Virtual Reality Museum Application for the Arts

Joshua Maddy* and Husnu S. Narman†
Department of Computer Sciences and Electrical Engineering, Marshall University
Huntington, WV, USA
Email: *maddy15@marshall.edu †narman@marshall.edu

***Abstract*—Most students are monetarily or physically inhibited from visiting private or public institutions. The Metaphysical Exhibit project goal is to give all ages a modern, technological take on the museum experience by providing a Virtual Reality alternative. By lowering the barrier of entry to a one-time purchase for the hardware and free software, any classroom or consumer can experience masterworks in an immersive environment. A rich collection of art pieces across the eras can be displayed under one roof by compiling public information on historical works. By utilizing Virtual Reality, the museum is easily distributed and portable. In this paper, we aim to develop a virtual museum with artworks and observe its effects on users. The developed application is capable of running on modern headsets, specifically the Meta Quest 2. To analyze the viability of the application in a classroom and personal setting, we especially find answers to the following questions: (i) Does experiencing the museum in this format feel analogous to prior exhibit experiences? (ii) What is the level of interest in exploratory, self-guided Virtual Reality content used in education from a student and teacher perspective? (iii) How can the experience be improved? The results show that the project was received positively by students and teachers as an introductory experience for the arts.**

***Index Terms*—Virtual Reality, Arts, Education, Unity 3D, museum**

I. Introduction

Most students generally lack exposure to the professional arts. The number of children and adults who reported receiving an education in the arts has been in decline [1], [2] as shown in Fig. 1. This decline is commonly attributed to an increase in pressure to perform in the STEM fields [3]. We believe that a foundational education in the arts is greatly beneficial to promoting a more creative and adaptive mindset, regardless of the fields that are pursued. We want to assist educators in the arts to help lay that fundamental foundation. To do this, we propose the Metaphysical Exhibition. The Metaphysical Exhibition is a Virtual Reality (VR) educational application focused on creating an immersive museum experience. By utilizing VR as the primary medium, levels of interactivity not previously possible can be implemented. The final stage of this project was meant to be more than a standard museum of objects, rather a museum of experiences. Displays and interactable elements will act as a catalyst for more engaging and effective learning opportunities for all users, especially K-12 students. VR museum applications have been explored from both scholarly and corporate viewpoints, as discussed in detail in Section II. We differentiate our offering by focusing on a wide range of movements through history, a diverse selection not limited by physical, distant galleries, and a wide range

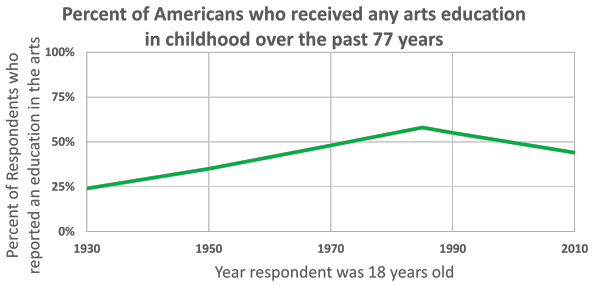

Fig. 1. Percent of Americans who received an education in the arts in decline past 1985 [2]

of supported virtual reality interfaces. Our approach creates a centralized collection of works sourced from a fragmented web of museums across the globe. We are able to populate the space with a wide variety of works which would not be possible in the real world. We achieve this by using public, Creative Commons-licensed material and not affiliating with a museum, deviating from the typical approach that prior works have taken.

Our *objective* in this project is to find answers to the following questions: (i) Does experiencing the museum in VRs format feel analogous to prior exhibit experiences? (ii) What is the level of interest in exploratory, self-guided VR content used in education from both a student and teacher perspective? (iii) What features or topics are missing from this application? and (iv) How can the experience be improved? These questions have been constructed expressly to relate to the primary topic of educational potential. Ultimately, the project is focused on determining if a virtual museum application, as described, would be of use to educators and students.

The *key contributions* of this paper is (i) implementation of the application based on the auto censorship model and custom interest arrangement based on the age group, (ii) carrying on field testing, and (iii) analyzing the observed experiences and feedback of users. Our result shows that such VR-based museum experience is received positively by students and teachers as an introductory experience for the arts.

