Open Metaverse with Open Software

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Abstract. The metaverse is an increasingly popular social interaction, gaming, and education platform. In recent years there has been a growing interest in the Metaverse by various commercial firms in order to promote economic transactions and the development of applications in the world of digital and virtual interaction. With the widespread adoption of the metaverse concept, there is a growing need for open standards and open-source code related to the metaverse to ensure interoperability and enable innovation. Open standards enable different systems to communicate and share data, while open-source code promotes collaboration and transparency in development. This manuscript describes the importance of open standards and open-source code for developing metaverse technologies. We discuss the benefits of open standards for interoperability and innovation and examine case studies of successful open-source metaverse projects. We also discuss challenges in implementing open standards and open source code in metaverse development, including intellectual property concerns and governance issues. The open standards and open source code are essential for the metaverse's growth and sustainability. The developers and policymakers should prioritize these principles to ensure a the development of inclusive and open virtual environment. Our work aims to generate immersive, multiverse reality scenarios using dedicated graphics platforms for generating virtual environments.

Keywords: Metaverse · Augmented Reality · Virtual Reality · Blender · Unity · Virtual environment

1 Introduction

The metaverse is a complex and dynamic system that requires a high degree of interoperability to function effectively. Without open standards, developers must create custom solutions for each platform, resulting in a fragmented and siloed ecosystem. Open standards like those developed by the Khronos Group and the W3C enable different platforms to communicate and share data, reducing friction and promoting innovation. Similarly, open-source code is critical for metaverse development. By making code freely available, developers can collaborate

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and build on each other's work, leading to faster and more robust development. Open source code also promotes transparency and accountability, as developers can inspect the code to ensure it is secure and performs as intended. Several successful metaverse projects like OpenSimulator and Second Life have been built on open-source code and open standards. These projects have benefited from the contributions of a large and diverse community of developers, resulting in rich and engaging virtual worlds. However, implementing open standards and open-source code in metaverse development can be challenging. Intellectual property concerns can limit the adoption of open standards, while governance issues can arise when multiple stakeholders are involved in development. Additionally, concerns arise about the sustainability of open-source projects, as volunteer developers may need more resources to maintain the code long-term. Despite these challenges, open standards and open-source code are essential for the growth and sustainability of the metaverse. As the metaverse continues to evolve and expand, policymakers and developers should prioritize these principles to ensure an open and inclusive virtual environment.

2 Related Works

The term Metaverse first appeared in author Neal Stephenson's 1992 science fiction novel Snow Crash [1,2]. Regarding this novel, the author describes a sort of virtual world in which it is possible to access the whole world and in which the main characters, human beings, enter and live in a parallel virtual world through a transformation into software, in which one acts in the form of Digital Avatars, through the use of Virtual Reality (VR) equipment, to carry out actions of daily life.

Inside the virtual world, there are Digital Avatars which are the digital representation of human users within the Metaverse, where a user can create various Digital Avatars which can be of different types to each other such as, for example, they can be human Avatars, animal avatars, imaginary creature avatars. Subsequently, the Digital Avatar gradually transforms into an ideal form, which mirrors the outward appearance and reflects the ego of the human user and acquires a well-defined social role [3–5]. As regards the construction of the Digital Avatar, this is defined by the user; indeed, a reasonable reconstruction of the face is significant. It is generally based on a 3D Morphable model [6–8] generated by the Principal Component Analysis (PCA) algorithm; only the performance is limited by the amount of data and the difficulty of facial expression. In recent years, the development of deep learning technology has made it possible to subsequently improve the degree of realism of the Digital Avatar to obtain highly photo-realistic 3D face models.

Concerning a 3D body reconstruction, many techniques are possible [9–11]. One of the most famous models is MANO, which adapts to the deep learning network to prevent, when scanning or acquiring data of the whole body, the low quality of the reproduction of the hands, as they are tiny [12]. By manipulating the Digital Avatar, the user creates its animation, thanks to the real-time

mapping of the user's movements, thus creating interactions [13,14]. Creating the virtual 3D scene [15] within the Metaverse is possible using two alternative ways: *physics-based construction* or *design-based construction*; both include the initialization phase, modelling and rendering. By studying in detail the construction of the virtual scene based on physics, laser scans are used to create digital twins whose name turns out to be 3D reconstructions [16].

