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Andrea Mantegna's Wedding Chamber:
An Early Renaissance Immersive Masterpiece Rendered as a Modern Extended-Reality Installation

Andres Montenegro, Purdue University, Fort Wayne, USA*
https://orcid.org/0000-0003-1559-2953

Audrey Ushenko, Purdue University, Fort Wayne, USA

ABSTRACT

The Wedding Chamber fresco, also known as Camera Picta, or La Camera Degli Sposi, painted by Andrea Mantegna at the dawn of the Renaissance, epitomizes the most outstanding expression of personal creativity and innovation from an artist that transformed the boundaries of representation and narrative inside the architectural space, to mix illusion and reality. He utilized the trompe l'oeil effect, the Oculus, and cinematic painted imaging on the walls, to reveal a world of fictional and symbolic situations combined with classical mythology. However, Andrea Mantegna playfully organized these compositional components, inaugurating a proto-technological system of visualization that transforms the viewer's perception in an immersive experience that goes beyond the mere effect of illusion. The research and the development of the installation described and explained with deconstruction of what Mantegna expressed masterfully at the end of the 15th century in the Saint Giorgio Castle in Mantua, Italy.

KEYWORDS

Cinematic, Haptics, Headset, Image Target, Immersive Environment, Latency, Presence, Real Time, Teleporting, Trompe L'oeil, Virtual Reality

INTRODUCTION

The pictorial and virtual simulation of Andrea Mantegna's fresco, *Wedding Chamber,* through an extended reality environment installation, is a project that has had almost five years of development. The constant observation of the device's manipulation by users, the responses obtained from its computing processes, the efficient access and usability of the head-up displays within headsets, and the body's performance as phenomenological mediation between the hardware and the software architecture of the immersive computer program world, are in a study process to obtain significant conclusions about how an immersive interactive installation must be implemented utilizing emerging

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technologies for visualization in manners that do not transfer to mass media spectacle, remaining just a curiosity novelty without getting feedback from peers, concerning cultural and academic scrutiny. This article explains the practical implementation of an experience tied to an immersive installation which is essentially incorporating all the required building blocks that emerging technologies possesses, to develop an immersive artwork through presence, i.e., the ability of a user to feel that they are in a virtual location.

The fundamental goal of this installation was to study the illusionistic space used by Andrea Mantegna in the real fresco located in Mantua, Italy. This reenactment has been achieved by an installation based on a collapsible and portable banners display, keeping the virtual space coordinates and measures, in terms of immersion, following the original room layout of Saint Giorgio Castle in Mantua, Italy. This immersive environment renders a conceptual development of the original fresco painted with mixed traditional media on its walls and ceiling. This interpretation of the real fresco maintains its compositional structure through outlines and color deconstruction, just keeping the factual depiction of the Oculus in the ceiling as a full reproduction of the original piece.

The installation originated in the fascination that early renaissance aesthetic paradigms have enticed in modern art. This fascination at first comes from an intuitive approach, and perhaps the more the subject is learned, the more attentiveness it generates. *Wedding Chamber* is one of the fundamental and seminal works of art created in Italy in the late 15th century, and it is essentially conceived as a byproduct of patronage, an institution well established at that time. However, *Wedding Chamber,* from the perspective of modern art, becomes a *rara avis* due to its exceptional atemporal narrative (Katz, 2008).

In a time when artists had to deal with religious and metaphysical narratives, this fresco masterpiece renders the indulgent and quasi-narcissistic accounts of the Gonzaga family on the walls of one of the Saint Giorgio Castle rooms. The dimensions of the room have a rather modest status compared with other halls and domes built and painted during the latest renaissance period. The fresco employs several artistic devices that render illusionistic exercises within the boundaries of a room. Among them, the *grisaille*, which articulates the illusion of masonry expansion conveyed through intricated decorative patterns that forebear the modern normal maps and spectral renderings in Computer Generated Images (Callet, 2013), the Oculus rendered in its vaulted ceiling, that inaugurates henceforth a standard construction featured in interior architecture during the Renaissance, that reached apotheosis and bombastic levels of mannerism during the 16th and 17th centuries in public and royal buildings, and the proto cinematic narrative, that articulates a timeline chronicle, but with evident diegetic efforts to transform the story in an immersive explorative engagement, are unfolded in each painted wall.

Therefore, the fascination with this whole piece of art remains the first phase of ingress inside its symbolic architectural world. Once its recreation starts using new media, the documentation process provides paths of development that establish the classification of each narrative episode, carrying out a journey that goes well back to the ancient Roman classic culture, spanning its whole confines. This trend meant the recovery and transportation of Humanism (Furlotti & Rebecchinni, 2008) as an ultimate consequence of the time in which Mantegna executed the fresco at the dawn of the Renaissance. The construction of this installation project based on *Wedding Chamber* proposes two ultimate purposes, the deconstruction of a humanistic narrative and the use of this narrative to access phenomenological knowledge (Lankford, 1984) through the study of audience usability.

THE XR IMMERSIVE INSTALLATION VISUAL INTERFACE OUTCOMES

Emerging technologies have become the critical catalyst for a new generation of experiences in different fields, from the scholarly and academic realms to the mass consumption of visual narratives adapted for wider audiences to learn about art, culture, and history. Those visual narratives could be part of the family of motion pictures, video games, documentaries, animated simulations, or infographics. The

catalyst denomination refers to the status of emerging technologies as consistent and effective agent creators of scenarios where cultural changes take place (Napoli, 2011). Since the digital revolution was initiated by the introduction of personal computers and the Internet, society wonders about how many waves of changes are still to come in modern culture. However, there was another revolution evolving at a much slower pace. Running from the pioneering experiences of filmmakers and computer scientists by the mid-1950s (Morton Heilig's *Sensorama*), going through the 1960s and 1970s, e.g., Ivan Sutherland's *Ultimate Display*, and Myron Krueger's *Videoplace* (1977), until the mid-1980s, when the concept of virtual reality was finally christened by Jaron Lanier and Thomas Zimmerman. Throughout almost six decades, the evolution of the emerging technologies archetype has been a constant breakthrough (Napoli, 2011).

Today, despite the time passed, virtual reality, augmented reality, and mixed reality are still considered emerging technologies, and their novelties capture the interest of an ever-growing audience that is willing to learn more about their benefits and contributions to cultural progress. In this sense, of the contribution to cultural progress and the improvement of critical components of society, these emerging technologies are displaying an overarch of possibilities that still are debatable in terms of functionality or viability by today's cultural commentators. However, the most we learn about how this gradual revolution has taken place, the better we understand that its prominence will not remain ephemeral. In fact, the emerging technologies revolution related to imaging and visualization has factually been present in our cultures throughout centuries and, to some degree, in prehistorical proto-developments (Grau, 2004).