The rest of the paper is organized as follows: Section II has a more thorough discussion of prior implementations of the VR museum concept and implementations from established museums, commercial ventures, and academic studies. Next, Section III describes the methodology for the application's design, museum layout, sourcing of artworks and their meta-

data, optimizations necessary to reach our target devices, and collection of feedback. The following Section IV addresses the usability of the application, its educational ability, and professional critique of its current state. Finally, section V presents concluding remarks with future works.

II. Related Works

The concept of a VR museum has been explored by both the scientific community and large institutions, as well as commercial ventures. Each of these categories has caveats to their implementations. Before providing detailed explanations of the previous works, to contextualize the topics of this paper, we define our implementation of Virtual Reality (VR) as a tracked headset and controllers with six degrees of freedom, such as an HTC Vive, Valve Index, or Meta Quest 2. This is in contrast to more limited implementations of VR, such as the older Oculus models or experimental Google Cardboard.

1) Museum Implementations: Various museums have and are in the process of experimenting with virtual reality as a medium. Long-standing institutions like the Smithsonian, the Victoria and Albert Museum, the Louvre, and Tate have all participated in experimental VR-based exhibitions [4]–[7]. Commonly, the exhibitions focus on an artist or a single work and recreate the work in a moving, three-dimensional space akin to a video or movie. These are well-crafted and detailed experiences; however, they are quite limited in content and are not designed to replicate the museum experience itself since they themselves are in a traditional museum. The design of this project contrasts the movie-like experience as it is focused on personal pacing, exploration, and a design favoring realism.

2) Commercial Implementations: Several applications with similar concepts have been published across various VR-related distribution platforms, specifically Steam and the Oculus Store. On Steam, a standout application called *The VR Museum of Fine Art* is a visually pleasing implementation of a virtual museum, including famous masterworks on canvas and sculpture [8]. The complication with this implementation is the lack of interactivity and hardware requirement. With its well-crafted visuals comes a significant performance requirement, meaning that the application cannot be deployed on many target hardware. Another alternative, titled *VR Museum: Art Through Time*, solves this hardware problem [9]. Developed for our target platform, the Meta Quest 2, it offers a virtual museum experience similar to the project. The primary differences between this project and the aforementioned implementation are the lack of sculptures and interactivity. It is limited in gallery scope and does not appear to focus on educational aspects of the works.

3) Studies: From the scientific studies examined, virtual reality is a largely untapped medium for educational content. A foundational study examining the efficacy of virtual reality museums determined that after the initial wow factor of VR, there was no significant difference in immersion or interest between a real, traditionally designed museum and its digital replica [10]. Additionally, a comprehensive study on VR in education concluded that the applications of VR in the classroom are incredibly promising: "The main advantage of Immersive VR seems related to the possibility for users to have first-hand experiences that would not be possible in the real world ... simultaneously offering unique opportunities for experiential and situated learning, as well as promoting students' motivation and engagement" [11]. This field study strongly supports the museum-experiential-learning hybrid application that is in development. Given these examples, it is reasonable to assume that a virtual museum would positively affect the target demographic's interest in education in the arts and technology.

III. Methodology

A. Application Design

1) Targeted Platform: The Meta Quest 2 [12] is the targeted platform for two primary reasons: cost and portability. The Meta Quest 2 is relatively cheap. Being an all-in-one system, it is easy to transport and simple to set up for a classroom setting. Without the complications of a tethered setup and high computation requirements associated with other VR platforms, the barrier to entry is lowered as much as possible for educators and general consumers. In a classroom setting, portability and cost are crucial to adoption and frequent usage.

2) Game Engine and Frameworks: We decided to develop the application on the Unity platform [13] for two primary reasons: accelerated development and device-agnostic code. Unity is a robust game engine explicitly designed to be multi-platform compatible and easy to develop. Another reason Unity was chosen for development is the Unity XR Toolkit [14], a cross-platform framework that allows for relatively painless scripting that will interface with any VR headset technology seamlessly.

This means that it is simple to port the application to other virtual reality devices. In development, the software was tested and validated on three headsets, the HTC VIVE, Meta Quest 2, and the Oculus Rift S. During development, the application was briefly migrated from Android (the base OS of the Meta Quest 2) to OpenXR (a PC-based interface) to run on an older model headset, the Oculus Rift S. This build was also tested on the HTC VIVE. No changes to the underlying code had to be made, and the transition was completely seamless.

All code for the application is written in Unity's preferred language, C#, and is relatively simple in its current form. Most of the foundational work, particularly the interoperability, is handled by the XR Toolkit and Unity's built-in feature set promoting accelerated development.

