Immersion in Virtual Reality for Studying Architectural Perspectives

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Abstract. What is the relationship between a viewer and a *quadratura* when the viewer gazes on this Architectural Perspective? In many cases, the viewer may be in different positions with respect to the centre of projection used to make the perspective while continuing to enjoy the illusory effect, but what are the perceptual sensations received from the depicted imaginary space? What elements condition the inclusion of the viewer? Can the use of Virtual Reality enhance the degree of inclusion, making the link between viewer and perspective more immersive? This contribution presents answers to these questions, using the *Sala dei Cento Giorni* painted by Giorgio Vasari in 1546 as an application. The numerous possibilities offered by Virtual Reality are implemented in the room, from the insertion of spherical images in visors with stereoscopic mode capable of creating full immersion, to viewing illusory digital spaces verified by different points of view, as well as perceptual control of the relationship between three-dimensional model and two-dimensional frescoes. Virtual Reality turns out to be a powerful tool of analysis and interpretation for this widespread cultural heritage.

Keywords: Architectural Perspective · Virtual Reality · *Sala dei Cento Giorni*

1 Introduction

This paper reflects on the possibility of using new technologies of representation to interpret Architectural Perspectives [1], that is, geometries painted on surfaces that create an illusory depth in the architectural space. These tools, which are generally used for communication [2–4], usually have a strong connection to the principles of perspective. Viewers observing perspective frescoes in person are heavily influenced by what the eye perceives, interpreting it as a dilated space, that is, an illusory space. To facilitate and enhance immersion in this illusory world, the use of new technologies such as Virtual Reality (VR) [5] have now become important [6]; they are very effective tools for fully immersing the visitor in this artificially constructed space [7]. Viewers therefore become immersed in a new world that enwraps and captures them, presenting a new and original experience dictated by a combination of what they see virtually (digital model) and their past (mental model).

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2 The Architectural Perspective-Viewer Relationship

One of the features of Architectural Perspectives, and perhaps also the most important, lies in the strong illusory power they are capable of transmitting. By applying perspective projection, these frescoes present a viewer's eyes with environments that, while painted on a surface, allude to spaces that extend beyond the walls.

The components that come together to create this illusion are the real space that holds the *quadratura* — the perspective fresco — and the viewer. In particular, one can analyse the relationship between the physical space and the painted perspectives, verifying the possible existence of a relationship between the painted imaginary architecture and the real architecture. In these cases, the viewer, observing the scene from the favoured point of view, is engaged in a new space determined by the sum of the three-dimensional space and the perspective image. In other cases, those where this unitarity is lacking, the viewer looks at the fresco as if viewing a painting located in the environment yet detached from it [8]. With regard to the perspective image painted on the surface of the wall, however, this is generally a central perspective, well controlled geometrically by

Fig. 1. In a *quadratura* it is possible to recognize a simulation of the architectural space that, though painted, illusorily break through the wall structure. In the church of San Francesco Saverio in Mondovì (Italy), Andrea Pozzo paints, among other things, the pictorial decorations that illusorily widen the space (Source: photo by authors).

the artist aside from exceptions inserted consciously. Finally, there is the viewer, who enjoys the perspective and the imagery it evokes in the mind. So that the illusory power inherent in the perspective projection may best be realized, we know that the viewer's eye should coincide with the centre of projection according to which the perspective was made. This is not always true, however [9]. In fact, there are various cases in which this association is not always respected, although the perceptual effect of the illusory space is maintained effectively. The relationship established between the viewer and *quadratura* is perceptual. The viewer, when placed in front of these knowingly frescoed surfaces, recognizes a simulation of space that is primarily architectural, alluding to illusory environments, spaces that extend beyond and ideally break through the walls.

Two sets come together at the moment of observation: the *viewer set*, which is characterized by elements such as physicality, mobility, the visual system, movements of the eyes and head, and the mental model shaped by the viewer's culture; and the *quadratura set*, composed of elements such as painting, perspective, the architectural layout, and possible characters that populate the scene. The *viewer set* is included in the *quadratura* set and all the elements of the former begin to integrate with those of the latter, becoming nearly an integral part of it. The inclusive power of the viewer in the *quadratura*, implemented due to the elements of the second set, may be traced to the imaginary strength that the viewer possesses, which is drawn from the mental model (Fig. 1). To increase the degree of inclusion, the use to new technologies such as Virtual Reality can produce a sense of greater immersion in the illusory/digital space for the viewer.

Fig. 2. The planes of the horizon in the *Sala dei Cento Giorni*: in red referred to the *viewer* and in blue to the *projection center* (Source: photo by authors).

