primarily sight, but also hearing and, at times, touch). In its less complex and easily applicable form, it is necessary to create one or more 360° spherical images of the three-dimensional model, which can then be set up using dedicated applications in the form of a virtual tour (e.g., *Lapentor*) or an immersive video (fig. 12), incorporating interactive hot spots and additional multimedia content.

The integration of the three-dimensional model within AR environments –accessible through mobile devices– and VR environments –experienced via immersive headsets, stereoscopic viewers, or other dedicated peripherals– offers a multilayered form of exploration. On the one hand, it preserves the historical visual experience, anchored to the original, frontal, and centralized viewpoint; on the other, it reveals the underlying perspective apparatus, articulated across multiple perceptual levels and 'navigable' from diverse viewpoints, exposing its limits, ruptures, and spatial reconstructions. AR and VR thus become instruments of

mediation between perception and construction, between what is shown and what is implied, between real and possible space. This approach allows the viewer to 'enter' the perspective illusion conceived by the artists, while simultaneously revealing the perspectival artifices and internal spatial relationships. It also provides both an immersive experience and a critical framework for interpreting the geometric processes of perspective projection. In this sense, digital technology functions as a methodological extension of the drawing, highlighting its structural, projective, and cognitive dimensions, and unveiling the complexity of an architectural space that is at once real, painted, and imagined.

Conclusions

The research aimed at showing how drawing is the preferred tool for investigating the spatial structure of the illusory architecture painted in the Guard Room of the Bourbon Royal Palace in Portici. The geometric analysis of the painted *quadratura* allowed us to recognize the consistency of the illusory design with respect to the real space that houses it, while at the same time highlighting the compositional freedom afforded by the absence of any static or structural constraints. Drawing takes on a revealing role: it allows us to uncover the rules and exceptions that govern the construction of painted depth, restoring the harmony of a system in which real architectural space and perspective space are integrated into a single organism through drawing. The structures identified not only make the logic of the project legible but also confirm the function of drawing as a medium through which the invisible takes shape and becomes perceptible. While in the original experience the observer was bound to a specific viewpoint, a restricted and above all static view, today's digital technologies allow us to overcome this limitation. Three-dimensional restoration and reconstruction in a digital environment, together with the potential of AR and VR, opens new possibilities for critical exploration and expanded enjoyment of cultural heritage, providing the complexity of the illusory space in an accessible version and highlighting the architectural coherence that underlies it. The result is that drawing as a design tool, both analog and digital, not only documents and interprets Baroque *quadratura*, but also makes them accessible and legible, revealing the hidden structure that supports their scenographic and spatial effectiveness.

Credits

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frame for painted spaces: quadraturism and space beyond physical boundaries and *The revealed space and its augmented fruition*, while Alessandra Pagliano is the author of *Section Drawing as structure of the illusory space* and the *Conclusions*.

Authors

Alessandra Pagliano, Department of Architecture, University of Naples Federico II, pagliano@unina.it
Barbara Ansaldo, Department of Architecture, University of Naples Federico II, barbara.ansaldi@unina.it

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