Designing and Evaluating a University Web-Based Metaverse: An A-Frame Implementation

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Abstract. *The Metaverse consists of interconnected 3D shared environments that support a wide range of human activities through diverse technologies and services. In recent years, many enterprises have invested substantial time and resources in developing proprietary Metaverse platforms. However, most of these efforts have resulted in isolated, non-interoperable systems. As a work in progress, this study investigates the potential of a Web-based University Metaverse to be replicated by other institutions and to support future interconnection. The paper presents the implementation of a Web-based Metaverse developed with A-Frame, and also reports preliminary results from a usability evaluation. It also outlines future directions for improving interactivity, and immersion.*

1. Introduction

The term *Metaverse* refers to a network of shared 3D environments that support a wide range of human activities through the integration of multiple technologies and services [Coronado et al. 2023, Dwivedi et al. 2022]. A fundamental characteristic of the Metaverse is interconnectivity, which allows users to move across different Metaverse Worlds [Choi et al. 2022, Coronado et al. 2023]. Nevertheless, companies have invested heavily in the development of isolated Metaverse platforms, such as Roblox[1], Decentraland[2], and Spatial.io[3]. As a result, more than 240 fragmented Metaverse initiatives currently exist [Yang et al. 2025].

Given these limitations, this work in progress investigates the potential of an open-source, Web-based Metaverse that offers the possibility of replication across institutions and, potentially, interconnection between them. Based on this premise, an institutional Metaverse project has been initiated using the A-Frame framework called Media Lab Metaverse. This Metaverse allows users to access the environment via web browsers on desktops, laptops, mobile devices, and Head-Mounted Displays (HMDs). Although the project still requires further refinement, it represents a concrete step toward an open-source Metaverse infrastructure.

2. Background

Several similar initiatives have proposed the creation of a Metaverse world. Therefore, it is essential to examine the characteristics and implementation strategies of these projects.

[1]https://www.roblox.com/
[2]https://decentraland.org/
[3]https://www.spatial.io/

- University Campus Prototype: Developed using the Unity Game Engine[4], this project also relied on Blender[5] for creating 3D models and integrated blockchain services to support a token-driven economy [Duan et al. 2021]. The environment included general and location-based chat functions, an AI-powered content creation tool for objects, and mechanisms to support a diverse range of user activities.
- City of Santa Cruz Simulation: Built with the Roblox Studio game engine, this work replicated the city with high visual fidelity. The authors digitized elements using a 3D scanner and modeled them with SketchUp[6] [Meier et al. 2020]. Although the environment offered a realistic urban representation, it did not integrate real-time or contextual data. Notably, the Roblox platform natively supports multiplayer interaction through voice and text chat features.
- DMZ Metaverse: This web application[7] employed an infrastructure that included the CUBRID database system, the Ext4 File System for 3D model storage, Angular[8] for the frontend, and Node.js[9] with HTML5 for managing dependencies. The system used WebGL for 3D rendering and relied on a RESTful API with JSON for data exchange [Choi et al. 2022]. Users could navigate exhibitions, access informational zones, engage in games, and communicate via text or voice chat.

Although interesting, these systems are not fully available for reuse or are based on some proprietary tools that limit their editing on purely open source platforms.

3. The A-Frame Web-Based Metaverse

A-Frame is a web framework for building virtual reality experiences, designed to simplify the creation of immersive environments [A-Frame 2025]. Built on top of Three.js, an abstraction for WebGL, A-Frame facilitates the development of XR-enabled web applications [Baruah 2021]. Based on these capabilities, the Web-based Metaverse was developed using A-Frame and other open-source technologies. The main requirements for guiding its development were: (A) Adopting the Web platform, in order to allow the use of the Metaverse across multiple viewing devices and to eliminate the need for software installation; (B) Supporting users through spatial audio and movements of avatar hands and head; (C) Supporting dynamic 3D objects, that is, objects that can be inserted into the environment at runtime and viewed and manipulated by users; (D) Being extensible, in order to progressively allow the implementation of new features.

At the moment, a fully functional version of the Web-based Metaverse is implemented[10], and consists of three main components: a graphical virtual-reality Web-based interface (using A-frame with Three.js and WebXR) that can be accessed on HMD devices, desktops, and smartphones, although there are differences in the functionalities embedded in each of them; a Web backend API (developed using TypeScript and Next.js) connected to a database system (a PostgreSQL[11] instance) for managing users and virtual

[4] https://unity.com/

[5] https://www.blender.org/

[6] https://www.sketchup.com/

[7] https://www.universe.go.kr/main

[8] https://angular.dev/

[9] https://nodejs.org/

[10] This version is publicly available at `https://metaverso.medialab.ufg.br/`.

[11] https://www.postgresql.org/

objects; and a WebRTC server (using Janus[12]) for interchanging audio and avatar names and movements in real time.

The system is being used for testing new ideas on creating interactions between physical and virtual spaces [Nascimento et al. 2024]. As an example of such goal, it currently features movable 3D scanned objects (Figure 1). These objects are retrieved from the database[13] in run time and originate from a 3D scanner located in a physical building. After scanning, the objects are converted to Base64 format and stored in the database. Figure 1 presents a user in the designed virtual environment of the Metaverse. Figure 1 shows an example in which a scanned action object is integrated into the Web-based Metaverse. The system also stores the position and rotation of each object in the database, ensuring their persistence across user sessions.

