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# A Virtual Space Built on a Canvas Painting for an "Augmented" Experience to Catch the Artist's Message

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**Abstract:** "Entering" a canvas to examine and learn about the work from unexplored points of view is an experiential "journey" in an environment reconstructed through the use and integration of innovative technologies, such as descriptive geometry and digital photogrammetry, solid modeling and immersive photography. Generating a "sense of presence" in the viewer means connecting it with immediacy to the artist's message and grasping even the most subtle elements of the painting that are difficult to understand, such as architectural inconsistencies or the play of perspectives that, very often, bring out the situations scripted, characterized by discoveries that prelude to the aesthetic pleasure as the multiplicity of meanings and the "stylistic overcoding" of the work is revealed. The research hypotheses were applied to a case study, or to the splendid "Last Supper" by the Flemish artist Gaspar Hovic, a canvas painted in oil (late 15th century AD) and kept in the Matrice SM Veterana Church di Triggiano (BA), where the representation of the suggestive moment of Jesus with the Apostles is carried out through numerous symbols, in an evocative architectural context rich in details. The pictorial subject provides a series of very interesting ideas suitable for research of the role of perspective. The inverse method of linear perspective was used to reveal the plants and sections corresponding to the perspective space of the painting, used as the basis for the reconstruction of the 3D model of the entire scenic composition. Although the painting represents the apparently rigorous application of the perspective technique, by "entering" the canvas it is possible to observe some exceptions to the geometric rules deliberately introduced by the artist, thus making the perspective restitution process an effective interpretative act of the work.

**Keywords:** Gaspar Hovic; painted architecture; perspective; 3D modeling; virtual tour; cultural heritage; geometry descriptive



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## 1. Research Aims

If experts in cultural heritage dissemination, such as the architect Emanuela Pulvirenti, believe that a painting can be analyzed "in just three steps" [1], centering the approach and the path of analysis and knowledge of the work in just three key words: technique, subject and poetics, similarly, the research project was focused on a specific objective: implementing a path of fruition and knowledge of an immediate and highly communicative pictorial work.

The free research project conducted by the Construction Technologies Institute of Bari goes beyond that of designing, creating and experimenting prototypes that are able to balance the form of representation (which allows the visualization of cultural data), the experience of the observer (supplementing elements that can provide engaging improved knowledge) and its interaction (active user involvement in the virtual world) [2].

The research aims to create a process of knowledge capable of offering insights into visual culture, not limited to the mere spectacle of information content, but it wants to represent a communicative formula used to create dialogue regarding the public, history and cultural heritage.

The implemented process for the case study led to the development of a new format for the transmission of knowledge of a pictorial work, mainly aimed at the dissemination

and enhancement of the cultural heritage, trying to make it clear to an observer, both specialist and non-specialist.

The method used by the painter to create the entire scene represented, with the aim of studying the geometric references, the prospective restitution, virtually reconstructing the scenography and transmitting the results of the research for dissemination in the cultural heritage sector, in order to extend the results of the survey conducted to a large part of the public.

However, in this process the virtual reconstruction is a delicate phase, where the perspective restitution must have the dictates of a philological restitution, thus proving a complex operation, as it does not end in a sterile operation of automatic translation from the image into perspective of a space to its plans, elevations and sections, but it is, on the contrary, a real interpretative act [3].

The results of the research, obtained in this first phase of the process, are the product of the painted image interpretation in the case study, where the perspective dictates the arrangement of space, time, narration and composition, thus bringing together the skills of descriptive geometry, history of art and representation and visual arts.

The format intends also to highlight some unresolved issues in this field, identifying in the introductory paragraphs a series of choices, recommendations and best practices to follow when designing applications for the use of cultural heritage through virtual spaces representations. The strengths and weaknesses of current approaches in this research area are also highlighted.

## 2. Literature Review: Virtual Reconstruction in Cultural Heritage

Orienting immersive and interactive technologies towards the knowledge of cultural heritage is an opportunity both in terms of conservation, study and communication of heritage, but also of culture creation, "contamination" and awareness. A process that has already started is the one in which the disciplines of representation and enhancement strategies produce more and more forms of advanced visualizations, informative and multimedia modeling [4], specializing in interpretative models for the analysis and representation of historical, cultural, aesthetic and environmental values of a cultural asset and its material and immaterial significance.

However, elaborating forms of representation of goods' cultural heritage, guaranteeing and legitimizing their value, access and use with the use of technologies and encounters, often results in a high cost for its realization [5], and above all, the generation of some derivative risk [6], such as that of confusing, in the distant future, the digital processing and artifacts introduced by man with the real cultural asset.

Virtual reconstructions for the representation of assets have become increasingly usable through technologically advanced and entertainment products [7], aiming at increasing the ability to disseminate and fascinate intangible heritage. Scientific reconstructions and digital entertainment products share the same methods of creation and use, to the point that lots of historical reconstructions risk being apparently completely similar to any 3D animation, with the real danger of losing the distinction between the two products in the short and long term. Designing a new methodology or technique of enhancement in the cultural heritage system often implies a historical-scientific reconstruction and a careful study of the cognitive process of knowledge of the asset, in a social and symbolic dimension, but, at the same time, it must also leave room for "emotions" and emphasize the experiential value in the knowledge process. In fact, immersive and interactive technologies are increasingly effective in a structured and flexible knowledge process, managing to give the emotional necessary imprint to increase the social value of the transmission and sharing of cultural content.

We are therefore witnessing an insidious phenomenon: to pull over dogmatically a historical reconstruction to an entertainment project, as if the past, or a part of it, is always and completely reproducible in its details, strongly damaging the historical reconstructions in a delicate process of affirmation of these innovative fruition techniques, mainly oriented to communication with the general public.

In fact, it could seem a priority to activate these practices by designing only the aspects related to the experience of use of the asset, evaluating a priori the economic sustainability and the potential diffusion in several communities and for different categories of users. In these cases, the recurring objective is to be able to activate a highly participatory and inclusive path of learning and sharing of cultural heritage, with the typical characteristics of the representative forms of social well-being.

Numerous research and surveys have already demonstrated the strong communicative connotation and the immediacy of the virtual revival of a work of art or a cultural asset, which, in most case studies, favors the perception and faster assimilation of historical concepts, even towards a non-specialist public. We are witnessing the production of numerous three-dimensional reconstructions that are more accessible to non-expert users. In this last context, the measurable advantage is certainly linked to the revaluation of cultural heritage, which is not seen as the exclusive domain of specialized scholars, but has become a resource for the economic development of local communities, where the world of cultural heritage is dominant.

The advantage of using a three-dimensional reconstruction for historical research purposes is difficult to evaluate, where the aim is to investigate the past and untie the knots to clarify an aspect or a historical event. With the evolution of 3D scanning technologies and the processing of three-dimensional digital models, case studies are multiplying, aimed at the restoration and conservation of the asset or even with the only intent of investigating a work of art. For a painting, for instance, small reliefs can support scientific research and display even the smallest detail to better understand how the artist worked. This is the case of the work "Alchemy" by the American painter Jackson Pollock, for which a high-resolution three-dimensional map of the geometry of the painting was drawn, making possible to study and analyze the material structure of the painting and producing a scientific metric documentation of the work [8].

Although, in this context, the use of three-dimensional reconstruction is not always applicable, as it is highly dependent on the sources and documents available. The study of the past, in fact, of which we have very often a few still images (photographs, paintings, etc.), is deeply linked both to what of the past has come down to the present day and to more or less historical-scientific hypotheses verifiable, where the arduous task of the historian is to discover, study and relate the different sources, including the information that can be deduced from a three-dimensional rendering. Furthermore, the introduction of digital 3D models is by no means trivial, as moving from two-dimensional visualization, based on photographs, drawings or paintings, to the possibility of exploring an object in its three dimensions implies the use of many specialized skills and high costs of realization.

In summary, the role of new 3D technologies is fundamental: on the one hand, they support scholars to simplify the management and analysis of scientific data and are an effective tool for the scientific verification of their hypotheses; on the other, they allow the general public to improve understanding of the past, as they are the recognized means of presenting and analyzing works of art in virtual places, such as the web, and in real places, such as museums or cities, thanks to interactive applications, personalized presentations and very realistic virtual environments.

However, the use of 3D modeling technologies in the field of visual arts is still limited, both among scholars and by the general public (web): for the former, due to the high costs [9] and the diffusion of still poorly performing devices; for the second, the main cause is the scarce availability of intuitive applications for use, where combining the simplicity of use of a user interface with the display of accurate 3D models and real-time navigation is a very complex operation [10,11].

In fact, virtual reality, augmented or mixed reality applications are fascinating opportunities today, but attracting more and more studies on the integrated development of new and performing high-resolution VR/AR/mixed viewers with a wide field of view is still highly expensive.

It is, therefore, a technological leap where art and science, strongly and contextually invested in the search for an innovative vision of the use of art are totally immersed in issues related to numerous fundamental elements such as: representation, communication, matter and perception, but also reproducibility, seriality, immersion, virtuality and usability.

### *2.1. The Concept of Virtual and Real: Realism, Sense of Presence or Telepresence, Immersion and Comfort*

In visual art, in order to offer a viewer a usable virtual space and represent the visual information of the real work, there are many different approaches (photographs, 3D images, panoramic views, Virtual tours, virtual reality applications, augmented reality applications, etc.). However, not all approaches are able to achieve the same result of accuracy and fidelity of the work; this is because each form of representation of reality will offer the observer different levels of "realism", "sense of presence", immersion and comfort [11], factors that together determine the overall quality of use [12] and can emotionally influence the observer's experience.

Some important definitions are summarized, which can strongly affect the design choices of representation of cultural contents, of the interaction of the observer and of his knowledge and experience of the work. Experts define the character of "realism" as the quality of representing a space accurately and faithful to real life [11]. If we apply this definition to images/photos of real spaces, this attribute refers to the visual quality and accurate representation these approaches can provide to the viewer, inducing in him the idea of observing something real even when it is not. The "sense of presence" is defined as the subjective experience of the observer of being in the place or even in the environment represented, even if different from the one he really is in [11]. According to Mel Slater [13], there is a notable difference between the term "presence" and the term "immersion" [14]. Immersion refers to the objective level of sensory fidelity that a virtual system provides [15] and can be greatly enhanced with the addition of audio, tactile and forced feedback [16] (objective viewer experience). Presence or "sense of presence" is also commonly referred to as "telepresence" [17], or virtual presence or mediated presence [18], terms considered in technical literature to be interchangeable [19], although some research has argued that the sense of presence and telepresence were different affective-motivational states [20]. In our approach, telepresence is the "sense of presence" in a remote environment [21].

"Comfort" refers to the presence or absence of visual fatigue, motion sickness [22], headache and eye strain, or the comfortable viewing of the virtual environment [23].

Virtual reality, augmented or mixed reality applications are fascinating and powerful opportunities, which attract more and more studies and technological progress [24,25], mainly focused on the development of new and performing high-resolution VR (Virtual Reality)/AR (augmented Reality)/MIXED (Mixed reality) viewers with a wide field of view, but these are still very expensive. Currently, the great potential of such systems is heavily concentrated on problems related to the design of systems and configurations capable of taking full advantage of the latest advances in the field of hardware, software and telecommunications networks (networks with low latency). The typical and fairly widespread scheme is to break the passive and contemplative figure of the art public, involving and making it more and more involved in the work itself [26], developing innovative interfaces that go beyond the concept of interactivity, to the point of creating, in the spectator, the strong illusion that his body can ideally "enter" the work. In this scheme, however, the viewer is not limited to observing but also uses other senses to live a real experience to remember, actively deciding what to see and the routes to take.

We believe these driven interactive realities, both in space and in telematic communications, can very often strongly influence the perception and vision of the viewer, who, by concentrating on his actions as a user, totally moves away from the correct exploration and investigation of the work, limiting himself to perceiving the playful and entertaining aspects of these virtual realities. Incorrect involvement is almost always motivated by a lack of knowledge and a total absence of those tools that are useful for the public to deepen the author's communicative message or that does not meet the readability require-

ments [27]. However, since the 1950s, psychological studies have shown that the "aesthetic emotion", that is the emotional state aroused by a work of art, is connected to art itself not for its immediately perceptible content, but rather because it presents sensory patterns, images and thoughts as forms that have the ability to convey something else and which, according to Arnheim, can be a "truly creative way of grasping reality" [28].

Recurring, for the purpose of involving the viewer, is also the use of dramatization and storytelling [29] which, by exploiting emotional processes to involve the public in art, are transformed into real works of techno-art, with the aim of capturing an ever more abundant public that triggers the spread of knowledge [30–32].

### *2.2. The Cognitive Process in Audiovisual Perception and Emotions*

Remaining in the field of visual arts, understanding the work is a learning process in which the relationship between the public and the work of art cannot be only superficial, but, on the contrary, requires a total relationship (a fil rouge): where vision, understanding and emotion must meet [33,34], such immersive and enriching forms in digital reproduction can be considered dangerous and very often trigger deleterious processes, such as the loss of the uniqueness of the work or the birth of metalanguages, where information science has not formulated communication languages and paradigms appropriate for this emerging domain yet [28].

The aim of the research, therefore, is the creation of a virtual environment where the onlooker can view, understand and get excited in his encounter with a pictorial work, reproducing the uniqueness of the moment in which the viewer is in front of the work of art, thus creating a unique and spontaneous process of vision; comprehension and emotion: a path where the viewer "enters" the canvas with his eyes (vision) and receives simple stimuli that can facilitate and not divert his grasp in the evocative charm of the environment reproduced and focused solely on the artist's message and on the emotions that he wants to arouse in the viewer.