Inside the Metaverse, there are two fundamental sources of information: one turns out to be the information from inputs from the real world, such as the information captured in the real world and visualized in the virtual world, and the information from the outputs of the virtual worlds, such as the information which the Digital Avatars, various digital objects and services of the virtual world generate. Considering the large amount of data, there is a need for authentication and access control, as well as data reliability, traceability and data privacy within the Metaverse [17,18]. From this, it is deduced that information is the central resource of the Metaverse and that it will eventually allow the coexistence of the virtual world with that of the real world. Social networks with mutual interactions between human beings interconnect human society [19]. Thus, the Metaverse shows singular characteristics that fully define it.

- *Immersivity*: it allows the user to feel completely immersed in the virtual world created by the computer in real-time. At the same time, it is essential to access the Metaverse through any device and browser [20], which respects the established specification (client-based rendering), and to allow more Digital Avatars to interact with other Avatars digital assets on multiple servers and allow users to search, view, trade and delete digital assets. In order to fortify the concept of greater immersion, some accessories are presented, for the future, which will allow more incredible sensation within the Metaverse to allow greater immersion [21]. Many companies are working on various innovations, such as the creation of a Metaskin [22,23]; this accessory enhances sensory sensation; this involves the use of a rubber containing a magnetic molecule, which is combined with Artificial Intelligence (AI) to allow the tactile sensation; this type of innovation is also extremely expensive today and in the development stage. Subsequently, the Meta bracelet is presented; when worn, this tool continuously traces the communication of the human nerve between the brain and the nerve. This tool is also based on Artificial Intelligence (AI). For a more excellent tactile sensation, meta gloves have been designed to improve the sensation of perception of objects or things touched. However, all these accessories are currently undergoing further studies and improvements.
- *Hyperspatiability*: it refers to breaking the limitations of time and space, as each user can move freely through various worlds with different spatiotemporal characteristics, thus allowing the experimentation of several different timelines, such as being able to experience set in past periods of history to experiences set in futuristic environments.
- *Sustainability*: it turns out to be particularly full of challenges, as, for one part, it should be an open economic cycle to allow the continuous interest

or curiosity of the user for the creation of new digital content or new digital innovations; on the other hand it should be a decentralized system to allow persistence over time and prevent it from being controlled exclusively by some entities [24].
- *Interpolarity*: it means that virtual world users can freely move through any sub-Metaverse simultaneously in different scenes and with different modes of interaction without interrupting the virtual experience [25,26].
- *Scalability*: it concerns the ability to manage multiple users and Virtual Avatars simultaneously, from the complexity of the scenes and the various modes of interaction, all with efficiency [27–31].
- *Heterogeneity*: it includes all the distinct implementations, distinct interfaces, types of data, communications, such as cellular and satellite communications, and the diversity of the human psyche of every human being [32].

Therefore, all these characteristics lead to a new space for social communication, with a high degree of freedom and a highly immersive view of the world. Virtual reality (VR) and Augmented reality (AR) are pillars in constructing the new world of Metaverse and have a wide range of applications across different fields. Some of the most common uses of VR include:

- *Gaming*: It provides an immersive experience to gamers, allowing them to feel as if they are a part of the game world. Indeed, one of the most popular uses of VR is in gaming [33].
- *Education and training*: VR can be used for educational [34,35] and training purposes [36,37].
- *Tourism and travel*: VR can be used to provide virtual tours of places that are difficult to access or that no longer exist. This includes virtual tours of historical sites, museums, and even space [38,39].
- *Sports*: VR can be used to simulate different sports environments, allowing athletes to train in a more realistic and immersive setting [40].
- *Architecture and design*: VR can be used to create 3D models of buildings and structures, allowing architects and designers to visualize their projects in a more immersive way [41,42].
- *Therapy and mental health*: VR can be used to treat anxiety disorders, phobias, and PTSD by creating a safe and controlled environment for patients to face their fears [43,44] but even to help patients in rehabilitation [45,46].
- *Marketing and advertising*: VR can be used to create immersive experiences for consumers, allowing them to interact with products and services in a more engaging way [47].
- *Art and entertainment*: VR can be used to create interactive art installations and immersive theatrical experiences.

