Metaverse: Survey on future of internet and its innovative applications*

Ansh Sindhwani[1,†], Sagar Ruhela[1,†], Anshul Bhatia[1,†], Ruchika Lalit[1,†] and Rahul Johari[1,*]

[1]**SWINGER** : **S**ecurity, **W**ireless, **I**oT **N**etwork **G**roup of **E**ngineering and **R**esearch,
University School of Automation and Robotics(USAR),
Guru Gobind Singh Indraprastha University, Delhi, India

Abstract

With key technologies like artificial intelligence, blockchain, internet of things and upcoming network capabilities of 6G mobile communication the current idea of the internet is bound to change. We expect a more immersive and interactive experience to enter our daily internet experience. Further creation of persistent, scalable and shareable virtual spaces will lead to the birth of Metaverse. The word Metaverse has been popularized in the common lexicon when the big tech giant 'Facebook' transformed itself as 'Meta'. Though the word itself traces its origin to Neal Stephenson's seminal 1992 novel, "Snow Crash", where it was introduced as a shared virtual reality space. Today the idea of metaverse remains similar where humans interact in a shared virtual environment that is beyond the current understanding of social media and internet browsing. The paper presents a survey on the future of the internet and considers its diverse applications, these applications include healthcare, education, digital tourism and digital twin which are pertinent to a modern idea of a more connected smart city. Through case studies like : "Gucci Visions" we aim to throw light on the current developments and future implications of this upcoming iteration in domain of Metaverse.

Keywords

Metaverse, Technology Integrations, Blockchain, Web3.0, City Digital Twin

1. Introduction

Considered to be a post-reality universe, the 'Metaverse' is a compendium of perpetual and persistent multi-usability platform/ environment that imbibes a fusion of physical reality with the digital reality. Although, there is no consensual definition for metaverse in the published literature, we can view it as a new iteration of the internet that will utilize a 3D modeled virtual world that can be accessed through VR Headsets, Augmented Reality glasses or a browser, allowing for multimodal interactions with digital products/services/spaces. It will be enabled by technologies like blockchain, artificial intelligence and advanced network infrastructure.

As a future tech-enabling universe, the 'Metaverse' does not denote a specific technology; but it does indicate the evolving bandwidth that may encompass human-to-human, human-to-technology, human-to-products/services/spaces, so on and so forth pluriverse worlds.

SCCTT-2024: International Symposium on Smart Cities, Challenges, Technologies and Trends, 29th Nov 2024, Delhi, India
* Corresponding author.
† These authors contributed equally.
rahul@ipu.ac.in(R. Johari); anshsindhwani007@gmail.com (A. Sindhwani); sagarruhela89@gmail.com (S. Ruhela); anshulbhatia.usar@ipu.ac.in(A.Bhatia);
0000-0002-7675-8550 (R. Johari); 0009-0007-9565-1277 (A. Sindhwani); 0009-0002-0615-5495 (S. Ruhela); 0000-0001-6243-2982(A.Bhatia); 0000-0002-9171-5014 (R.Lalit)

Metaverse is evolving through unique, innovative and tech-enabled methodologies to aid the future of communications and interactions in real-time. In the realm of the fast-evolving communications and aesthetics associated with the Open-Source Platforms, there are new challenges in the contemporary iterations of the Metaverse: featuring especially the social, immersive VR platforms that are compatible with massive multiplayer online video games, open game worlds and equivalent AR collaborative space(s) and Brain- Computer Interfaces (BCIs) / Brain-Machine Interfaces (BMIs)/ smart brain.

The metaverse traces its roots to Neal Stephenson's seminal 1992 novel, "Snow Crash," where it was introduced as a shared virtual reality. This initial conceptualization, though born of fiction, sparked the imagination of technologists and creators. The subsequent evolution of technology, particularly within the gaming sphere, began to transform this fiction into reality. Early instances of the metaverse were encapsulated within multiplayer online games, serving as precursors to the expansive interconnected digital landscapes we envision today. Games like Second Life[25] pioneered user-driven persistent virtual environments, where social interactions, creativity, and commerce flourished. These early endeavors laid the groundwork for the metaverse's development beyond entertainment.

Gaming, a cornerstone of the technological realm, played a pivotal role in the metaverse's evolution. Virtual worlds, exemplified by iconic titles such as World of Warcraft[26], Roblox[27] and Minecraft[28], emerged as foundational spaces that demonstrated the core attributes of the metaverse. These platforms transcended mere games, serving as interconnected realms where participants collaboratively shaped their experiences. The success of these gaming platforms highlighted the allure of immersive digital environments that facilitate real-time interactions, creativity, and exploration. Users found themselves drawn into these virtual landscapes, experiencing a sense of presence and connectivity that foreshadowed the metaverse's broader potential.

The concept of the metaverse has expanded beyond gaming and entertainment, infiltrating diverse sectors and applications. Social media platforms are increasingly incorporating metaverse-like features, enabling users to engage in virtual events, interactions, and commerce. Moreover, the advent of advanced technologies such as virtual reality (VR) and augmented reality (AR) has propelled the metaverse's progression. As these technologies continue to evolve, the metaverse's promise becomes even more apparent. Interconnected virtual worlds and digital identities hold the potential to revolutionize not only entertainment but also education, collaboration, commerce, societal interactions and even management of a city. The evolution from science fiction to this burgeoning digital reality underscores the metaverse's significance as a transformative force that stands poised to reshape the way we connect, learn, and experience the digital world. It has implications in sectors like tourism, governance, traffic management, environmental sustainability and urban planning.