Throughout history, there have been scholars and artists who have recognized the representative shortcomings of planar projection. Leonardo Da Vinci, for example, still considered the classical perspective projection "artificial", as he believed that the projection that best reproduced the image seen by the human eye was the one he called "natural perspective projection" [35,36], that is, the projection of the environment on a spherical surface, with the view point fixed at the spherical origin. The spherical representation has been touted by some cognitive scientists as the sturdiest model for spatial reasoning [36,37] and it is the virtual space representation we have adopted in our virtual reconstruction.

However, alongside the instrument of representation it is essential to understand if the virtual environment is able to provide not only a complete spatial knowledge, but also the emotions related to it; in this way, each work of art, material or immaterial, will come alive and the ways of fruition will be able to be profitably transformed into an active combination of interactivity and even intercreativity practices.

A group of researchers from the Catholic University of the Sacred Heart, from the University of Bergamo and the Polytechnic University of Valencia, tried to understand how it is possible to use virtual reality as an emotional medium, or as a "medium" that is able to generate emotions in the user; trying to link this aspect to the sense of presence generated during the experience [38]. Specifically, the researchers developed three different variants of the same virtual park, all characterized by the same objects and the same dimensions, but modifying the sounds, shadows and lights and the textures of the environmental elements as well. The changes were made in such a way as to make the first variant an anxious space, the second a neutral one and the third a relaxing one, identifying anxiety and relaxation as emotional states to be sought during the virtual reality experience.

In the typical process of building a virtual environment, it is a common practice to focus on just three constituent elements of which the environment is made up: content, geometry and dynamics [39].

In general, the content consists of the quality of the elements or objects in the environment, whose shape, size, color, texture and other parameters can be varied, while maintaining the characteristic of being objects of the virtual world. The content-related aspects also include the representation of moving objects, as well as static objects, to which the user naturally attributes an ability to interact, defining them as "actors" because they participate in the simulation of the environment, not as a context but as subjects inhabiting it and whose movement and actions are not directly caused by the user. Typically, the user himself, the viewer of the art, can be represented three-dimensionally in the virtual environment in the form of an actor, or simply be a dimensionless point of view.

The geometry of a virtual environment is everything that refers to its physical extension, of two or three-dimensional configuration, in a large or limited extension, of large or small scale, which can represent closed environments or open spaces, starting from a simple room up to complex urban areas.

Finally, the dynamics concern all of those aspects related to the methods and rules of interaction between the contents of the environment and their interaction with the user. The objects contained within the virtual environment must respect the laws of physics in order to be credible in the eyes of the user, "behaving" and interacting with each other in an appropriate manner with these laws and being consistent with what is expected in the real world.

Aiming at the virtual environment development relying on just these three elements (contents, geometry and dynamics) we believe it is not an effective virtualization process in the field of visual arts, as the only deepening of these aspects certainly covers and well promotes knowledge on the part of the spectator about the more "mechanical" and physical elements linked to the ways in which a work of art was created (vision). All those aspects related to the technique comprehension are certainly contemplated, to the extent of being able to grasp even the stylistic differences, which in general allow you to easily identify the author or, in any case, the movement to which he belongs. In this way, what is depicted in a painting, that is, the subject and what it represents, can be reproduced with extreme historical accuracy, to the point of allowing the viewer to glimpse right away the so-called pictorial genre (understanding). However, the difficult challenge is, instead, to contextualize in the virtual environment the expressive intentions of the artist, the elements and symbols on which the artist, often instinctively or with desired artistic methods, intends to communicate a poetic sense to the viewer and a specific message (emotions). Therefore, we believe that a virtual construction process in the visual arts must also focus on the expressive intentions or emotions that the artist plans to communicate, without deforming or obstructing them to the general public, while preserving aesthetic emotions.

The artist teaches us to have a vision of things, says Gombrich [40,41], which makes our attention shift to an aspect of reality that we had never thought of before [42]. This was the fundamental premise of the research path undertaken; that is, to design and implement a different path of knowledge of the pictorial work, which could favor the viewer and support him in elaborating, entirely personally [43], the representation of the artist's message and, at the same time, favoring an immersive sense and allowing him to "enter" the canvas, rather than moving away.

The research focused on the construction of a user-friendly and low-cost interface for a virtual tour [44], a technological tool with which the observer will be able to know and examine the work from unexplored points of view, which, inevitably, are hidden in a 2D representation.

The 3D reconstruction and the immersive environment will provide the observer the necessary knowledge about the code used by the artist for the correct reconstruction of the message represented, facilitating the communication of the poetic meaning and triggering the aesthetic emotion.

It is quite common today to break the aesthetic emotion with the myriad emotions of the viewer. In the enhancement of cultural heritage, there are numerous experiments in this context with the collection of copious surveys, including the public, to verify the feelings and emotions that are generated in the viewer in these virtual environments [45–47].

It focuses on the sense of involvement perceived by the user as an important element and its impact on learning is assessed [10], triggering and stimulating his motivation, which is considered a strong mediating element in the learning process.

This is the reason why many designers of virtual environments and dynamic applications (VR, AR and MIXED) mainly aim at the implementation of increasingly pushed, evolved and expensive interactive mechanisms and user feedback, all oriented to improve its feeling of involvement. However, the sense of emotional involvement should not be totally confused with the immersive sense and the user involvement. If the immersive sense is pushed (think, for example, of dynamic applications with gesture [26,48] or locomotion [49–52] implementation techniques), the risk is to create innumerable emotions in the spectator-actor, even uncontrolled (during the design), which totally deviate from the poetic sense of the artist, generating virtual works of different intangible heritage [53]. For these reasons, our process aims at the implementation of user interactions that are limited only to the spectator's "sense of presence" or "social presence", an effective tool in the sense of involving the spectator [10], but which does not evolve towards a sense of uncontrollable "immersion" that can translate or deform the authenticity of the poetic message, leaving the difference between the digitized cultural artefact and the authentic unaltered work. A virtual tour is a dynamic and interactive application that favors all of these characters just described [54].

Virtual tours, even if they require user-controlled interactions and inputs (for example by clicking with the mouse), do not technologically evolve towards extreme forms of "diving", even if they have their own "non-passive" display character. Virtual tours offer users a unique perspective, as they are dynamic applications that, built on real images with spherical projections, give the user the possibility to experience a virtual space (the use of 3D viewers for stereoscopic vision is allowed) in an almost realistic sense, generating a sense of presence and telepresence in the viewer [17,18], allowing "increased" but controllable attitudes (perspective views and maintenance of the viewer's perspective [55]) towards the virtual space and favoring mechanisms of mediation in the cognitive process [7]. The results of a recent study have shown that the virtual tour is a highly comfortable tool, to the extent of reducing the psychological stress of people through two types of presence (the sense of presence and telepresence) and that telepresence has a greater impact in generating affective-motivational states with respect to the sense of presence [20].

The work is thus enriched by new pictorial features and elements, in an environment reconstructed through the use and integration of different and innovative technologies: digital photogrammetry and descriptive geometry [56], solid modeling and immersive photography (spherical projection) and the virtual tour, where the viewer, an active protagonist, is able to know the artist's message immediately and also grasp elements of the painting that are difficult to understand, such as architectural inconsistencies or the play of perspectives that, very often, highlight situations scripted and have their own profound meaning.

Although living in an era where technology has transformed numerous human activities, art keeps remaining the only stronghold against innovations and has not undergone changes, but limits itself to exploiting technology in its favor, mainly in fruition. This was the direction taken in our research project and principally in the specific field of visual and digital arts, where technology is considered as a digital magnifying glass that allows its users (scholars and the general public of the web) to benefit, in a different way, from the exhibited works aiming at the development of tools oriented to a scientific path of knowledge of the work of art.

It is essential to aim for historical research that is disclosed and explained correctly, but above all understood in the right direction and seen from the correct perspective, that of a historical study that has a precise purpose: to investigate and re-propose a fragment of the past, making performing and powerful tools available, without falling into the temptation to "complete" a source and create false information [32].

The immediacy of the three-dimensional visual medium in the usable virtual space has to favor the perception and assimilation of historical concepts, even by a non-specialist

public, but enriches the new artefact of the research results, preserving the distinction of the two products: opera and 3D artifact.

In fact, in visual and digital art, the concept of virtual cannot be limited only to the treatment of recreated in 3D environments, but also to everything transferring the presence or the relationship between user and process, between object and its use and perception to distance of objects and processes.

Our research work was also enriched by the interesting results and the pioneering work of the researcher Franz Fischnaller [57], who has been working for a long time on the hypothesis of the virtual space usable on the net (the general public), on the dislocation of spaces that can be used virtually and enters the complexity of these intertwining with the variety of hypotheses and different solutions.

For the Russian filmmaker Dziga Vertov, the camera was a cine-eye [58], or rather a powerful means that allowed us to see reality better; in our research, the indispensable means is the 3D model of reality, a virtually usable space with which better see a work of art.

The purpose of our research was, therefore, to create a methodology aimed at the three-dimensional reconstruction of a painting, even in conditions where the perspective deck suffers from irregularities, and on the basis of the above-described format. The restitution operations, carried out on the case study, highlighted a series of exceptions made by the artist, which most likely were introduced for the exaltation of the message or the aesthetic value and harmony of the final image for the ideal painting observer. The scientific objective is to highlight the choices made by the artist or even the exceptions or inaccuracies, thus providing a specialist public with an information base useful for the construction of new interpretative hypotheses or for the identification of the pictorial techniques used.

The digital model thus becomes perceptive/immersive; it is our cine-eye [59], a particularly useful tool to bring the user closer to the knowledge, comprehension and personal learning of the work of art, supporting him in his cognitive path through the most appropriate views. The representation is designed to allow the user to verify, analyze and interpret some specific aspects of the canvas under consideration that would otherwise be difficult to examine only by observing the work from the outside. It does not claim to represent the architectural scene and the characters present in the smallest details, but simply wants to prepare a synthetic and realistic overview to increase the visitor's experiential learning phase, putting him before the reconstruction of an environment that reveals anomalies and perspective dissonances difficult to perceive by an untrained human eye.

## 3. Case Study: The Last Supper Painting by Gaspar Hovic

The artist chosen in this scientific path is the Flemish painter Gaspar Hovic, an important witness of Apulian mannerism in the 14th century. XVI–XVII [60].

The painting under study is the splendid "Last Supper" by the aforementioned Flemish artist (see Figure 1a). It is a canvas painted in oil (late 15th century AD) and kept in the Mother Church of St. Maria Veterana of Triggiano (BA) (see Figure 1b) in the Chapel of the Blessed Sacrament (see Figure 1c), where the representation of the suggestive moment of Jesus with the Apostles is made through numerous symbols, in a particular architectural context. The canvas (3 m high by 2 m wide) appears to be in a good state of conservation, even if many details have lost their original liveliness and are therefore not very legible. It is unclear the year in which the artist finished the painting since the discovery of the date, next to the signature, is illegible in the penultimate digit (1583 or 1593?). From recent research carried out by prof. Lofano Francesco, it seems in fact that the artist was present in the Bari area on both dates.

The work was chosen because it is well suited to the research objectives, as it has a sufficiently irregular perspective layout.


**Figure 1.** (**a**) Gaspar Hovic, "Last Supper", 1583–1593(?); (**b**) facade of the church of St. Maria Veterana; (**c**) Chapel of the Blessed Sacrament of the St. Maria Veterana Church.

Hovic, updated on the novelties of Roman, Emilian and Venetian paintings, also through the mediation of prints, became the spokesperson for a sacred painting firmly inspired by the dictates of the Counter-Reformation. His are mainly simple compositions with a traditional structure, in respect of Catholic orthodoxy, intended for popular use. However, the historian Lofano believes that "the artist will never completely solve the problems originating from the space-figure relationship in scenes characterized by a certain animation and greater iconographic complexity, not solving the problems related to the perspective relationships and the relationships between the plans" [61].

### *3.1. Gaspar Hovic's Apulian Activity*

Hovic's activity has been the subject of significant attention from monastic and ecclesiastical clients, also evidenced by the fact that Bishop Antonio Puteo hosted the painter for a certain period in his Apulian residence [60], a period in the service of the prelate; this was a fairly widespread practice in the same decades in other Italian centers and at the court of high prelates. It is the day after the Council of Trent (officially opened in 1545 and concluded in 1563), a period in which the Catholic Church strongly reaffirms the didactic and educational role of sacred images which, with the simplicity of colors and figures, were able to convey important Christian messages to all God-fearing people,

and the ecclesiastical province of Bari is among the first in Italy to celebrate the provincial synod called in 1567.

However, the period of the Bari commission also testifies to the fact that Gaspar Hovic, in addition to the activity conducted at the service of the new religious orders and prelates of post-Tridentine culture, was also active for bourgeois and aristocratic clients since the end of the sixteenth century. Before dwelling on the canvas, the subject of this study, let us try to analyze, albeit briefly, the style and the various influences the artist has matured, and we will trace in the work in question.

The first works of the Bari period develop on archaic systems with few figures, organized in a balanced manner and coming directly from the observation of the Byzantine icons of which Puglia was rich at the end of the sixteenth century, where the schematic composition of the scene and subjects preserved clearly the characters of Italian and international mannerism; this is an aspect that will characterize all of his work, with a literal adherence to the pictorial model he presents without a reinterpretation even from the chromatic point of view [62].

It is known, in fact, that the overall artistic activity carried out by Hovic in Puglia has triggered a series of mannerist novelties, not revolutionary, but peaceful and harmless and in transition to even more significant ones. Hovic, in the Apulian microcosm and at the turn of the centuries, XVI–XVII, plays an innovative and rejuvenating role of the pietistic conformism, modifying over time his style, first set on rigidly axial schemes and representative of a "sacred" immobility, a style characterizing his first pictorial production for ecclesiastical commission, to arrive at scenes of greater iconographic complexity and characterized by a certain animation, as in the work under study, which can also be traced back to pictorial production to commission of lay extraction.