B. Museum Design

1) Planned Exhibit Categories: The Metaphysical Museum will include famous or influential pieces of public domain art, historical objects of global or US-centric interest, botanical samples, and skeletal displays. To maintain a reasonable scope for this research, the initial release has been restricted to influential artworks. As of this initial version, there are 180 pieces of art across twelve periods, ranging from Classic Medieval to American Realism, representing over 32 influential

Fig. 2. The primary entrance to the Italian Renaissance exhibit, framing Leonardo da Vinci's *The Last Supper*.

artists. Both framed paintings and sculptures are represented. A selection of screen captures is pictured in Figs. 2, 3, 4, and 6.

2) Current Exhibits and Layout Flow: The current exhibits are Classic Medieval, Mannerism, Italian Renaissance, Baroque, Romanticism, Impressionism, Ukiyo-e, Tonalism, Art Nouveau, Expressionism, and Realism. The design of the building is intended to promote a near-linear exploration of these periods. As shown in Fig. 5, the viewer starts from the central room, moves upward into the Italian Renaissance, and then they can travel counter-clockwise to view the periods in a close to linear order. However, there are many gateways that can be used to completely circumvent this motion and go on with their exploration of the exhibits.

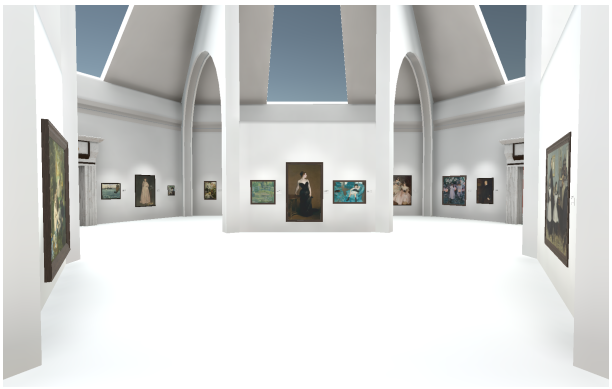

Fig. 3. The center of the Impressionism exhibit, in the distant focus, is (from left to right) one of Monet's *Water Lilies*, John Singer Sargent's *Madame X*, and Marry Cassat's *Little Girl in a Blue Armchair*.

3) Exhibit Design: Each exhibit is designed with real standards in mind. Each painting is hung with its center at 6', or as close to 6' as possible. Each art piece has a corresponding label listing the title, year, artists, media, credit line, and copyright. Pieces are hung in their corresponding period exhibit and generally grouped by the artist. Each artist with an available self-portrait has their self-portrait hung.

In an effort to increase immersion, chairs are spread through the majority of exhibits for optional sitting views. Each chair is modeled to be at average chair height, so the viewer may sit

Fig. 4. The Realism section of the Realism and Expressionism exhibit. To the right is Ilya Repin's *Ceremonial Sitting of the State Council*.

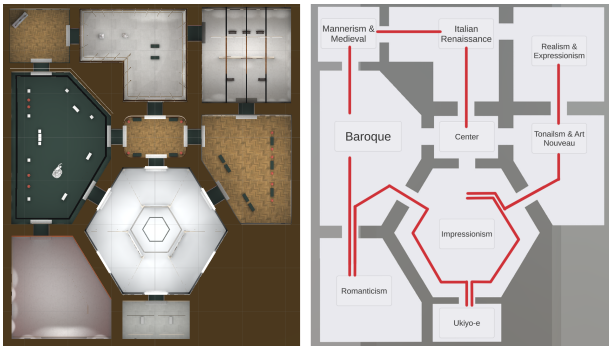

Fig. 5. Two top-down views of the current museum layout. The left represents the textured, decorated scene, and the right shows the intended flow through the artistic periods.

in their own chair in the real world, approximating the digital chair. An example of these chairs is shown below in figure 6.

Fig. 6. The edge of the Tonalism and Art Nouveau exhibit. To the left is a sample of James Abbott McNeill Whistler's works, and to the right is a selection from Alphonse Mucha. Red chairs and upholstered wooden benches are seated in front of the paintings for optimal viewing.

4) Movement and Accessibility: The movement system for the Metaphysical Museum is both standard and flexible. It allows for room-scale movement, ray-based teleportation, and snap-turning for anti-nausea orienting. On top of this is a teleportation menu that allows for easy, instantaneous movement from one exhibit to another. Each display has an

instance of this teleportation menu on the left pillar, shown in Fig. 2. By including various modes of transportation, it is intended that each user may move however they feel most natural, whether that be by standing and walking in a room-scale environment or seated.