3 Architectural and Geometric Interpretations of a *Quadratura*

The different types of *quadratura* disseminated in Europe both geographically and over time attest to the different means through which the two systems mentioned above interact. These relationships should be analysed starting with the possibility of using the real spaces that host the paintings, in particular verifying the possible positions of the ideal point of view to fully enjoy the illusory space. Indeed, in contrast to a virtual space, the possibilities of moving within a real environment frescoed with illusory perspectives are limited — in height, for example — and this condition entails a series of notable consequences for the perception and interpretation of the space that is represented.

To better investigate these dynamics, we refer to two different positions: the centre of projection, O', that is, the point of view drawn from geometric analysis of the perspective, and the viewer, V', that is, the person physically present in the real space. By recognizing whether the perspective system painted on the individual surfaces of the real environment refer to a single illusory space or not, we can identify at least four different recurring types of relationships in a *quadratura*:

- Unitary perspective system with positions O' and V' that coincide (wall and volt of the corridor into the rooms of Sant'Ignazio at the Chiesa del Gesù in Rome painted by Andrea Pozzo);
- Unitary perspective system with positions O' and V' that do not coincide (Anticamera del Concilio at Palazzo Farnese in Caprarola);
- A perspective system divided into multiple images corresponding to the same number of positions O' and V' that coincide (Palazzo Lancellotti in Rome painted by Agostino Tassi);
- A perspective system divided into multiple images corresponding to the same number of positions O' and V' that do not coincide (the Sala dei Cento Giorni by Giorgio Vasari and his scholars);

The last case is particularly important for the goals of our investigation since it introduces another question in the process of critically interpreting a *quadratura*: Is the space returned in a realist key, that is, according to what is returned in a geometric key by the observer, or is it returned in a surrealist key, that is, according to what is perceived by the observers view?

To answer this question, we refer to the *quadratura* in the *Sala dei Cento Giorni* in Palazzo della Cancelleria in Rome painted by Giorgio Vasari in 1546. This is a non-unitary perspective system in which the centre of projection O' for each of the four perspectives painted on the vertical walls occupies a different position, though always located on a horizontal plane about 5 m above the floor (Fig. 2). Since viewers moving within this space are physically limited to moving on a plane that is notably lower, they perceive a deformed illusory space due to this displacement. To the viewer's eyes, the horizontal planes of the tread of the stairs or the floor of the porticoes appear to be inclined and directed towards the interior of the room, exactly as what occurs with the inclined plane of the stage in a theatre space (Fig. 3).

Defining the relationship between the illusory spaces returned by the centre of projection and those perceived by the viewer is of fundamental importance for interpreting and understanding a *quadratura*. It also presents an important opportunity to investigate the potential offered by VR tools that share the same projective language with the centre of projection. We propose to introduce these tools already in the study and analysis of an Architectural Perspective, even before entrusting it with its crucial and now widely recognized role in the communication and dissemination phase.