From research carried out at the end of the 21st century, the canvas is a copy of a fresco kept in the oratory of the Gonfalone in Rome made by the Roman painter Livio Agresti in 1569 (Figure 2a).

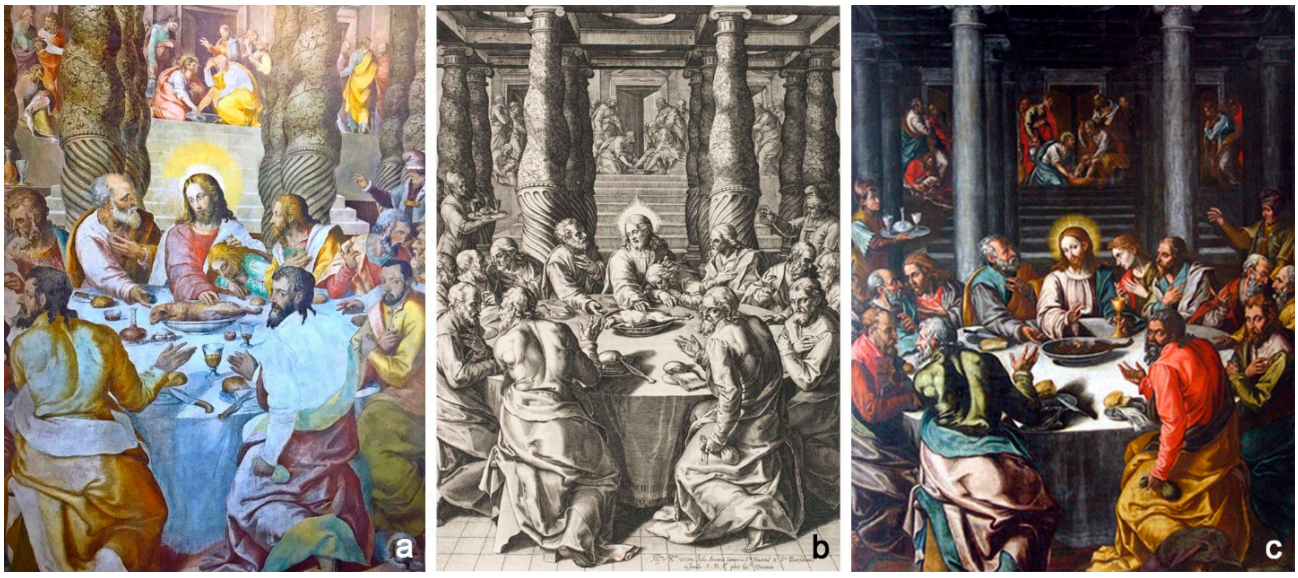


**Figure 2.** (**a**) Fresco by Livio Agresti, "Last Supper", 1569; (**b**) Cornelius Cort engraving, "Last Supper", 1578; (**c**) unknown painter, "Last Supper", Church of San Rocco di Montorio.

Here, we find, unlike the fresco from Triggiano, some divergent elements such as the shape of the Ionic columns and the scene of the washing of the feet. For the columns, Agresti uses a twisted type to recall the style adopted in the columns of the temple of Jerusalem or the columns of the first funeral temple of the original tomb of the apostle Peter, which are still preserved on a small altar in the basilica of St. Peter in the Vatican. The scene of the washing of the feet, replaced by a simple basin put in the foreground in the triggianese

canvas, is present on the staircase at the bottom of the colonnade in the Roman painting composed of the characters told by the Gospels.

Works very similar to the Roman one, which differ only in some small details, can be found in different places in Italy (for example "Last Supper" engraving by Cornelius Cort in 1578 (Figure 2b) located in Bergamo (BG), Accademia Carrara Department of Prints and Drawings, "Last Supper" by an unknown painter located in the church of San Rocco di Montorio al Vomano in the province of Teramo (Figure 2c).

The discontinuity of Hovic's style greatly influenced Apulian painting of the 16th century and owes Hovic a "sample" of pictorial models existing outside his own territory and the definitive desertion of archaic and Byzantine models, to enter the new dimension of the Mannerist style, which, breaking away from the original Venetian environment, definitely turned towards Naples and its painters, defining the local pictorial taste throughout the seventeenth century. Followers such as Andrea Bordone, Alonsus de Corduba and Nicolaus Dalmata imitate his art.

### *3.2. Iconography*

The scene represents the moment in which Christ pronounces the famous phrase: "In truth, in truth I tell you, today some of you will betray me" and the disciples, ready to eat the meal consisting of loaves and sacrificial lamb, placed almost in the center table in front of Jesus, begin to become agitated and ask him one after the other: "Is it me?", showing and highlighting their human frailty.

The entire scene materializes on the canvas through the method of representation of the central perspective. The reading order of the moments represented is very linear. We find four levels of reading which represent different actions. The story starts from the space of the basin positioned at the bottom left of the scene, a symbol of the washing of the feet. In other similar works, this moment is present on a staircase at the bottom of the colonnade with the characters mentioned in the Gospels (Figure 1a).

The story then moves to the central part of the representation with Christ and the apostles seated around the table, ready to eat the meal consisting of the bread and the sacrificial lamb. The table, covered with a white tablecloth, is strongly illuminated and has a circular shape as it symbolizes communion, the Eucharist. Jesus occupies the place of honor in the center of the circle of the apostles and represents the central axis of the compositional scene.

Immersed in a strong light, he has a mild and intense gaze, full of solemnity and suffering for what is happening in those moments. His right hand is resting on a plate where a sacrificial lamb typical of the Jewish tradition is placed. The left hand is instead on the head of John who, sitting to his left, tenderly rests his head on his chest to tenderly enjoy those last moments. To the right of Jesus is Peter who has his gaze completely turned towards him. His eyes appear full of sadness and concern over the announcement of the betrayal. The position of his hands, the right on the table, the left towards his chest, express his sincere desire to be faithful to him, although aware of his own fragility. Diametrically opposite to Peter, Judas Iscariot is seated in the foreground on the right who, disturbed by the words of the betrayal uttered by Jesus, turns his gaze towards the observer, avoiding that of Christ. He still holds in his left hand, specially kept lowered, the bag containing the thirty denarii, symbol of betrayal. The remaining apostles present in the scene are not easy to identify; the iconographic representation does not help us to identify them exactly. It can be hypothesized that the apostle Thomas is the character portrayed with his right hand raised and his finger outstretched, characteristic of always questioning the words of others.

On the next floor, behind the table, but before the colonnade, we find two other figures extraneous to the sacred table: the host, (on the right) who authoritatively gives orders to a servant (on the left) in the act of serving the diners. He holds a tray on which an amphora, a bottle and a chalice are placed, the Eucharistic symbol of Christ's sacrifice.

Finally, on the last reading level, we find the representation of a colonnade that could symbolize a temple. This, together with the rigorous perspective layout traced by the tiles,

creates the environment where the whole action takes place. The hole in the back of the scene is certainly a reminiscence of the frescoes that the painter took as a reference (Figure 2).

## 4. Materials and Methods

The initial goal is, therefore, to design and implement a virtualization process of a painting focused on the observer and referred to works on canvas, inside which there are architectural objects. This last feature is fundamental in the procedure adopted, as it allows you to identify one or more vanishing points and thus reproduce the entire 3D scene from the viewer's point of view; otherwise, in paintings or representations consisting only of human figures, this procedure is not applicable.

The aim of the digital process is to transform a two-dimensional work of art into a three-dimensional one, implementing thus the virtual 3D space of the representation and perceiving it in a more direct manner. In this phase, the geometric analysis of the two-dimensional work is fundamentally aimed at the digital restitution of the perspective references and preparatory to the modeling of the virtual scene.

The second phase is dedicated to the reconstruction of the 3D model, a delicate phase where the comparison between the geometric hypotheses, derived from the perspective restitution, and the real geometry of the objects present in the scene is important for a correct and faithful 3D reconstruction of the entire stage representation. The next step is to convert the 3D model into a dynamic form, associating it, through spatial references, to a virtual space accessible to the general audience and to allow users to test a virtual experience.

When observing the painted canvases or the altarpieces of Mannerist painters, it is not difficult to find oneself in front of paintings that seem to be the result of rigorous executions of the perspective rule, where a single point of view has the role of ordering the vision of the scene; however, very often, it turns out that the drawing returned by the geometric reconstruction does not confirm these expectations and geometric rules. Most of the time, these anomalies are not attributable to an error in applying the rule, but are the result of astute tricks operated by the painter, introduced to better emphasize the Gospel message to be transmitted to the observer, even at the expense of the correct application of the technique.

Ferreting the illusions implemented in a painted image is not a trivial matter; it requires the use of investigation procedures and rules that support the acquisition of spatial data in the subsequent three-dimensional modeling phase. Furthermore, in the case study, the pictorial scene sees the presence of both in perspective architectural elements and human figures, elements commonly combined in the scene, and which have led the research towards two different approaches for the realization of the three-dimensional model.

Creating an immersive model of a pictorial scene means having a floor plan of the entire environment depicted in the work immediately available. In our case, this goal was achieved using the perspective restitution technique, a geometric construction that is based on the identification of the essential elements of the central vertical frame perspective in order to reconstruct them in the overturned plan. Inserting the human figures into the 3D model instead has provided the use of photogrammetric restitution with a specific methodology capable of reconstructing the textured three-dimensional characters.

For the purpose of designing the content of the virtual construction, aiming at a fair balance between realism, telepresence and comfort, the viewer of the art has not been represented three-dimensionally in the virtual environment in the form of an actor (avatar) but is simply a dimensionless point of view that "views" and "understands" the pictorial scene in the virtual space that can be used, even from the web, and in the same perspective view desired by the artist, faithfully reconstructed in 3D.

To create and "increase" the viewer's sense of telepresence, the scene was reproduced from life, with real human figures and real objects (lamb, bread, period clothes, saltshaker), as well as acquired with photogrammetry techniques for the purpose of 3D modeling.

The reconstruction of the 3D model, complete with the architectural elements and human figures, was compared with the canvas under study, verifying the reliability of the perspective scene created by the artist in the work. The comparison highlighted some anomalies in the representation of the table and a part of the diners in the painting, anomalies that were highlighted within a further three-dimensional model created with the aim of making the perception of the perspective error more immediate and explanatory, used by the painter within an immersive platform created ad hoc.

The three-dimensional reconstruction obtained, in fact, aims to create an explorable model for the use of the painted space by users. Thus, a virtual augmented interactive-immersive learning tool is built. An immersive platform is created where users can interact in real time and within the 3D model, exploring the entire perspective space from multiple points of view.

The technologies adopted make this process replicable also on other works without exceeding the construction costs. The methodology identified can be easily applied to two-dimensional works in which there are, in addition to human figures, architectural objects defined by lines converging in one or more vanishing points, which therefore allow the reconstruction of a plan, which is the starting point for the realization of the immersive three-dimensional model (Figure 3).

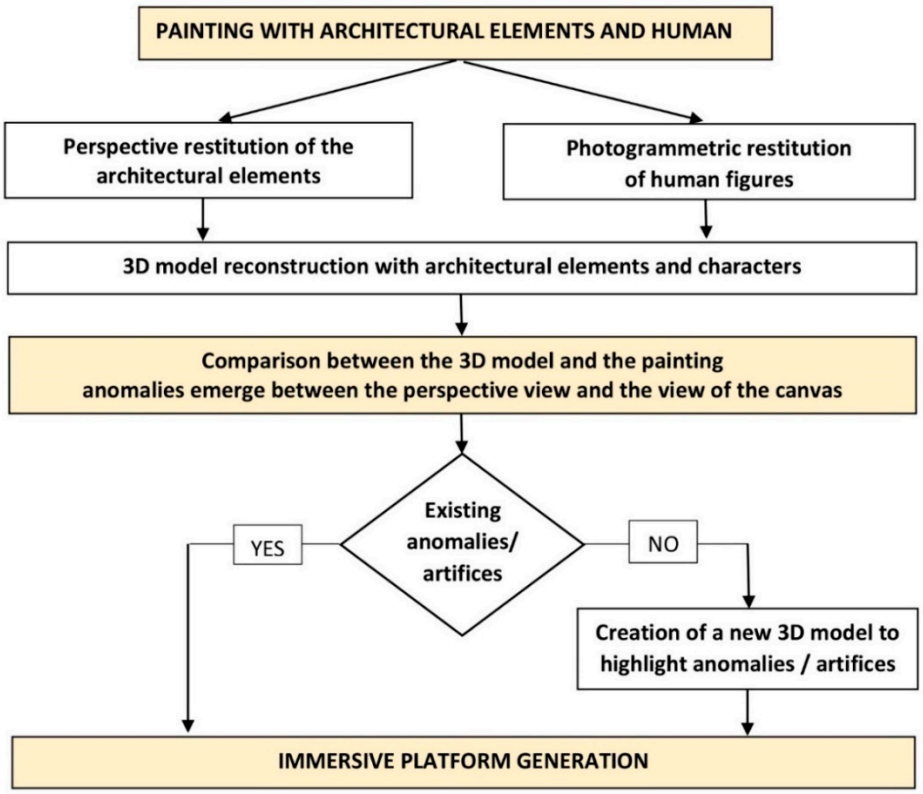


**Figure 3.** Flow chart illustrating the methodology.

### *4.1. The "Perspective Restitution" of the Architectural Elements*

There is a moment in the history of art when two-dimensional pictorial representations began overcoming the representation itself in favor of a visual experience that involved the viewer, bringing him into the third-dimension reality. The first example of painting with the presence of a perspective scene inside it dates back to 1344, with "Annunciation" by Ambrogio Lorenzetti (Figure 4), where we see represented below the figures a floor of checkerboard tiles that becomes an index of the spatial values for the bodies as well as for the intervals" [63,64].