C. Artwork Sourcing and Copyright

As the project deals with images of artwork, the issue of copyright is forefront. Even if the piece of art has long been in the public domain, the image that represents it may not. For this reason, most real-world objects have been sourced from publicly available archives of creative commons zero (hereafter CC0, free for any usage) models and scans. Some pieces, in particular sculptures, are licensed as Creative Common Attribution-Noncommercial, meaning that their usage prohibits the sale of this application. Given the nature of the application, there was no plan to monetize it, so this restriction is not concerning but should be noted nonetheless. The primary sources of used media are Wikimedia [15] for framed works and Sketchfab [16] for sculpture. Large museums, such as the Smithsonian Institution, the National Gallery of Art, and the Metropolitan Museum of Art, are also used as primary sources, as they each have freely available digital collections under the CC0 license.

D. Handling Metadata and Crediting

All metadata for an art piece is handwritten as a .json file containing detailed information about the source, attribution(s)/credit line, license, title, artist(s), date, medium, and real-world size. These .json files were used to populate the labels for each individual artwork. With this information, there is a concrete line back to a reputable source. With this link, each work in the museum can be traced back to its repository of origin, in which the user may explore more about the work.

E. Optimizing for the Meta Quest 2

As the Meta Quest 2 is a mobile device, optimization is a major concern. The application is expected to run at a constant 90 Frame Per Second (FPS) to achieve a comfortable experience, so every chance to reduce load should be taken to minimize the chance of future performance problems. The two major forms of optimization that were a focus from day one are mesh optimization and image optimization.

1) Mesh Optimization: As per Oculus' developer recommendations, the maximum range for triangle count for the Meta Quest 2 is 750k - 1mil triangles - a single 3D scan of a statue can easily exceed that cap. In order to fit multiple detailed scans of sculptures on the Meta Quest 2 with no noticeable performance hit, each object would have to be re-meshed to a fraction of its original triangle count. This was done by using a combination of Instant Meshes, Blender 3D, and Adobe Substance Painter.

Instant Meshes is an open-source application for re-meshing large objects into more reasonably dense representations. This was used to take 750k triangle scans down to 10k -15k triangle objects. From this reduction, the object would be edited in Blender by hand, further refining the approximation made by Instant Meshes. After refinement, the model would be collapsed using Blender's decimate modifier with a custom vertex weight map, removing more triangles towards a target goal of 7k - 10k. After the model has been sufficiently reduced in Blender, it is ported to Adobe Substance Painter, where it is unwrapped automatically. Adobe Substance Painter then bakes the information from the original scan to the reduced object as a normal map, restoring most of the detail to the object without the performance hit. A collage of the process can be seen to the right, in Fig. 7.

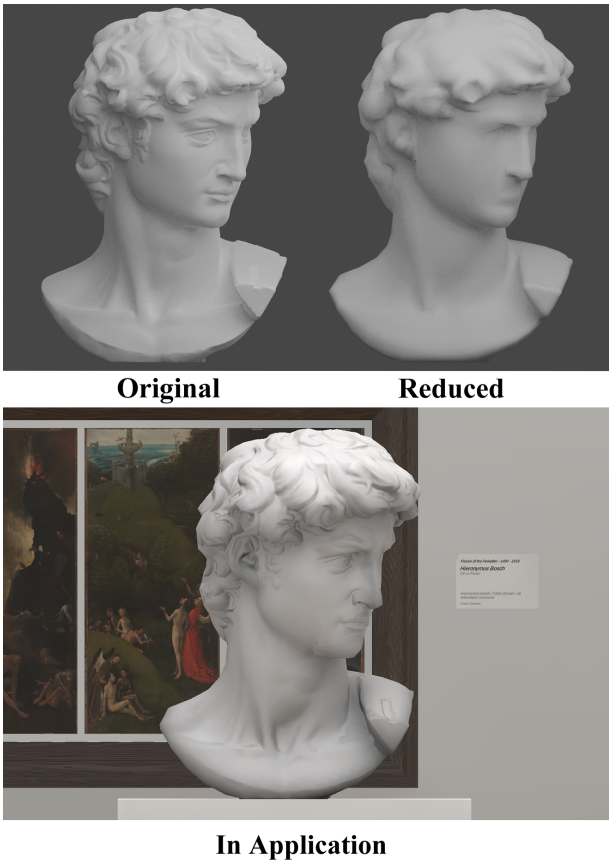

Fig. 7. Stages of simplification. The original bust of David top left, reduced at top right, and the final in-application version's bottom center. David bust by Thomas Flynn, licensed under Creative Commons Attribution.