2. Review of Literature

The formal text explains that Metaverse comprises multiple components namely - hardware components, software components and content. The hardware consists of head mounted displays and input devices. Software cater to the need of motion rendering, sound and speech recognition, scene/object recognition and scene/object generation. The third component is the content. Content is the pillar of Metaverse that is crucial for providing the immersive experience promised by the idea.[1] The Metaverse relies on content as its foundational element, ensuring an engaging experience through well-crafted narratives and user-generated activities. Focusing on story authenticity, immersive engagement, and conceptual coherence, content creation can be approached through a paradigm shift or by repurposing existing material. Environmental design encompasses scene creation, color and lighting, audio elements, sampling and aliasing, navigational aspects, and real-

life content. User movements, characters, and avatar personalities all contribute to behavioral modelling.
However, achieving the proposed metaverse idea is a multi-staged process. As elaborated by [2] achieving duality will require sequential stages, namely (I) digital twins, (II) digital natives, and eventually (III) co- existence of physical-virtual reality or namely the sureality. Digital twin refers to a replica of real-world objects and environments on digital platforms. They try to simulate the real characteristics of an object in the digital world. Once these digital copies are made the next stage is to create "digital natives." This basically refers to creation of new content exclusive to the metaverse realm. In the third and last stage, the metaverse could become a self-sustaining and persistent virtual world that co-exists and interoperates with the physical world with a high level of independence. As such, the avatars, representing human users in the physical world, can experience heterogeneous activities in real-time characterized by unlimited numbers of concurrent users theoretically in multiple virtual worlds.

The role of blockchain technology is critical in realizing the shared virtual reality. In a shared virtual environment like metaverse, blockchain technology will provide a means of digital ownership. It enables trusted ways of proving authenticity as well as interoperability. A blockchain infrastructure can ensure that authentic data is loaded to the metaverse. Blockchain will also play a pivotal role in establishing the metaverse economy by providing a means of exchange in the digital world. [3]

Immutable Identifiers i.e. NFTs in Web3.0 open new challenges, but also dynamic experiences. Several industrial leaders have stated that the Metaverse's full potential can only be attained if it is constructed on open standards. The Metaverse Standards Forum provides leading standards organizations and companies a platform to foster interoperability standards for an Open Metaverse. An NFT, for example can be utilized in a 2D Smartphone game or an 3D virtual headset apart from being shown in digital and physical art galleries. Immutability feature of blockchains makes it a significant factor driving in new digital and hybrid economic activities. It allows for scalable and reliable methods to demonstrate authenticity and interconnectivity.

In [4] authors introduce Metaverse-as-a-service where they suggested a concept of metaverse platforms as a service to business owners and alike over the network. Facilitating scalable computing resources on demand over the internet is a common facility available to business users and individual users. Using products like google drive, office 365 is not uncommon. All these follow an "as-a-service" model under the aegis of cloud computing. similarly, we can offer services relevant to Metaverse where key technologies related to Metaverse can be provided. Services such as platforms, infrastructures, software, and artificial intelligence (AI), could be provided as through Metaverse-as-a-service (MaaS). As FAANG companies enter the Metaverse space, Like Microsoft, Samsung, NVIDIA, and others, it won't be long before many cloud-based services would offer Metaverse-as-a-Service (MaaS) option, allowing businesses to profit from the technology with lowered entry barriers.

3. Applications of Metaverse

Introduction of augmented reality and virtual reality in gaming and entertainment is the starting point of a more immersive internet and better human computer interfaces. Games like Pokémon Go, Fortnite and Minecraft provide a better social gaming environment allowing users to collaborate and compete in real time. Hence, entertainment and gaming are natural applications of metaverse. But the applications of metaverse are not limited to gaming and entertainment. Various studies regarding potential applications have been published. These applications include healthcare, advertising, education and e-

commerce to name a few. Metaverse has a potential of changing our life, society and economy through its innovative and immersive applications.

I. EDUCATION

Education and experiential learning through metaverse are at the forefront of these applications. One can imagine being trained in virtual environments and through immersive simulations before practicing in the physical world. This will increase efficiency and proficiency of the apprentice. Learning in the metaverse will also lower the cost of training and lower the time of training as the apprentice will not be limited by the availability of teachers. Metaverse learning will expand the reach of education as it will not be limited to geographical bounds catering to a wider audience.

In [5] authors highlight the possibilities and limitations of Metaverse education. The authors also introduce the idea of 4 types of metaverse that can be used for educational purposes. These are (1) augmented reality, (2) virtual reality, (3) mirror world and (4) lifelogging. These modes of metaverse can be successfully implemented for creating virtual labs, training modules and overlaying on the physical world for an enhanced pedagogy. Students can learn visually through 3-dimensional digital twin, overlay information on physical objects, interact with artificial intelligence enabled characters of historic figures, create virtual tours of historic places and make science models in virtual reality to gain hands-on experience and learning.