**Figure 4.** A. Lorenzetti, "Annunciazione", 1344.

This is the first time the lines of the pavement converge towards a single point, in what will subsequently be defined as the "vanishing point". "The painters of the Renaissance were pleased to suggest depth through the representation of tile floors" [40] because, assuming them of equal size, their progressive diminution could be interpreted as a moving away and, therefore, arouse the impression of a depth of field. In this way, the painter aimed to create a more evocative and illusory pictorial scene, transferring the spatiality of reality on the two-dimensional plane. When then, within the scene, architectural background structures also began to appear, the composition became even more suggestive and captivating.

Undoubtedly, the perspective used within a painting is a method of representation that manages to materialize, on a two-dimensional plane, the depth of space through intuitive-illusionistic mechanisms involving the observer and leading him in a physical–mental transport of senses and emotions, to discover the representations depicted from time to time.

Representations of this kind often lead the "expert reader" to a deeper analysis of the scene, in particular of the perspective technique. They lead the reader to verify the perspective space by highlighting the regularities or inconsistencies designed to better understand the painter's wishes. This is possible thanks to the perspective restitution which is the most suitable tool for verifying the geometric technique through the restitution of the plan and the corresponding two-dimensional sections.

Certainly, the image of the painting in question, acquired at high resolution, supported the analysis of the architectural elements and allowed to identify with greater precision the essential elements of the perspective, useful for the construction of the two-dimensional plan [65–67]. Below is the description of the work phases that led to the reconstruction of the plan of the represented environment.

- Identification of the essential elements of the perspective: "main point" ($V_0$), "distance circle" with center $V_0$ and radius equal to the observer's distance from the painting ($V_0D_1$ or $V_0D_2$), "fundamental line"(f), "straight line horizon"(o);
- Perspective rendering of the floor and the table with scaling of the drawing;
- Perspective restitution of the stools;
- Perspective rendering of the columns;
- Construction of the final overturned plant (2D).

#### 4.1.1. The Identification of the Essential Elements of the Perspective

From a first visual analysis of the pictorial scene, it is evident that the representation is structured according to the geometric rule of the central vertical painting perspective [65],

with the vanishing point positioned in the center of the canvas. It has multiple functions. First, it dictates the geometric rules for the correct composition of the painting. Second, it represents the architectural scene and the message the author wants to send. Third, it controls the entire virtual space of the scene by verifying the regularities and inconsistencies present in the drawing.

The restitution of the painted space in central perspective was carried out using the inverse procedure of the linear conical perspective. Therefore, it was necessary to identify the essential elements that make up the perspective, first of all the position of the "main point $V_0$". Usually, this point is where all the depth lines in the scene converge. It is not always unique; often 3–4 different "main points" can be identified. They are generated by the painter to highlight parts of the scene rather than others.

In the canvas in question, two "main points" have been identified: "$V_1$", determined by the lines of the grouting of the pavement, and "$V_2$", determined by the depth lines of the terminal strips of the capitals (Figure 5a). Their function, however, does not seem to be linked to any particular perspective choice, so, for a better reconstruction of the two-dimensional scene, a unique point of view has been identified for the entire construction ("$V_0$" see Figure 5b) in a middle position between the two.

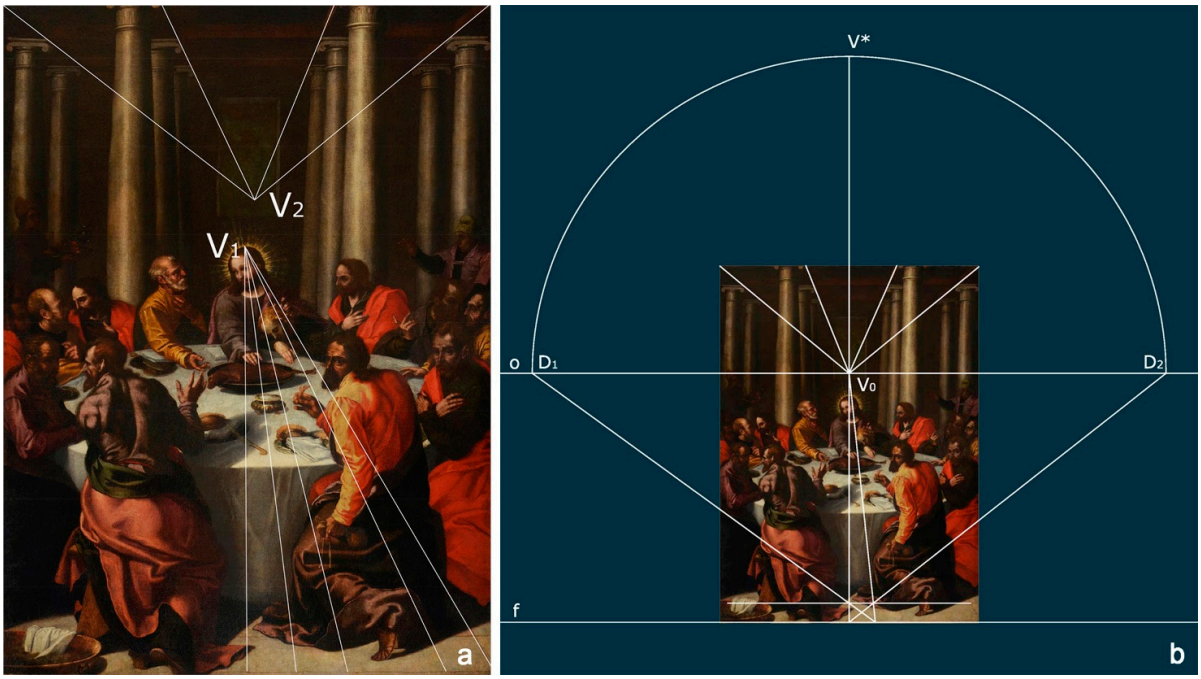


**Figure 5.** (**a**) Depth lines not converging in a single point; (**b**) identification of the essential elements of the perspective.

The internal orientation of the perspective was completed by first identifying the "horizon line" (o) passing through "$V_0$". Then, the "fundamental line" (f) was identified, assumed to be fictitious and (not having a certain metric datum) coinciding with the last horizontal grouting of the tiles, as is common practice in the case of perspective restitution of architectures painted on a vertical plane. Finally, the "distance circle", with center $V_0$ and diameter $D_1$-$D_2$, determined by the diagonals of the central floor tile (Figure 5b), was identified.

After the perspective reference of the painted image has been identified, the geometric analysis and graphic rendering of the painted space plane were carried out using the overturning method applied to perspective on the vertical picture plane.

The following geometric analysis shows that the space of the canvas is characterized by a substantially regular layout, characterized by a strong symmetry along the vertical axis passing through the $V_0$ point.

However, the space painted by Hovic is not free from irregularities, both due to the executive difficulty due to the size of the painting, and due to a series of exceptions

made by the artist to support purely aesthetic choices, aimed at highlighting the message rather than the correct geometric rule.

#### 4.1.2. The Perspective Rendering of the Floor and Table with Scaling of the Drawing

The floor, located below the figures, is the most representative index of the spatiality of the scene. The reconstruction process was ultimately based on the geometric reference of the tiles of different shapes visible in the lower part of the painting (see Figure 6b): rectangular and square. Starting from this geometric data and considering the lack of representation in the scene of numerous tiles, the missing tiles were reconstructed directly on the overturned plan. The entire distribution of the floor was thus created with a compositional plot, detecting a well-determined rhythm, which repeats and replicates a rectangular module every four square modules (see Figure 6a).

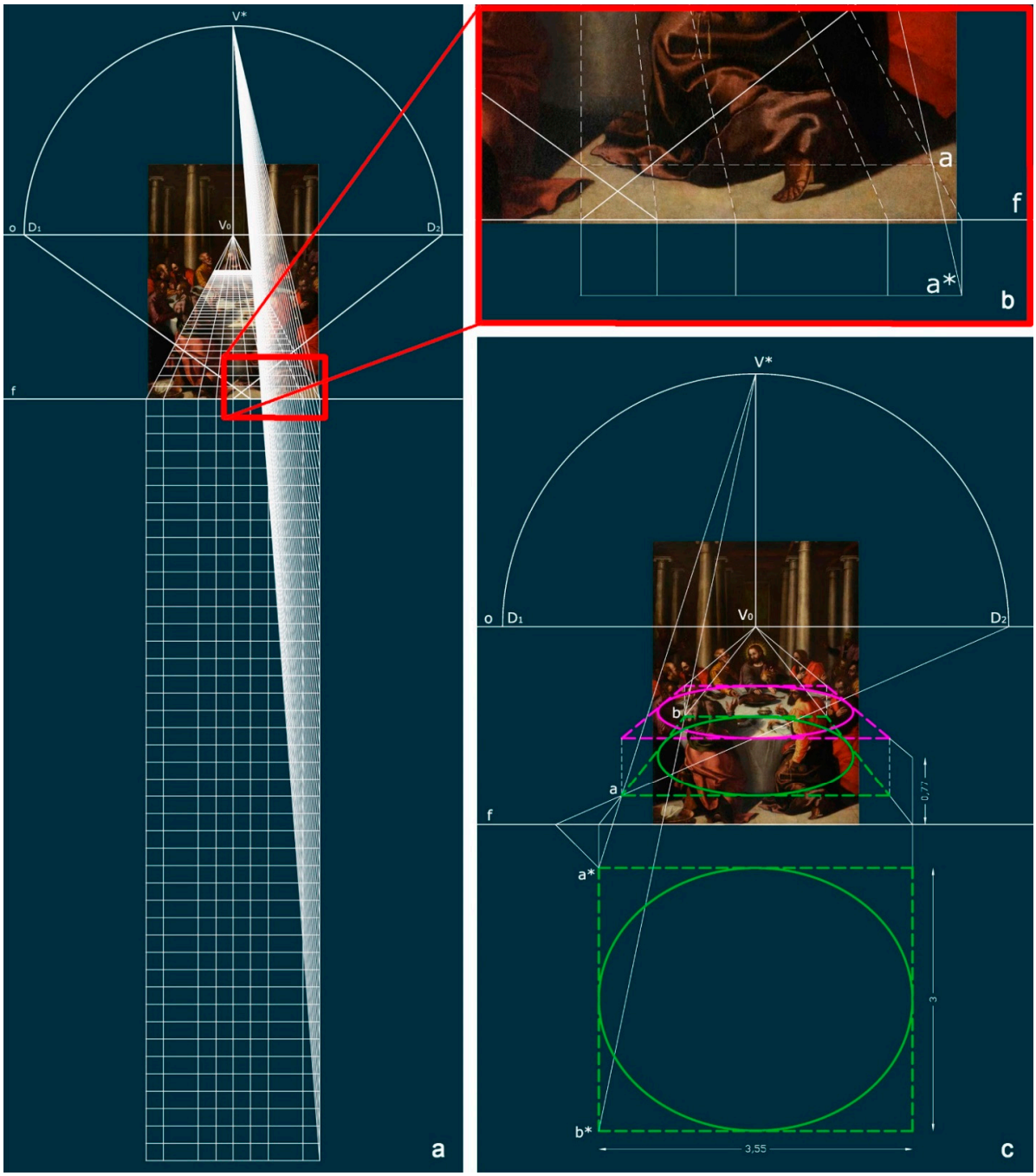


**Figure 6.** (**a**) Perspective rendering of the floor; (**b**) detail of visible tiles; (**c**) perspective restitution of the table.

The reconstruction of the table was carried out by inscribing the ellipse of the support surface inside a trapezoid, arranged with the two parallel sides to the fundamental line, generating thus, in the overturned plan, an elliptical table (see Figure 6c).

The geometric references of the table were fundamental to scale the entire restitution. In fact, lacking a certain metric data to which to relate and having the need to correctly proportion the architectural elements, the design was scaled according to the height of the dining table. Considering that this height usually varies from 70 to 80 cm, an intermediate measure of 77 cm has been assumed. By adopting this hypothesis, it was possible to give more reliable measurements to the architectural elements present in the scene. As initially specified, we consider this interpretation valid because the objective of the research is not the meticulous reproduction of the architectural scene, but the creation of an overall vision capable of highlighting the perspective dissonances present in the painting.

#### 4.1.3. The Prospective Restitution of the Stools

From the analysis produced so far and from other case studies [68], it is evident that subjecting a painted image to a perspective restitution very often means revealing that the scene is not always the result of rules, but also of derogations or artifices deliberately introduced or by natural expedients. It is precisely of the artifice that we speak when we focus on the perspective representation of the two stools in the foreground.

The following images (see Figure 7a,b) show the perspective restitution of the two stools, left and right in the foreground, reconstructed on the depth lines and faithful to the painter's drawing. They highlight a reconstruction in the overturned plan, geometrically impossible for the reconstruction of the real shape of a stool.