2) Image Optimization: Given that the museum is displaying art, the size and quality of image textures are paramount. The maximum image scale for the Meta Quest 2 is 4096px x 4096px, so all sourced images were either left at the original scale or resized to fit. Many scans are of extremely high quality, often nearly raw images, meaning that compression was necessary. The first round of compression was performed with Radical Image Optimization Tool, or RIOT, which, when tweaked, reduced most file sizes to less than 5MB without any noticeable change in quality. The second round of compression occurred when importing the images into Unity, in which they are again compressed.

In testing, it was determined that for most paintings, the difference between a 4k and 2k texture was negligible. Given this evaluation of quality, only a handful of extremely large paintings are displayed in 4k, while most are displayed in 2k. Physically large paintings are displayed in 4k so as to maintain a consistent range of pixel density. Favoring 2k image files further optimizes the experience and alleviates the GPU's RAM.

As shown in Fig. 8, the application runs at the maximum resolution and framerate of the target device, 2 * 1920px * 1832px and 90 FPS, respectively by utilization of the GPU and CPU stay within reasonable bounds[1].

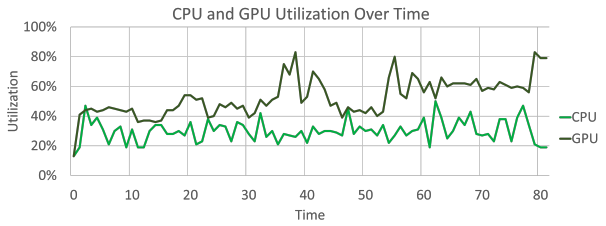

Fig. 8. CPU and GPU utilization over 80 seconds of usage. CPU trended near 40%, GPU over extensive testing trends at the max of 80%.

F. Collection of Feedback

Preliminary participants have been sourced from a Marshall University College of Engineering and Computer Science promotional activity that tens of users attended. Participants were informed of the purpose of the research project and were asked to participate. All participants were between the ages of 7 and 18. Participants were instructed to wear and adjust a Meta Quest 2 headset, after which they were lightly guided through the controls of the Meta Quest 2 and the layout of the digital space. Participants were encouraged to stand, but nearly all remained seated. After this introduction, they were encouraged to explore the space for as long as they would like. Some participants spent only five to ten minutes, while others repeatedly returned and spent over a half-hour in the experience. Unfortunately, measurements of time were not accurately noted. The feedback was collected through a questionnaire consisting of the five questions listed below.

1) Have you ever used a virtual reality headset before? (2 options: Yes or No)
2) Have you visited a museum in the past year? (2 options: Yes or No)
3) What was your favorite aspect of the experience? (3 options: Viewing the paintings, Viewing the sculptures, or Walking through the rooms)
4) From easy to hard, how did you feel about navigating around the virtual space? (1 to 5 scale from Hard to Easy)
5) Was the experience comfortable or disorienting? (1 to 5 scale from Disorienting to Comfortable)

[1]The current version video with CPU and GPU usage can be watched from: https://youtu.be/L2FeGMFQB7o

Moreover, Dr. Rachel Danford, a professor at Marshall University's College of Arts and Media, was interviewed. She specializes in art and architecture of Late Antiquity and the early Middle Ages. During the development process, Dr. Danford also tested the application and provided crucial insight into its usability, educational potential, and critique of its design for improvements. As this tool is educationally focused, it was crucial to have input from an educator of the arts rather than only students.

IV. Results

A. Usability

The most important measurable metrics for usability and comfort in VR are FPS and utilized resolution. The higher and more stable the FPS, the more likely a user will not experience motion sickness or discomfort in VR. The higher the utilized resolution, the more potential for heightened immersion.

Due to designing the application with optimization at the forefront, no compromises were made in FPS or resolution. The Meta Quest 2 has a per-eye resolution of 1920px x 1832px, and the application utilizes the full resolution at all times. In rigorous testing with this maximum resolution, the Metaphysical Museum maintains a constant 90 FPS in all settings. This means that the user experiences no stuttering or de-sync, providing a smooth and realistic experience at the highest possible resolution.