3 The Proposed Solution

The development of Virtual Reality and Augmented Reality applications is constantly increasing. Creating a virtual world that is tangible to users and easy to

manage requires special hardware/software tools and trained professionals who are able to develop and then over time maintain the IT and software infrastructure needed to deliver services to users. The main software that developers must use when creating virtual worlds is the Video Game Engine, i.e. an application that allows the management of three-dimensional models, the simulation of lighting in real time and not, the use of any special graphic or sound effects, and above all the possibility of making the user interact with this virtual world using various input devices. These softwares are mainly used for the creation of video games, but can also be used for cinema, advertising and much more. Moreover, the video game product itself respects many of the characteristics sought in the Metaverse, making it the perfect base from which to start and then customise it according to each case.

Today, there are many graphics engines that can be adapted to the different needs of developers. The characteristics of a graphics engine vary depending on the target group you want to reach and the type of applications you want to realise. For the creation of complex three-dimensional virtual environments, the most widely used graphics engines are Unity[1] and Unreal Engine[2], which offer a complete development environment to manage the resources needed to create interconnected and customisable environments. The two engines have aspects in common and some differences. Both make it possible to create interactive virtual worlds and to take care of both the graphical aspects and the aspects of interaction with the scenario and ambient sound. If one wants to achieve a very high degree of graphical detail, Unreal Engine, particularly in the recently released version 5, allows for excellent results, but it will be necessary to take into account that users will have to be equipped with very high level hardware to fully enjoy the gaming experience realised. Unity, on the other hand, has a lower learning curve, a larger community, and allows the creation of applications with a very good graphic quality, suitable for both mobile applications and native applications for users' operating systems. Very high graphical results can also be achieved with Unity, but the time developers will have to dedicate to this will usually be greater. Preferences between graphics engines will depend on the implementation choices and objectives of the final product. Unity is suitable for the creation of complex environments and interactions using the programming language C# and offers several paid and/or free addons that can be downloaded from the official store. Unreal Engine, on the other hand, departs from its flexibility with programming languages in favour of complex and layered functions that maintain high graphical fidelity and an expensive but extremely realistic lighting system.

These graphics engines either do not offer any tools for the creation of three-dimensional models or offer simplified solutions that are only useful for a few special cases. Therefore, they will necessarily have to be flanked by professional three-dimensional modelling software in order to be able to create the 'physical' appearance of the environment in question using simple import-export

[1] https://unity.com/.
[2] https://www.unrealengine.com.

mechanisms of the available resources. Programs such as Blender[3], Cinema 4D[4], Autodesk Maya[5] and ZBrush[6] belong to this category, and are among the most well-known and used in the sector, both at a professional and amateur level. Thanks to the synergetic use of these tools, it is possible to obtain most of the virtual products available on the market, including video games, professional and non-professional simulators, illustrations and animated sequences in film or television series format.

With a view to creating increasingly complex environments, developers should take into account the enormous potential offered by the open source world. Among the aforementioned software, Blender is in fact distributed free of charge and under an Open Source licence by the *Blender Foundation*, and has been providing developers with a stable and reliable environment to create their works since 1998. Open source software plays a crucial role in the development of the metaverse and other three-dimensional environments. One example of this is the popular virtual world platform Second Life[7], which was released with open source code. Second Life was developed by Linden Lab, the teams has made their entire client software open source, allowing developers to create their own modifications and extensions. This has led to a thriving community of developers who have built everything from custom avatar animations to entire regions within the virtual world. The openness of the Second Life platform has not only fostered innovation and creativity but has also ensured the longevity of the platform by allowing it to evolve with changing technology and user needs.

Another example of the importance of open source in the metaverse is the OpenSimulator project[8]. OpenSimulator is an open-source software platform that allows users to create their own virtual worlds, similar to Second Life. However, unlike Second Life, OpenSimulator is completely open source, meaning that anyone can modify and improve the code. This has resulted in a diverse ecosystem of virtual worlds, each with its own unique features and user community. Moreover, the open nature of the OpenSimulator project has encouraged collaboration between developers and users, resulting in a community-driven platform that is responsive to user needs.

