future internet

Article

The Meta-Metaverse: Ideation and Future Directions

Mohammad (Behdad) Jamshidi [1,*], Arash Dehghaniyan Serej [2], Alireza Jamshidi [3] and Omid Moztarzadeh [4,5]

[1] The International Association of Engineers, 37-39 Hung To Road, Hong Kong, China
[2] Department of Mechatronics Engineering, Qazvin Branch, Islamic Azad University, Qazvin 3471993116, Iran
[3] Dentistry School, Babol University of Medical Sciences, Babol 4717647745, Iran
[4] Department of Stomatology, University Hospital Pilsen, Faculty of Medicine in Pilsen, Charles University, 323 00 Pilsen, Czech Republic
[5] Department of Anatomy, Faculty of Medicine in Pilsen, Charles University, 323 00 Pilsen, Czech Republic
* Correspondence: bmj.jmd@gmail.com

Abstract: In the era of digitalization and artificial intelligence (AI), the utilization of Metaverse technology has become increasingly crucial. As the world becomes more digitized, there is a pressing need to effectively transfer real-world assets into the digital realm and establish meaningful relationships between them. However, existing approaches have shown significant limitations in achieving this goal comprehensively. To address this, this research introduces an innovative methodology called the Meta-Metaverse, which aims to enhance the immersive experience and create realistic digital twins across various domains such as biology, genetics, economy, medicine, environment, gaming, digital twins, Internet of Things, artificial intelligence, machine learning, psychology, supply chain, social networking, smart manufacturing, and politics. The multi-layered structure of Metaverse platforms and digital twins allows for greater flexibility and scalability, offering valuable insights into the potential impact of advancing science, technology, and the internet. This article presents a detailed description of the proposed methodology and its applications, highlighting its potential to transform scientific research and inspire groundbreaking ideas in science, medicine, and technology.

Keywords: meta-metaverse; sustainability; biology; genetics; economy; medicine; environment; gaming; digital twins; Internet of Things; artificial intelligence; machine learning; psychology; supply chain; social networking; smart manufacturing; politics

Citation: Jamshidi, M.; Dehghaniyan Serej, A.; Jamshidi, A.; Moztarzadeh, O. The Meta-Metaverse: Ideation and Future Directions. *Future Internet* **2023**, *15*, 252. https://doi.org/10.3390/fi15080252

Academic Editors: José Gómez-Galán, Diego Vergara and Dimitris Mourtzis

Received: 4 June 2023
Revised: 16 July 2023
Accepted: 25 July 2023
Published: 27 July 2023

1. Introduction

The Metaverse is a novel and promising technology in the digital realm that has the potential to transform healthcare, science, technology, entertainment, economy, and training by providing realistic experiences for people and professionals [1]. It combines various cutting-edge technologies, including artificial intelligence (AI), virtual reality (VR) [2] and augmented reality (AR) [3], Internet of Things (IoT) [4,5], robotics, blockchain [6], and quantum computing [7]. This convergence of technologies opens new avenues for delivering high-quality services in all aspects of our lives. The combination of these technologies creates a highly engaging and personalized experience and provides intelligent solutions that eliminate barriers between customers and providers, as well as enhance the supply chain and sustainability [8]. For example, the Metaverse has the potential to provide immersive training experiences for medical professionals, allowing them to practice surgeries and procedures in a simulated environment, leading to improved patient outcomes [9]. Additionally, it can facilitate remote collaboration among scientists and researchers, accelerating the pace of scientific discovery. The Metaverse can also enable seamless virtual commerce experiences for consumers, increasing efficiency and reducing environmental impact [10]. Healthcare is an essential aspect of promoting and maintaining the physical, social, and mental well-being of people worldwide, and healthcare systems play a significant role in this regard, while also contributing significantly to the economic growth and industrialization of countries [11]. With the advent of digital healthcare, there has been a revolution in the sector, which has enhanced the interaction between caregivers, patients, and other stakeholders [10].

Furthermore, the relationship between the Metaverse and sustainability holds great importance, as sustainability represents a crucial matter that must be tackled by harnessing the capabilities of this highly efficient technology [12]. The Metaverse is anticipated to have a substantial influence on sustainability globally, affecting the environment, economy, and society [13–15]. If consumption and population growth continue to rise without sustainable practices and proper recycling, it could result in the depletion of vital natural resources [16]. Numerous media outlets and businesses recognize the potential of the Metaverse to enhance the economy and financial profitability [17]. However, they emphasize the importance of maintaining a balance by considering environmental, social, and ethical factors. Conversely, the Metaverse has the potential to significantly reduce carbon emissions [18,19]. This is achievable by substituting physical goods with digital ones, minimizing the need for physical mobility and construction through virtual interactions, and conducting simulations in cyberspace rather than physical space. Furthermore, emerging digital spaces are likely to cause less harm to the environment compared to their predecessors due to advancements in technology. If individuals opt to purchase fewer physical items and instead consume and acquire more digitally, the Metaverse could lead to a future that is less reliant on material possessions [16].

Many technology development companies prioritize sustainability goals, aiming to adopt more energy-efficient practices to reduce their carbon emissions. For instance, the Metaverse can facilitate green networking technologies, such as minimizing the number of physical data centers, by storing data and information in the cloud [20]. It is essential to design Metaverse platforms in a way that requires fewer specialized hardware resources and high computing power. Having a small number of Metaverses instead of thousands of Metaverses developed by many organizations might be more efficient [16].

The Metaverse has the potential to revolutionize diverse domains, such as education, entertainment, communication, commerce, and social interactions [21]. It can completely reshape the way we learn, engage in entertainment, connect with others, conduct business, and interact in society. It allows people to connect in a virtual world that is almost as realistic as the physical world, but with endless opportunities for imagination, discovery, and experimentation [22]. Although the Metaverse is already a highly potent and transformative technology, it will become even more significant and influential as it evolves and progresses. One possible future version of the Metaverse is an entirely decentralized and open-source platform, which empowers users to create and own their virtual assets and experiences. This type of Metaverse would be more democratic and accessible, enabling people from all over the globe to contribute to its development. Another potential future version of the Metaverse involves the integration of advanced technologies like AR/VR and AI. The Metaverse provides immersive advantages for both individuals and businesses, including cost reduction by eliminating the need for physical infrastructure and maintenance [23].

However, to achieve its full potential, the Metaverse needs to be more adaptable and applicable. This means that the platform must be flexible and responsive to changes in user needs and preferences. In addition, the Metaverse needs to address technical challenges such as interoperability, security, and scalability. To achieve these goals, it is important to have a more effective design that meets the essential requirements. In this paper, we propose a new approach to improving the performance of the Metaverse within a comprehensive virtual environment called the "Meta-Metaverse". This approach involves connecting Metaverse platforms and digital twins to each other. A digital twin is a virtual representation of a physical object, system, or process. By connecting digital twins to Metaverse platforms, it is possible to create a more seamless and integrated virtual experience. The utilization of fractal patterns as an infrastructure concept connects metaverse platforms and digital twins, enabling access to digital representations of various elements [24–27]. The infrastructure, organized in a fractal-like structure, accommodates multiple layers, each with its own digital version. Metaverse platforms provide virtual environments for user interaction, while digital twins represent virtual replicas of physical entities. The interconnectivity within the fractal-based infrastructure allows seamless navigation between layers and fosters a comprehensive understanding of the digital world. This concept enables detailed exploration and immersive experiences, opening up new possibilities for simulations and enhanced understanding across domains.

This paper aims to present the Meta-Metaverse as a groundbreaking idea that can transform various fields of science, technology, and life. It is inspired by a combination of the Metaverse, fractal concepts, and parallel universes. The paper has been organized into six sections. Section 1 introduces the problem and the proposed solution. Section 2 outlines the motivation and need for presenting this approach, including the current limitations of existing methods and the potential benefits of this new approach. In Section 3, we explore how the concepts of fractals and parallel universes inspired the development of this approach, highlighting the theoretical underpinnings and practical implications. Section 4 presents the possible connections between different platforms that could be employed to leverage this approach for a variety of applications. This section covers several ideas that demonstrate the potential of this approach to revolutionize fields such as physics, biology, computer science, and finance. In Section 5, we provide a detailed discussion of the key findings and implications of this approach, highlighting its strengths and limitations. Finally, Section 6 offers concluding remarks, summarizing the key contributions.

2. Motivation

Developing advanced versions of the Metaverse could contribute to an even more immersive and interactive virtual world that resembles reality. The importance of advancing the Metaverse lies in its potential to enhance and transform numerous facets of our existence, encompassing education, amusement, and trade, while additionally fostering novel modes of social engagement and cooperation [28]. Additionally, it can address the environmental and physical limitations of the physical world by providing a virtual space for people to connect and engage with each other. The Metaverse offers a variety of activities beyond socializing and gaming, such as shopping, learning, teaching, cultural exchange, work, and even creating and participating in a new society. Although the Metaverse is considered a new technology, it represents a transformative process that shows how technology can integrate into our everyday lives. However, one concern is that users may lose track of time due to their reduced awareness of their physical bodies while immersed in VR [29,30].

The advancement of technology has progressed so quickly that what used to be considered science fiction, such as self-driving cars and commercial space travel, are now within reach. This progress has also made it possible to create limited versions of Metaverses on gaming platforms, which were once only imagined in science fiction. Additionally, many companies are investing millions of dollars in developing their own Metaverses and applications, creating a new economy. In the realm of education, digital tools are now commonly used by teachers and students for activities such as online classes, sharing of materials, and testing [31]. The implementation of advanced tools, like AR glasses that provide students with virtual content in class, is already underway. Nevertheless, the lack of compatibility between these various technologies presents a challenge for transferring data and content. The Metaverse has the potential to enhance the learning experience by allowing virtual interactions between students and teachers that mirror those in a physical classroom. In fact, the technology is already being used to teach health sciences, including virtual surgery and flight simulators. By integrating VR, the Metaverse, and AI, educational content can be tailored to individual students, which facilitates monitoring and evaluation of their progress by teachers [31].

Despite the progress made, there are still some important challenges to employ this technology more efficiently. Integrating digital twins into the Metaverse is one way to improve its applicability. Digital twins are digital representations of physical assets, processes, or systems that can be used to simulate and analyze their behavior. This would allow users to interact with virtual replicas of real-world assets and systems, enabling better decision-making and performance optimization. The Metaverse needs to be redesigned to provide more advanced avatars that can offer doctors detailed information to speed up diagnosis and treatment. Rather than just providing a digital version of a person, the Metaverse can enable doctors to access different layers of information, such as medical history, genetic makeup, and current symptoms, to diagnose and treat patients more effectively. Developing the Metaverse to its full potential requires going beyond conventional forms and exploring new ways to make the platform more advanced and efficient [32]. This necessitates a commitment to research and development and collaboration between various stakeholders, including technology developers, healthcare providers, and policymakers. Together, we can create a more powerful and transformative Metaverse that can meet the challenges and opportunities of the digital age.