Authors of [8] created a virtual campus of Nanyang Technical University, Singapore through the Nvidia omniverse platform called NTUniverse. NTUniverse allows students to engage in virtual hands-on activities, online discussions, and collaborative team projects. It serves as a platform for interactive and immersive learning experiences in STEM education. The platform also supports the learning of abstract mathematics concepts through interactive manipulation of virtual objects. This approach helps students grasp complex ideas like Vector Cross Product and Skew line Distance by interacting with virtual models.

II. HEALTHCARE

Healthcare in metaverse points towards to the virtual environment consisting of various technologies like augmented reality (AR), virtual reality (VR), and extended reality (XR) to give the healthcare its functionality and medical process. In the healthcare virtual simulation or healthcare metaverse people can conduct lots of thing from their home like conducting more immersive and real consulting with doctors, patients can meet with doctors in 3d world. Use of digital twins for surgery planning and real time analysis and monitoring. These technologies offer innovative solutions for telemedicine, medical education, mental health support, and clinical care which is used for solving common person problem way better than before. On top of that healthcare in metaverse enables lots of immersive training for medical students through which the training is fast, accurate and precise. Inside the Virtual world students can practice surgeries and other medical procedures. The author(s) of [24] discuss a partnership with 8chili [30], a California-based software business and Global Healthcare Academy (GHA) aims to establish an EdTech platform that will enable medical education and healthcare to be accessible across the metaverse. More than 200 hours (about one week and a half's worth) of virtual reality (VR) content covering a wide range of subspecialties, such as paramedics, cancer, dentistry, orthopedic, neurology, spine, and ENT, have already been released by the alliance. The author(s) of [24]also describes an EdTech platform called Studyum[29] that offers spaces where group projects for student training or education would be organized. It encourages cooperation throughout society by using a reward system. Users receive tokens for each class they attend, video they watch, and homework they turn in. As a result, it offers various learning materials and training programs according to performance and training. An example of a trainer may be a "celebrity surgeon," who would be paid for his education and provide awards to pupils in honor of their accomplishments.

III. SMART CITIES AND DIGITAL TWIN OF CITIES

Smart Cities are going to use digital technology and data driven approach to make our lives and work easy. We can access lots of services from our home with the help of smart cities. Some of those services includes meeting people online, intercountry meeting, business opportunities, smart governance, more enhance online shopping and entertainment. With the help of metaverse and others technologies like artificial intelligence, digital twins, augmented and virtual reality, blockchain, and cloud computing, the concept of smart cities is possible which can also be used to create an interconnected and immersive virtual environment in which users or common public easily interact with the help of avatars. Now the concept of smart cities not just concept but governments around the world are making cities smart by investing huge sum of money example Seoul (The capital city of South Korea) plans to invest $3.3 billion to become metaverse city, even UAE also announced its plans towards making a virtual or smart city. There are lots of benefits from smart cities like improving teamwork with the help of real time collaboration with the help of Extended reality (XR), new business opportunities with the help of Virtual Reality(VR).