From Lascaux and Pompeii to Giotto's Arena Chapel and Renaissance frescoes ending with the panoramic paintings of the nineteenth century (Roubaud's *Borodino Battle*), all indicate the eagerness and masterful efforts of artists to render an immersive narrative that involves the physical space as a requirement to experiment a walk-in journey through imaging renderings. Recent events promoted by museums and high-tech companies launched immersive visual experiences that recalled the work of Van Gogh and Monet as spectacles of sensing their masterpieces as contemplative multimedia projections. Apparently, these novel events housed in museums and galleries have two purposes, the introduction of emerging technologies to widespread in the art world a trend of development to potentially be embraced by artists (Soccini & Marras, 2021), and the reinvention of museums to generate an even stronger outreach by transforming universal masterpieces in cinematic experiences (Mateer, 2017).

The Internet promised the dissemination of art and culture by offering access to vast audiences using a virtual modality of museums and exhibits. Also, online galleries adopted a common trend to promote online exhibitions as a quick response to the recent pandemic disruption that has affected the whole wide world. However, the Internet, as a virtual showcase, is still limited by mobile imaging. Obviously, it is no longer a novelty; the fact that you can get access to the Louvre Museum via a virtual walk, a gazing action in 360 degrees, or by experiencing masterpieces visualization using smartphones inserted in low-cost headsets.

However, the virtual reality apparent dimension of spectacle requires a very important component to establish a common cunning experience, the configuration of presence, to absorb and grasp the immersive precincts of a painting, sculpture, or installation (Jacucci et al., 2009). It does not mean that presence is unlikely to be experienced through the Internet. In fact, systems and capabilities of remote immersion have been in the works for more than two decades, and a downside to tethering a headset system to a computer to visit a museum is no longer a technical barrier. The problem is the meaningful dimensions of presence and space required to fully explore through your body mediation. The situation is being presented as a playable immersive masterpiece.

There is a distinct situation happening when a viewer experiences an artwork in a place, and it is the phenomenological reduction of what the spectator finds in that simulated place, which is the playable aesthetic context of the art object. For that reason, the implementation of a remote virtual

masterpiece requires a physical location to recreate the phenomenological space to finally construct the required amount of presence that viewers and users will expect to perform (Coelho et al., 2006).

It is compulsory to notice why immersive emerging technologies such as virtual reality, augmented reality, and mixed reality are so involved with aesthetics and how their imaging deficiencies have been resolved by basically dispelling some devices glitches that were in constant testing for years (e.g., motion sickness and disorientation; Cummings & Bailenson, 2016). Today it is possible to develop an installation with the embedded notion of presence but also incorporate other associated phenomena like haptics, locomotion, and interaction gestures, to make the phenomenological reduction of an event an *epoché* momentum, i.e., bracketing or suspension of judgment (term used in aesthetic and philosophy).

The essential technological approach to a masterpiece like the one Andrea Mantegna conceived at the time of its patronage commission (1465–1474) is a monumental endeavor due to the immense systems of meanings embedded in the walls and ceiling of the room where the fresco is located, in Saint Giorgio Castle, Mantua. The methodological approach to understanding Mantegna's intentions must follow its historical context at first. However, its main virtue is the exceptional and outstanding status of atemporality to render basically an allegorical narrative about a ruler's family life, based on existents or attributed virtues. The ideal representation of the Gonzaga family's "good government" exposes ceremonial and solemn renditions of the Gonzaga family, and its court in the fresco's walls, as a sequence of events registered by a somewhat proto-cinematic camera (Mateer, 2017).

However, the complex systems of ornaments and allegorical depictions based on classic mythology transliterated in the fresco might respond to Mantegna's intention to construct or articulate a whole world of humanistic overtones. In that dimension, *Wedding Chamber* is like a tribute to the eidetic representation of the Lucian of Samosata's *The Dome* written in the second century AD (Montenegro & Ushenko, 2021). *The Dome* unfolds through *ekphrasis*, the depiction of an ideal architectural environment where reflections about symbolical objects achieve rigorous dimensions of essential reductions based on classical antiquity worldly events. We wonder if Andrea Mantegna followed Samosata's method to intentionally echoed *The Dome* in *The Camera Picta*, or perhaps, was a personal

Figure 1. Immersive XR installation display

Figure 2. Navigation system interface

creative exercise of reducing the Gonzaga family's every virtue, rendered through the solemnity of an ideal world. Then, the fresco's elements, the ornamental ones, and the personalities become a visual collection of events.

In the immersive virtual installation, the fresco's original narrative account extrapolates situations that hypothetically could have happened; however, this extrapolation has a more formal way of working towards the compositional aspect of the figure's personality. Each character or personality occupies a designated place on the fresco's walls. Each wall distributes scenes that offer an account that stages a critical moment in the Gonzaga family's life. Mantegna utilizes the walls as camera views to emphasize the officious moments the characters perform. The fresco's visual interface can be organized in the following selection of compositional events:

Figure 3. Interactive access to scenes

SEEING FORESHORTENED CHARACTERS FROM SUCCESSIVE POINTS OF VIEW

The modality of interacting with the characters, to enable an extrapolated attitude in front of the virtual camera that the users drive in the VR headset, is to grab from the walls a specific character that can be manipulated with the hand controller. The action is like pulling out the character from the flat wall then it becomes volumetric. The action of seeing the character foreshortened is an action that the headset of the virtual camera allows. Since the grabbed object remains in hand, the foreshortening angle is applied in real time. This can be executed by grabbing a 3D character model version or by triggering the 2D drawing version of it. The user can then activate the character with the hand controller while exploring the 3D model.

THE FIGURES OF THE IMMERSIVE FRESCO IN MOTION

The presence of motion is determined by extrapolating the still figures in the fresco to an eventual action rendered as a possible animated outcome. What is going to be the next action that Ludovico Gonzaga performs once he receives the letter from the Duke of Milan? Is he going to stand up with a concerned gesture, or is he going to adopt a conventional stance lacking any emotion? These actions can be rendered by animating the 3D character version of Ludovico. A technical aspect that has not been resolved yet in the world of modeling and animation is the exact likeness of what you see in the original fresco by scanning the 2D picture to 3D and what is possible to construct in the 3D model version of it. At this moment, the most plausible method to produce the likeness of the 3D model is by executing topological modeling of Ludovico's head, then apply on it the UV mapping obtained from different face renditions from the fresco or portraits of him. In this stage, the photographic documentation of Ludovico's face is mapped and wrapped into the model's topology. The same modeling and mapping approach applies to each character of the fresco's scenes.