3. Fractals and the Meta-Metaverse

Fractals are complex and repetitive designs that appear in many natural occurrences, like mountain ranges and snowflakes, as well as in computer-generated and mathematical designs [33–35]. They possess self-similarity, meaning that the design repeats itself at varying scales. Fractals are adept at representing complexity and detail compactly, and their most defining trait is their infinite level of intricacy [36]. As you zoom in on a fractal pattern, you will find smaller and smaller copies of the overall design, and the pattern repeats indefinitely [37]. This occurs because fractals are produced using a set of equations or rules that generate a geometric form that repeats itself on different scales. Aside from their application in describing natural phenomena, fractals are employed in various fields, such as engineering, computer graphics, and physics. Different types of fractals exist, each with its own distinct set of rules and properties, such as the Mandelbrot set, Julia set, and L-systems [38–40]. These varied fractals offer vast potential applications, and they have been utilized to model a wide range of phenomena, from the growth of plants to the movement of stocks in the stock market.

Fractals are mathematical patterns that display self-similarity, indicating that the same pattern repeats at different scales [41,42]. This feature provides fractals with their characteristic "fractal" appearance, which seems "rough" or "broken" due to the irregularity of the pattern. Fractals can be found in various natural and artificial systems and are used in many fields for diverse purposes. In physics, fractals model numerous phenomena, including the mass distribution in the universe, plant growth, and fluid flow. Computer science employs fractals to create computer graphics and design algorithms for solving complex problems [43,44]. Engineering utilizes fractals in designing antennas and other structures that work effectively across a broad range of frequencies. Fractals are also used in the medical field to study the structure and function of biological systems [45], such as the vascular system and the lungs [46], and in psychology to investigate perception and cognition and their role in visual information processing [47]. In summary, fractals are a valuable tool for comprehending and modeling complex systems in diverse fields, with significant applications in science and technology.

Fractal principles have been employed in the creation of computer networks and communication systems in order to enhance the speed and effectiveness of data transmission [36]. By making use of the self-repeating patterns that exist within the data being transmitted between nodes, these systems can be designed to transmit data more efficiently. Fractals are utilized in order to optimize the design of these systems, leveraging the self-similar patterns to improve the speed and efficiency of data transmission. The application of fractal concepts to the design of computer networks and communication systems has thus led to significant improvements in the transmission of data between nodes.

The concept of utilizing fractal patterns as an infrastructure idea to connect several metaverse platforms and digital twins within each other offers a unique approach to accessing and exploring digital representations of everything in the world, ranging from materials to phenomena. This idea involves organizing the infrastructure in a fractal-like structure, where each layer contains its own digital version. At the core of this concept lies the self-similarity and infinite intricacy of fractals. By adopting a fractal-based structure, the infrastructure can accommodate multiple layers, each representing a different level of detail or abstraction. Just as a fractal repeats its pattern at varying scales, this infrastructure enables the integration of various metaverse platforms and digital twins, connecting them within the overarching framework. Metaverse platforms serve as one layer within the fractal-based infrastructure. These virtual environments allow users to interact with digital content and each other. By incorporating metaverse platforms into the infrastructure, users can access and engage with digital representations of objects, systems, and phenomena in a simulated or real-time manner. Digital twins, on the other hand, represent virtual replicas or representations of physical entities. Within the fractal-based infrastructure, digital twins can exist at multiple layers, corresponding to different levels of detail. For example, a building's digital twin can be represented at a coarse level within a metaverse platform and at finer levels within specialized digital twin platforms. This multi-layered approach facilitates comprehensive simulation, analysis, and monitoring across various granularities.

The fractal-based infrastructure ensures interconnectivity between different layers and platforms, creating a cohesive and seamless digital ecosystem. Users can navigate through the layers, transitioning between levels of detail and abstraction effortlessly. This interconnectivity also enables the exchange of data and information between different layers and platforms, fostering a comprehensive understanding of the digital world. One of the primary advantages of this infrastructure is the ability to access details. By traversing through the layers of the fractal-based structure, users can delve into the specifics of objects or phenomena. Starting from a higher-level representation within a metaverse platform, users can progressively zoom in, revealing more intricate digital twins at finer levels. This approach empowers users to explore and interact with the digital versions of everything, gaining insights into materials, systems, and phenomena with unprecedented depth. The concept of utilizing fractal patterns as an infrastructure idea to connect metaverse platforms and digital twins offers a novel approach to accessing and comprehending the digital world. By leveraging the self-similarity and infinite intricacy of fractals, this infrastructure allows for multi-layered integration, interconnectivity, and detailed exploration. It opens up new possibilities for immersive experiences, comprehensive simulations, and enhanced understanding across a wide range of domains.

4. Possible Connections and Implementation

In this section, we delve into the potential applications and versatility of the Meta-Metaverse. We present three distinct structures that highlight the adaptability of this approach across various domains [48–50]. These structures are inspired by nesting software and enable seamless data flow and integration of functionalities between platforms as follows:

- Ring Structure: The ring structure forms a circular arrangement, connecting each Metaverse platform to its neighboring platforms. This closed-loop configuration facilitates efficient data transfer and communication, ensuring a continuous flow of information. The output of one platform seamlessly becomes the input for the next, creating an uninterrupted chain of interconnected platforms;
- Series Structure: The series structure connects Metaverse platforms linearly, one after another. This allows for sequential data processing, where the output of one platform serves as the input for the next. It enables step-by-step transformation of information as it progresses through the connected platforms, facilitating progressive analysis and refinement;
- Hybrid Structures: Hybrid structures combines elements of both series and parallel configurations. It comprises interconnected platforms that operate in series for some data flows and in parallel for others. This provides flexibility and adaptability, allowing for a combination of sequential and parallel processing based on specific application requirements. In these structures, nested structures have been used. These represent a

hierarchical arrangement of Metaverse platforms, akin to nesting software. Platforms exist within larger platforms, forming a nested network. This structure enables encapsulation of functionalities and modularization of processes, enhancing scalability and flexibility. The nested structure enables seamless connections and interactions between platforms, creating a comprehensive and interconnected ecosystem.

By adopting these interconnected structures, our approach to Metaverse platform networks harnesses the advantages of nesting software, facilitating efficient data flow, seamless communication, and integration of functionalities across platforms [51]. These structures serve as the foundation for creating a dynamic and interconnected Metaverse ecosystem, unlocking new possibilities for immersive experiences, collaborative environments, and transformative applications in diverse domains.

The formulation of the methodology that utilizes fractal patterns as an infrastructure idea for connecting metaverse platforms and digital twins holds significant importance due to several key aspects, including connectivity and timing. These aspects play a crucial role in establishing reliable communication and creating immersive connections within the digital landscape. Furthermore, emphasizing the need for a mathematical framework to extend and define this idea can pave the way for valuable research and advancements across diverse fields of science and technology. Connectivity is a fundamental aspect of the proposed methodology. By structuring the infrastructure using fractal patterns, it becomes possible to establish connections between different metaverse platforms and digital twins. This interconnectedness allows for seamless navigation and data exchange, enabling users to explore and interact with a comprehensive digital ecosystem. The ability to connect different platforms and digital representations opens up new possibilities for collaboration, information sharing, and immersive experiences that transcend the limitations of individual platforms.

Timing is another crucial consideration in this methodology. The concept of timing recognizes the importance of allocating sufficient time to explore and engage with each layer and platform within the fractal-based infrastructure. As users traverse through various levels of detail and abstraction, the complexity and richness of the virtual worlds they encounter increase. By understanding the significance of timing, users can fully immerse themselves in each platform, appreciating the intricate details and gaining a comprehensive understanding of the digital representations they explore. It is essential to highlight the potential benefits and advancements it can bring to various scientific and technological fields. By defining the methodology in mathematical terms, researchers can develop rigorous models, algorithms, and frameworks that facilitate further exploration and advancements. Mathematical formulations enable precise description, analysis, and prediction of the behavior and interactions within the fractal-based infrastructure. This opens doors for research in fields such as network theory, data science, computer graphics, artificial intelligence, and more. By extending and defining the methodology in a mathematical manner, researchers can explore the theoretical underpinnings, develop efficient algorithms, and propose novel applications across diverse domains. For example, in network theory, mathematical formulations can be used to optimize the connectivity and efficiency of the interconnected metaverse platforms. In data science, mathematical models can facilitate the analysis and interpretation of vast amounts of digital twin data. In computer graphics, mathematical representations can enhance the realism and visual fidelity of virtual worlds.

4.1. Ring Connection

Our proposed network structure involves connecting Metaverse platforms in a ring-like fashion, forming a closed loop. Each platform in the network receives input data from the preceding platform and processes it to generate output data, which serves as input for the subsequent platform. Figure 1 illustrates the structure of the Metaverse platforms in a Meta-Metaverse arrangement. Each block represents a Metaverse platform, while each line represents the connections between the platforms. This arrangement forms a ring network configuration, where data flow sequentially through the platforms.

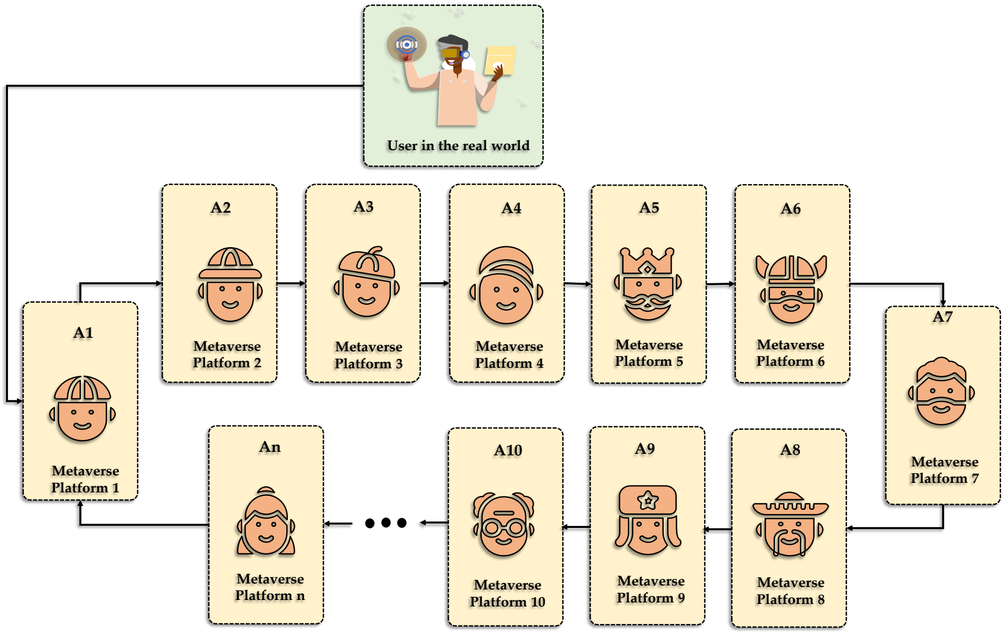

Figure 1. Structure of the Metaverse platforms in a Meta-Metaverse arrangement, showcasing the ring network configuration.