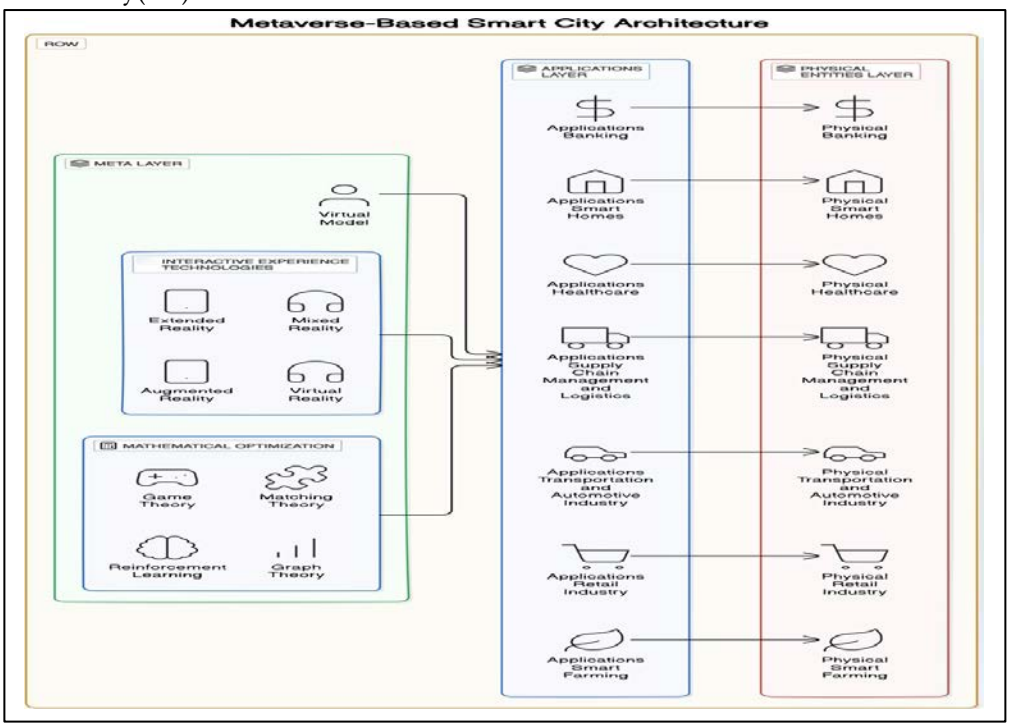

Figure 1: Metaverse Based Smart City Idea

IV. DIGITAL TOURISM AND RECREATION

Digital tourism in metaverse refers to use of virtual reality to mimic the travel experience for user from their home. This will allow user to explore and interact with digital models of real-world monuments and exotic destinations. This concept leverages various immersive and scalable technologies. These include the use of artificial intelligence, AR/VR and 3D modelling. The concept goes beyond making a digital twin of real-world monument and opens doors for making new virtual experiences. People can travel virtually with friends or other users in the metaverse, joining group tours or exploring destinations together, replicating the social aspects of physical travel. The metaverse can also allow tourists to travel through time to witness historical events. Digital tourism brings accessibility to tourism for people with physical disabilities and financial constraints.

V. DIGITAL RETAIL AND E-COMMERCE

Digital retail and ecommerce through Metaverse bring a new stage of online shopping, with

virtual environment providing tailored shopping experience. In metaverse customers can browse virtual stores and try products virtually. Metaverse allows user to purchase both NFTs and real-world goods that would be delivered at customer's location after purchase. The retail stores can be equipped with AI powered sales avatars for a more realistic and immersive experience.

Figure 2: Evolution of commerce with metaverse

4. Key Technologies related to Metaverse Development

Metaverse is an amalgamation of multiple existing technologies which serve as fundamental pillars to metaverse and its immersive nature. The key technologies that are driving the democratization of metaverse include (i)Artificial Intelligence, (ii)virtual reality and augmented reality, (iii)cloud computing, (iv)5G internet, (v)blockchain and (vi) internet of things. These technologies provide scalability for virtual environment, immersion, help in content creation and provide interconnections

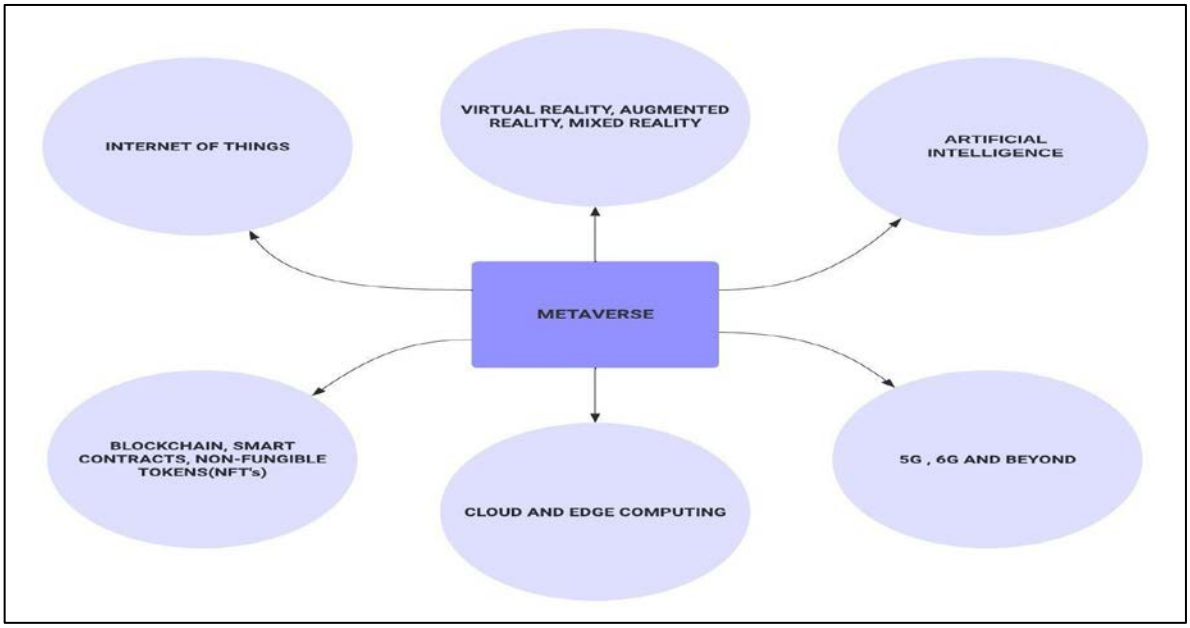

Figure 3: Key Technologies for Metaverse

These technologies are pivotal to provide features that are pivotal to metaverse and beyond reality experience. These key metaverse features are based on literature review with brief description and presented in the table 1.