INTERACTIONS WITHIN THE ILLUSIONISTIC SPACE

The architectural environment inside the room is determined by the vaulted ceiling. The ornamentation in the ceiling displays a chief masterpiece of illusionistic effects, determining the expansion of the ceiling boundaries. In such a display of trompe l'oeil virtuosity, there is a purpose, which is the

Figure 4. Characters in different stances and positions

Figure 5. Animations of characters

symbolical rendering of the monumental solemnity of Rome's past glory. How can these components of the illusionistic painting technique be transferred to computer graphics? Using normal mapping or displacement maps. In the installation, a section of the balcony ledge in the Oculus opening has been developed to understand the possible conjunction of illusionistic depth and 3D model volumetric extension (Montenegro & Ushenko, 2021). *Wedding Chamber* contains a lesson on painted ornamentation. However, its main layout can be extracted using a stylization of the vaulting structure. The scene of the letter and the court chorus of characters are rendered in a rather dioramic scheme, utilizing the walls' boundaries and the limits where the vaulted ceiling is built. The court characters present a rather hieratic disposition, but they are acting with loftiness inside this space. A study of the depth of this wall scene will expand the scene in a depth-of-field modality.

THE ILLUSIONISTIC EXTENSION AND ENHANCEMENT OF THE REAL ARCHITECTURAL SPACE

This specific segment of study basically is focused on the most complex area of the fresco: The ceiling. In the VR installation, the computer models render the naked surface of the ceiling to understand how Andrea Mantegna conceived the vaulted ornamentation and the space surrounding the medallions that render the Roman emperors' effigies. In this study, the most outstanding component is the extraction of the illusionistic space. The complexity of this masterpiece exposes two challenges for the modern methods of laser scanning. Is laser scanning using cloud points likely to capture the bumping map of the ceiling? Or is it going to just scan the bare vaulted ceiling with just a flattened texture map? The installation develops structural sections where the ornamental patterns traverse the ceiling using interlaced patterns as a painted work. There is a challenge in the fact that computer models eventually recreate such a work. In the installation, the painted works were translated to modeled surfaces.

STAGES IN CONSTRUCTION LAYERS

The installation development has expanded in depth the different scenes represented in each wall section. An example is the scene in which Ludovico is receiving his son as a cardinal. There is a staging situation, in which the characters are not necessarily posing from reality. They have a symbolic placement. Such is the case of the Emperor Friedrich III of Habsburg and Christian I of Oldenburg,

Figure 6. Mapping coordinates of the vaulted ceiling

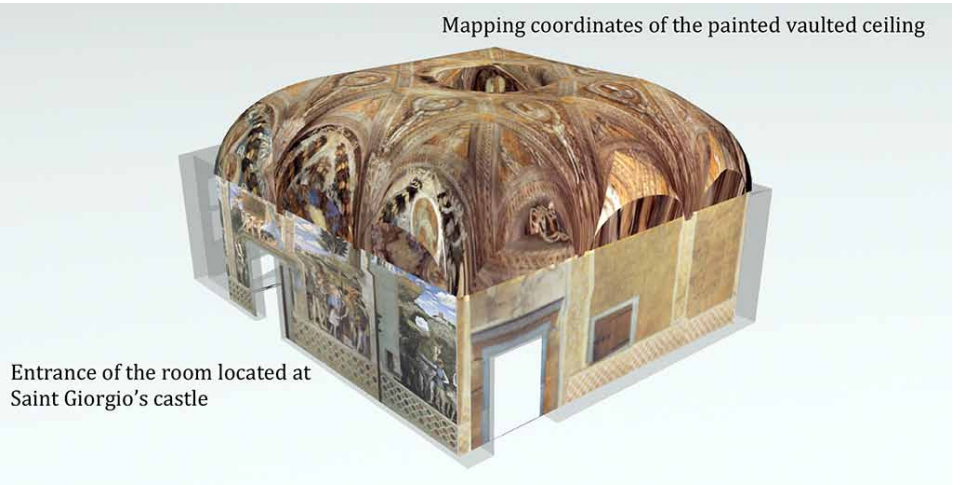


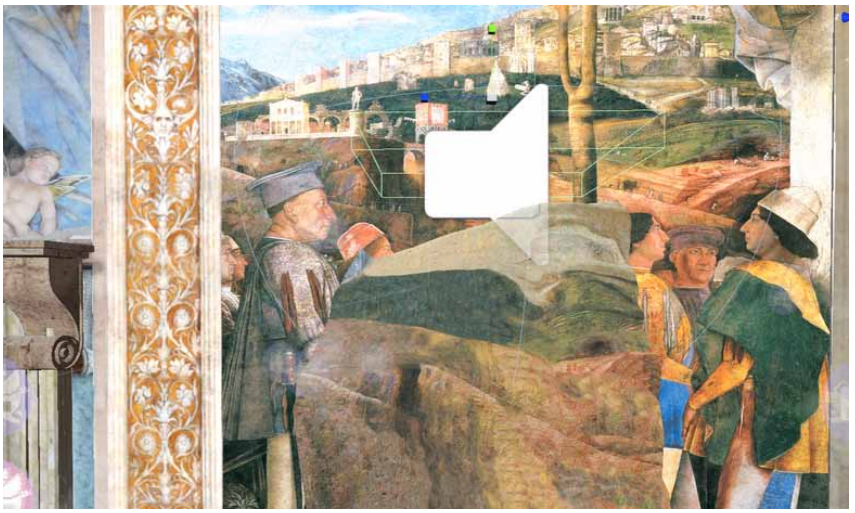
Figure 7. The simulated room version of Wedding Chamber

King of Denmark. They are not actually in the scene as a real fact; it is just a fictional presence to enhance both Ludovico Gonzaga's and Francesco Gonzaga's investiture. However, the solemn and hieratical placement of the characters has a background landscape that does not necessarily render depth in a naturalistic manner.

This structure can be dissected utilizing planes. The first plane, in which the character placement exposes a kind of cinematic plane, and then comes the background that is divided into two planes, one that structures a fictional topography and the plane behind the transition to a walled city. Perhaps to some extent unnecessary to reconstruct, the topography and the city present an interesting fictional rendition of Rome. Mantegna, at the time of the fresco's creation, did not travel to or has been in Rome at all. Despite the close distances of travel for modern standards inside Italy, this panel in the fresco exposes the worldly status of Mantua as a city-state, and how the world of Mantegna remained

Figure 8. Detail of the meeting panel

Figure 9. Models of the fictional landscape



within its boundaries. In the meeting, there is a compositional structure that divides the depth of field into layers. The other panels represent more fictional landscapes but with real locations. The fictional topography exposes a symbolic representation of real places.

THE ARTISTIC OUTCOMES OF THE INSTALLATION

One of the installation's essential components is how it extracts the fresco's information from the working standpoint of an artist. Visual artists recognize processes that are familiar to their skills when they observe an artwork. These processes are related to color and space. The first question is about how the Fresco technique is executed; how its process involves the traditional and systematic

use of materials. One of the very effective features of an immersive installation is to describe to the viewer how the physical painted layers emerge. In the original place of the fresco, viewers and visitors can remain in the room for just five minutes. That time is insufficient to observe with detention the pigments application, the brush strokes, and the way the stucco is receiving the pigments. The next items explain how these features are available for visualization in the immersive installation.