Equation (1) presents the mathematical model that governs the connections of the Meta-Metaverse. This equation presents a conceptual model that helps us understand the timing and data transmission in a Meta-Metaverse platform. In this mathematical model, imagine a Meta-Metaverse platform consisting of multiple interconnected metaverse platforms. These platforms are connected in a ring-like arrangement, forming a cohesive network. When a user wearing a VR headset explores this interconnected system, they can see various virtual worlds associated with each platform. The equation captures an important aspect of this experience: timing. It suggests that as users navigate through the different metaverse platforms, they need to allocate an appropriate amount of time to fully engage with each platform. The equation implies that the more metaverse platforms a user visits, the more time they will require to explore and immerse themselves in the associated virtual worlds. This concept is significant because it highlights the need for users to spend sufficient time within each platform to fully grasp and appreciate the virtual experiences offered. By allocating ample time, users can delve deeper into the intricacies of each platform and make meaningful connections with the virtual worlds they encounter. Thus, Equations (1)–(5) are conceptualized to serve as conceptual representations of the relationship between time and the user's journey through the interconnected metaverse platforms. The equation emphasizes the value of time in enhancing the user's overall experience and understanding of the virtual environments they explore.

This approach relies on the self-similarity and intricate nature of fractals to create a structure where each layer has its own digital version, allowing for seamless connections and exploration. Within this infrastructure, users can navigate through various layers of detail and abstraction, much like zooming into a fractal pattern. As users delve deeper, they encounter more intricate digital representations known as digital twins. In this fractal-based infrastructure, digital twins exist at multiple levels, corresponding to different levels of detail. For instance, a digital twin of a building can have a coarse representation within a metaverse platform and more detailed representations within specialized digital twin platforms. It enables seamless transitions between different layers and platforms, allowing users to explore the digital versions of everything, from materials to phenomena. This interconnectedness facilitates the exchange of data and information, creating a comprehensive and holistic view of the digital world. This cyclical flow of data ensures a continuous exchange of information, enabling users to seamlessly navigate and interact within the Metaverse. The ring network structure we propose offers several advantages for the Metaverse:

The interconnected platforms enable smooth transitions between different virtual environments, allowing users to effortlessly move from one platform to another while maintaining continuity and immersion throughout their Metaverse experience. By establishing a cohesive and interconnected environment, the ring network structure ensures a consistent and seamless user experience, enabling users to explore various virtual spaces, engage in different activities, and interact with diverse content without encountering disruptions or inconsistencies. The ring network architecture provides flexibility and scalability for the Metaverse ecosystem, allowing easy integration of additional platforms into the ring. Equation (1) can be represented as follows:

$$
\begin{aligned}
& MetaMetaverse(time_1, time_2, time_3 \ldots, time_n, \\
& Metaverse_1, Metaverse_2, Metaverse_3, \ldots, Metaverse_n, X) = \\
& \sum_{time=t_0}^{t_n} \Bigg\{ \Big(\sum_{time_1=t_0}^{Range(t_1)} User(VR) \rightarrow Metaverse_1(f_{1,1}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}), f_{1,2}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}), \\
& \ldots, f_{1,3}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}), f_{1,w}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}) \\
& \times \Big(\sum_{time_2=t_1}^{Range(t_2)} Metaverse_2(f_{2,1}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}), f_{2,2}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}), \\
& \ldots, f_{2,3}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}), f_{2,w}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}) \\
& \times \Big(\sum_{time_2=t_2}^{Range(t_3)} Metaverse_3(f_{3,1}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), f_{3,2}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), \\
& \ldots, f_{3,3}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), f_{3,w}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}) \\
& \ldots \\
& \times \Big(\sum_{time_2=t_2}^{Range(t_3)} Metaverse_n(f_{n,1}(x^m_{Mm,1}, x^m_{Mm,2}, x^m_{Mm,3}, \ldots, x^m_{Mm,v}), f_{n,2}(x^m_{Mm,1}, x^m_{Mm,2}, x^m_{Mm,3}, \ldots, x^m_{Mm,v}) \\
& \ldots,, f_{n,3}(x^m_{Mm,1}, x^m_{Mm,2}, x^m_{Mm,3}, \ldots, x^m_{Mm,v}), f_{n,w}(x^m_{Mm,1}, x^m_{Mm,2}, x^m_{Mm,3}, \ldots, x^m_{Mm,v}) \Bigg\}
\end{aligned}
\tag{1}
$$

This expansion enhances the available functionalities and accommodates the evolving needs and demands of Metaverse users. However, there are certain drawbacks to the proposed ring network structure:

- The cyclical flow of data within the ring structure limits non-linear interactions and branching scenarios within the Metaverse, constraining users' navigation and interaction outside the predefined path established by the platform connections;
- High demand or processing requirements in specific platforms may result in bottlenecks as data flow sequentially through the platforms. This can lead to latency issues or reduced performance for users accessing those platforms;
- The ring network configuration lacks redundancy and alternative paths, making it susceptible to technical issues or disruptions in a single platform that can impact the entire network's functionality. This can potentially affect user experiences and system reliability;
- In terms of implications and future considerations, our research suggests the following:
- Further exploration of alternative network topologies, such as mesh networks or hybrid configurations, can address the limitations of the ring structure, offering enhanced flexibility, fault tolerance, and adaptability for the ever-expanding Metaverse ecosystem;
- By leveraging network engineering principles, we can optimize the design, scalability, and functionality of interconnected platforms within the Metaverse, contributing to the creation of a more robust and immersive digital realm for users.

4.2. Series Connection

The Meta-Metaverse, depicted in Figure 2, employs a series mode of network configuration. This means that the platforms are interconnected in a linear fashion, with each platform connected one after another. The series network configuration establishes a sequential connection between the Metaverse platforms. In this setup, data flow from one platform to the next in a linear manner. It ensures that information is transmitted in a specific order, following a predetermined path. Equation (2) describes a mathematical model for the Meta-Metaverse network in the present arrangement.

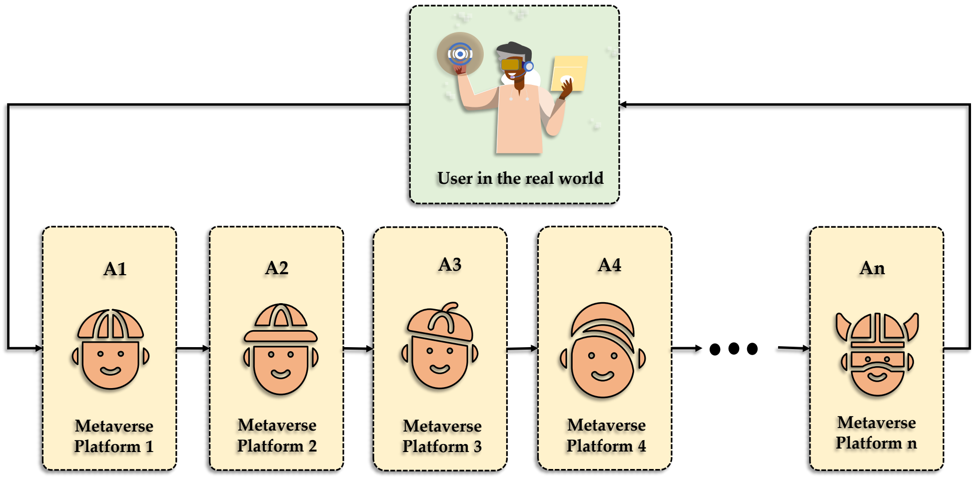

Figure 2. Network structure of the Meta-Metaverse in a series configuration, where each block represents a Metaverse platform, and each line denotes the connection between the platforms. The series network facilitates sequential data flow and streamlined communication within the interconnected platforms.

Advantages of the series network configuration:

- The series network enables a streamlined flow of data between the platforms within the Metaverse. By establishing a linear connection, it facilitates efficient communication and seamless information transfer. This ensures that data reach their intended destination without unnecessary delays or detours;
- The linear structure of the series network simplifies the maintenance and troubleshooting process. Due to its linear nature, it becomes relatively straightforward to identify and resolve issues. Network administrators can trace the connection path between platforms, making it easier to pinpoint any disruptions or problems. This simplification of the maintenance process enhances the overall efficiency of managing the network.

Disadvantages of the series network configuration:

- The series network presents challenges when it comes to scaling. As each new platform needs to be connected in series with the existing ones, there are inherent limitations on the number of platforms that can be effectively integrated into the network. Adding new platforms requires extending the linear chain of connections, which can become complex and potentially lead to performance degradation or bottlenecks;
- Single Point of Failure: The series network is susceptible to disruptions or failures in any individual platform. If one platform encounters technical issues or disruptions, it can have a cascading effect on the connectivity and functionality of subsequent platforms in the series. In other words, the failure of one platform can disrupt the entire chain of communication, potentially leading to system-wide interruptions. This vulnerability to a single point of failure highlights the need for redundancy and backup solutions to mitigate such risks.

$$
\begin{aligned}
&MetaMetaverse(time_1, time_2, time_3 \ldots, time_n,\\
&Metaverse_1, Metaverse_2, Metaverse_3, \ldots, Metaverse_n, X) =\\
&\sum_{time==t_0}^{t_n} \Bigg\{ \sum_{time_1=t_0}^{Range(t_1)} User(VR) \rightarrow Metaverse_1(f_{1,1}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}), f_{1,2}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}),\\
&\ldots, f_{1,3}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}), f_{1,w}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v})\\
&\times \sum_{time_2=t_1}^{Range(t_2)} Metaverse_2(f_{2,1}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}), f_{2,2}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}),\\
&\ldots, f_{2,3}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}), f_{2,w}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v})\\
&\times \sum_{time_2=t_2}^{Range(t_3)} Metaverse_3(f_{3,1}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), f_{3,2}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}),\\
&\ldots, f_{3,3}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), f_{3,w}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v})\\
&\ldots\\
&\times \sum_{time_2=t_2}^{Range(t_3)} Metaverse_n(f_{n,1}(x^m_{Mm,1}, x^m_{Mm,2}, x^m_{Mm,3}, \ldots, x^m_{Mm,v}), f_{n,2}(x^m_{Mm,1}, x^m_{Mm,2}, x^m_{Mm,3}, \ldots, x^m_{Mm,v})\\
&\ldots,, f_{n,3}(x^m_{Mm,1}, x^m_{Mm,2}, x^m_{Mm,3}, \ldots, x^m_{Mm,v}), f_{n,w}(x^m_{Mm,1}, x^m_{Mm,2}, x^m_{Mm,3}, \ldots, x^m_{Mm,v}) \rightarrow User(VR)\Bigg\}
\end{aligned}
\tag{2}
$$

4.3. Deep Series Connection

The Meta-Metaverse represents a unique network structure where the Metaverse platforms are nested within each other, called deep series connection. In this configuration, each platform is contained within another platform, forming a hierarchical arrangement. Figure 3 illustrates a deep series connection within the Meta-Metaverse network structure. In this configuration, the platforms are interconnected in a sequential manner, similar to the series mode described earlier. However, what distinguishes the deep series connection is the presence of multiple layers or depths within each platform. Each platform in Figure 3 contains nested sub-platforms, forming a hierarchical arrangement.