Feature	Description
Immersion	Allowing users to interact and engage through multiple channels, these mediums can be virtual reality, augmented reality, chatbots, 3d-game objects. This can be obtained using AI, AR/VR, haptic technology
Realistic	The experience of metaverse should be close to real world. Use of game physics simulations should be implemented.
Digital Ownership	the system should be able to have protocols and data structures enabling digital ownership in decentralized manner. This can be achieving through blockchain technology
Scalable	The system should be able to support the growing number of avatars, virtual worlds, 3d-objects and users
Interoperable	Able to communicate with other virtual environments and systems, Avatars or digital user should be able to switch between virtual environments with same virtual identity

Table 1: Description of metaverse features

5. Current progress in Metaverse

Currently Metaverse is in developmental stage and big companies are betting on its success. Notably "Meta" is extensively working on building virtual environments and better hardware for accessing the Metaverse. This hardware includes better AR and VR headsets as well as new haptic based hardware like haptic gloves, haptic suits etc. for better interaction with the metaverse.
Games like Roblox, Fortnite and Minecraft are working on there VR versions as a step forward towards metaverse. Today most major companies have a VR or AR headset offerings. Microsoft HoloLens [31], Apple's Vision pro [32] and Meta quest [33] are some prominent examples. Sandbox [34], decentraland [35] and somium space [21] are some prototypes of metaverse.

6. Case Study

Considering the upcoming changes towards metaverse the team analyzed "Gucci Visions" and as precursors towards the new iteration of internet. The team has presented a use case diagram, flow diagram and a sample algorithm which can serve as intuitive models for creation of a more immersive and experiential internet that is the metaverse.

Gucci Visions is virtual model of Gucci's premium store in Italy which aims to portray the company's vision for the future, Metaverse and virtual reality visits of the store. it gives a digital/virtual tour of "Palazzo Della Mercanzia", it sets a precedence for Metaverse tourism, metaverse marketing and E- commerce. The model navigates through the store and provide an immersive experience of the store through virtual reality. This serves as a precursor to the realm of digital tourism through metaverse. The team studied the virtual environment and have presented a use case diagram in figure 2 and a flow diagram in figure 3. These virtual tours can be beneficial for smart cities.