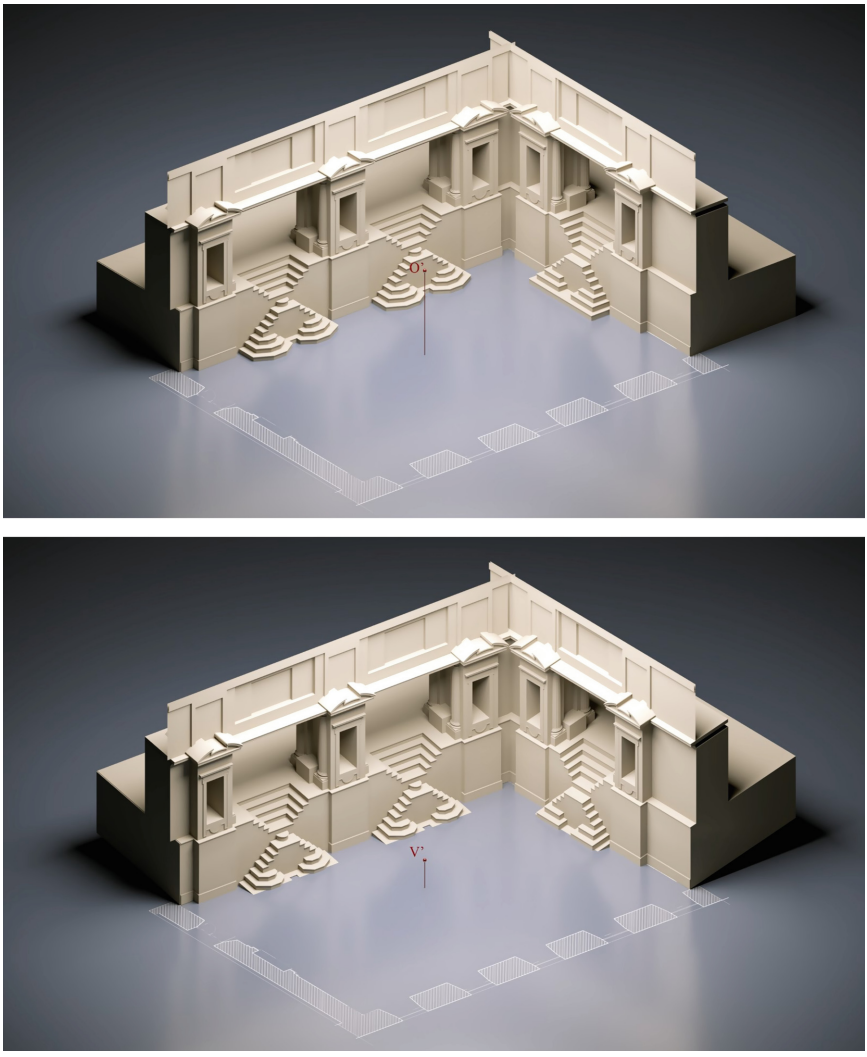

Fig. 3. The illusory space model: realist from O' (top) and surrealist from V' (bottom).

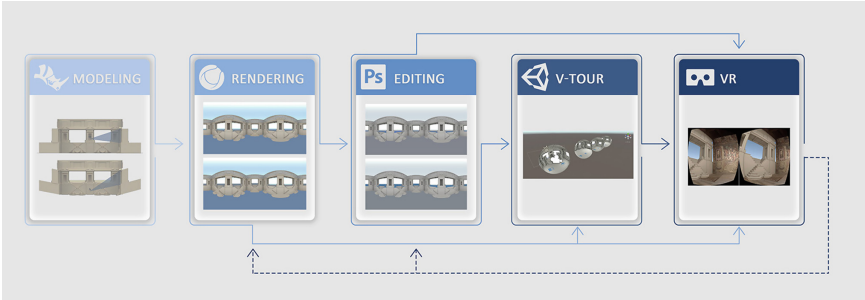

Fig. 4. Workflow of the different steps for the study of architectural perspectives through VR.

4 Virtual Reality Experimentation with Restricted Points of View

With the use of VR, it is possible to analyse the role of the viewer in relation to a *quadratura.* The *viewer set* becomes the focus of this experimentation, expanding on the perceptual aspects involved in first viewing the perspective images and then the spatial models. The method relies on equirectangular images that, if viewed with a visor in stereoscopic mode, give the sensation of being immersed in a three-dimensional environment.

The process to view the room in VR mode consists of various steps (Fig. 4), starting with the modelling system that enables the set to be realized in the first place: the real space with frescoes and three-dimensional models of the illusory architecture alluded to by the perspective images in realist and surrealist keys.

The different configurations are then rendered directly in the equirectangular form. The resulting product is already suitable for being visualized [10], but the equirectangular images can also be adjusted post-production, even acting directly on the drawings in a spherical mode. This step quickly allows alignments and notable elements to be highlighted or verified, but different configurations can also be assembled in a single image to compare the effects.

With the resulting drawings, it is possible to proceed in two ways. The first is to view the individual image with one of many appropriate applications; the second entails a further step to arrange a virtual tour.

Both modes are appropriate for different purposes. While the first is very simple and a visualization can immediately be achieved in a single panorama, the second is appropriate for the comparative observation of different images, but its realization is longer and more laborious.

The workflow established thus is particularly effective because it allows different hypotheses to be verified and tested very quickly. The same process may be followed by adjusting the configurations once they have been tested in VR, working on them even at different moments in the workflow.

It is therefore possible to digitally recreate the images, placing the virtual camera at given notable positions. The use of static images allows the observation to be restricted by focusing attention on specific projective/perceptual aspects, concentrating on testing the role of the centre of projection.

Fig. 5. Equirectangular image of the south wall with the model of the illusory architecture inserted into the *Sala* from the viewer's elevation.

Placing the point of view at the centre of projection of a specific wall, and therefore at a height of 5 m, the relationship between the surrealist model and the frescoes present in the rest of the room can be seen. In this configuration, there are no particular disagreements with the perspective images on the other walls. However, inconsistencies emerge if the point of view is placed at the observer's height. In this way, in fact, the surrealist model reveals its nature and the objectively horizontal planes of the portico and steps are surprisingly tilted.

Following this, a series of configurations were made involving the alternation of a realist model rendered by O' and the surrealist model rendered by V' observed from notable points of view. This operation allows the efficacy of the models to be assessed and it highlights how the planes of the loggia and the steps are not visible from the viewer's height in the realist model (Fig. 5).

Moving from one virtual scenario to the other leads to real-time understanding of the effects and differences between the various configurations, showing the potential of VR intended as an interpretational process. These possibilities for interactive observation also allow new suggestions to be developed for visiting the painted illusory spaces, helping to understand the choices made by the artist when creating the work.