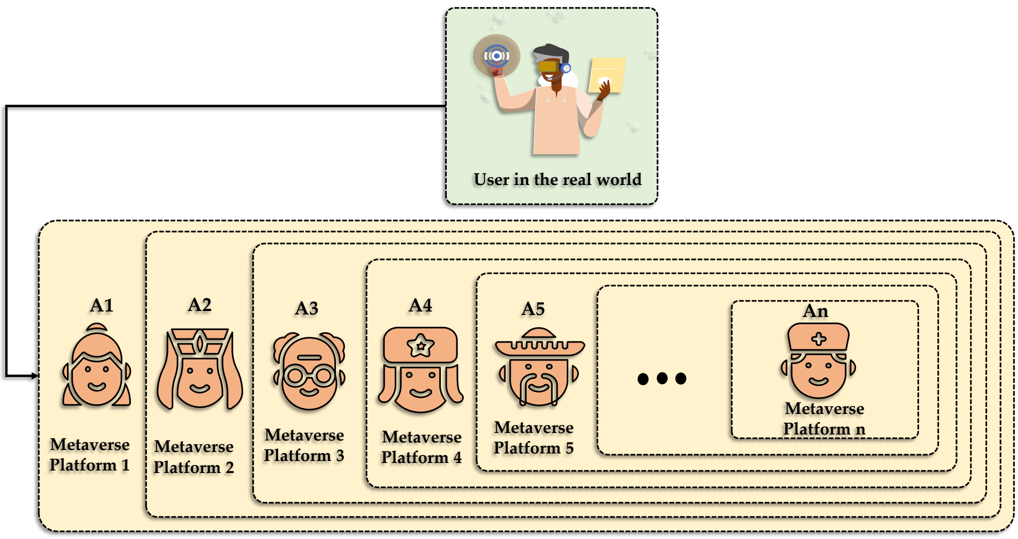

Figure 3. Illustration of the deep series connection in the Meta-Metaverse network structure, showcasing nested platforms with multiple layers.

This nesting implies that the functionality and data flow within the network are organized in a cascading manner. Data flow from the outermost layer of one platform to the corresponding layer of the next platform, and so on, until they reach the deepest layer.

Equation (3) describes the data flow within the deep series connection of the Meta-Metaverse network structure, accounting for the nested layers and connectivity factors. This nested structure can be beneficial for describing various phenomena that are composed of multiple layers, including biological, environmental, engineering, and economic systems. By envisioning platforms nested within one another, we can analyze the interactions and relationships between different layers of a complex system. This hierarchical organization allows for a deeper understanding of how each layer influences the overall behavior and functioning of the system. For instance, in biological systems, such as ecosystems, the nested platform structure can represent the interdependence between different trophic levels. Each nested platform could represent a specific level in the food chain, showcasing how energy and resources flow from one level to the next.

$$
\begin{aligned}
&MetaMetaverse(time_1, time_2, time_3 \ldots, time_n,\\
&Metaverse_1, Metaverse_2, Metaverse_3, \ldots, Metaverse_n, X) =\\
&\Bigg\{ \sum_{time_1=t_0}^{Range(t_1)} User(VR) \rightarrow Metaverse_1(f_{1,1}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}), f_{1,2}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}),\\
&\ldots, f_{1,3}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}), f_{1,w}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v})\\
&(\sum_{time_2=t_1}^{Range(t_2)} Metaverse_2(f_{2,1}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}), f_{2,2}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}),\\
&\ldots, f_{2,3}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}), f_{2,w}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v})\\
&(\sum_{time_2=t_2}^{Range(t_3)} Metaverse_3(f_{3,1}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), f_{3,2}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}),\\
&\ldots, f_{3,3}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), f_{3,w}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v})\\
&\ldots\\
&(\sum_{time_2=t_2}^{Range(t_3)} Metaverse_n(f_{n,1}(x^m_{Mm,1}, x^m_{Mm,2}, x^m_{Mm,3}, \ldots, x^m_{Mm,v}), f_{n,2}(x^m_{Mm,1}, x^m_{Mm,2}, x^m_{Mm,3}, \ldots, x^m_{Mm,v})\\
&\ldots,, f_{n,3}(x^m_{Mm,1}, x^m_{Mm,2}, x^m_{Mm,3}, \ldots, x^m_{Mm,v}), f_{n,w}(x^m_{Mm,1}, x^m_{Mm,2}, x^m_{Mm,3}, \ldots, x^m_{Mm,v}))))) \Bigg\}
\end{aligned} \tag{3}
$$

This hierarchical representation enables the study of ecological dynamics, such as predator-prey relationships and nutrient cycling. Similarly, in environmental systems, the nested platform structure can depict the different layers of the Earth's atmosphere, from the troposphere to the stratosphere and beyond. Analyzing the interactions between these nested layers can help understand phenomena such as climate change, air pollution, and atmospheric dynamics. In engineering systems, the nested platform structure can be applied to describe the layers of complex infrastructure projects. For example, in a transportation network, each platform could represent a different mode of transportation, such as roads, railways, or air routes. Understanding the interactions and dependencies between these nested layers is crucial for optimizing efficiency, managing traffic, and improving transportation systems. Moreover, the nested platform structure can also be relevant in economic systems, such as supply chains. Each nested platform could represent different stages of production, from raw materials to finished products. Analyzing the interactions and dependencies between these nested layers helps identify bottlenecks, optimize resource allocation, and enhance overall economic efficiency.

In summary, the Meta-Metaverse with deep series connection, with platforms nested within each other, provides a powerful framework for describing phenomena composed of multiple layers. This hierarchical representation can be applied to various domains, including biology, environment, engineering, and economics, enabling a comprehensive understanding of complex systems and their interconnections.

4.4. Hybrid Connections

The hybrid connection between Metaverse platforms in the Meta-Metaverse network structure offers a unique opportunity to realize a wide range of phenomena within the world of the Metaverse. By combining various network configurations, both mentioned and non-mentioned, this hybrid approach enables the integration of diverse capabilities and functionalities within the Metaverse ecosystem. The hybrid connection allows for the seamless blending of different types of network structures, such as series, parallel, mesh, or tree configurations. Each network structure brings its own set of advantages and characteristics, which can be leveraged to facilitate the realization of different phenomena within the Metaverse. Figure 4 depicts the hybrid connection model within the Meta-Metaverse network structure, emphasizing the combination of different network configurations. This hybrid model integrates series, parallel, mesh, and tree connections, leveraging their respective strengths to enable a wide range of phenomena within the Metaverse. The figure serves as a visual representation of the flexible and adaptable nature of the hybrid connection, showcasing how different network structures can coexist and interact.

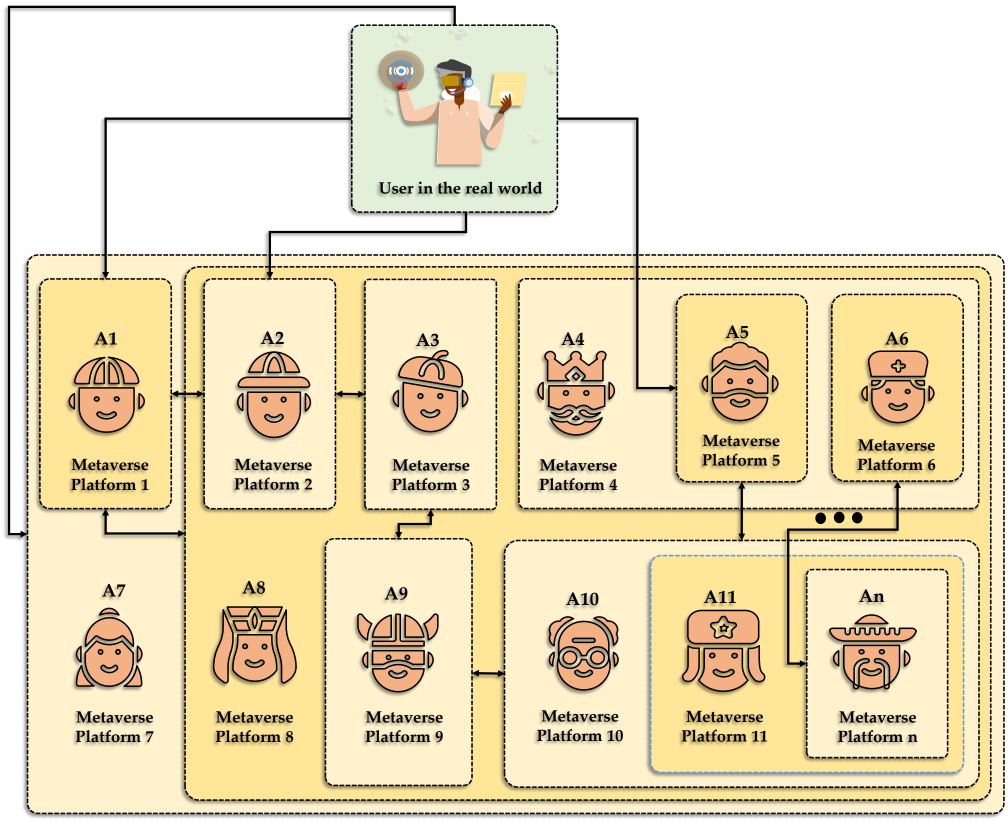

Figure 4. Visualization of a specific configuration within the hybrid connection model, showcasing the interconnectedness and interplay of different network structures to support complex interactions and experiences in the Metaverse.

In addition, Figure 5 depicts an alternative hybrid configuration within the Meta-Metaverse network structure. This specific configuration represents a distinct arrangement of interconnected platforms and layers, highlighting a different approach to hybrid connections. It emphasizes a unique combination of network structures that have been tailored to support complex interactions and experiences in the Metaverse. For instance, the series mode of connection facilitates sequential connectivity, ensuring the smooth flow of data between platforms. This is particularly useful for modeling phenomena that require a step-by-step process or ordered information transfer.

The incorporation of parallel connections within the Meta-Metaverse framework enables simultaneous communication and data exchange among multiple platforms. This feature enhances collaborative experiences and facilitates real-time interactions within the virtual environment. It proves particularly valuable when simulating complex systems or facilitating multiplayer interactions within the Metaverse, as it allows for seamless and synchronized engagement across different platforms. Furthermore, the adoption of a mesh network configuration within the Meta-Metaverse architecture establishes a distributed and interconnected structure. This decentralized communication approach offers several benefits, including enhanced resilience against single points of failure. By distributing the communication pathways, the system becomes more robust and resilient in the face of disruptions. This network configuration is especially advantageous when modeling phenomena characterized by a high degree of interconnectivity or when ensuring reliability and continuity of communication is critical. To provide a formal representation of the hybrid connection models employed in the Meta-Metaverse, we present Equations (4) and (5) in the manuscript. These mathematical descriptions offer a precise framework for understanding and implementing the proposed approach. They contribute to the overall comprehensibility and technical foundation of the research, allowing for a more rigorous exploration of the concepts and their implications.