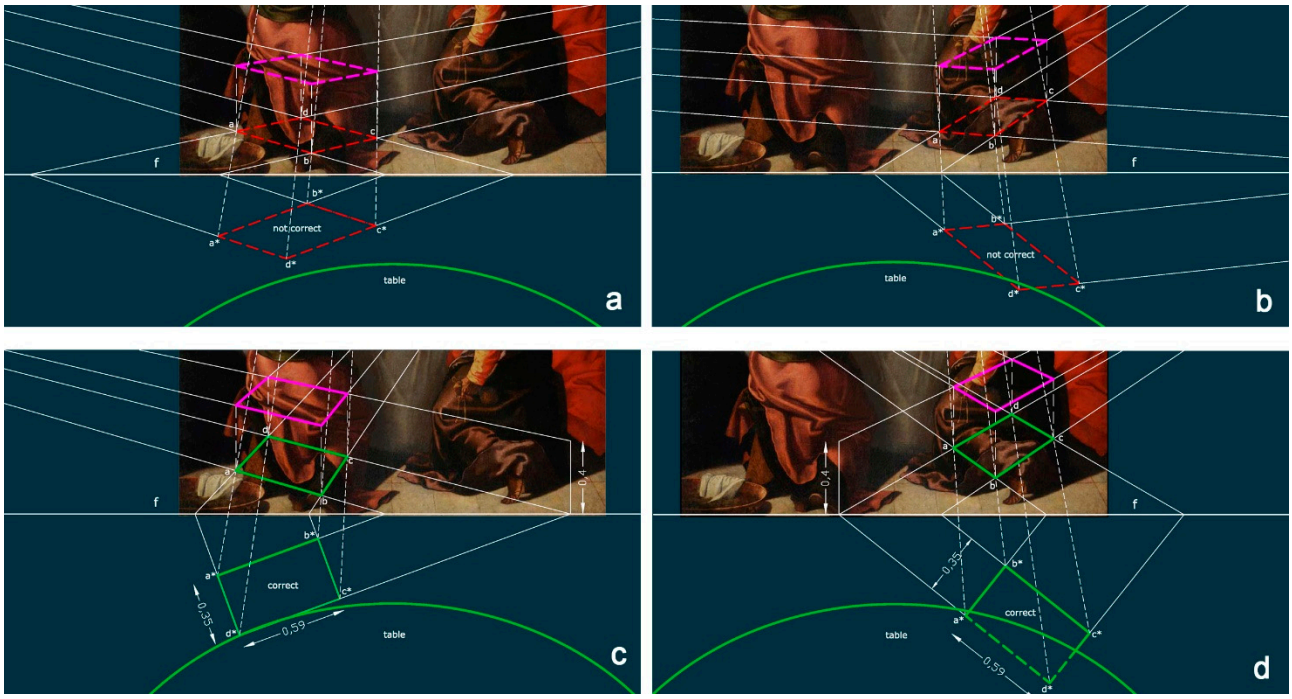


**Figure 7.** (**a**) Perspective restitution of the left stools according to the painter's perspective; (**b**) perspective restitution of the right stools according to the painter's perspective; (**c**) perspective restitution of the left stools according to the correct perspective; (**d**) perspective restitution of the right stools according to the correct perspective.

Consequently, we proceeded to the 3D reconstruction of the stools, giving them the shape of a parallelepiped, in order to have, in the overturned plan, the correct definition of their plan and the right perspective in the painting (see Figure 7c,d).

#### 4.1.4. The Perspective Rendering of the Columns and the Construction of the Final Overturned Plan (2D)

The columns represented behind the table are not traceable to any of the five architectural orders; they would seem Ionic, due to the presence of the volute capitals, but the high molded band, close to the collar, does not make them objectively similar to this order.

The restitution process focused only on a part of the columns, inserting the remaining part of them directly into the overturned plan and according to the axes of symmetry (see Figure 8a). The returned columns have a diameter of about 70 cm and a height equal to about 4.80 m (outside the capital). These geometric dimensions do not coincide in proportions with the metrics of any architectural order, defined by the treatise authors of the sixteenth century. Their dimensions are not even comparable with the dimensions of the column for example, identified by Vignola in his manual [69]. According to the dimensions of Vignola's manual, the height of an Ionic column (base plus shaft plus capital) with the right proportions had to be equal to 18 modules, where each module has a diameter equal to half the base diameter of the returned column.

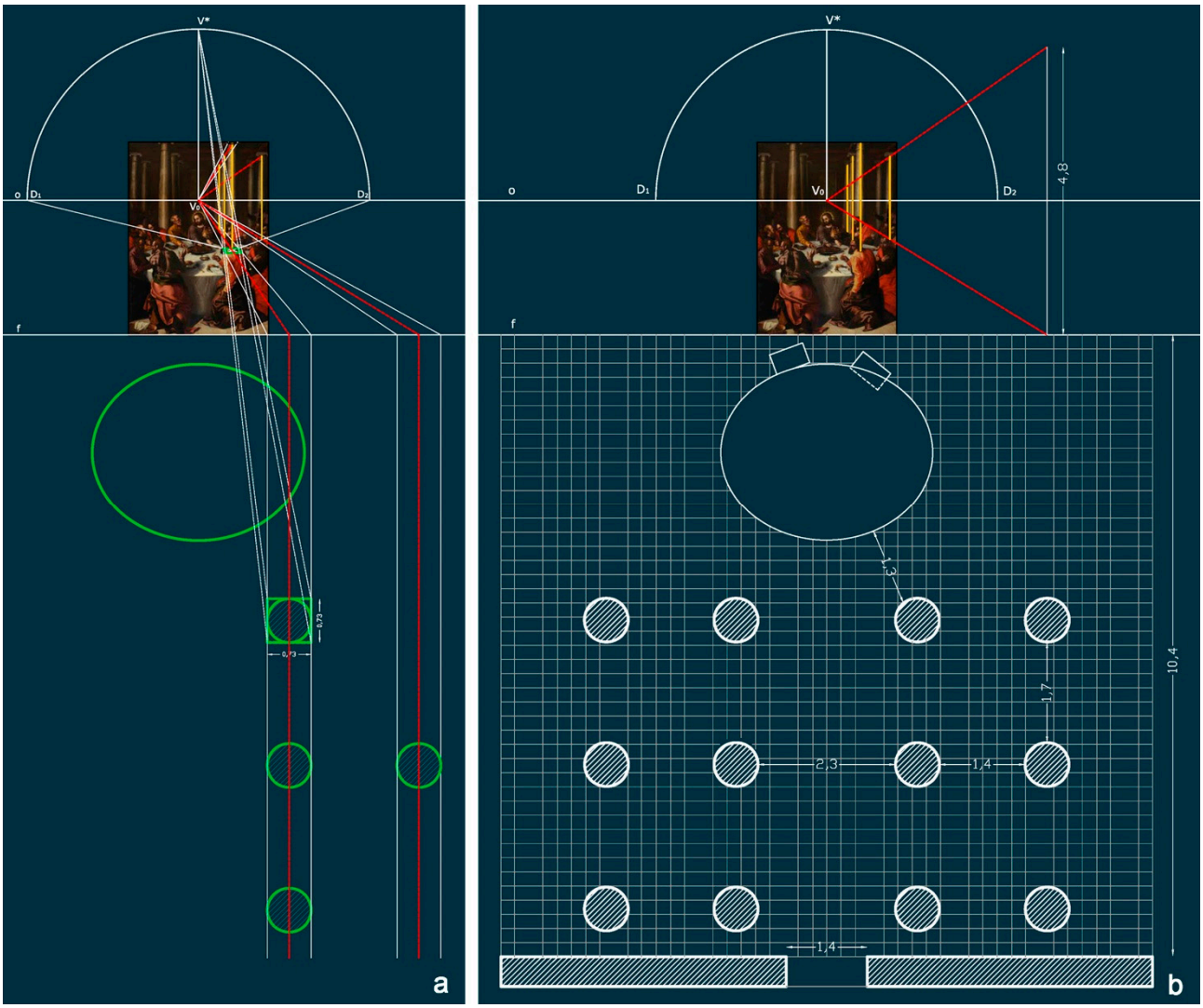


**Figure 8.** (**a**) Return of the columns; (**b**) overturned plan of the architectural elements identified.

Therefore, a total height of 35 cm × 18 cm, or 630 cm$^2$, should have corresponded to a column base with a diameter of about 70 cm. By subtracting from the total the height of the capital, not considered by us and equal to 12 parts (about 24 cm), the total returned height should have been 6.06 m, therefore much higher than that represented by Hovic.

This demonstrates that the importance of the Gospel message is far more important than the proportional rules.

Once the columns had been returned, it was possible to complete the reconstruction of the two-dimensional plan, which will be used for the creation of the spatial model of the entire room (see Figure 8b) represented in the scene, inside which the guests will be inserted and dislocated around the table.

### *4.2. The "Photogrammetric Restitution" of the Characters*

For the three-dimensional reconstruction of the characters in the pictorial scene, a method has been studied that can also be used in other contexts in which the economic component plays an important role. The photogrammetric technique has been taken into consideration rather than that of the laser scanner, as its current implementation (image-based methods and automatic image matching procedures, even web-based) has made it possible to have a wider range of tools.

Mainly, it is used to reconstruct architectural elements or static objects such as objects, facades or soils. Instead, to detect dynamic elements, such as non-statuary animated characters, we generally resort to the use of many cameras, even up to one hundred, positioned in different points, but all oriented towards the subject to be detected and synchronized between them [70] so as to simultaneously acquire the photographs in a very short amount of time.

This method, however, was discarded because while ensuring high accuracy in the reconstruction phase, it involves the use of considerable financial resources, due to the large number of cameras to be used.

For this reason, while accepting some inaccuracies, it was decided to detect the different subjects of the scene with a single camera. Therefore, each character was placed in the same position in the painting and photographed from different angles for a total of about 300 photos per character (Figure 9).

An initial hypothesis of using mannequins or 3D models of human subjects was instead followed by the decision to use voluntary actors with somatic characteristics similar to the characters in the painting, dressed in costumes that conform to those of the scene. The latter have ensured that much sought-after hyper-realistic reproduction, to the detriment of some imprecision of form found in the post-processing phase.

The photographic shots were processed automatically with the use of Agisoft Metashape Professional software (version: 1.5.2—Agisoft LLC—Russia), through a first phase of "alignment". This reconstructs the network of photographic shots taken during the acquisition phase, determining their positioning and orientation in the space of the camera. This processing is the result of a complex mathematical calculation that the software performs by comparing the different photographic images, recognizing the various homologous points and calculating the different shooting angles and distances.

The images processed by the aforementioned software generated the point cloud of the photographed subject. This cloud has been verified, cleaned of foreign elements (chairs, tables, floor) and sent to the subsequent processing for transformation to mesh. Finally, the 3d models obtained were texturized and scaled ready to be inserted into the three-dimensional architectural reconstruction of the pictorial scene.

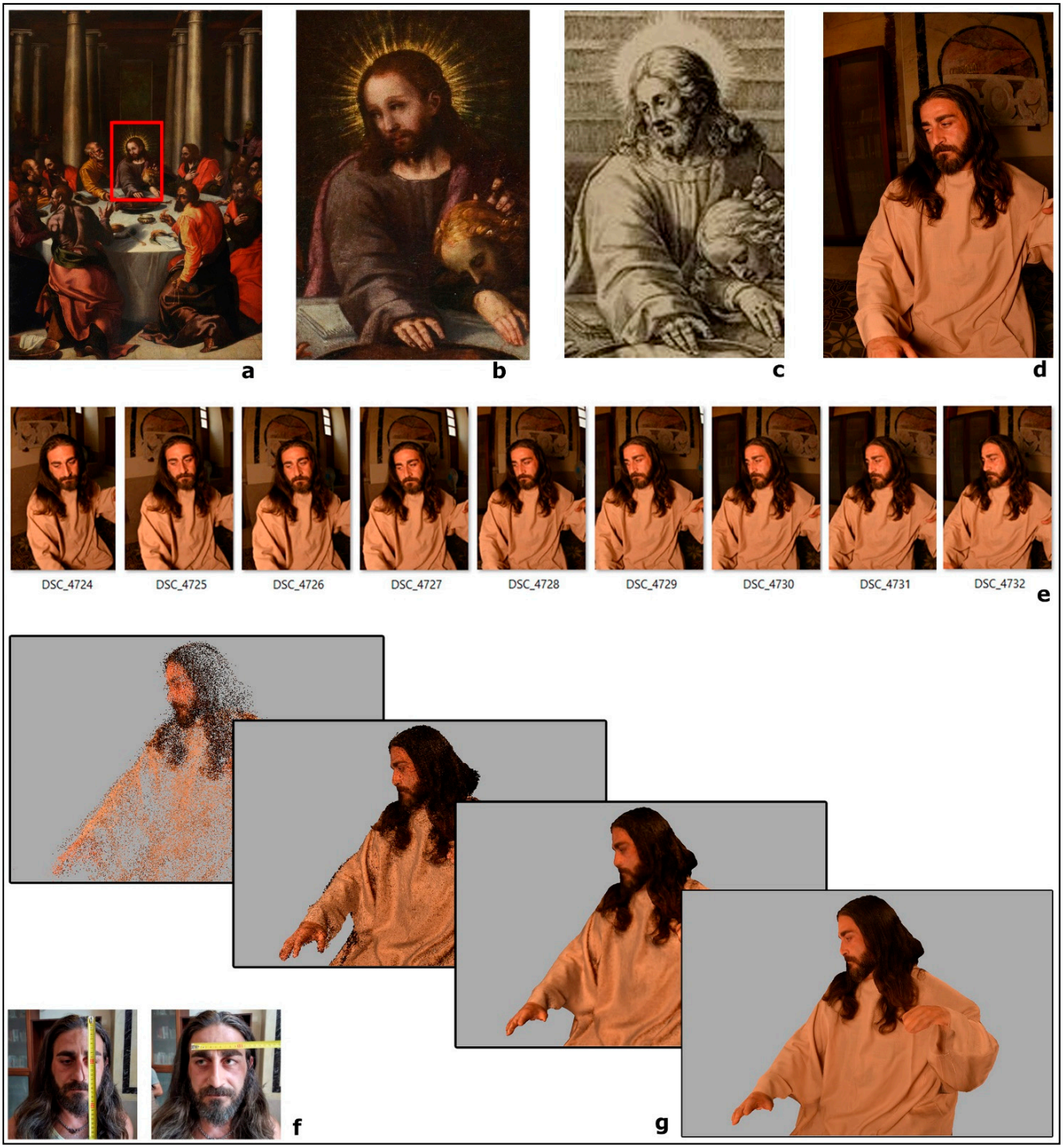


**Figure 9.** (**a**) Gaspar Hovic, "Last Supper", 1583–1593(?); (**b**) Gaspar Hovic, "Last Supper", 1583–1593(?), detail of Christ; (**c**) Cornelius Cort, "Last Supper", 1578, detail of Christ; (**d**) actor who portrays the Christ; (**e**) sequences of photographic shots; (**f**) survey of two measures for the scaling of the virtual character; (**g**) processing from the point cloud to the textured character.