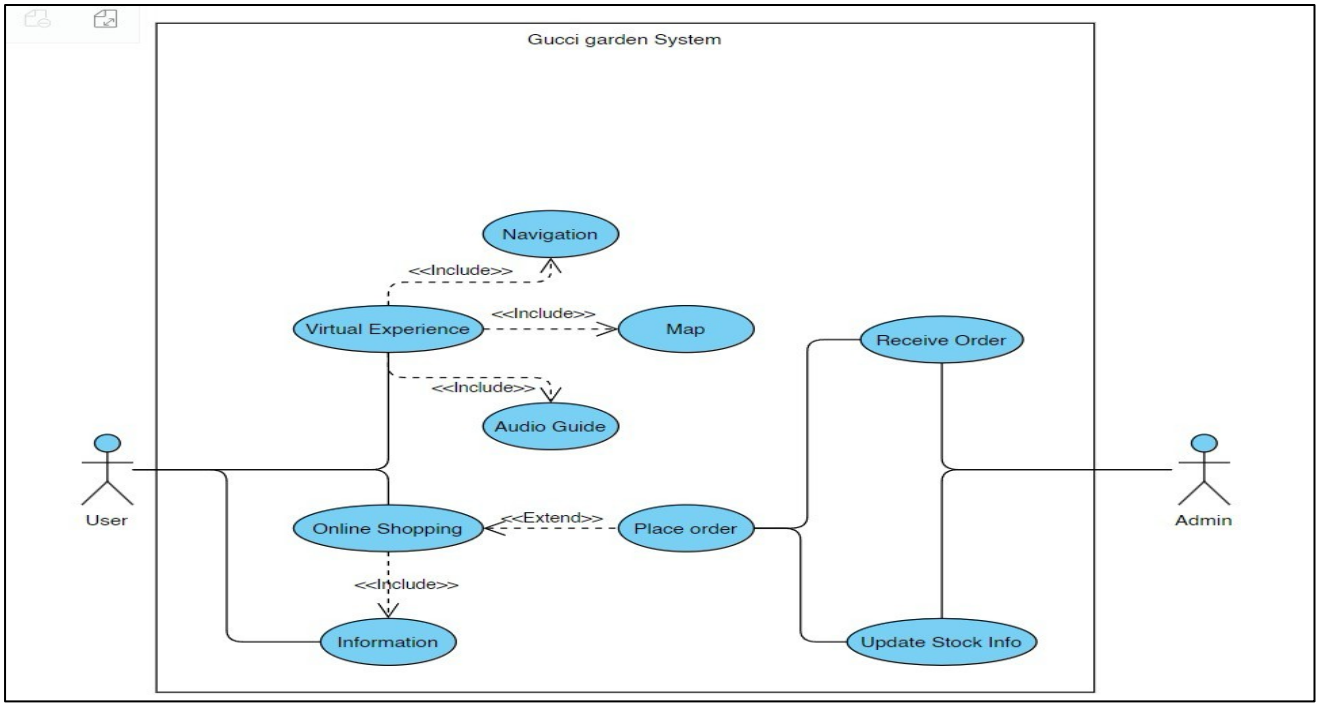

Figure 4: use case diagram of Gucci Garden

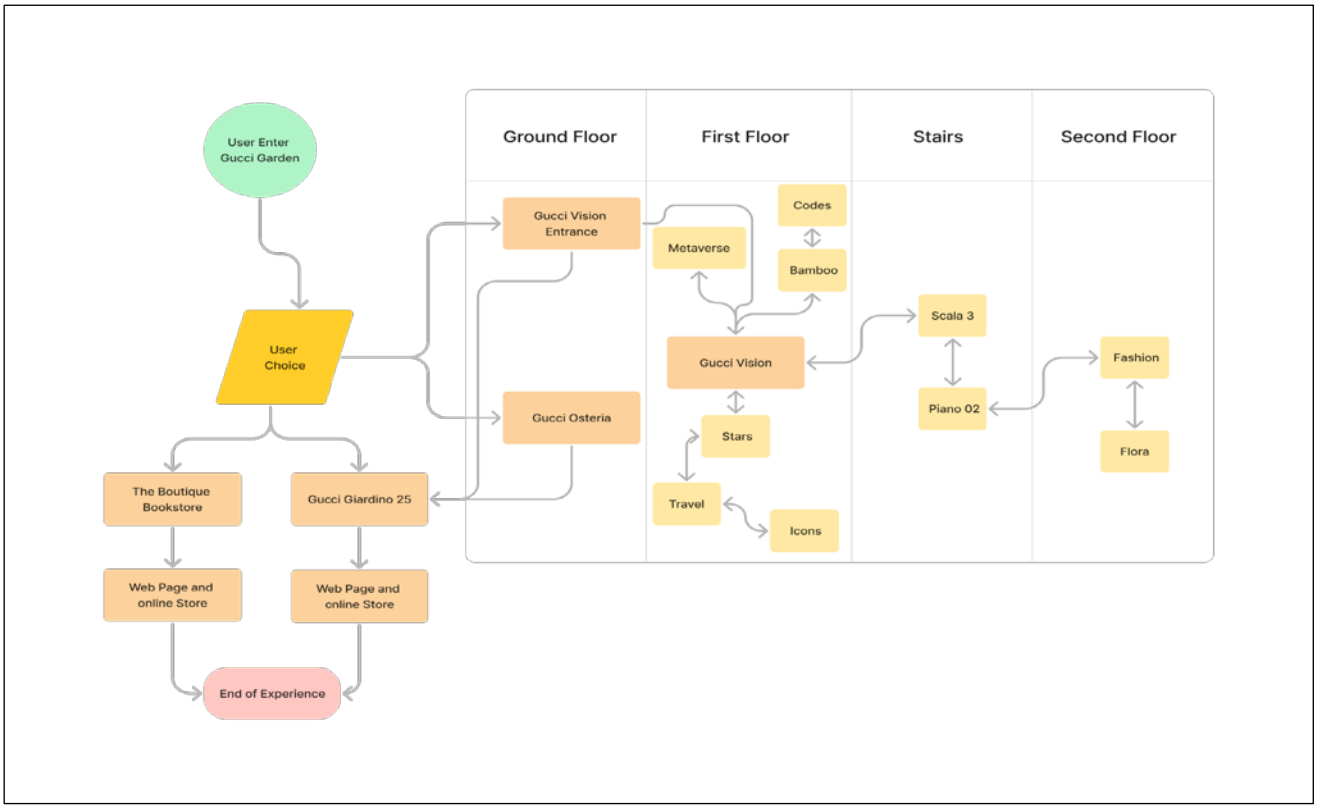

Figure 5: flow diagram of Gucci Garden

Algorithm : Metaverse Algorithmic framework for Gucci Garden Case Study
[URL : https://guccipalazzo.gucci.com/#/en/360/piano-1/travel]

Notation

1: S_r – Server
2: B_r – Metaverse Broker; where B_r is with in S_r
3: F_r – Frame
4: S_f – Frame per second
5: A_v – Avatar
6: $A_v[\ ]$ – Array of Avatar where every $A_v \epsilon\ A_r$
7: $VA_s[\ ]$ - Values Table of Avatar at Server
8: $VW_s[\ ]$ - Virtual Walkthrus
9: M_q – Manenquin
10: $M_q[\ ]$ – Array of Manenquins in Studio
11: G_s - Gucci Stores
12: G_v – Gucci Visions
13: G_o – Gucci Osteria
14: G_g – Gucci Giardino
15: $V\ G_{vl}[\ ]$ – Glasses/Lenses available in Gucci Visions
16: $V\ G_{lp}[\ ]$ – Array of products available in Gucci Osteria
17: $V\ G_{gp}[\ ]$ – Array of products available in Gucci Giardino
18: C_r – Customer
19: C_{rb} – Customer Bucket

Pre-requisite :
Customer enters Gucci Store(G_s)

Trigger :-
20: A_v welcomes C_r
21: C_r set up S_f
22: A_v prompts C_r for valid G_s ; where in valid $G_s \epsilon\ [G_v \,||\, G_v \,||\, G_v]$
23: if G_s is G_v
24: {
25: C_r interacts with M_q during $VW_s[\ ]$ in G_v
26: $C_{rb} \leftarrow V\ G_{vl}[\ ]$ }
27: elseif (G_s is is G_{lp})
28: {
29: $C_{rb} \leftarrow V\ G_{lp}[\ ]$ }
30: else
31: {
32: $C_{rb} \leftarrow V\ G_{gp}[\ ]$
33: }
34 : else
35: {
36: print (“Not a Valid G_s”);
37: print(“Try again”);
38: }
39: Sold Item information updated with $B_r(S_r)$;

7. Challenges to Metaverse

Currently development of Metaverse faces several challenges for its full realization. These challenges span across multiple dimensions. These challenges include technological, social, ethical and economic challenges. Table 2 presents the various challenges to Metaverse based on the reviewed literature.