Assertions concerning usability are supported by the aforementioned questionnaire. General trends pointed to users being able to easily navigate the virtual space as shown in Fig. 10 and being comfortable as shown in Fig. 9. Although having such positive feedback, there could be more improvement. For example, a common response during discussions with the participants was that the teleportation trigger location was unnatural because of the allowed transportation between walls.

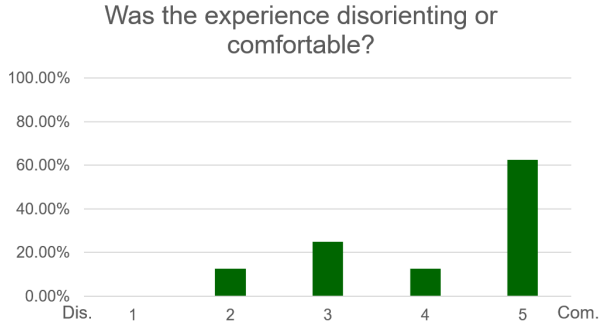

Fig. 9. User reported level of comfort, from comfortable to disorienting. There are not enough reports for statistical significance, but the responses appear to skew towards a comfortable experience, with the majority feeling indifferent.

B. Educational Ability

This version of the Metaphysical Museum covers a wide range of artists and art pieces across hundreds of years of art history. The breadth of culture and history is more expansive

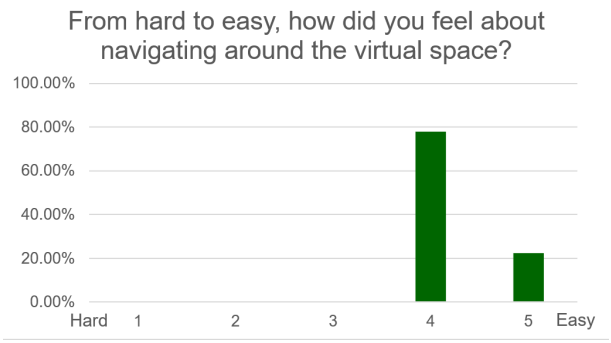

Fig. 10. User reported ease of navigation, from easy to hard. All respondents reported the navigation as easy.

than most real museums, as we have sourced information from across the globe. In its current form, a user can view all crucial information about the work's title, year, artist, medium, credit line, and domain status. This is the basis for more expansive information fields, as well as links to reputable external sources for deep dives into artists and their works.

In the questionnaire, one-third of testers reported that they preferred walking through the rooms of the virtual space more than viewing the artwork or viewing the statues as shown in Fig. 11. We see this as a point of improvement and expect more users to be interested in the pieces. We expect that adding more interactivity and tour-like features will increase interest in the pieces over the space as a whole.

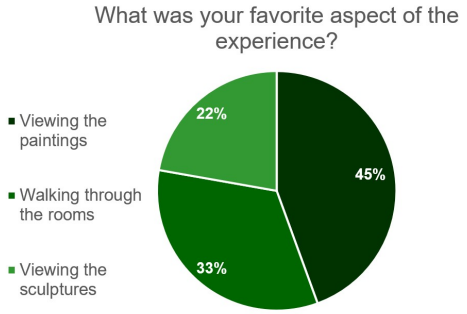

Fig. 11. The majority of users reported that they preferred viewing the statues or paintings, but a substantial amount were more interested in the surrounding space.

In the aforementioned critical interview, we discussed the application's potential usage in a classroom setting. During this feedback session, it was suggested that the application would be best used as a tool to depict the scale and presence of artworks in ways that are not possible through a slide presentation. Other interviewed testers were receptive to the usage of the application, specifically as an introductory tool for learning about historical works.

V. Conclusion and Future Works

The Metaphysical Museum is highly optimized and designed for smooth operation, promoting a pleasant user experience. The project has been received well during development, and if this trajectory is continued, it is expected to be quite immersive and effective. During preliminary testing, we have identified restrictions and are actively developing fixes for these issues. In its current state, the application has more opportunities to increase interactivity and, subsequently, efficacy in educating the user. Through testing with actual users, we have found that there is a significant interest and niche for using this technology in the classroom, specifically as a way to communicate the scale and introduce the fine arts. With the results given, we anticipate that as this application evolves we will fully achieve our goals of providing a unique educational application for the classroom.