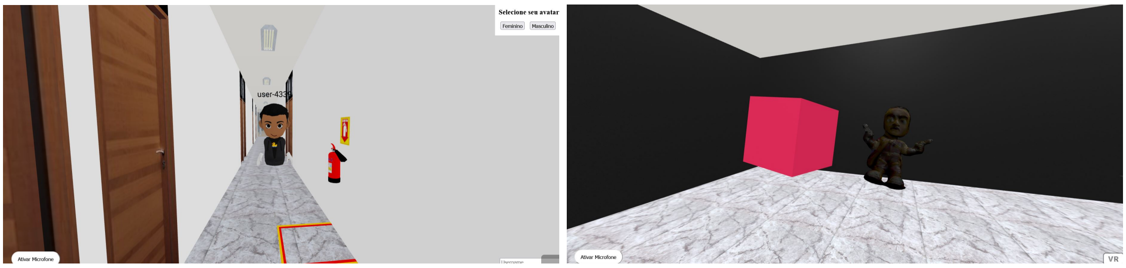

Figure 1. (a) Media Lab Metaverse; (b) Interactive Objetcs.

4. Usability Evaluation of the System

Once a fully functional version of the web-based Metaverse was implemented, a usability evaluation of the system was conducted. This evaluation ensured that the system requirements worked correctly, and that the usability, attractiveness, and user interaction were captured. Since the majority of Metaverse platforms are similar to game platforms, such as Roblox, Sandbox, Minecraft, Fortnite, and Spatial.io; the present study opted to use a Game User Experience Questionnaire, namely the GUESS-18.

GUESS 18 evaluates nine factors: Usability/Playability, Narratives, Play Engrossment, Enjoyment, Creative Freedom, Audio Aesthetics, Personal Gratification, Social Connectivity, and Visual Aesthetics [Keebler and Shelstad 2020].

4.1. Evaluation Setup and Results

For the experiment, each participant used a Meta Quest 3 Head-Mounted Display[14]. Researchers instructed participants to think aloud while freely exploring the Web-based Metaverse. After spending five minutes in the virtual environment, participants completed the GUESS-18 questionnaire. The experiment was conducted individually, ensuring that participants did not interact with one another during the session.

The research team invited nine participants to take part in the study. However, one participant (P7) reported symptoms of cybersickness, which led to the interruption

[12]https://janus.conf.meetecho.com/
[13]https://www.postgresql.org/
[14]The project was approved by the university's ethics committee under the CAEE identifier 88208025.5.0000.5083 and number 7.726.908.

of the session and the exclusion of their responses from the analysis. Figure 2 presents the results grouped by factor. Overall, the Web-based Metaverse received a total score of 45.62 out of a maximum of 63 points, corresponding to 72% of the highest possible score.

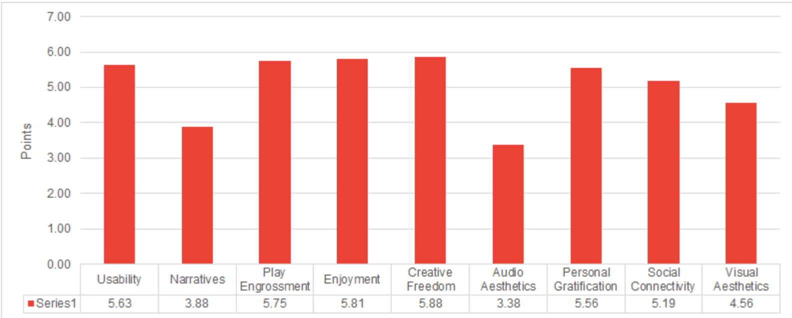

Figure 2. GUESS-18 Results.

4.2. Discussion

The GUESS-18 showed that six factors (Usability, Play Engrossment, Enjoyment, Creative Freedom, Personal Gratification, and Social Connectivity) received a high average score of 5.60 (see Figure 2). In contrast, Narratives, Audio Aesthetics, and Visual Aesthetics scored significantly lower, with average values of 3.88, 3.38, and 4.56. Therefore these factors should be improved.

During the experimental phase, participants raised several relevant questions. Some asked whether it was possible to open the building's door; however, the current environment is rendered as a single static GLB model, which does not support such interactions. One participant (P8), for example, attempted to grab and use a fire extinguisher inside the building (see Figure 1). Others (P2, P3, P4, and P6) expressed that incorporating more interactive objects would significantly improve their experience.

In the other side, the main requirements for the system worked correctly. The users could successfully interact in the environment through the Meta Quest Browser. The environment correctly supported the users movements. They could freely move inside the environments, and their avatar was correctly updating its position. Also, the users could see and interact with the dynamic objects inserted in the environment. Then, it confirmed the correct work of the requirements.

5. Conclusion

It was possible to build a Web-based Metaverse using A-Frame and other open-source technologies. This study presented the main requirements the are guiding the development of Metaverse: (A) Allow the use of the Metaverse across multiple viewing devices, (B) Supporting users through spatial audio and movements of avatar hands and head, (C) Supporting dynamic 3D objects, (D) Being Extensible, in order to progressively implement more features.

Also, this study executed a Usability Evaluation of the Metaverse. Participants reported a generally positive experience, (resulting in an average total score of 45.62 points). However, a broader participant base is needed to strengthen the validity of these findings.

Participant feedback suggests that the environment would benefit from the inclusion of more interactive elements. Incorporating entertainment-oriented features is essential to sustaining user engagement and keeping the Metaverse “alive”.

As this is a work in progress, future development will focus on improving interactivity, visual fidelity, and audio feedback, while ensuring browser performance remains efficient. Once the Web-based Metaverse reaches a more mature stage, making the project open-source will be a crucial step to enable replication by other institutions.

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