#### 4.2.1. The Photographic Equipment

To obtain a correct alignment, it is necessary that the software recognizes some fundamental parameters that are part of those technical peculiarities of the camera: the pixel size of the frame, the type of lens used and the calibration parameters of the lens. This operation is essential to determine and compensate for all parallax and offset errors of the camera

in order to obtain an accurate calculation of the triangulation between the spatial position of the point where the shot was taken and its homologous point.

It is necessary to have good photographic equipment, opting for Single-Lens Reflex (SLR) cameras instead of compact ones. It is well known, in fact, that in consumer cameras, the size of each single pixel is much smaller than that of a professional-type camera. This difference is due to a greater background noise (NOISE) caused by the increase in the electric current circulating in the electronic circuitry of the sensor. In this way, images are obtained where the contours of a photographed subject, in the same ambient light conditions, are not as detailed as those taken by a professional SLR, while the identification of these details is absolutely essential to accurately determine the homologous points.

An important role is played by the choice of the lens, which must satisfy certain requirements for identifying the calibration data to be applied in the alignment process.

From experience, software that use "Structure from Motion" methods [4] such as Agisoft Metashape Professional or 3DF Zephyr software (version: 5.007—3Dflow srl—Italy), struggle to process images when very short focal length lenses are used because these have extremely high characteristics of distortion, chromatic aberration and vignetting in the peripheral area. At the same time, however, they have a greater depth of field and also a wider field of view that allows a better identification of points in common. Depth of field that in longer focal lenses is less evident such as not to be suitable in surveys of close subjects that have fairly pronounced protruding parts.

Considering these aspects, we are oriented to use short focal length lenses, taking into account only the central shooting area by means of an automatic cropping set in the camera, an area in which all those errors are minimized, thus obtaining ideal and highly detailed shots of the alignment process.

The table below (Table 1) describes the features of the camera to generate a good image.

**Table 1.** Camera features.

| Camera Features | Recommended Choices |
|---|---|
| Resolution | 34 MPx |
| Focal length | 16 mm (cropping set: 24 mm) |
| Sensor sensitivity | ISO 800 |
| Aperture | F/6.3 |
| Shutter time | 1/100 sec |
| White balance | 4100 K |

#### 4.2.2. The Preparation of the Camera for Shooting

In addition to the camera, the lighting of the subject to be shot is also important. It is preferable to have a strong and diffused illumination because this allows to use low sensitivities of the sensor.

The ideal lighting for the relief of the characters was obtained using a spotlight with 11-Watt LED technology with a color temperature set at 4100 K, with a fairly pronounced rectangular shape. The photographic shots were performed trying to orient the camera perpendicular to the plane to be shot with an overlap between adjacent frames of about 60%.

The average acquisition time for each character was around 5 min. We proceeded with the photographic acquisitions starting from the head of each actor and gradually descending in a spiral towards the lower part of the body. This is because the head, but especially the limbs, are the parts of the body that are most affected by involuntary movements, especially if the latter are stretched out in particular attitudes. In this way, the actor's "tiredness" aspect was dammed in maintaining the same position.

For the scaling of the subjects shot, some measures were acquired through the use of a metric roll.

*4.3. The Virtual Reconstruction of the Scene*

The stage of reconstruction of the scene was carefully prepared in compliance with the historical and artistic investigations of the pictorial work, previously conducted. Starting from the overturned plan obtained from the descriptive geometry (see Figure 10a), the environment was modeled with 3DStudio Max software (version 2020.3.2—Autodesk-USA), in full scale, extruding the architectural elements (see Figure 10b,c) and inserting the characters detected with complete textured asset from digital photogrammetry (Figure 11).

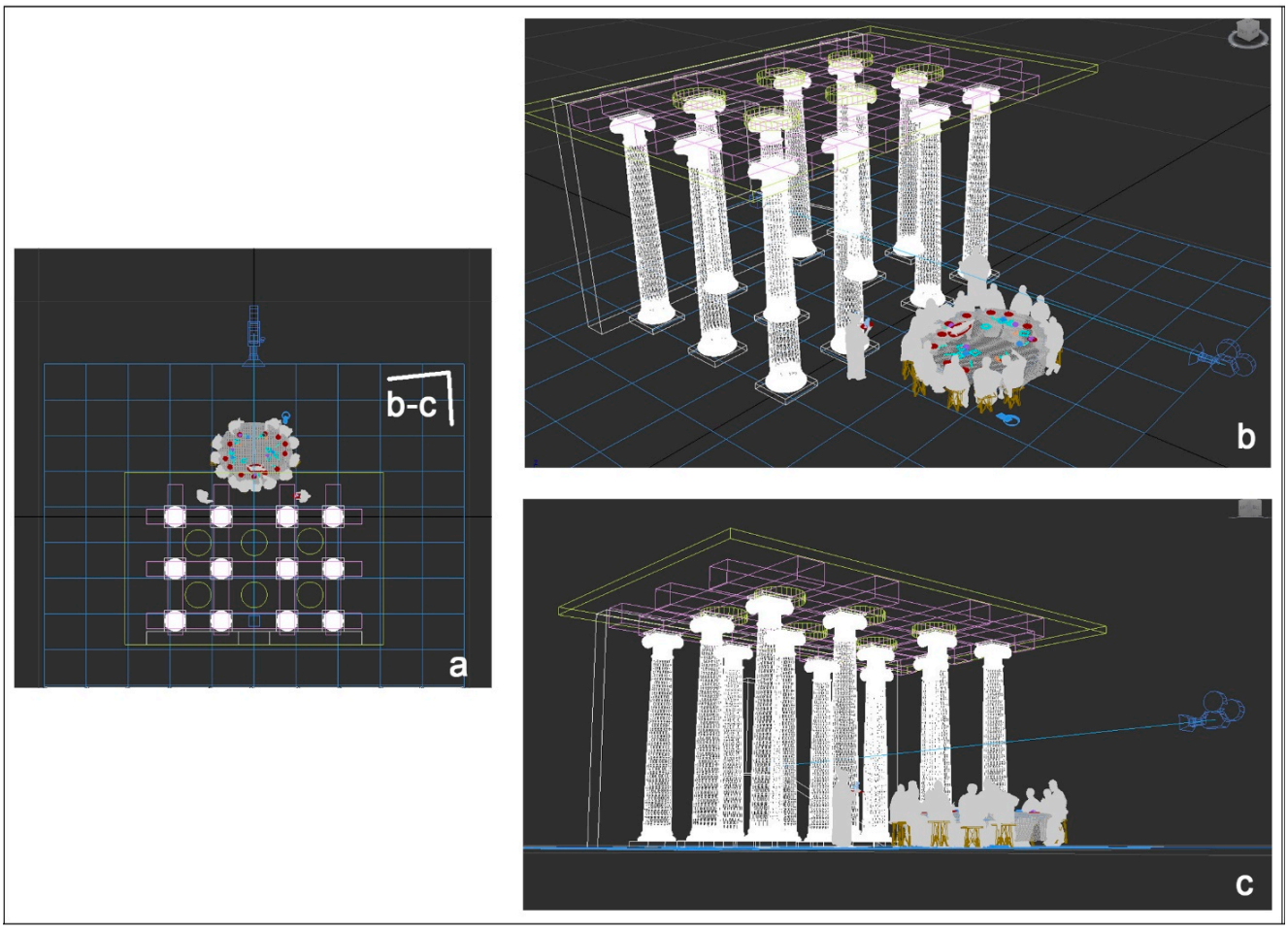


**Figure 10.** (**a**) Plan of the scene reconstructed from the perspective restitution; (**b**) top view of the scene; (**c**) bottom view of the scene.

The pseudo-ionic column was built using Boolean processes, adding three geometric elements together: a parallelepiped as a base, a tapered cylinder at the top as a stem and an Ionic capital imported directly from the web and duly scaled to match the size of the stem. Subsequently, with the copy command, the entire column was multiplied 11 times as indicated by the plan taken from the descriptive geometry.

Using the "box" element, both the back wall with the rectangle in subtraction relative to the central opening and the coffered ceiling were created.

The table and the tools present on it were imported directly from the web, except for the saltshaker which was built through processes of extrusion, revolution and the Boolean sum of profiles and simple objects.

**Figure 11.** View of the table with the textured characters.

The greatest complexity was found in the realization of the tablecloth element which, to become closer to the one depicted, had to have a smooth and flattened appearance in the upper part and at the same time wavy and falling in the front. For this type of element, the software provides a modifier called "Cloth" that allows you to deform one plane over another, assuming a shape very close to that of a cloth that rests on a body.

The reconstruction was completed the moment the stage lights were put in. With the aim of recreating the same brightness of the painting, two different light sources were adopted: one of the bull's-eye spot type, and the other unidirectional (Figure 12).

The first, using a white light projector, was placed at a height of about 7 m from the ground (with the target directed towards the center of the table) and set with a light output of 6000 lm, an external cone of 36° and an internal one more intense than 27°. This is the main light source in the scene and hits the characters and objects on the table, generating well-defined shadows.

The second light source, of the unidirectional type, is placed at a height of 3.5 m and at a distance of 12 m from the colonnade. It has a total power of 30,000 lm, but is characterized by an attenuation to 11 m in order to produce a slight clear reflection along the front of the columns and a darkening effect at the rear.

As for the materials of the objects in the scene, where possible, their coloring was taken directly from the painting. For the characters, this was not necessary, as digital photogrammetry automatically preserved the corresponding coloring of the subjects portrayed.

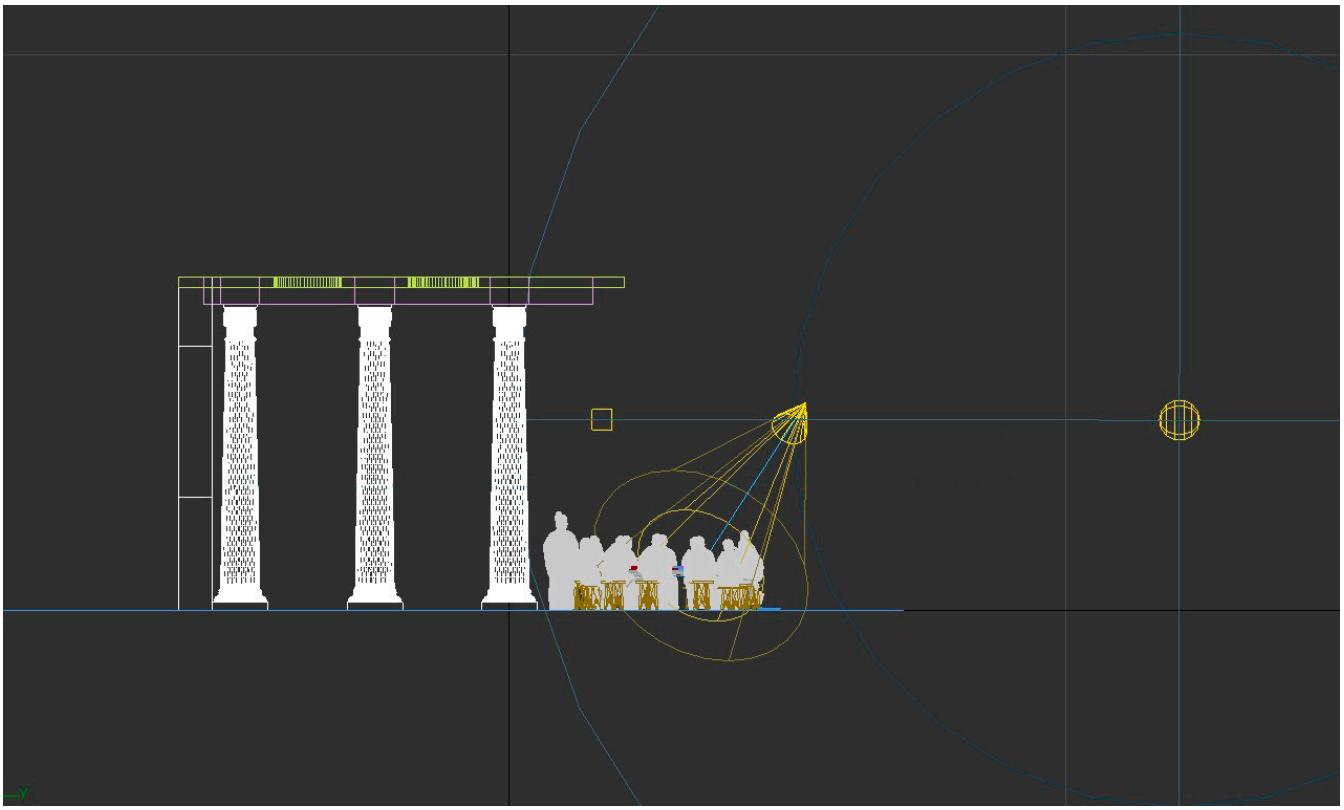

**Figure 12.** Side view with stage lights.

## 5. Results and Discussion

There are paintings in which the perspective rule is rigorous and perfectly executed; there are others in which the rule is not always respected, an aspect that, most of the time, is not attributable to an error in execution, but is the result of tricks made by the painter to emphasize the message represented. For the case study chosen, the painting is attributable to the painter precisely because of his "intimate layout that marks the work" [61], which is why the artist has deliberately introduced numerous tricks to break the formal schemes and registers, creating "particular" prospective relationships. In order to represent the artifices introduced by the artist, not easily found with the naked eye in the pictorial representation, a substantial activity of analysis and comparison was carried out between the different perspective views elaborated on the virtual reconstruction of the scene and the high-resolution image of the opera. The following are the main steps of the comparison and analysis process carried out.