Although we have an immense experience with this project, our plan is to expand this project in certain ways. Firstly, the application can be more interactive. The experience is already quite immersive; however, there is significant room for improvement in terms of interactivity. For example, audio tours, objects to pick up and examine closely, and non-traditional and exploration-focused exhibit layouts are all planned features that would greatly enhance the interactivity, utility, and immersion of the application. Secondly, the application accessibility can be expanded. It is important that the application is as accessible as possible within the constraints of VR. One simple addition is a height adjustment feature so that people who are seated are able to experience the museum the same as people who are standing. Mobility should not be a hindrance in a VR experience. Finally, the design and diversification of arts can be increased so that diversification and more artists across the globe can be represented in this application. This means a redesign of the digital space, with particular care in better representing the context of works - particularly frescoes. It is also planned to expand beyond the arts into biology and history.

Acknowledgements

We thank Dr. Rachel Danford for the valuable suggestions. We also thank the SURE: Summer Undergraduate Research Experience, Creative Fellowship, NASA Fellowship, and Summer Research Award programs for supporting this project.

References

[1] M. C. Dwyer, "Reinvesting in arts education: Winning america's future through creative schools." *President's Committee on the Arts and the Humanities*, 2011.

[2] N. Rabkin and E. C. Hedberg, "Arts education in america: What the declines mean for arts participation. based on the 2008 survey of public participation in the arts. research report# 52." *National Endowment for the Arts*, 2011.

[3] T. Beveridge, "No child left behind and fine arts classes," *Arts Education Policy Review*, vol. 111, no. 1, pp. 4–7, 2009.

[4] "Beyond the walls: Experience the smithsonian american art museum in virtual reality," https://americanart.si.edu/beyond-the-walls, accessed: 2022-11-18.

[5] ""mona lisa beyond the glass": the louvre's first virtual reality experience," https://www.louvre.fr/en/what-s-on/life-at-the-museum/mona-lisa-beyond-the-glass-the-louvre-s-first-virtual-reality-experience, accessed: 2022-11-27.

[6] "V&A Curious Alice: the VR experience," https://www.vam.ac.uk/articles/curious-alice-the-vr-experience, accessed: 2022-11-18.

[7] "Tate modigliani vr: the ochre atelier," https://www.tate.org.uk/whats-on/tate-modern/modigliani/modigliani-vr-ochre-atelier, accessed: 2022-11-18.
[8] F. Sinclair, "The vr museum of fine art," https://store.steampowered.com/app/515020/The_VR_Museum_of_Fine_Art/, accessed: 2022-11-27.
[9] J. Nau, "Vr museum: Art through time," https://www.oculus.com/experiences/rift/2581900071911230/, accessed: 2022-11-27.
[10] J. Marín-Morales, J. L. Higuera-Trujillo, A. Greco, J. Guixeres, C. Llinares, C. Gentili, E. P. Scilingo, M. Alcañiz, and G. Valenza, "Real vs. immersive-virtual emotional experience: Analysis of psycho-physiological patterns in a free exploration of an art museum," *PLOS ONE*, vol. 14, no. 10, pp. 1–24, 10 2019. [Online]. Available: https://doi.org/10.1371/journal.pone.0223881
[11] A. F. Di Natale, C. Repetto, G. Riva, and D. Villani, "Immersive virtual reality in k-12 and higher education: A 10-year systematic review of empirical research," *British Journal of Educational Technology*, vol. 51, no. 6, pp. 2006–2033, 2020.
[12] S. Schramm, "A national imc campaign for meta quest 2," Master's thesis, Western Michigan University, 2022. [Online]. Available: https://scholarworks.wmich.edu/honors_theses/3537
[13] X. Luyao, D. Honghai, L. Jianfeng, and Z. Hao, "Development and application of virtual collaborative experiment technology based on unity platform," in *2018 IEEE International Conference of Safety Produce Informatization (IICSPI)*, 2018, pp. 546–550.
[14] J. Linowes, *Unity 2020 Virtual Reality Projects: Learn VR development by building immersive applications and games with Unity 2019.4 and later versions*. Packt Publishing Ltd, 2020.
[15] "Wikimedia," https://www.wikimedia.org/, accessed: 2022-11-28.
[16] "Sketchfab," https://sketchfab.com/, accessed: 2022-11-27.