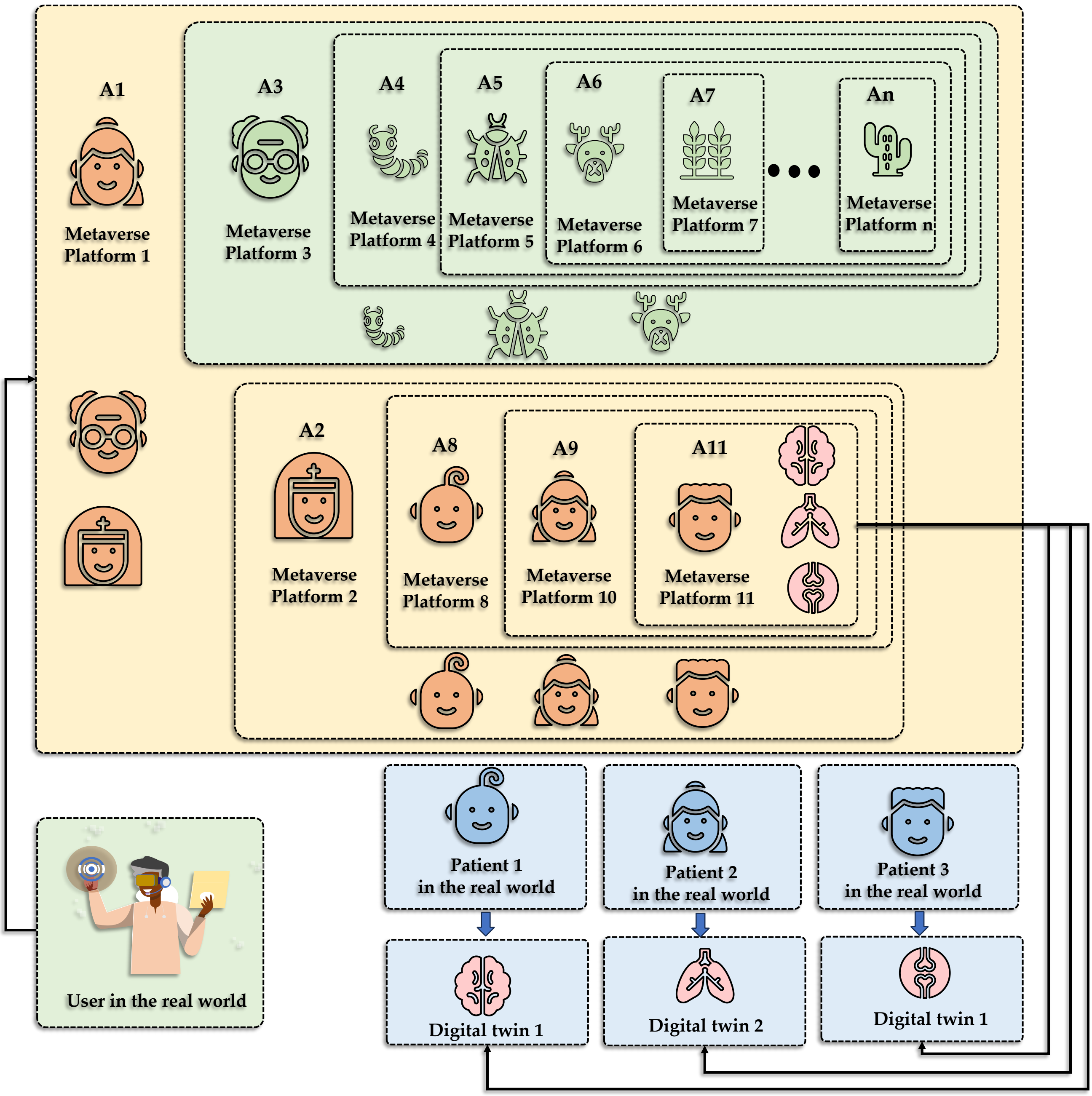

Figure 5. Illustration of a distinct configuration within the hybrid connection model, showcasing the interconnected platforms and layers, and highlighting the unique network structure designed to enable complex interactions and experiences in the Metaverse.

The utilization of parallel connections, coupled with a mesh network configuration, within the Meta-Metaverse presents opportunities for enhanced collaboration, real-time interactions, decentralized communication, and resilience against disruptions. The mathematical descriptions provided in Equations (4) and (5) further support the technical underpinnings of the proposed hybrid connection models.

$$
\begin{aligned}
&MetaMetaverse(time_1, time_2, time_3 \ldots, time_n,\\
&Metaverse_1, Metaverse_2, Metaverse_3, \ldots, Metaverse_n, X) =\\
&\sum_{time=t_0}^{t_n} \Bigg\{ \Big(\sum_{time_1=t_0}^{Range(t_1)} User(VR) \rightarrow Metaverse_1(f_{1,1}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}), f_{1,2}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}),\\
&\ldots, f_{1,3}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}), f_{1,w}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}))\\
&\times \Bigg\{ \sum_{time_2=t_1}^{Range(t_2)} User(VR) \rightarrow Metaverse_2(f_{2,1}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}), f_{2,2}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}),\\
&\ldots, f_{2,3}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}), f_{2,w}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}), Metaverse_3) \Bigg\}\\
&\times \Bigg\{ \sum_{time_3=t_2}^{Range(t_3)} Metaverse_3(f_{3,1}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), f_{3,2}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}),\\
&\ldots, f_{3,3}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), f_{3,w}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), Metaverse_2)\\
&+ \Bigg\{ \sum_{time4=t_3}^{Range(t_3)} User(VR) \rightarrow Metaverse_4(f_{4,1}, f_{4,2}, f_{4,3}, \ldots, f_{4,w})\\
&+ \sum_{time_2=t_2}^{Range(t_3)} Metaverse_5(f_{5,1}, f_{5,2}, f_{5,3}, \ldots, f_{5,w}, Metaverse_6)\\
&+ \sum_{time_6=t_5}^{Range(t_6)} Metaverse_6(f_{6,1}, f_{6,2}, f_{6,3}, \ldots, f_{6,w}, Metaverse_5)\\
&+ \Bigg(\sum_{time_7=t_6}^{Range(t_7)} Metaverse_7(f_{7,1}, f_{7,2}, f_{7,3}, \ldots, f_{7,w})\\
&\times \Bigg[\sum_{time_9=t_8}^{Range(t_9)} User(VR) \rightarrow Metaverse_9\,(Metaverse_8) + \sum_{time_{10}=t_9}^{Range(t_{10})} Metaverse_{10}(Metaverse_n) \Bigg] \Bigg)\\
&+ \Bigg(\sum_{time_9=t_8}^{Range(t_9)} Metaverse_9(f_{9,1}, f_{9,2}, f_{9,3}, \ldots, f_{9,w}, Metaverse_8)\\
&\times \Bigg[\sum_{time_{11}=t_{10}}^{Range(t_{11})} Metaverse_{11} + \ldots + \sum_{time_n=t_{n-1}}^{Range(t_n)} Metaverse_n(Metaverse_{10}) \Bigg] \Bigg) \Bigg\} \Bigg\}
\end{aligned}
\quad (4)
$$

Moreover, the tree network structure, although not explicitly mentioned, can be integrated into the hybrid connection. It enables hierarchical organization and efficient distribution of information, making it suitable for representing phenomena with layered or nested components. By combining these different network configurations in a hybrid manner, the Metaverse platforms gain the flexibility to realize a wide range of phenomena. Whether it includes simulating complex biological systems, representing economic models, emulating environmental dynamics, or even constructing virtual worlds, the hybrid connection approach provides the necessary infrastructure to support diverse and immersive experiences within the Metaverse. The hybrid connection between Metaverse platforms offers a versatile and adaptable network structure that enables the realization of various phenomena. By incorporating different network configurations, the Metaverse ecosystem can harness the benefits of each structure and create a rich and interconnected environment that caters to the diverse needs and experiences of its users.

$$
\begin{aligned}
&MetaMetaverse(time_1, time_2, time_3 \ldots, time_n,\\
&Metaverse_1, Metaverse_2, Metaverse_3, \ldots, Metaverse_n, X) =\\
&\sum_{time=t_0}^{t_n} \Bigg\{ \Big(\sum_{time_1=t_0}^{Range(t_1)} User(VR) \rightarrow Metaverse_1 (f_{1,1}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}), f_{1,2}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}),\\
&\ldots, f_{1,3}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}), f_{1,w}(x^1_{M1,1}, x^1_{M1,2}, x^1_{M1,3}, \ldots, x^1_{M1,v}))\\
&\times \Bigg\{ \Bigg(\sum_{time_2=t_1}^{Range(t_2)} User(VR) \rightarrow Metaverse_2 (f_{2,1}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}), f_{2,2}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}),\\
&\ldots, f_{2,3}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}), f_{2,w}(x^2_{M2,1}, x^2_{M2,2}, x^2_{M2,3}, \ldots, x^2_{M2,v}))\\
&\left(\sum_{time_9=t_1}^{Range(t_9)} Metaverse_9(f) \left(\sum_{time_{10}=t_9}^{Range(t_{10})} Metaverse_{10}(f) \left(\sum_{time_{11}=t_{10}}^{Range(t_{11})} Metaverse_{11}(f) \right) \right) \right) \Bigg)\\
&+ \left(\sum_{time_3=t_2}^{Range(t_3)} Metaverse_3 (f_{3,1}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), f_{3,2}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), \right.\\
&\ldots, f_{3,3}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}), f_{3,w}(x^3_{M3,1}, x^3_{M3,2}, x^3_{M3,3}, \ldots, x^3_{M3,v}))\\
&\times \sum_{time_3=t_2}^{Range(t_3)} Metaverse_4 (f_{4,1}(x^4_{M4,1}, x^4_{M4,2}, x^4_{M4,3}, \ldots, x^4_{M4,v}), f_{4,2}(x^4_{M4,1}, x^4_{M4,2}, x^4_{M4,3}, \ldots, x^4_{M3,v}),\\
&\ldots, f_{4,3}(x^4_{M4,1}, x^4_{M4,2}, x^4_{M4,3}, \ldots, x^4_{M4,v}), f_{2,w}(x^4_{M4,1}, x^4_{M4,2}, x^4_{M4,3}, \ldots, x^4_{M4,v}))\\
&\ldots\\
&\times \sum_{time_3=t_2}^{Range(t_3)} Metaverse_8 (f_{8,1}(x^8_{M8,1}, x^8_{M8,2}, x^8_{M8,3}, \ldots, x^8_{M8,v}), f_{8,2}(x^8_{M8,1}, x^8_{M8,2}, x^8_{M8,3}, \ldots, x^8_{M8,v}),\\
&\ldots, f_{8,3}(x^8_{M8,1}, x^8_{M8,2}, x^8_{M8,3}, \ldots, x^8_{M8,v}), f_{2,w}(x^8_{M8,1}, x^8_{M8,2}, x^8_{M8,3}, \ldots, x^8_{M8,v})) \Bigg\}
\end{aligned}
\tag{5}
$$