Going back to the real dimensions of an object or an environment represented on a perspective image is a widely documented problem in the architectural field [71]. The reconstruction process is only possible if hypotheses are advanced on the position of the point of view, on the angle of view and on some properties of the geometric entities that make up the scene (such as the parallelism between segments, perpendicularity between planes, dimensional relationships, position of known points, etc.).

If you have a photo, the reconstruction of the scene is simpler because the visual axis is known, and, knowing the focal length of the lens used for shooting, it is possible to uniquely determine the point of view. In this case, the 3D reconstruction takes place with automated processes through the use of cad and photogrammetric software. Therefore, thanks to algorithms understanding the scene, it is possible to obtain perspective images identical to those of the image taken.

If, on the other hand, you have a drawing or, as in the present research, a painting, for the reconstruction of the scene, it is necessary to identify special points (paragraph 4.1.1)

which are based on hypotheses. In this case, the 3D construction of the scene takes place manually with the of "camera matching" techniques [72]. Cad software for 3D modeling has "cameras" or "photographic devices" that simulate the physical effects of a real lens. For artistic representations with a central perspective, it is necessary to assume the position of the grip point and the focal length. In this case, to make the scene of the painting coincide with the image obtained from the virtual camera of the reconstructed model, it is necessary to proceed with an iterative adjustment of the grip point and the focal length. Therefore, since the method is not based on a mathematical expression, due to the manual adjustment procedure, it is not very rigorous, but resolutive.

The first step of the research was to generate an image of the scene similar to that of the painting under study from the three-dimensional model reproduced in full scale. Using a 25 mm virtual camera (identified as the most suitable for the purpose after trying different focal lengths), positioned at 2.25 m from the ground (observer height; see Figure 13a), the scene was rendered, obtaining Figure 13b.

The position of the virtual camera (2.25 m) is not random, but is obtained directly from the geometric construction; specifically, it is the measurement of the distance between the fundamental line and the horizon line.

By comparing this image with the one of the paintings (see Figure 13c), it was possible to verify whether the painter actually respected the geometric rule.

In Figure 13b, we find a certain correspondence with the architectural elements of the painting, in particular with the columns and the coffered ceiling, while various transgressions are found in the remaining elements. Compared with the virtual reproduction, we find that in the painting, the characters have a much larger physical size, the tools are much larger and the table has a different view (see Figure 13c).

Therefore, it is clear how, on the whole, the geometric rigor has failed. Surely if the painter had reconstructed the scene based only on technique, he would have obtained a less effective representation from the point of view of the Gospel message as the main subject, the banquet would have had a minor stage presence and, paradoxically, the architectural structure of the colonnade behind it would have occupied the largest space of the canvas (see Figure 13b). On the contrary, since the painter is interested in representing the supremacy of the harmonic rendering of the image over the technique, he had to necessarily rework artifices to place the figure of Christ at the center of the representation and give the right space to all the apostles, as well as to all sacrificial lamb and the utensils placed on the table. At this point, the research tried to identify which were the artifices applied by the painter in the representation.

The first artifice concerned Christ, the apostles and the tools on the table, which certainly have undergone an enlargement since, from the virtual reconstruction, they are seen smaller than those in the painting. Consequently, to verify this hypothesis, while keeping the camera settings, a new image was generated (see Figure 14a). After trying various percentages of magnification, the 150% magnification was adopted as the apostles seem to have assumed a size closer to that of the painting (see Figure 14b) even if, analyzing the result in detail, the figures in the foreground are still a little too big, while Christ and the apostles adjacent to him are still too small compared with the canvas (see Figure 14c). Unfortunately, the magnification alone does not lead to an acceptable result, so the focus has been shifted to the table.

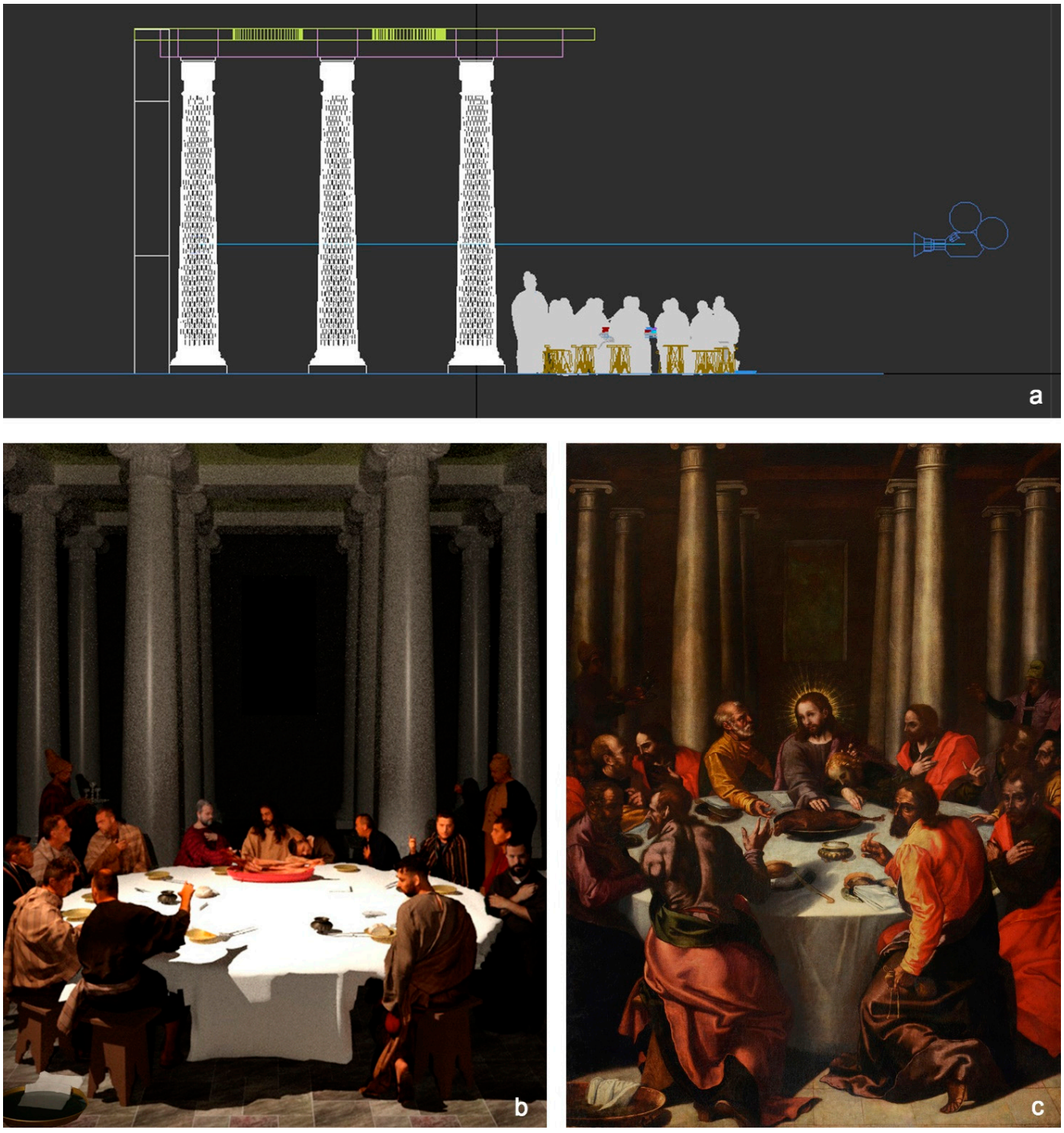


**Figure 13.** (**a**) Side view of the scene with indication of the position of the camera at 2.25 m from the ground (25 mm camera); (**b**) image taken from the reconstruction of the virtual model; (**c**) G. Hovic, Last Supper.


**Figure 14.** (**a**) Side view of the scene enlargement of the characters and position of the camera at 2.25 m from the ground (25 mm camera); (**b**) image taken from the reconstruction of the virtual model; (**c**) G. Hovic, Last Supper.

The second artifice in fact involved the table, which in the three-dimensional model is seen to be much more squashed than that of the painting. At first sight it would seem that it was designed with a much higher center of view than that used for the reconstruction of the colonnade (see Figure 14a). As a result, the previous viewpoint was raised to 6m and a 50mm camera was used (see Figure 15a). The image generated (see Figure 15b) was decidedly closer to that of the canvas (see Figure 15c) as the table took on a shape much closer to that of the canvas. In addition, the view from above slightly crushed the figure of the apostles, who consequently took on the right size.


**Figure 15.** (**a**) Side view of the scene with enlargement of the characters and position of the camera at 6 m from the ground (50 mm camera); (**b**) image taken from the reconstruction of the virtual model with enlargement of the characters and position of the camera at 6 m from the ground; (**c**) G. Hovic, Last Supper.

In conclusion, it is therefore possible to state that the painter used various devices to create the picture: two different points of view, a method widely used in the representations of time, and the enlargement at his discretion of the tools and characters depicted with the aim of emphasizing the Gospel message by placing Christ in a privileged position, at the center of the whole representation, in the role of the absolute protagonist of the scene. Figure 16a,c displays the view of the virtual model from the room only placed in the first point of view (at 2.25 m from the ground, focal of the room 25 mm) which re-proposes the representation of the columns, the floor, the figure of the host and the boy as they are presented in the canvas under study.

Figure 16b,d instead shows the view of the virtual model from the room placed in the second point of view (6 m from the ground, focal length of the room 50 mm) which reproduces the representation of the table and the apostles exactly how it is presented in Hovic's painting (Figure 17).


**Figure 16.** (**a**) Side view of the scene enlargement of the characters and position of the camera at 2.25 m from the ground (25 mm camera); (**b**) side view of the scene with enlargement of the characters and position of the camera at 6 m from the ground (50 mm camera); (**c**) G. Hovic, Last Supper.


**Figure 17.** (**a**) Overlay of image 17d on image 17c; (**b**) G. Hovic, Last Supper.

The perspective restitution has also reconstructed the opening placed on the backdrop of the scene (Figure 18) which measures 1.40 m wide by 2.70 m high and is 2 m from the floor (Figure 19).