Allowing developers and students to freely access and modify the existing code of the metaverse projects, open source software can reduce barriers to entry and encouraged innovation. This will led to a proliferation of new virtual world platforms and applications, each with its own strengths and weaknesses. Morehover, this competition will led to better software for users, as developers are incentivized to create more user-friendly and feature-rich platforms.

Another key advantage of open source software in the metaverse is the ability to audit and verify the code. Because the source code is freely available,

[3] https://www.blender.org/.
[4] https://www.maxon.net/it/cinema-4d.
[5] https://www.autodesk.it/products/maya/overview.
[6] https://pixologic.com/.
[7] https://secondlife.com/.
[8] http://opensimulator.org.

the communities can inspect the code to ensure that it is secure and free from malicious code. This will help to prevent security breaches and other issues that could compromise user data or the stability of the virtual environment.

Today, a number of large companies and multinationals, such as Meta, are investing large amounts of capital in the development of hardware and software for virtual worlds. It is important to reflect and ponder on the implications these environments will have on people's lives and social relationships. Is it really acceptable to immerse ourselves in environments where there is no control over the privacy of our data and where we are unable to know what is being done with what is being collected in real time by the hardware being used?

Our research group pushes and coordinates many students both within the Bachelor's degree courses and in the thesis courses that aim to realise three-dimensional environments and works. First of all, it must be kept in mind that there is a big difference between the licence under which a graphics engine is released and the licence under which an application (such as a Metaverse) is released. Even if the graphics engines used have closed or partially closed source codes, we feel it is important to teach students the importance of sharing the source code of the projects with appropriate licences such as the GPL or MIT via secure and reliable platforms such as GitHub[9].

4 Case Studies

We present some use cases of metaverses developed by our research team also in collaboration with students in the Virtual Reality Systems course of the Computer Science degree program at the University of Perugia[10].

Although such projects are developed by young students who do not yet have the maturity of professional developers, they show how it is possible to implement very interesting use cases, often related to individual hobbies and passions, that introduce the realisation of metaverses at zero cost and with a very high degree of portability. The use of commercial software, if it is deemed appropriate to adopt it, will enable these young people to achieve higher quality standards and to embark on a successful professional life.

4.1 Virtual Theatre

This use case is extremely interesting and suggestive and originated from the passion for dance and classical music culture. It was implemented using Blender for the creation of shapes and models, which were then imported into Unity for movement and interaction management. Figure 1 shows some images of the scenario and a dancer performing dancing to a piece of classical music.

[9] https://github.com/.

[10] The course has been delivered since 2000 and introduces students to the realisation of virtual worlds with Web3D, Blender and Unity technologies. Particular attention is paid to achieving high quality standards in terms of scene realism, navigation speed and effective user interaction, optimising all aspects of project development.



Fig. 1. Scenes of the virtual theatre and of a boy dancing.

This metaverse allows user interaction in the playback of the music track, having all the tools to control the various parameters and control the dancer's movements.

4.2 Monuments and Landscape Views

Metaverses that reproduce landscape views, physical meeting corners in cities, and areas with monuments, constitute extremely stimulating scenarios where virtual visitors can experience pleasant interactions. These environments also lend themselves very well to conveying important social and cultural messages and keeping traditions and cultures alive, which over time tend to disappear due to changed habits and lifestyles.

This approach allows for the development of digital culture. It favours the digitization process of cultural heritage, which would bring significant advantages on a national scale, particularly in Italy and Europe.

4.3 Rooms and Places of Entertainment

During the period of the COVID-19 pandemic, some students recreated home environments such as virtual rooms, living rooms or offices and tried to recreate social and entertaining situations, as it was not possible to go to social venues due to government restrictions. The Fig. 2 shows 4 projects realised during the Virtual Reality course at the University of Perugia.