5. Directions

In an increasingly digitized world, the transfer of real-world assets into the digital realm and establishing their interconnected relationships has been a challenge. While the concept of the Metaverse has made strides in this direction, it is limited in scope and falls short in achieving comprehensive digitalization across various domains. To address this need, this research introduces a new approach to Metaverse technology called the Meta-Metaverse. By enhancing the immersive experience and creating realistic digital twins of complex phenomena, assets, and objects, the Meta-Metaverse aims to revolutionize the application of the Metaverse. Drawing inspiration from parallel universes, fractal phenomena, and existing Metaverse technology, the proposed methodology leverages a multitude of Metaverse platforms and digital twins with interconnected communications. Through this strategy, we gain valuable insights into the potential impact of advancing science, technology, and the internet. By incorporating a multi-layered structure of Metaverse platforms and interconnected digital twins, the Meta-Metaverse offers enhanced flexibility, scalability, and innovative solutions to overcome existing technological challenges. These platforms and digital twins are arranged and connected within each other, resembling nesting software, allowing for their coexistence and expanding the capacity, scalability, and versatility of traditional Metaverse technology. The adoption of the Meta-Metaverse approach has the potential to transform scientific research, foster groundbreaking ideas, and make significant contributions to various domains such as healthcare, medicine [52], biology, genetics, environmental engineering, economy, supply chain, trading, shopping, marketing, interior design, politics, and social networking. In the following subsections, we will explore the application of the Meta-Metaverse to each of these topics, showcasing its potential to reshape and optimize these domains in the digital realm.

5.1. Healthcare, Medicine, and the Meta-Metaverse

To address these challenges, healthcare services need to be accessible to individuals at their homes, and the recent COVID-19 pandemic has highlighted the urgent need for innovation and adaptation in the healthcare sector [53–55]. In this post-pandemic era, there has been a paradigm shift in healthcare, with consumers taking an active role in decision-making and the adoption of virtual healthcare systems, data analytics, and unprecedented collaborations in therapeutics development, which has compelled stakeholders to innovate and adapt to these changing circumstances [10].

At present, advanced hospitals and universities employ technologies like AR, VR, and AI to aid surgeons in performing surgeries more efficiently by offering a 3D view of the patient's body [56,57]. These technologies do have some drawbacks, such as creating realistic surgical objects in a computer-generated space, offering limited resolution and pocket-size immersion, and being limited to specific clinical settings. The Metaverse, however, has the potential to tackle these problems by providing a realistic environment for interactions among patients, doctors, and objects. Additionally, the Metaverse has numerous benefits such as personalized health data monitoring, patient clinical data analysis, and the elimination of physical and paper-based records [58]. Despite the advantages of using the Metaverse in healthcare services, there are some challenges to its implementation [59]. These include the risk of compromising user privacy, the high cost of the technology, disagreement between healthcare organizations and institutions on launching the technology, ethical issues, potential threats to human health, the risk of depression, violence, and self-harm, possible negative effects on cultural security and overall health status, widening the gap between developed and developing countries, and the potential for inappropriate use on the dark web, such as human trafficking for organ and body part removal [58].

In the medical field, a Meta-Metaverse program might leverage virtual reality (VR) or augmented reality (AR) technology to enable healthcare practitioners to visualize and interact with patient information in a three-dimensional (3D) context. Such a solution could encompass various capabilities, such as:

- Displaying 3D models of patient anatomy, enabling doctors to examine and explore different bodily systems with enhanced precision;
- Creating virtual simulations for learning and training, allowing medical students and professionals to practice medical procedures and study various health conditions in a controlled and safe environment;
- Enabling virtual consultations and telemedicine, so that patients can meet with their healthcare providers remotely and participate in more interactive sessions;
- Providing virtual rehabilitation and therapy options, letting patients carry out their exercises and treatment plans in a virtual setting;
- Supporting virtual research and development, enabling scientists and researchers to collaborate and experiment with novel ideas in a virtual laboratory;
- Facilitating virtual conference and event hosting, enabling medical professionals to attend and participate in conferences, lectures, and other events remotely;
- Implementing these features would require specialized software and hardware, such as VR headsets, AR glasses, and motion tracking devices, to deliver a fully immersive and interactive experience.

The Meta-Metaverse can be used in psychology to analyze patterns in human behavior, cognition, and emotion, such as how people interact with each other and brain wave patterns. This approach can also help study cognitive processes like attention and perception, as well as emotional expression. For example, it can be used to study communication patterns and how people adapt to changes in their virtual environment. Additionally, the Meta-Metaverse can be used in real-time analysis of brain disorders like epilepsy and schizophrenia, and to understand how people process visual information and remember things. The Meta-Metaverse has the potential to revolutionize psychology by helping us understand complex patterns in human experience and behavior.

Moreover, the Meta-Metaverse has the potential to enhance medicine in numerous ways. It can be applied in various fields such as analyzing disease development, molecular structures, medical images, and physiological signals, among others. To illustrate, the AR/VR and IoMTs-supported Meta-Metaverse platforms and infrastructures can be developed to monitor and examine patterns in brain activity, heart rate, and blood pressure, in order to predict the likelihood of heart disease and detect anomalies in medical images such as MRI scans and X-rays. Additionally, this technology can also evaluate the structure and organization of molecules such as DNA and proteins, and predict their functions based on folding patterns. Furthermore, the Meta-Metaverse can predict the progression of diseases such as cancer and Alzheimer's disease by examining patterns of progression. Consequently, the Meta-Metaverse can be utilized in medicine to comprehend the intricate relationship between different factors and agents that cause diseases, as well as the underlying physiological disease progression, molecular structures, medical images, and treatment procedures.

On one hand, the implementation of AR and VR technology in sexology, the field of human sexuality, can be beneficial in multiple ways. For instance, it can be utilized to create interactive and engaging educational experiences that educate people on sexual health, pleasure, and communication. These experiences can be tailored to suit individuals of all ages. Moreover, AR and VR technology can be implemented in therapy to assist individuals and couples in resolving sexual issues within a safe and regulated environment. Specifically, VR technology can be used to develop simulations of various scenarios, enabling individuals to practice communication and coping skills concerning sexual intimacy. Additionally, AR and VR technology can be employed in sexology research, allowing researchers to study human sexual behavior and responses under controlled circumstances. This could facilitate a better comprehension and handling of concerns pertaining to sexual health and well-being. Although AR and VR technology can also be utilized to create immersive and interactive sexual experiences for entertainment purposes, it is crucial to approach such content with care and only participate with informed consent.

On the other hand, the Metaverse has the potential to be applied in the sexology field in various ways. One such application is the development of virtual environments that provide a secure and controlled space for individuals to explore and express their sexuality. These environments can be used for sexual education, therapy, or research purposes. Additionally, the Metaverse can function as a platform for virtual sexual experiences, either for entertainment or as a means for individuals to safely discover and express their sexuality. However, it is vital to approach this kind of content with prudence and only engage in it with informed consent. Moreover, the use of the Metaverse in sexology raises several ethical and legal issues, including consent, privacy, and safety, which should be thoughtfully analyzed and addressed.

5.2. Biology, Genetics, and the Meta-Metaverse

The conventional Metaverse has the potential to be utilized in the field of biology in various ways [19,60–62]. One such application is the utilization of VR environments to simulate and model biological systems and processes [63,64]. For instance, VR can aid in visualizing and manipulating intricate biological data, such as genetic sequences or protein structures, in a more interactive and intuitive manner. It can also be used to develop simulations of biological systems, such as ecosystems and cell cultures, that enable researchers to test hypotheses and assess the impact of different variables on these systems [65]. Another prospective application is the use of the Metaverse as an online platform for education and outreach, enabling individuals to learn and explore biological concepts in a more immersive and interactive way. However, the implementation of the Metaverse in biology raises a number of ethical and legal concerns, including privacy and security, which should be thoughtfully analyzed and addressed.

The Meta-Metaverse technology can be applied in biology to gain insights into the structures and patterns underlying genetic sequences, various biological systems, and processes. Researchers can utilize this technology to investigate the organization and structure of biological systems, such as the branching patterns of blood vessels and the distribution of neurons in the brain and assess blood flow efficiency and the way plants optimize photosynthesis. Furthermore, this technology can be used to examine the patterns of biological processes, including cell growth and development, cell division, and cell migration. Moreover, the Metaverse can be employed to understand the patterns of ecological systems, such as the distribution of species in ecosystems and the way ecosystems change over time, and to study the patterns of biodiversity and ecosystem response to disturbances. Finally, the Meta-Metaverse platforms can be utilized to analyze the patterns of genetic sequences, including the distribution of nucleotide bases in DNA, gene regulation, and gene expression and interactions. Thus, the Meta-Metaverse technology has the potential to enhance biology research by enabling scientists to understand various biological systems, processes, and genetic sequences in a more effective and efficient manner.

5.3. Environmental Engineering and the Meta-Metaverse

The Meta-Metaverse approach has potential applications in the field of environmental engineering, enabling a better understanding of the complexities underlying natural systems, environmental pollution, management strategies, and risks [66–68]. One such application is the modeling and simulation of natural systems, such as river networks and coastlines, which can be analyzed through the use of various Metaverse platforms. This technology can help to define the distribution of sediment and the ways in which rivers respond to changes in their environment. Additionally, the Meta-Metaverse can be used to study patterns of environmental pollution, including the distribution and movement of contaminants in ecosystems, as well as the impact of oil spills in the ocean [69]. The Meta-Metaverse approach can also aid in recognizing patterns of environmental management, such as changes in resource use and waste production over time and assessing the effectiveness of different management strategies in urban areas. Moreover, this technology can assist in studying patterns of environmental risks, including the likelihood and consequences of natural disasters and exposure to environmental hazards, such as air pollution. In summary, the Meta-Metaverse approach has the potential to positively impact various aspects of environmental engineering.

5.4. Economy and the Meta-Metaverse

The Meta-Metaverse technology holds promise for widespread application in the field of economics, enabling researchers to better comprehend the intricate factors that shape various aspects of the economy [70–72]. Specifically, this approach can be used to analyze financial markets, economic growth, inequality, and complexity. For instance, the Meta-Metaverse can be employed to investigate fluctuations in stock prices, patterns of market volatility, and the risk of market crashes. It can also be utilized to study patterns of economic growth, such as changes in GDP and other economic indicators, and to explore variations in economic growth across different countries and the likelihood of economic recessions. Moreover, fractal analysis can help to understand patterns of economic inequality, including the distribution of wealth and income within a society, and to investigate the patterns of wealth inequality and the potential for social unrest. Lastly, the Meta-Metaverse can analyze patterns of economic complexity, such as the interactions between different sectors of an economy and the patterns of trade, and examine the influence of different sectors on one another. In summary, the use of the Meta-Metaverse in economics can provide researchers with valuable insights into the complex patterns and structures that underlie financial markets, economic growth, inequality, and complexity.