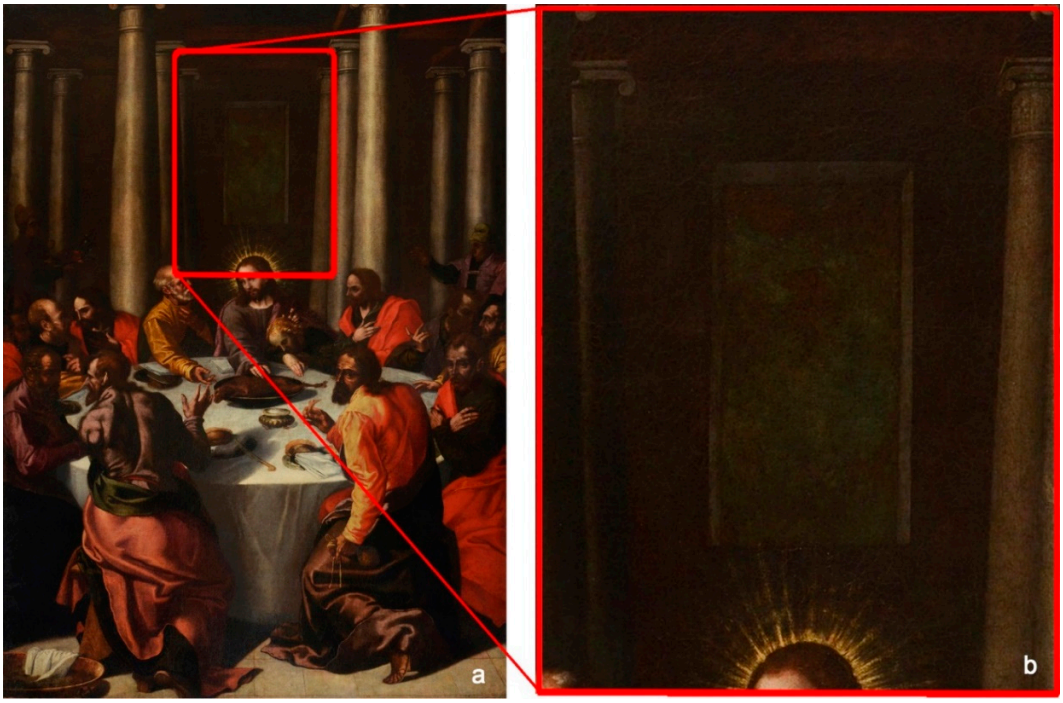


**Figure 18.** (**a**) G. Hovic, Last Supper; (**b**) particular punching.

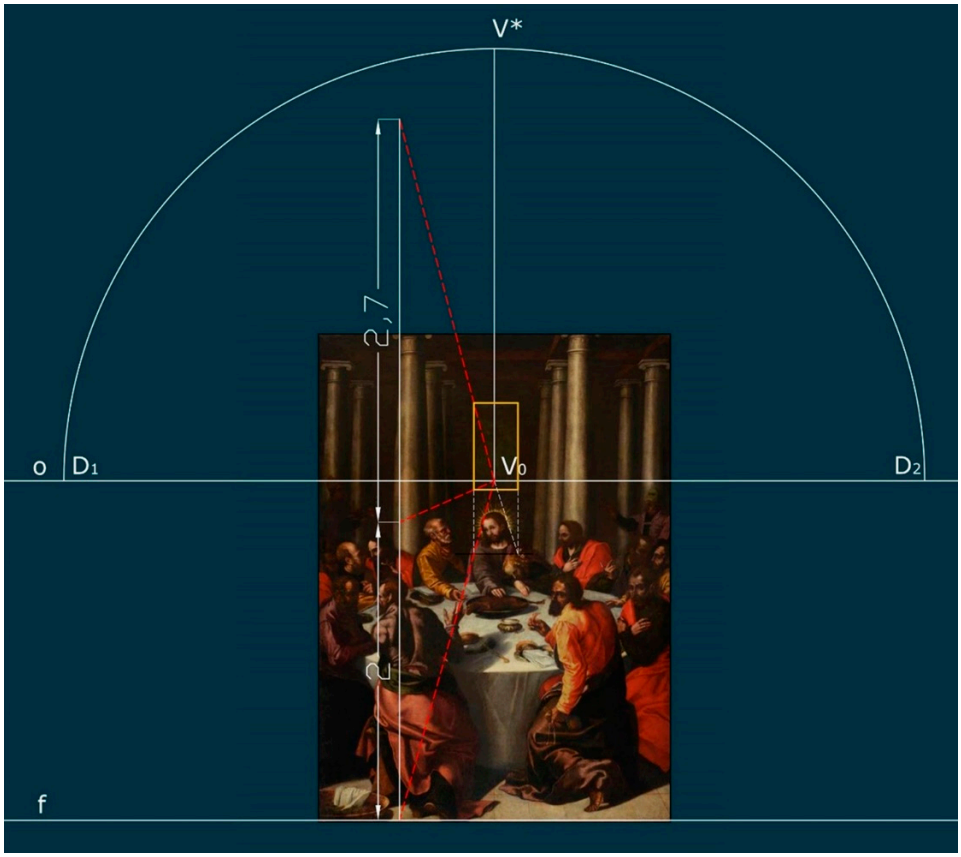


**Figure 19.** Dimensioning of the opening with the perspective restitution.

This might look like a window, but one could say that it is instead a door, reminiscent of the representation of Agresti. This opening, in fact, in the upper part, has the jambs depicted in flight towards the center of view $V_0$, while in the lower part it is truncated, without the jambs' flight lines (see Figure 18b). It is as if the steps present in the painting by Agresti (see Figure 2a) were missing, creating a second floor to depict the washing of the feet, later replaced by Hovic with the insertion of the symbol of the basin positioned in the foreground, lower left.

*The 360° Immersive Experience*

Once the lighting adjustments, necessary for the construction of the desired lighting effects represented in the painting, have been created, within the solid modeling, many virtual cameras have been created having the gaze of each individual character as their center of view (Figure 20) with the goal to develop an immersive 360° shooting (112 Mpx resolution). The objective of this operation was to implement an application, also usable via web (http://www.itc.cnr.it/ba/app/ultima_cena/, accessed on 18 June 2021), where the user, even a remote observer of the works, in a real and lively environment, was able to interact with the environment and the materialized 3D scene, in compliance with the format identified in the research process.

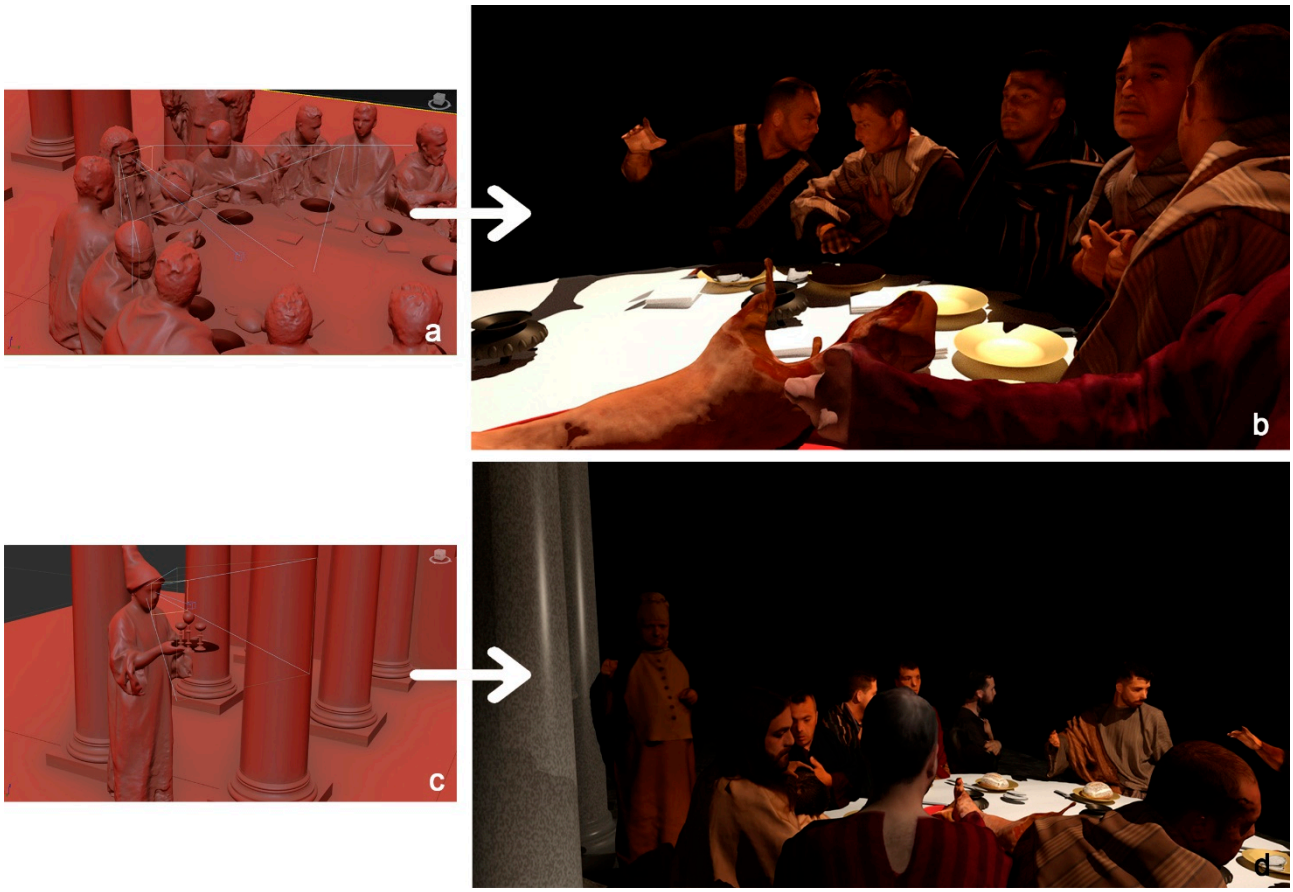


**Figure 20.** (**a**,**b**) Virtual camera positioned on Jesus and relative view; (**c**,**d**) virtual room positioned on the servant and relative view.

For this technological choice, it was preferred to develop an environment combining the virtual world (materialized canvas) with the real world (observer), capable of providing a simple and innovative service in terms of 3D observer–environment interactivity. The challenge was to create an interactive approach that was not pushed, but one that was able to arouse emotions and immediately transfer the artist's message. This involved

a very careful study of the message and the design of an interface strongly related to user experience (UX—User Experience) and interaction [73,74].

A Virtual Tour (VT) was thus created (Figure 21), where the user can immerse and position himself inside the scene, imagining himself in the place of Matthew, Peter, Jesus (see Figure 20a,b), servant (see Figure 20c,d), etc. or even of the host who gives orders, generating in the viewer the feeling of "being there".

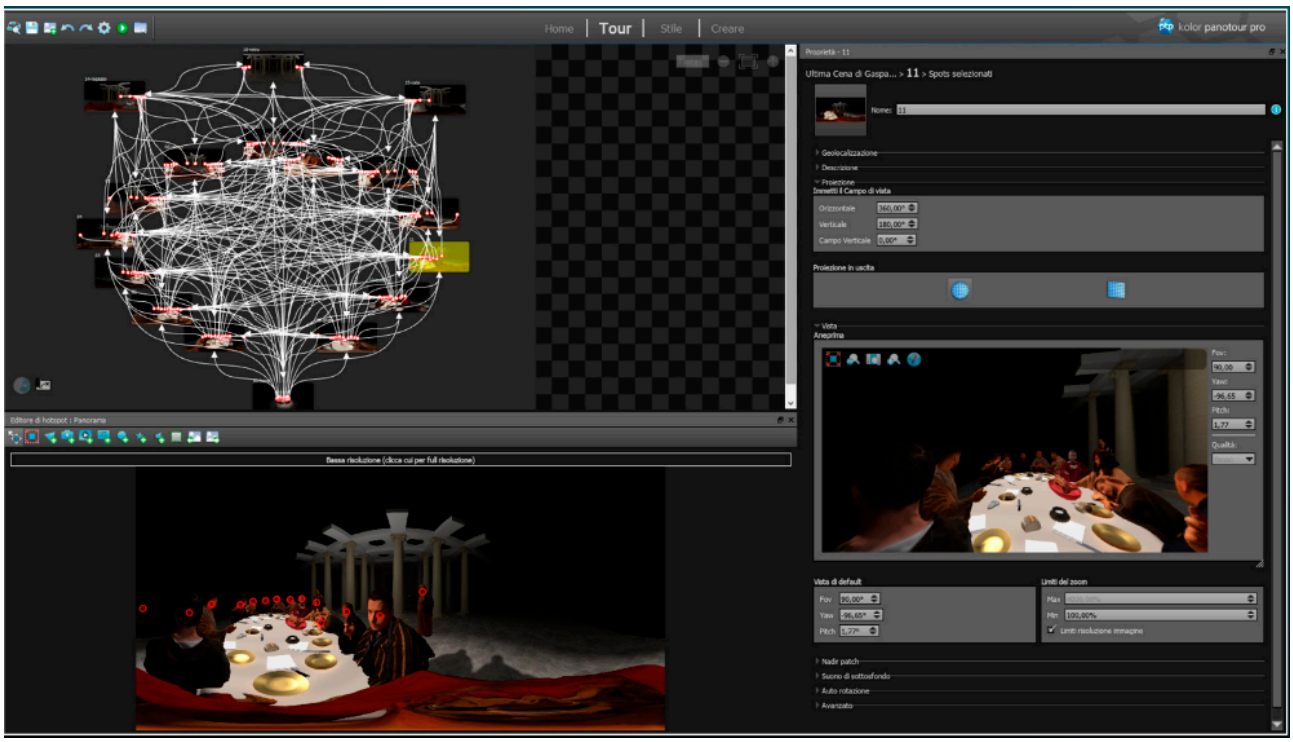


**Figure 21.** Creation of the Virtual Tour.

The design of the VT did not focus on the scenic effects of the virtual space or on the forms of interaction (gesture), but on high resolution images of the reconstructed scene, enlarging various parts of the work and respecting the artist's perspective games, showing the observer all those aspects that would probably have escaped non-expert viewers of art history.

The solution was to insert "connected" hotspots in the immersive photography; that is, areas associated with the information they wanted to represent and enhance (artifices), presenting them to the user in a uniform, coherent and natural way. The textual indications on the content and its meaning have been reduced to a minimum, to avoid events as a source of involuntary distractions. This visual experience, reachable from any device, takes on greater depth and sensation in the VR (Virtual Reality) mode through the stereoscopic use of the VR viewer, where the use of the gyroscope comes into play and offers the user the feeling of being inside the work (telepresence), taking advantage of the freedom to orient oneself in all directions and thus making the VT interface a UX that creates an engaging visual experience. This creates a path in which the viewer "enters" the canvas with his eyes and receives simple stimuli that can facilitate and not divert his understanding from the evocative charm of the reproduced environment (Figure 22).


**Figure 22.** Seen through the stereoscopic use of the VR viewer.

## 6. Conclusions

The research project mainly addressed issues and problems related to fundamental elements such as the representation and perception of pictorial works, but also reproducibility, virtuality and usability in digital art processes. The goal of the research achieved was to go beyond the concept of virtual, not limiting itself to the sole treatment of environments recreated in 3D, but elaborating a virtuous process of cultural enjoyment of unknown goods and works and aiming at building a new relationship between user and process, based on a new perception of objects in the painting [75].

The perspective restitution operations highlighted the choices made by Hovic in the representation of the narrated event and the numerous artifices introduced by the artist to meet the narrative needs. The results of the geometric analysis are a good starting point for further investigations that may be conducted on the painting technique adopted by the artist. They provide important interpretative hypotheses for some parts of the painting, which today appear considerably faded and evanescent due to the ongoing deterioration process (rear part of the colonnade), compared with the marked visibility of the other parts. The 3D model obtained can be used for the construction of an artefact that can also be explored with the use of touch, thanks to the use of 3D printing or the creation of perspective tables with sculptural low reliefs for the use of the painted space by blind users [76].

The purpose for future research will be to study and understand how to increase the perceived level of realism and "telepresence" during the remote observation of real places, through VR 360° viewers, with the aim of producing useful guidelines for designers of VR systems to optimize the viewer-camera configuration [77].

The sense of presence will be measured with a questionnaire accessible via web and the questions will be articulated on a study conducted by Slater et al. [78,79] on the sense of presence.

If the web audience has the sensation of "being in a real place", they will be highly focused on the "place". It has also been shown that this type of experience increases the enjoyment and involvement of the observer, to the point of stimulating the intention to undertake a journey towards the real place, or to a real tourist destination. A highly

involved and satisfied audience feels at ease in that environment and is strongly attracted to that place. A low telepresence 360° VR interface otherwise discourages audience involvement and is believed to be the main cause of dissatisfaction [20].

Therefore, the next goal of the research, which we intend to pursue, is to study the attitude and behavior of people towards VR 360° technology and affective-motivational states in a virtual tour experience, through detection mechanisms. and monitoring (questionnaires, web consents, etc.) of user feedback and their satisfaction, which would influence people's intention to visit a tourist destination [2,80,81].

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