EXPERIENCING THE FRESCO'S COLOR DECONSTRUCTION

In the VR installation version of the room, the users can point a ray cast from the controllers to the wall's scenes. They can point out to the center of the wall, then a deconstruction of layers establishes the possible way Mantegna initiated the layout of the pigments over the stucco. However, this action included in the installation, represents mostly speculative knowledge and therefore is in conjunction with the way scholars have already documented. In this case, the speculative disposition of the color layers can change in alternate order. At this point, the exact account of how Mantegna proceeded with the color works is in the process of research. The user anyway can display the animated layout of color layers in cascade mode, with the first component to appear being the fresco's tracing outlines. In the installation, the deconstruction of color criteria is based on the direct observation of the chromatic and physical, structural composition (Lin et al., 2019). The first action is to identify the color range of blues, then the range of reds, then the color range of greens, and finally, the color range of shadows. This basic scheme is in RGB plus K (i.e., black, and gray tones). The next action was to identify the shading values of each color range.

ARCHITECTURE, TOPOGRAPHICAL SPACE, AND SYMBOLS TRANSFORMED INTO 3D MODELS

The immersive installation components must deal with the modality of translating the illusionistic presence of symbols and ornamentations. In the fresco's panels, some of the elements rendered are naturalistic, like the almost naïve fictional topography containing natural elements like trees, mountains, caves, and cliffs. Those are sprinkled with architectural landmarks like castles and towers in a classical roman and early renaissance mix. There is a rendition of the Acropolis of Palestrina, the Valley of Aniene, the castle in the Rocca Pia, and the natural arch in the Mount Lessini at Verona.

Figure 10. Fresco outline deconstruction

Figure 11. Color layers deconstruction

Figure 12. Color layers blended

The backdrop of the meeting in its upper section represents Rome, and it is depicted as an almost mythical city according to Mantegna's imaginative arrangement. Some of the components are the Pyramid of Gaio Cestio, the Aurelian Wall, and the Coliseum. In the installation's VR world, the components rendered in 3D are *The Temple of the Primeval Fortune, The Natural Arch*, and *The Castle of The Rocca Pia* (Signorini, 2007).

INCREASING UNDERSTANDING OF THE ORIGINAL FRESCO'S LAYOUT

The original fresco is perhaps intended to capture the viewer's erudite interest. However, without the academic accounts from researchers and scholars, a superficial observation of the fresco's layout composition offers little clues about how to identify its formal and rich narrative. The viewers must become immersed in a world of references and ideas that Andrea Mantegna articulates like an artistic and architectural journey inside the fresco's panels, as the frames of a camera introduce a story. It is an invitation to perform an immersive, imaginative journey inside a world full of erudition. On top of

Figure 13. Immersive XR installation display

Figure 14. Immersive XR installation display

that, the structural fresco's layout represents a formal framework to display symbols, emblems, and seals. In the walls, it is evident the precinematic views that act like orthographic cameras, rendering the lifesize figures like being inside a diorama arrangement. In the wall that renders the scene of the letter story and the court display, it is quite clear that Mantegna's intention was to frame a panoramic view of a situational episode like the plane of a panoramic scene. He uses the surface of the whole wall containing small receding and protruding areas, and those maintain the illusionistic focus of the scene.

The layout of the sequential episodic narrative is presented in a horizontal reading. Then, once the attention is diverted toward the upper border of the scenes, the layout changes to the appearance of the lunettes, that display seals and symbols, the deer, the great Dane, the tower, the Hydra, the sun, the rock, the bird (*Tortora*), the tree trunk, and the wings. Over the symbol's lunettes, the layout changes to the ogival arches containing the narrative of the myths of Orpheum, Ariadne, Hercules, and the Hydra. These little scenes are difficult to appreciate with a closer gaze due to their disposition in the

Figure 15. Interactive ray-cast to grab 3D objects

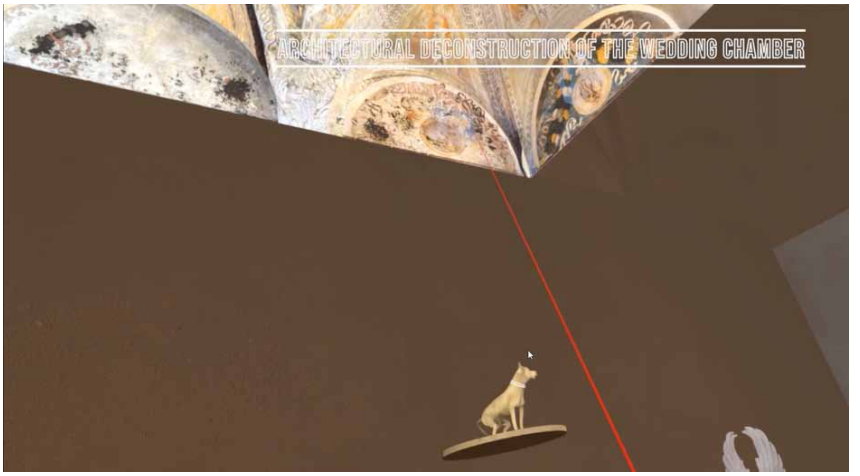


Figure 16. 3D deconstructed ceiling medallions

ceiling bottom layout. Then in the flattened section of the ceiling, the Ceasar's medallions designed with amazing grisaille details display the Roman Emperors, Octaviano, Julius Cesar, Tiberius, Caius Germanicus (Caligula), Claudio, Nerone, Galba, and Otho (Otone).

The medallions surround the Oculus that occupies a prominent section of the whole painted ceiling. The Oculus obliges the viewers to gaze upward to observe the characters looking down in a quite natural and less solemn attitude, accompanied by *putti* peeking out through the Oculus intricated baluster balcony. In fact, the viewer must exercise and accomplish a body performance to follow the ceiling fresco layout from below, which technically would be an action consistent with six degrees of freedom. In the VR installation, in the simulated physical area of playing, the viewer can experience the real coordinates and dimensions of the fresco. This is an essential condition to configure the required presence that the viewer's body would experiment.