5.5. Gaming and the Meta-Metaverse

It is common for computer games to feature other games or mini games within them. This can serve to provide players with additional content and variety, or to offer a change of pace during gameplay [73–76]. These inner games or mini games may be accessed through a menu or portal within the main game, and upon entering them, players will be transported to a new game environment. The inner game will have its own rules, objectives, and gameplay mechanics, which players will need to engage with in order to progress or succeed.

Visually, this concept can be represented as a series of nested environments or layers, with the main game at the outermost level and the inner games contained within [77,78]. The inner games may appear as smaller, self-contained environments or screens within the larger game world [79]. This could be illustrated as a series of concentric circles or squares, with the main game depicted as the outermost layer and the inner games shown at progressively smaller layers within. Alternatively, the inner games may be portrayed as portals or doorways that lead into separate game environments embedded within the larger game world. The concept of the Metaverse in gaming refers to a virtual space that is shared by multiple users and combines elements such as virtual worlds, augmented reality (AR), and the internet. This space enables players to engage in a wide range of activities and interact with each other and their surroundings through virtual reality (VR) avatars. The Metaverse is created by merging virtual enhancements with physical reality and maintaining virtual space.

The use of the Metaverse in gaming is intended to provide players with a more immersive and interactive experience. Players can explore virtual worlds, complete challenges and quests, and socialize with other players. In some cases, games may incorporate AR elements, making the gameplay experience more realistic and interactive. The potential of the Metaverse is vast, and it has the power to transform the way games are designed and played. For example, game developers may create persistent virtual worlds that evolve based on player actions and interactions. This could lead to a more dynamic and ever-changing gaming experience where players have a direct impact on the direction and progress of the game.

The Meta-Metaverse has versatile applications in gaming, allowing for intricate and visually captivating designs. Its usefulness can be seen in various aspects of game design, such as level design, character design, and visual effects. For level design, the Meta-Metaverse can produce realistic landscapes and environments with intricate details. Similarly, in character design, it can create intricate textures and patterns for clothing and armor, among other things. The Meta-Metaverse is also capable of generating complex visual effects like water, fire, and environmental elements like clouds and foliage. In the future, the Meta-Metaverse is expected to be widely used for generating realistic terrain that mimics natural landscapes. Moreover, the repeating patterns can be combined in various ways to produce a vast range of environments, which adds to the infinite diversity of the game world. The approach discussed in the previous statement can also be utilized for generating height maps, which are grayscale images that represent the terrain's height at each point. These height maps can then be used to create 3D meshes of the terrain that can be rendered in the game. Various Meta-Metaverse platforms can generate height maps, each with unique properties and characteristics. The parameters of the fractal algorithm can be adjusted to fine-tune the terrain's appearance to fit the game's requirements. Furthermore, the Meta-Metaverse can be used to create a sense of infinite diversity in a game world by using different algorithms and platforms to generate various terrain types like forests, deserts, and mountains. By altering the algorithms' parameters, a wide range of environments can be produced. Therefore, using the Meta-Metaverse to generate terrain and create diverse game worlds enhances the game's believability and immersiveness by producing realistic and varied landscapes and environments.

Moreover, there are various ways in which players can move between games using the Meta-Metaverse approach. One such way is by switching between different platforms, which is expected to be a popular feature of many Meta-Metaverse-powered gaming platforms. Another method is through cross-platform play, which enables players to play with or against each other across different gaming platforms that support the Meta-Metaverse. For instance, a player using a PC can play with another player on a mobile device. Additionally, some games may include portals or gateways that allow players to travel between different virtual worlds or dimensions within the Meta-Metaverse environment. Connecting to external Meta-Metaverse-based platforms on the cloud or edge layer is another potential area of research for gaming. This would allow players to access other games or virtual worlds through external Meta-Metaverse-based platforms. Using third-party Metaverse-based platforms is also a fascinating way to enjoy the Meta-Metaverse applications in the gaming world. In summary, there are various methods through which players can move between different Metaverse-based games, depending on the features and capabilities of the games and platforms used.

5.6. Supply Chain and the Meta-Metaverse

The Metaverse has a supply chain system that involves various processes and organizations responsible for producing, handling, and distributing goods and services in AR/VR environments [80–82]. To illustrate how the supply chain operates in the Metaverse, here are ten examples. Firstly, companies can create and sell virtual objects and experiences for use in the Metaverse, including clothing, furniture, and virtual spaces [83]. Secondly, virtual real estate can be bought, sold, and rented in the Metaverse, and companies can specialize in developing and managing virtual real estate [80,84]. Thirdly, companies can offer virtual event spaces for rent or sell tickets to virtual events like conferences or concerts. Fourthly, the Metaverse can offer virtual tours of real-world locations, and companies can create and sell these virtual experiences [82,85].

Moreover, the Metaverse can be used for virtual education, healthcare, retail, entertainment, workspaces, and transportation. Companies can create and sell virtual educational experiences or materials, develop virtual healthcare solutions or offer virtual healthcare services, create virtual stores, offer virtual entertainment experiences, rent virtual workspaces, and sell virtual office software and tools or develop virtual transportation infrastructure [86–88]. In terms of supply chain management, the Meta-Metaverse supply chain can be a network of interconnected virtual organizations and processes that is self-similar across different scales or levels. An example of a fractal supply chain is a network of suppliers and manufacturers that produce and distribute goods to retailers and customers, where similar processes and relationships are at play at each level of the network [87].

The Meta-Metaverse supply chains are distinct from linear supply chains, which are more hierarchical and have a clear chain of command from top to bottom. Meta-Metaverse supply chains are decentralized and flexible, emphasizing collaboration and partnerships, making them more resilient and adaptable to changes in demand and market conditions. This approach can be applied to the food supply chain in various ways, as demonstrated below. First, modular and scalable production techniques can be employed for food processing to adapt to changes in demand. Second, multiple distribution channels, including direct-to-consumer, wholesale, and retail, can be utilized to ensure a flexible and resilient distribution network. Third, food waste reduction efforts can be improved by identifying and addressing waste at every level of the supply chain. Fourth, modular, reusable, or biodegradable packaging materials can be integrated into the supply chain for packaging design. Fifth, multiple layers of safety measures can be implemented throughout the supply chain to ensure food safety. Sixth, digital traceability systems can be used to track food products from farm to fork, enabling transparency and accountability. Seventh, partnerships and networks can be fostered to encourage collaboration within the food supply chain. Eighth, customer engagement can be enhanced by using multiple channels to connect with customers and understand their needs and preferences. Finally, innovation can be encouraged in the food supply chain by fostering experimentation, learning from failure, and iterative improvement at all levels of the supply chain.

5.7. Trading, Shopping, Marketing, and the Meta-Metaverse

The Metaverse could offer various applications for shopping, including the ability for companies to create virtual stores, allowing customers to try on clothing, accessories, or makeup virtually, and virtual fitting rooms where customers can try on clothes in a virtual environment [89–92]. Additionally, companies could offer virtual personal styling services, host virtual marketplaces, and provide virtual product demonstrations. The Metaverse could also enable virtual events, virtual gift-giving, virtual loyalty programs, and virtual customer service [93].

The benefits of the Metaverse for shopping could include greater convenience, personalized shopping experiences, immersive experiences, a wider selection of goods, increased accessibility for people with disabilities, enhanced customer service, and increased security [94]. Customers could shop from anywhere with an internet connection, and virtual personal styling or customized product recommendations could provide a more tailored shopping experience [95]. The Metaverse could also make shopping more engaging and enjoyable through VR fashion shows and virtual product demonstrations. Additionally, it could potentially offer a greater selection of goods than physical stores, and shopping from home could be more accessible for people with disabilities or mobility issues. The Metaverse could also provide enhanced customer service through virtual customer support and increased security by eliminating the need to physically handle or transmit payment information [96].

The Meta-Metaverse concepts can potentially assist shoppers in making informed and strategic decisions about their purchases in the context of shopping. One way to apply the Meta-Metaverse in shopping is by analyzing the patterns and structures of different products and their prices over time. For instance, the Meta-Metaverse can help to identify products with fluctuating prices and those consistently priced at a certain level. This information can enable shoppers to make informed decisions about when to purchase products to get the best value for their money. The Meta-Metaverse can also be used through algorithms and machine learning techniques to analyze vast amounts of data, including customer reviews, ratings, and product specifications, to identify trends and patterns that may not be immediately apparent to the human eye. By providing valuable insights and data, the Meta-Metaverse can help shoppers make more informed and strategic decisions about their purchases. As a result, the Meta-Metaverse will play a crucial role in the field of shopping and consumer decision-making.

There are multiple ways to utilize the conventional Metaverse for marketing and advertising purposes. Some potential applications include creating virtual storefronts for customers to browse and purchase products, hosting virtual events or trade shows, displaying targeted and interactive virtual ads, and using virtual influencers to promote products and services [97,98]. The Metaverse offers an immersive and shared environment that can engage and reach a wider audience than physical events.

The Meta-Metaverse can also be utilized in marketing in various ways, such as designing visually appealing marketing materials, analyzing customer behavior to identify purchasing patterns, targeting marketing campaigns to specific subgroups within a larger market, measuring the effectiveness of marketing campaigns, predicting future market trends by analyzing historical data, and optimizing marketing strategies by identifying the most effective tactics and channels to reach target markets.

5.8. Interior Design and the Meta-Metaverse

The Metaverse is a digital world that can be accessed through the internet and has several potential uses in interior design [99–103]. One of the ways it can be applied is by creating virtual showrooms or design studios, which would allow designers to showcase their work to clients in a virtual environment. This would enable clients to explore and interact with the designs in a more immersive way, aiding them in their decision-making [104,105]. Another way the Metaverse can be used in interior design is by utilizing virtual reality technology to create immersive, interactive design experiences. By doing so, designers can offer their clients the opportunity to experiment with various design options in a virtual space. In addition, the Metaverse could be employed as a platform for online interior design consultations, offering a more convenient and efficient design process for clients. Therefore, the Metaverse offers many potential applications in interior design, allowing designers to create more immersive and interactive design experiences for their clients. By incorporating the Meta-Metaverse approach into interior design, the aforementioned uses of the Metaverse can be further enhanced. Some of the benefits of utilizing fractal concepts in interior design are as follows:

- Intricate, repeating patterns can be created, adding visual interest to the design;

- A sense of depth and movement can be incorporated into the design, increasing its complexity and visual appeal;
- Design layouts can be analyzed and optimized by understanding the flow and functionality of interior spaces, leading to more efficient and effective designs;
- Historical design data can be studied to identify patterns and predict future design trends;
- Designers can work more efficiently and effectively by understanding the most effective design strategies;
- Overall, the Meta-Metaverse approach can help designers create more visually interesting and complex designs, optimize design layouts, and predict future trends in interior design.