Challenge	Description
Scalability	Creating a Metaverse that can handle millions of users parallelly across vast virtual spaces is a prominent challenge. Metaverse requires vast amount of 3d rendering, blockchain mining and implementation of AI models.
Hardware Limitation	Current hardware for virtual reality and augmented reality is limited in there capabilities. Currently these devices have limited battery life and are bulky. Hardware that supports Haptics is currently in early developmental stage.
Network speed and Latency	Metaverse needs high network bandwidth and low latency, even better than the currently available 5G mobile internet and Wi-Fi 6
Content Creation and Management	Metaverse relies on vast amount of 3D models, Digital environments, Animations and Avatars. Creation of these high-quality objects are time consuming and expensive. Managing this content is complex across platform. It requires help of generative AI and increased skilled workers.
Privacy and Security	This expanded iteration of internet is expose more public to new security threats and higher privacy concerns.
Digital Governance and regulations	With increased use of NFTs, Cryptocurrencies and an expanded digital environment, Metaverse require some oversite and policy changes to ensure citizens safety from cyber harassment, cyber frauds and prevent any occurrence of Criminal activity.

Table 2: Challenges to Metaverse

8. Conclusion

Metaverse represents a shift in how we will perceive internet and web based services in times to come. Its goal is to create a scalable virtual and augmented reality based ecosystem which is more immersive. It aims to blend the physical and digital world. As highlighted by this paper Metaverse converges technologies like artificial intelligence, blockchain, IoT, Virtual reality(VR), Augmented reality (AR). Frameworks “gucci garden” are trying to leverage the given idea and form a precursor to Metaverse.

Smart Cities can leverage Metaverse for citizen centric services, real time information sharing and promote digital tourism. They can use metaverse for virtual city council meetings and monitor various services through a synergy of physical and digital world. The aforementioned Case study showcase early implementations of Metaverse that point towards a broader future where virtual environments become essential to industries like retail, tourism, urban planning, and entertainment

References

[1] Park, Sang-Min, and Young-Gab Kim. "A metaverse: Taxonomy, components, applications, and open challenges." *IEEE access* 10 (2022): 4209-4251.

[2] Lee, Lik-Hang, Tristan Braud, Pengyuan Zhou, Lin Wang, Dianlei Xu, Zijun Lin, Abhishek Kumar, Carlos Bermejo, and Pan Hui. "All one needs to know about metaverse: A complete survey on technological singularity, virtual ecosystem, and research agenda." *arXiv preprint arXiv:2110.05352* (2021).

[3] Gadekallu, Thippa Reddy, Weizheng Wang, Gokul Yenduri, Pasika Ranaweera, Quoc-Viet Pham, Daniel Benevides da Costa, and Madhusanka Liyanage. "Blockchain for the Metaverse: A review." *Future Generation Computer Systems*143 (2023): 401-419.

[4] Ahsani, Vesal, Ali Rahimi, Mehdi Letafati, and Babak Hossein Khalaj. "Unlocking Metaverse-as-a- Service The three pillars to watch: Privacy and Security, Edge Computing, and Blockchain." *arXiv preprint arXiv:2301.01221* (2023).

[5] Kye, Bokyung, Nara Han, Eunji Kim, Yeonjeong Park, and Soyoung Jo. "Educational applications of metaverse: possibilities and limitations." *Journal of educational evaluation for health professions* 18 (2021).

[6] Mustafa, Bahaa. "Analyzing education based on metaverse technology." *Technium Soc. Sci. J.* 32 (2022): 278.

[7] Hwang, Gwo-Jen, and Shu-Yun Chien. "Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective." *Computers and Education: Artificial Intelligence* 3 (2022): 100082.

[8] Sim, Jing Kai, Kaichao William Xu, Yuyang Jin, Zhi Yu Lee, Yi Jie Teo, Pallavi Mohan, Lihui Huang et al. "Designing an Educational Metaverse: A Case Study of NTUniverse." *Applied Sciences* 14, no. 6 (2024): 2559.

[9] Chengoden, Rajeswari, Nancy Victor, Thien Huynh-The, Gokul Yenduri, Rutvij H. Jhaveri, Mamoun Alazab, Sweta Bhattacharya, Pawan Hegde, Praveen Kumar Reddy Maddikunta, and Thippa Reddy Gadekallu. "Metaverse for healthcare: A survey on potential applications, challenges and future directions." *IEEE Access* (2023).

[10] Dilibal, Cinay, and Yalcin Tur. "Implementation of developed esantem smart healthcare system in metaverse." In *2022 International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT)*, pp. 1027-1031. IEEE, 2022.

[11] Koo, Huilyung. "Training in lung cancer surgery through the metaverse, including extended reality, in the smart operating room of Seoul National University Bundang Hospital, Korea." *Journal of educational evaluation for health professions* 18 (2021).