THE TECHNOLOGICAL OUTCOMES OF THE INSTALLATION

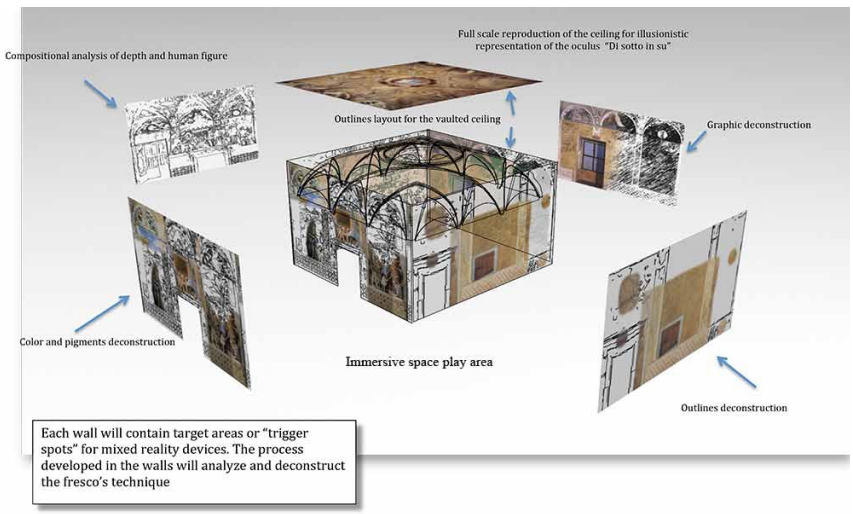
To develop the VR installation space, a visit to the fresco in situ was required to obtain the construction coordinates. At the location, we were able to stay in the room for more than five minutes on our first visit. We obtained later permission to stay within the room without sharing the time with the public during the next two visits. At that time, measurement took place, the assessment of the historical construction dimensions, and later additions to the original reshaped windows were acknowledged. A photographic panoramic sequence was taken to make a photo stitching of the room's walls. The ceiling was photographed from below to obtain a wide frame shot as well. This step was very important due to the relevance of the ceiling artwork and the Oculus's rich detail. In that moment, the use of laser scanning was not an option due to the phase of budget for the exploratory study. The visit to Saint Giorgio Castle was supported by a travel grant from Indiana University and Purdue University.

The laser scanner option, perhaps powerful and practical due to the capture of the room's features through cloud points, in the end, was deemed unnecessary due to the focus of the study. The focus of the study was the room location where the fresco stands, and for laser scanning, we consider that a more helpful resource for the capture of large buildings layouts. In the case of *Wedding Chamber*, we needed just the adjacent architectural surroundings like the main access entrance and exit. In fact, the fresco's room has just two public entryways and an exit door. Once the basal information was obtained, the room's layout measurement and the immediate process of the 3D room modeling, the first stage of development of the VR immersive installation began.

TRANSLATING THE SPATIAL COORDINATES OF THE FRESCO TO 3D MODELS

The manipulation of the spatial coordinates of the fresco's room was relatively an easy task; however, a relatively small room, it contains significant elements to consider. In the walls of the court scene, a receding window provides natural lighting, but that space also is painted with additional motives. The room's entrance contains a threshold structure protruding from the wall, and the same feature is present in the exit door as well. Those details were essential to translate the space simulation in those sections of the walls. The physical room is 8.1 × 8.1 m (26 × 26 in.) and 3.9 m in height (13 ft.). In the modeling process, those measures are critical to simulate the vivid, immersive presence in the XR model version. In computer graphics, scale modeling is important due to the simulation

Figure 17. Immersive XR layout deconstruction in interactive panels



nature of the software used to build the 3D room. It is so important to keep the original measures due to the game engine interpretation. The software used to model the room was Autodesk Maya, the game engine program to implement the immersive space was Unity, and the platform to process the VR environment settings and actions was VRTK (Virtual Reality Tool Kit). The simulation of the immersive space requires real measurements to properly apply physics, expressed in gravity, rigid body status of objects, and the simulation of real-world collision events.

CONFIGURING THE ANIMATION OF THE ELEMENTS PRESENT IN THE FRESCO

Animation was an important component to develop in the VR immersive room. The extraction of the ornaments as 3D objects provides a critical variable of simulation. Modeling could have been implemented through laser scanning to capture the protruding elements present in the walls, like the shield shape insignias below the lunettes. However, the ornamented cups and symbols are vividly painted as grisaille. i.e., gray monochrome painting motives that imitate sculpture or protruding surfaces. Laser scanning, in the end, renders those details as normal maps belonging to the original surface but not detached from the captured geometry.

The task instead was to model those ornamental elements, existent as real objects, painted using grisaille, as 3D polygonal meshes converted into virtual entities (Thibault et al., 2019). It was necessary to model them with even topology to properly reduce polygon count and to develop animated rotation. The animation is known as turntable animation, to observe the rendition of the object's physical presence. Another animated process included was the subtle animation in idling mode of some of the characters present in the scenes. This feature was developed to render Friedrich III of Hapsburg, Ludovico, Francesco, Segismondo, Barbara, and Federico Gonzaga in real time. Also, the scene of the letter delivery was reenacted with realistic animation. Components like the Oculus cylindrical balcony, and the ogival arches where the myth narratives occur, were animated as well.

A VERSATILE, INEXPENSIVE, AND EXPEDITED ACCESS TO VISUALIZATION

The physical installation was conceived to recreate a play area parameter. The Virtual Reality devices and systems implemented in the installation require two conditions for use: the stationary play area and the traced play area. The physical installation includes the banners set for a traced play area. The

Figure 18. 3D interactive object pulled out from the panels

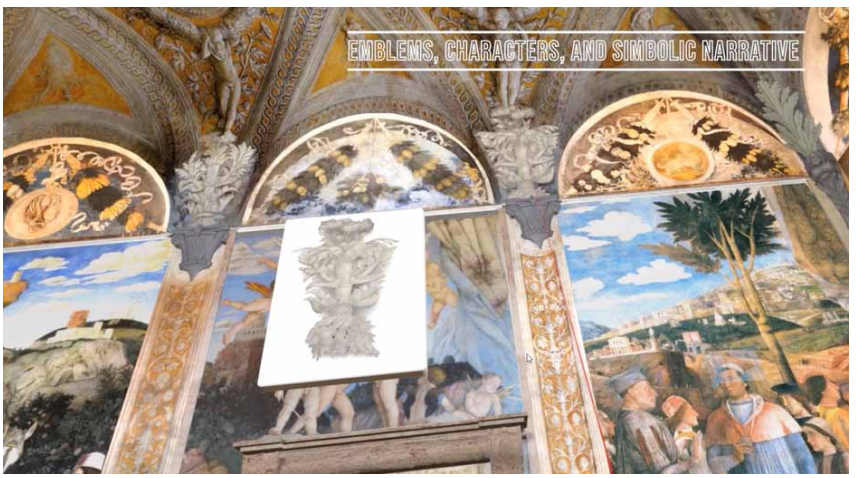


Figure 19. Friedrich III and Federico Gonzaga animations

users can walk inside the physical/virtual enclosure, and when they trespass to its limits, the headset video signal stops and shows the surrounding area through video. In such a case, the play area can be expanded to provide more room for interaction and navigation via extended reality.