In the particular case of the *Sala dei Cento Giorni*, the use of VR validates the hypotheses formulated during the geometric studies of the frescoes. According to these, the artist from Arezzo, forcing the perspective rules by means of conscious exceptions, aimed to favour the viewer's immersion in the illusory scene by revealing the horizontal layout of the portico which would otherwise not be visible (Fig. 6).

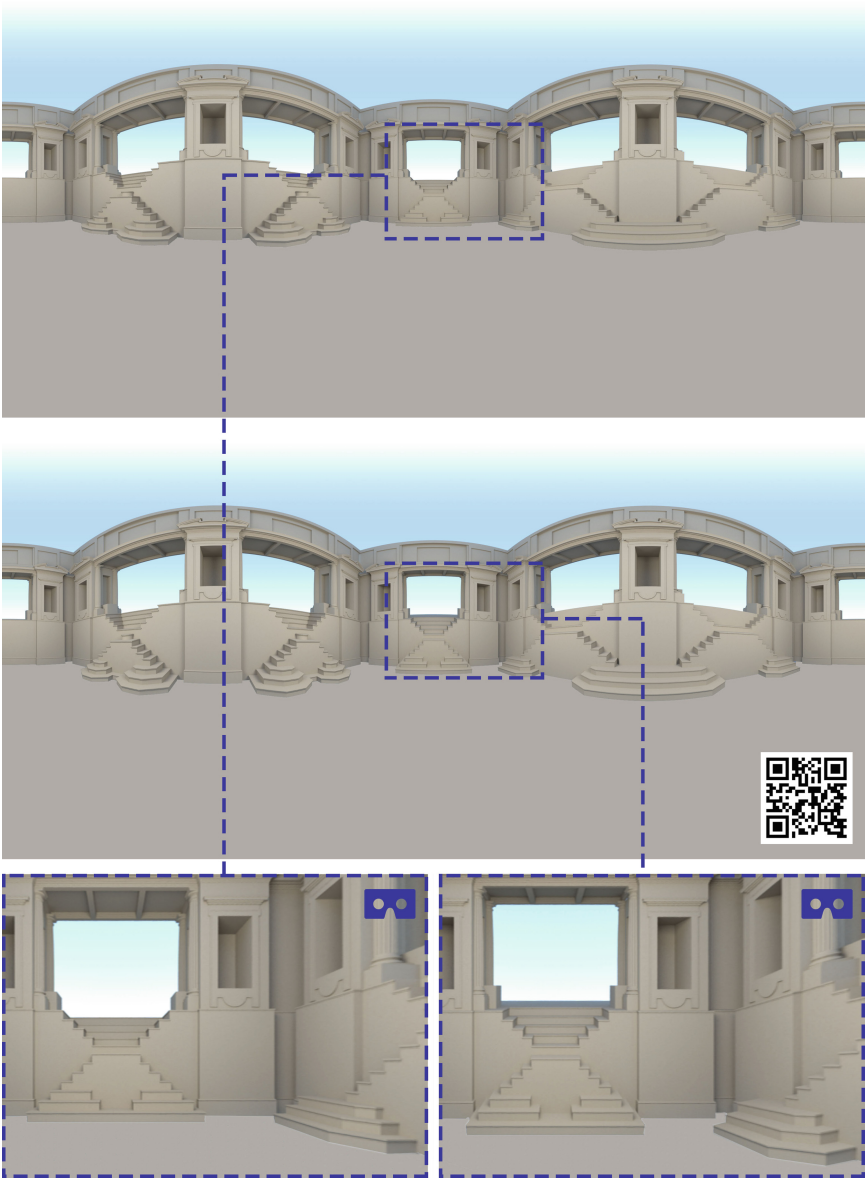

Fig. 6. Two equirectangular images showing the realist and surrealist models as seen from the viewer's elevation. The slight differences between the two models are better explained in the observation through the VR visor, accessible using the qr-code.

5 Conclusion

This study presents a critical interpretation method for Architectural Perspectives in which VR tools actively intervene in the investigation and critical analysis of the illusory space (Fig. 7). The same projective language shared by the two systems — VR and linear perspective — presented an opportunity to investigate the experimental potential of the former, which is no longer relegated exclusively to the communication and dissemination of this cultural heritage. The immersive nature of VR tools amplifies the inclusiveness inherent in the perspective and allows for dynamic, interactive exchange when analysing the relationships that combine the illusory space and perceived space. The analysis was aimed at in-depth understanding of the work studied through formulating hypotheses and critical interpretation of the design choices (often notwithstanding the rules of perspective) followed by the artist when creating the work.

Among possible developments, the research also aims to transfer this critical interpretational content to *Interactive Thematic Virtual Environment* (ITVE) systems, implementing VR with real-time graphical, documentary, sound, or even digital information.

Fig. 7. A summarizing image showing how a viewer can synchronously explore the real, illusory, and virtual spaces of the *Sala dei Cento Giorni* by means of VR.

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