[12] Kim, Jooyoung. "Advertising in the metaverse: Research agenda." *Journal of Interactive Advertising* 21, no. 3 (2021): 141-144.

[13] Samarnggoon, Keattikorn, Supara Grudpan, Noppon Wongta, and Konlawat Klaynak. "Developing a Virtual World for an Open-House Event: A Metaverse Approach." *Future Internet*15, no. 4 (2023): 124.

[14] Wang, Fei-Yue, Rui Qin, Xiao Wang, and Bin Hu. "Metasocieties in metaverse: Metaeconomics and metamanagement for metaenterprises and metacities." *IEEE Transactions on Computational Social Systems* 9, no. 1 (2022): 2-7.

[15] Lim, Wei Yang Bryan, Zehui Xiong, Dusit Niyato, Xianbin Cao, Chunyan Miao, Sumei Sun, and Qiang Yang. "Realizing the metaverse with edge intelligence: A match made in heaven." *IEEE Wireless Communications* 30, no. 4 (2022): 64-71.

[16] Liu, Guangyuan, Hongyang Du, Dusit Niyato, Jiawen Kang, Zehui Xiong, Abbas Jamalipour, Shiwen Mao, and Dong In Kim. "Fusion of Mixture of Experts and Generative Artificial

Intelligence in Mobile Edge Metaverse." *arXiv preprint arXiv:2404.03321* (2024).
[17] Huynh-The, Thien, Quoc-Viet Pham, Xuan-Qui Pham, Thanh Thi Nguyen, Zhu Han, and Dong- Seong Kim. "Artificial intelligence for the metaverse: A survey." *Engineering Applications of Artificial Intelligence* 117 (2023): 105581.
[18] Aslam, Anjum Mohd, Rajat Chaudhary, Aditya Bhardwaj, Ishan Budhiraja, Neeraj Kumar, and Sherali Zeadally. "Metaverse for 6G and beyond: The next revolution and deployment challenges." *IEEE Internet of Things Magazine* 6, no. 1 (2023): 32-39.
[19] Wang, Yuntao, Zhou Su, Ning Zhang, Rui Xing, Dongxiao Liu, Tom H. Luan, and Xuemin Shen. "A survey on metaverse: Fundamentals, security, and privacy." *IEEE Communications Surveys & Tutorials* 25, no. 1 (2022): 319-352.
[20] "Gucci visions", Gucci,last accessed on 27th june 2024 , https://guccipalazzo.gucci.com/#/en/.
[21] Somnium Space documentation, "Somnium space", last accessed on 30th august 2024 https://somniumspace.com/documentatio
[22] Yaqoob, Ibrar, Khaled Salah, Raja Jayaraman, and Mohammed Omar. "Metaverse applications in smart cities: Enabling technologies, opportunities, challenges, and future directions." *Internet of Things* (2023): 100884.
[23] Allam, Zaheer, Ayyoob Sharifi, Simon Elias Bibri, David Sydney Jones, and John Krogstie. "The metaverse as a virtual form of smart cities: Opportunities and challenges for environmental, economic, and social sustainability in urban futures." *Smart Cities* 5, no. 3 (2022): 771-801.
[24] Bansal, Gaurang, Karthik Rajgopal, Vinay Chamola, Zehui Xiong, and Dusit Niyato. "Healthcare in metaverse: A survey on current metaverse applications in healthcare." *Ieee Access*10 (2022): 119914-119946.
[25] "Official Site: Second Life - Virtual Worlds, Virtual Reality, VR, Avatars, and Free 3D Chat." Official Site | Second Life - Virtual Worlds, Virtual Reality, VR, Avatars, and Free 3D Chat. Accessed October 13, 2024. https://secondlife.com/.
[26] Entertainment, Blizzard. "World of Warcraft®: The War WithinTM Now Live!" World of Warcraft. Accessed October 13, 2024. https://worldofwarcraft.blizzard.com/en-us/.
[27] "Home - Roblox." Roblox Corporate. Accessed October 13, 2024. https://corp.roblox.com/.
[28] "Welcome to the Official Site of Minecraft." Minecraft.net. Accessed October 13, 2024. https://www.minecraft.net/en-us.
[29] "The Future of Decentralized Learning." Studyum. Accessed October 13, 2024. https://www.studyum.org/.
[30] "HINTVRTM Training and Engagement." 8chili. Accessed October 13, 2024. https://www.8chili.com/.
[31] "Microsoft Hololens: Mixed Reality Technology for Business." Microsoft HoloLens | Mixed Reality Technology for Business. Accessed October 13, 2024. https://www.microsoft.com/en-in/hololens.
[32] "Apple Vision Pro." Apple. Accessed October 13, 2024. https://www.apple.com/apple-vision-pro/.
[33] Meta Quest MR, VR Headsets & Accessories. Accessed October 13, 2024. https://www.meta.com/quest.
[34] "The Sandbox Game - Own the Future. Play, Create, Earn." The Sandbox. Accessed October 13, 2024. https://www.sandbox.game/en/.
[35] "Decentraland Player Documentation." Decentraland Documentation. Accessed October 13, 2024. https://docs.decentraland.org/player/.
[36] "WebXR Device Api." W3C, September 27, 2024. https://www.w3.org/TR/webxr/.