The VR systems implemented included the HTC VIVE Pro, Oculus Quest 2, and HTC VIVE Plus. For the HTC VIVE Pro, the settings establish a play area set by two sensors commonly known as lighthouses. Those sensors keep the play area fully active. Then the immersive action deploys an efficient navigation or walkable zone within the two sensors' range. Oculus Quest 2 has built-in sensors and tracking cameras (Turner et al., 2016) in the headset and works as either a tethered or wireless device as well. In the Oculus Quest 2, a playable area is required, and the tracing of the play area can be executed wearing the headset. The HTC VIVE Plus headset implements the same technology developed by the Oculus Quest 2, and it is an alternative to develop a different platform setting for other preferences.

ORGANIZING THE LAYOUT

The original Oculus component in the fresco is a fascinating subject. The Oculus can be deemed as a proto-technological device to render visual imaging from below. This technique was widely used through the Renaissance and later periods as a mostly decorative standard illusionistic component. This technique is known as *di sotto in su* ("seen from below"). The illusion in the real Oculus works like an open window to show the blue sky and depict an anecdotical fictional situation where symbols interact with characters. The mastery of an almost perfect orthographic top view works is interlaced with the decorative elements of its balcony. The foreshortening of the putti standing on the balcony ledge is an art lesson to follow.

In the VR immersive room, the Oculus components render 3d models in a virtual opening displaying a simulated perspective. The fascinating aspect of a virtual simulation is its effectiveness in placing 3D models to produce instant foreshortening. The VR immersive installation produces that feature also to develop a sense of presence (Hruby et al., 2018). The physical installation includes an interpretative graphic development of the Oculus that basically implements augmentation. This is a panel hanging from the ceiling where the installation was set. The viewers can point the camera component of their tablets or smartphones toward the panel to obtain a 3D narrative deployment

through a variety of augmentations. This resource has the main goal of studying how audiences can obtain a mobile digital version of the *di sotto in su* phenomenon.

IMPACT IN THE COMMERCIAL AND ARTISTIC WORLDS

The immersive environment artistic installation *Wedding Chamber* will offer any targeted audience an opportunity to engage with one of the most significant monuments of the western artistic tradition. Users can easily hold and operate the installation devices through effective usability standards. The audience will be able to appreciate the way Mantegna opened ways of communicating his style and the techniques of the fresco he painted. Viewers will be able to grasp the psychological power of Mantegna's images and the innovations of his visual storytelling. This experience presents what is increasingly being called *digital art history* (Lin et al., 2019), a term that delineates a variety of innovative practices incorporating technology into research and teaching.

This construction will also be instructive in what is a demonstrative method of interfacing traditional representational skills within digital imaging, a crucial understanding for today's audience to grasp the scope and relevance of emerging technologies. This installation piece is not in itself a scanned photogrammetric reconstruction of the original fresco located in Mantua; it is an engaging virtual work that studies a great monument of art from the past. In a more expanded discussion, this installation could be located suddenly in the middle of a pungent exchange of validations or negations about its legitimate aspiration as an art installation. However, its primeval proposal, in the end, is the interpretation and perhaps the appropriation of a chief masterpiece to develop a meaningful and genuine portrayal of aesthetic principles that will not be compromised as a commodified art staple.

It is interesting to mention that the art world is having its first meaningful encounters and analysis regarding immersive technological installations as the first expressions of commodified products (Horning, 2021) under the guise of art pieces. Nevertheless, it is understandable that the art world poses significant questions and concerns in front of initiatives coming from museums to attract audiences around potential prominent subjects in art. In the Field Museum of Art in Indianapolis, a permanent display called *Lumen*, which implements an emerging technology such as immersive mapping projections, offers a concrete example of what some commentators like Rob Horning (2021) called making an experience into a commodity; the theatricality embedded in this technological piece, exhibited as an immersive production, would be eventually intended to squeeze the novelty attraction from audiences to basically promote a trend of imaging consumption.

Figure 20. Oculus interactive animated narrative

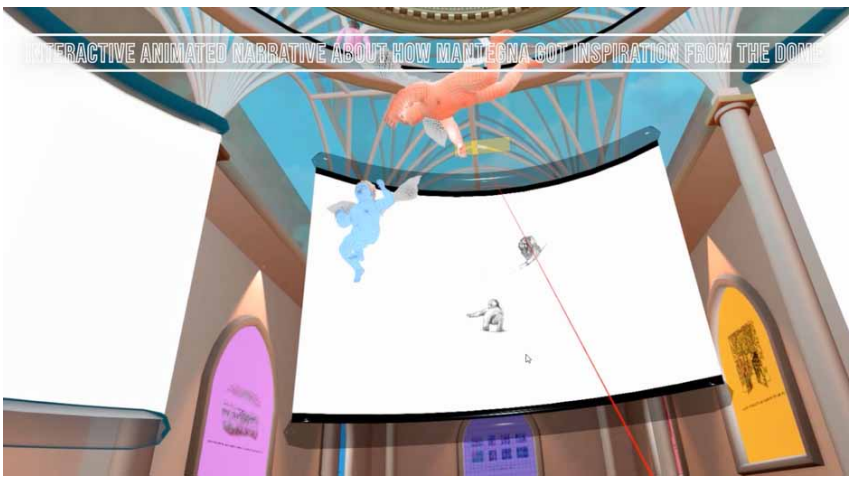
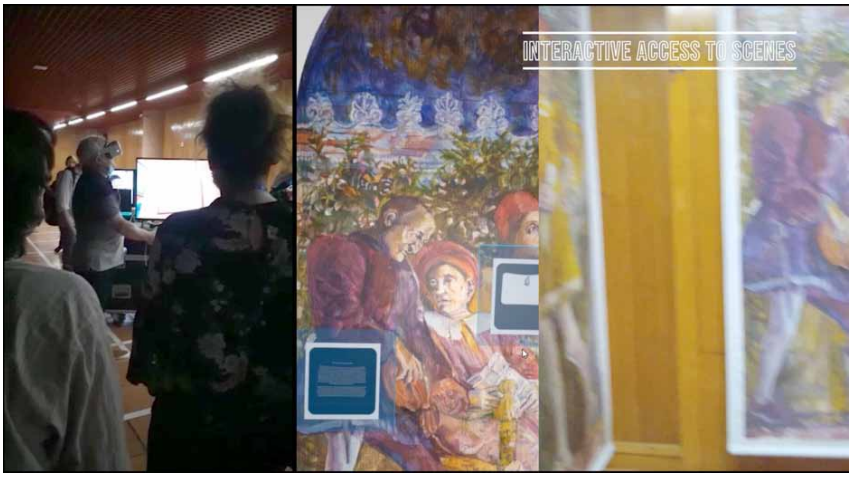


Figure 21. Immersive XR interactivity



Still, the art world is trying to cope and accept what emerging technologies offer as creative and artistic tools for creation and development. In galleries and exhibitions, it is common to encounter multichannel installations and sensing experiences that implement interactive systems, to some extent, to engage viewers. However, a full circle of paradigms that immersive digital technology has currently developed potentially would be of great contribution, such as presence, interactive 3D animation, teleportation, haptics, remote grabbing, and physics simulation, to mention some of the relevant ones, have not been fully incorporated as valid and viable practices in creating immersive digital art yet. The world of genuine art and technology, integrating meaningful aesthetic archetypes deemed as legitimate artistic experiences, is currently in construction by emerging artists and is providing incipient groundbreaking lessons of novel art practices to the cultural elites.