Fig. 2. Scenes of Virtual environments developed during the COVID-19

The realisation of an interactive environment must necessarily include the integration of features that enable users to communicate such as text and/or voice chat. In one project, which we have made publicly available on GitHub[11],

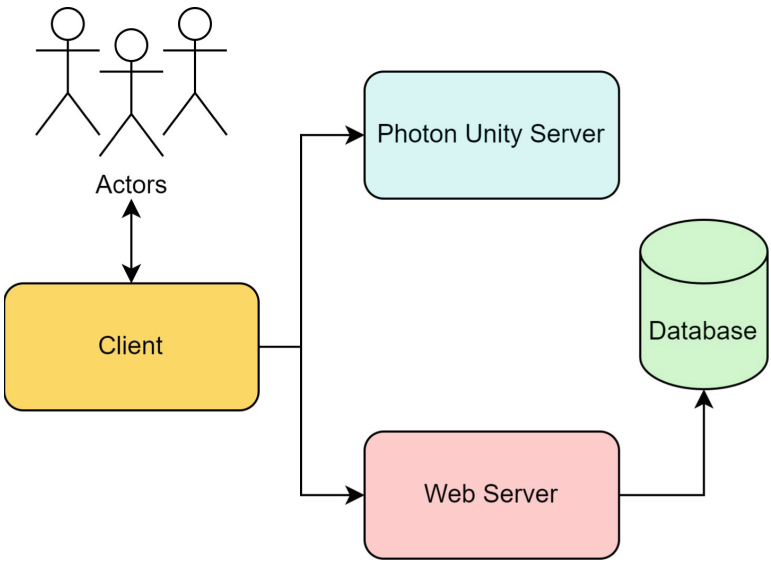

Fig. 3. Metaverse infrastructure

[11] https://github.com/DamianoP/openMetaverse.

we have created an environment where users can connect and communications are managed by a backend server with a MySQL database.

A significant piece of the application is shown in Fig. 3.

Users use a client, which is generated by the compilation of the metaverse from the Unity project. The client connects to an Apache Webserver on which PHP code is executed. The Webserver allows users to authenticate themselves with a username and password and checks that they are registered users within the database. If users are authenticated, they access the metaverse. Voice chat and text chat are then provided by a second server called Photon Unity Server.

5 Conclusions and Future Work

The metaverse is a digital realm that has become increasingly popular for social interaction, gaming, and education. The widespread adoption of the metaverse concept has created a growing interest among various commercial firms to promote economic transactions and the development of applications in the world of digital and virtual interaction. However, in order to ensure interoperability and enable innovation, there is a need for open standards and open-source code related to the metaverse. This article has discussed the importance of open standards and open-source code for developing metaverse technologies. We have highlighted the benefits of open standards for interoperability and innovation and examined case studies of successful open-source metaverse projects. In addition, we have discussed challenges in implementing open standards and open-source code in metaverse development, including intellectual property concerns and governance issues. One of the more significant benefits of open standards is that they enable different systems to communicate and share data. That is crucial for developing the metaverse because it allows users to move between different virtual environments seamlessly. Open standards also promote innovation by encouraging collaboration among developers and allowing for the creation of new tools and technologies. Open-source code is equally essential for the development of the metaverse because it promotes collaboration and transparency. Open-source code allows developers to build upon each other's work, accelerating the pace of innovation. In addition, open-source code provides greater transparency in development, which is crucial for ensuring the security and privacy of users. However, challenges are also associated with implementing open standards and open-source code in metaverse development. One major challenge is intellectual property concerns. Developers may hesitate to share their work if they are concerned about others profiting from their ideas. Another challenge is governance issues. With multiple stakeholders involved in metaverse development, there may be conflicts over who has the final say on development decisions. Despite these challenges, open standards and open-source code are essential for the growth and sustainability of the metaverse. Developers and policymakers should prioritise these principles to ensure the development of inclusive and open virtual environments. Our work aims to generate immersive, multiverse reality scenarios using dedicated graphics platforms to develop virtual environments. By incorporating

open standards and open-source code into the development of the metaverse, we hope to create a more collaborative and transparent environment that will promote innovation and benefit users.

Acronyms

The following acronyms are used in this manuscript:

AI Artificial Intelligence
AP Application Programming Interface
AR Augmented Reality
GPL GNU General Public License
IT Information Technology
JS JavaScript
KB KiloByte
MB MegaByte
MIT Massachusetts Institute of Technology
PCA Principal Component Analysis
PTSD Post-traumatic stress disorder
VR Virtual Reality
W3C World Wide Web Consortium

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