The problem resides in the lack of strong and consistent attention from the art world that properly addresses the theoretical foundations of what would be acknowledged as "art and technology." Some authors and intellectuals like Lev Manovich (2002, 2013, 2020), Oliver Grau (2004, 2010, and Grau et al., 2019), and Edmond Couchot (2018; Couchot & Soulages, 2002; Couchot & Hillaire, 2003; Couchot & Lambert, 2016), have been writing about it consistently for years, and it seems their insights would not have permeated enough the reluctant epidermic layer of the "serious art spheres." Another concern is the danger posed by high-tech companies and corporations in creating a monopoly or consortium that would affect the licensing of technologies that eventually impel the freedom of the individual artist. From that extent, the legitimation of an art installation implementing XR must achieve the necessary unravelment to dispel any classification within the dismissive commodification category.

It is the meaningful aesthetic content the one to produce the intelligible event in an immersive installation, not the possible theatrical spectacle suggested by some observers and commentators nor the omnipresent electronic nature of the medium. However, the promotional and commercial status would be a legitimate byproduct of what an immersive installation would eventually generate (Marr, 2020). Today, the available platforms that offer on-demand cinema as art, like the Criterion Collection, are based on a commercial model. Cinema as art anyway requires a theatrical format and location for projection anyway. The same applies to subjects like documentaries, short film animations, and video games that eventually achieve or aspire to become art pieces. It is the aesthetic and meaningful cultural experiences as content (Beck et al., 2020), the one that will implement the artistic validation of an installation potentially involved in a commercial venture, not the technological object fixation.

RESPONSIVENESS AND THE USER INTERFACE

The computer program of the installation was programmed in C# for interactive and immersive responsiveness. A consistent sequence of usability tests has been conducted to refine and streamline the user's experience. The main roadblock to familiarity with the use of controllers and hand gestures for novel users is the distribution of triggers and directional pads. The users must discover the hand controller's mapped keys with the assistance of a graphic message to introduce the manipulation of the controllers with specific step-by-step examples. Even with that assistance, the users require practice and quick responses from the interactive components of the immersive installation interface (Li & Du, 2009). A map with the most standard actions for interaction, integrated into the 3D objects, has been designed in the program in the form of a head-up display. Those actions are the trigger, the navigation and teleporting pad, and the grip button. This triplet of actions can facilitate navigation and interaction if they are introduced graphically through a rollover map when a first-time user experiences initial contact with the controllers.

However, in the VR installation program, an option for just using the hands primarily as controllers has been implemented. The users can see the hands acting as controllers in the VR headset. Therefore, when they activate the finger action for triggering or grabbing an object, they can see the fingers manipulating the joystick pad, the trigger button, and the grip side button in real time. These controller actions are standard for the two systems used in the VR program. HTC VIVE Pro has a flat directional pad, then by using the thumb activates displacements or walk-in within the immersive environment. The Oculus Quest 2 has an equivalence to a joystick that presses forward to teleport or activates the locomotion.

The mixed reality component of the physical installation is the HoloLens technology. The HoloLens headset executes interactivity by just the recognition of the users' hands. There are no physical controllers to help to navigate or teleport. The system first develops an environment mapping (Naemura et al., 2002) to plant the interactive 3D objects in the scene. This configuration is essential to determine the digital position of 3D interactive objects. In this case, the viewer can freely walk within a safe area (Baradaran Rahimi et al., 2022), and there is no problem in seeing the real world through the headset due to the overlapping nature of the 3D content.

In the physical VR immersive installation, there are, therefore, three channels of interactivity, the virtual reality immersive environment that uses the headset and controllers, incorporating sensors for the detection of a play area; the mixed reality channel that provides the interaction within the same VR

Figure 22. Head-up interface using ray cast pointer

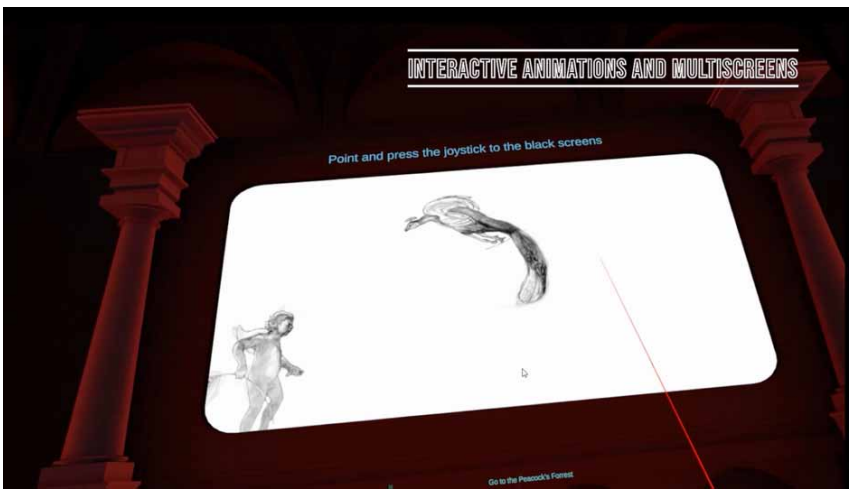


Figure 23. HoloLens mixed reality interactive animations

Figure 24. HoloLens interactive 3D object

space coordinates using the HoloLens headset, and the augmented reality interaction by triggering 3D objects that respond to targets or markers (Papagianis, 2010). The targets and markers are embedded in the hanging panels or banners, along with tactile manipulation over the screen of an iPad Pro or smartphone. These three channels make the physical installation an intensive exercise of discovery (Du et al., 2018), but at the same time produce a link of communication between the virtual immersive play area, the mixed reality components, and the augmented reality interactions. The conjunction of these three channels has been denominated XR, which is the definition of extended reality.

ASSOCIATED RESEARCH METHODS

The concept of this immersive XR installation required an important amount of research, planning, development, and implementation solely based on the technological platforms needed to generate the visual content that ultimately conveys the implicit discourse, narrative, or message, articulated around

a conceptual architecture that ponders the virtual and the physical space as performative interactive scenarios (Gemeinboeck, 2021). However, it is important to distinguish in the installation its content as the primary subject of research to achieve the construction and articulation of the content along with the technological resources. There is a strong research component associated with the historical, aesthetic, and artistic background of the subject of study around the Gonzaga family *Weltanschauung* deployed in the original frescos' narratives in Mantua.

Moreover, there is the presence of Andrea Mantegna's artistic mastery as a subject of study inconspicuously alluding to *The Dome* of Lucian of Samosata as a classical influence from antiquity in terms of how this classic satirist *ekphrasis* method excerpts (Dunlop, 2009), influenced the manner in how Andrea Mantegna articulates a secular, and humanistic narrative in a time when religious commissions were the expression of patronage, and cultural expressions of society. There was of course a research effort to finally make the technological compilation of content inside the installation, a research endeavor around its historical background, a research endeavor focused on its artistic components, and finally, a research endeavor that scrutinizes its contemporary cultural components, shrouded inside Mantegna's imagery, and rendered as illusionistic devices of representation (Christiansen, 2009).

However, after the whole effort of the compilation and construction of the installation, its associated research method is geared toward the usability effectiveness for viewers. The concurrent component of the installation, as an instrument of research, intends to find out how users will finally effectively manipulate its implicit content to verify the responsiveness of the whole interactive system embedded as a playing and performing interface.

Consequently, the XR immersive installation exposes two research component methods, one that is implicit in the project development and the second one that is derivational to expound the installation as an instrument to observe the user's experience. The installation's functionality is an outstanding outcome that naturally is expected from an immersive experience of this kind, and its functionality must be explained in practical terms. What is its purpose, or ultimate intention, and its impact on artists, scholars, and the general audience interested in emerging technology trends. The research activity from the systemic model defines the way the installation is utilized to process outcomes and behaviors (Khenak et al., 2020) from users and viewers. Basically, the way each node operates is by having attached a query generator that records the actions or behaviors in each flow node when the users press triggers or generates motion or movement using the controller's accelerometer component. This creates a spreadsheet based on two variables, persistence, and frequency (Roth et al., 2019), of the behavior to be observed in the node. In addition, for all nodes that require measuring motion and locomotion, a mapped image file showing the trajectory of the vector is registered also based on persistence and frequency. In the end, the data information collection is tallied to basically assess the immersive space awareness locomotion, the progressive acquisition of usability skills, and the level of user engagement.

CONCLUSION

The installation was presented at several international and regional venues. The effectiveness of interactions and responsiveness of the installation work depends heavily on the viewer's feedback. For this reason, the associated study of user experience has become a critical component in terms of a seminal analysis of data. The follow-up observation of user experiences indicates two important variables that surfaced during the playing mode of the installation that directly impacts how the viewer responds, the novelty of teleporting as the navigation within the immersive scenario and the hand's manipulation of interactive objects. These two variables are persistently demonstrating that an immersive installation that implements XR (extended reality) necessarily requires a physical space to unfold the user's body performance (Khenak et al., 2020).

The user requires to explore the immersive space; seated or standing still like a conventional gaming behavior will not provide the perceptual dimension contained in any emerging new media offering interactive artwork (Khenak et al., 2020). Teleporting provides the opportunity to execute

great strides in a large scenario, but this action will not necessarily replace or overturn the perceptual haptic approach to any interactable 3D object nearby the landing of a teleporting stride. The user will require to hold, duck, or jump to where any 3D interactive object is located. The locomotion modality implies actions like teleporting, sliding, and walking, and these behaviors (Khenak et al., 2020) can be executed in an alternate mode, depending on what the users prefer to execute.

However, it is important to emphasize that these are conventional behaviors present in Virtual Reality immersive systems, and the mixing of the real world within the immersive device is a transitional modality that makes possible the implementation of the extended reality environment. Teleporting and controller interactions define the purpose of XR understood as extended reality. The users will pass through the detached stage from the physical world (immersive VR) to the presence in the physical world overlapped with digital 3D objects. This transition originates from the headset technology, which allows a toggle mode. Today, most of the headset devices integrate this technological modality, which makes possible the travel from immersion to the extension modality when the device's camera sensors enable "seeing through," and this can be triggered by any 3D object that would be linked to that specific stage. At this point, the installation has resolved this important aspect, which is the relationship between an immersive digital world and the physical environment of the installation. The effectiveness of this paradigm relies on the user's expedited use and the observation of specific data (Roth et al., 2019). This is tied exclusively to the controllers' usability at this point.

This implies a primary stage of educational use of controllers and hands as drivers for the interaction. This phase of the installation functionality has been presented in conferences such as ARTECH Conference 2021 in Aveiro, Portugal, at the 2021 Fort Wayne's Taste of The Arts Festival in Indiana, and at the 2022 6th CAGA Conference of Expanded Animation, at the Hochschule University in Luzern Switzerland. In the two academic venues, the installation was presented in front of peers to basically demonstrate the intuitive approach of an informed audience, and the venue of Fort Wayne, Indiana, Taste of The Arts Festival, included a general audience to test first-time users' usability behaviors. The observational data of usability performances were organized according to informed and uninformed audience feedback. The collection of this information in terms of statistics has made possible the improvement of future content development, thinking in better programming to implement an even more effective and expedited user engagement and presence within the installation. These improvements have helped to turn the phenomenological discovery (Roth et al., 2019) of the implicit content into a tangible and observable subject.

Once extended reality is universally recognized as the agent that generates the immersive environment paradigm, it will cover important and prominent colloquies about its advent beyond its initial wonderment. Then it will come to the natural familiarity of its interfacing, considering the user's body as a physical countenance. This will materialize a cultural understanding of what presence means in terms of a phenomenological definition (Roth et al., 2019). The phenomenological responses generated from our individual and social bodies (Coelho et al., 2006) will reverberate in the benefits of a global and universal language construction associated with an extended reality immersive environment.

Digital objects within an immersive environment will work as vehicles of expanded apperception surveying the physical and visible world, generating new levels of interpretation of reality and novel manners to produce responses in conjunction with the body not only to mimic or simulate physical routines but to perform unique methods of human consciousness or self-awareness, to grasp better our cultural systems and singular world.

COMPETING INTERESTS

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Andres Montenegro is an associate professor of computer animation at Purdue University Fort Wayne. He participated in the 2013 International Animation Festival of Annecy, France, winning a residency in Paris at the DoubleMetre Animation studios for his animated short film, The Little Quest of Petrovsky. His last animation film, The Alley, has been screened in several international film festivals, including the International Film Festival in Canton, Guangzhou, China. His immersive XR environment was presented at ARTECH 2021: 10th International Conference on Digital and Interactive Arts, in October 2021, in Aveiro, Portugal.