5.9. Social Networking and the Meta-Metaverse

Social networking involves utilizing the internet and online platforms to create relationships with others [15,106]. This can involve activities such as connecting with friends and family on social media, joining online communities and forums, and engaging in group discussions or chat rooms [107–109]. VR involves using technology to generate computer-generated environments that allow users to interact with it in a way that seems realistic [110]. This is generally done with the help of VR headsets or other specialized equipment, which makes it possible for users to see, hear, and interact with virtual environments as if they are physically present in those environments. In recent times, social networking and VR have intersected more frequently, with the creation of VR platforms that allow users to socialize and connect with each other in virtual spaces. These VR social networking platforms can provide a more immersive and interactive way for users to connect with each other and can offer a more convenient and accessible means for people to socialize and meet, regardless of their physical location.

The conventional Metaverse has the potential to enhance social networking and friendship-making applications [111], and the Meta-Metaverse can make this experience even more effective and enjoyable for users. Although conventional Metaverse applications have their own benefits, one way in which it can improve these applications is by offering a more immersive and interactive social experience. In the Metaverse, users can communicate and socialize with each other using avatars and other virtual representations, creating a more meaningful and engaging connection. Another benefit of the Metaverse is that it provides a convenient and accessible platform for communication and connection, allowing users to connect with others regardless of their physical location. This can help people meet and connect with others who share similar interests or backgrounds, making social networking and friendship-making more accessible and convenient. Overall, the Metaverse has the potential to enhance social networking and friendship-making applications by providing a more immersive, engaging, and convenient platform for connecting with others [112].

Therefore, the Meta-Metaverse has various potential applications in friend-making apps. One way to utilize the Meta-Metaverse is by analyzing social connections and relationships among users of a friend-making app to identify opportunities for growth and improvement. This analysis can provide insights into how users are interacting and forming connections within the app, allowing developers to enhance the user experience and encourage more meaningful connections. The Meta-Metaverse can also be used to predict which users are likely to form connections based on shared interests and characteristics, enabling the app to recommend potential friends to users. Moreover, the Meta-Metaverse can evaluate the strength and stability of social connections within the app to identify which connections are most valuable and should be prioritized for resources and efforts. The Meta-Metaverse can also optimize social features such as algorithms and user interface design to make the app more user-friendly and effective in fostering connections. By utilizing the Meta-Metaverse to understand and improve the social features of friend-making apps, developers can create a more engaging platform for users to connect and form relationships.

5.10. Politics and the Meta-Metaverse

The Metaverse has the potential to transform political systems by creating a new platform for people to engage and participate in the political process [22,113–115]. The Meta-Metaverse approach can significantly improve the Metaverse's capacity to achieve this goal.

The conventional Metaverse can aid political governments by enabling more inclusive participation in the political process, allowing people who cannot attend meetings or rallies to participate virtually [112,116–118]. This can make the political process more accessible and representative of diverse perspectives. Moreover, the Metaverse can provide a new space for political discourse and debate, allowing people to engage in immersive and interactive discussions about political issues. This can lead to a more informed and engaged citizenry.

- The Meta-Metaverse-based governance can structure political systems hierarchically, with each level of government having equal power and responsibility. This can promote decentralized decision-making and balance of power;
- Meta-Metaverse-based political parties can be structured within each other, with each unit having equal decision-making power. This can foster internal democracy and prevent concentration of power in a single faction;
- Meta-Metaverse-based voting systems can be designed to reflect society's diversity, ensuring that individuals have equal say in decisions that affect them. This could include liquid democracy or quadratic voting;
- Meta-Metaverse-based constitutions can be structured to apply at different levels and branches of government, protecting citizens' and governments' rights and responsibilities;
- Meta-Metaverse-based budgeting can ensure fair and transparent allocation of resources by giving each level of government equal control over its budget;
- Meta-Metaverse-based political campaigns can promote internal democracy and prevent concentration of power within a single group or faction;
- Policymaking based on the Meta-Metaverse can distribute decision-making power evenly across different levels and branches of government, making the process transparent and inclusive;
- The Meta-Metaverse media can enhance transparency and prevent concentration of power within a single group or faction;
- Meta-Metaverse-based public engagement can give the public a meaningful role in shaping policy decisions that affect them;
- Meta-Metaverse-based education can promote internal democracy and prevent concentration of power within a single group or faction by giving each branch or unit equal decision-making power.

Imagine multiple virtual spaces where people can interact with each other and with virtual objects and environments in real-time, with various Metaverse platforms allowing for detailed exploration. This can enable more people to participate in democratic processes, including those who are unable to attend physical events. The Meta-Metaverse, a specific Metaverse platform, could provide a platform for immersive and interactive forms of political participation, such as virtual town hall meetings, and lead to more transparent and accountable decision-making through technologies like blockchain and edge computing. While the potential benefits of the Meta-Metaverse for democracy are largely theoretical, it could lead to more inclusive and accountable forms of democracy.

5.11. Smart Manufacturing and the Meta-Metaverse

Smart manufacturing involves using advanced technologies and techniques to improve manufacturing efficiency, productivity, and other aspects of the process [119]. The Meta-Metaverse could enhance smart manufacturing by providing a virtual platform for collaboration, communication, training, and data visualization [120–125]. This could result in increased efficiency, productivity, and effectiveness in the manufacturing process. The

Meta-Metaverse could facilitate collaboration and communication among manufacturing teams, offer training and simulation platforms, and enable more accurate analysis of manufacturing process data through immersive and interactive data visualization platforms. The Meta-Metaverse could be applied to creating production plans, designing manufacturing processes, optimizing the supply chain, quality control, resource allocation, maintenance plans, production scheduling, inventory management, addressing inefficiencies in manufacturing processes, and improving collaboration among different entities in the supply chain.

6. Discussion

The concept of ubiquity in virtual worlds is directly related to the primary requirement of a fully realized Metaverse [126–130]. This requirement is to provide a cultural and interactive environment for humans that is as compelling as the physical world. The physical world is ubiquitous in several ways. First, it is physically present everywhere, and we cannot escape it. Second, our existence in the physical world is easily recognizable and distinct from others, primarily due to our physical embodiment, which includes our face, body, voice, fingerprints, and retinas. We also have a few universally applicable artifacts such as our signature, birth certificates, passports, licenses, social security numbers, bank accounts, and credit cards, which enhance our identity. Additionally, our identity is reflected in our preferences for things like books, music, movies, and food, as well as the memorabilia associated with our lives. Even though our perception of the physical world may vary, it is still ubiquitous, and we cannot escape its presence. This is true regardless of our state of consciousness or whether we are alive or not. Similarly, although our identity can be questioned or stolen, there is always an authentic version of ourselves with a core set of artifacts that authentically represents us [131].

The Metaverse is a virtual world where individuals come together and interact, and just like in the physical world, there is a requirement for transportation. The utilization of systems such as public transportation and sharing economy applications (such as car-sharing, bicycle sharing, and e-scooters) in Metaverse systems have the potential to be successful because blockchain technology and avatars provide a more efficient means of conducting identity verification and payment processing. As a result, implementing transportation systems with Metaverse technology presents significant benefits and possibilities [132–135].

The role of the Metaverse in integrating new technologies into education is expected to be crucial. However, concerns have been raised regarding the potential loss of physical interaction between students and teachers, as well as the limited access to this technology for some educational institutions. Moreover, the Metaverse may introduce new behaviors that could have a negative impact on real-world relationships and culture, posing a significant challenge for society when adopting this technology. In the present day, the use of filters in social media apps have become common for improving our appearance, and popular Instagram profiles often dictate our travel destinations and restaurant choices. Previously exclusive to magazines and newspapers, such content is now easily accessible on platforms such as Tik Tok, YouTube, and Instagram [31].

Fractal theory has found applications in some areas of quantum physics as a means of better understanding certain phenomena [136]. In particular, the concept of fractal dimension has been utilized to examine the complexity of quantum wave functions, which describe the behavior of quantum systems and investigate how these systems can display self-similar behavior at different scales [137]. Fractal concepts have also been used to study quantum chaos, which is the behavior of quantum systems that are highly sensitive to initial conditions, similar to chaotic systems in classical physics. Researchers have employed fractal concepts to explore the quantum behavior of chaotic systems and comprehend how quantum systems can exhibit fractal-like behavior. Additionally, fractal concepts have been applied to study the properties of quantum systems at the interface between classical and quantum behavior, such as the quantum-classical transition in the behavior of large molecules. In all of these cases, fractal concepts have enabled researchers to understand how the properties of quantum systems can exhibit self-similar behavior and how this behavior can be related to classical physical phenomena [138].

Fractals have become increasingly relevant in computer science, and have been applied to a wide range of problems within the field. Fractals are particularly useful in computer science because of the self-similarity they exhibit, which has made them a valuable tool in various applications. One significant application of fractals in computer science is image compression, which involves digitally representing images in a manner that is efficient for storage and transmission. Fractals can be employed to accomplish this task by capturing the self-similar patterns present in the image, which can then be represented using a small set of parameters called a fractal code. This allows for more efficient storage and transmission of images, as the fractal representation requires less space than the original image. To reduce the time and resources required for image storage and transmission, it is crucial to represent images digitally in an efficient manner, and fractals have proven to be especially useful in this regard due to their ability to capture self-similar patterns and represent them using a compact set of parameters [139].

Fractals have found applications not only in image compression but also in computer graphics, particularly in creating realistic images of natural objects such as landscapes and trees. Fractal algorithms are used in this field by recursively applying self-similar patterns to generate the overall structure of the image. This approach allows for the creation of intricate and complex images that are difficult to produce using standard computer graphics techniques. Fractals have been utilized in computer graphics to generate highly detailed and realistic images of natural objects, such as landscapes and trees, through the use of fractal algorithms that apply self-similar patterns to create the overall structure of the image. This technique enables the creation of intricate and complex images that are challenging to produce using traditional computer graphics methods [140].

The use of fractal concepts extends to the field of algorithms and computational complexity, where they are employed to represent algorithm structures and comprehend the relationship between the complexity of an algorithm and the size of the input. By aiding researchers in designing more efficient algorithms and gaining insight into the boundaries of computation, fractals play a crucial role in this area. In fact, fractals have numerous applications in computer science and have been instrumental in solving various problems in the field. Their ability to capture self-similar patterns and be expressed using a limited number of parameters has proven particularly advantageous in image compression, computer graphics, and the design of computer networks and communication systems. Therefore, fractals have greatly contributed to improving the efficiency and effectiveness of algorithms and computational complexity research.

The results highlight the importance and potential applications of fractals in various fields of science and technology. Fractals, with their self-similar patterns and infinite intricacy, offer valuable insights and solutions in different domains. One significant finding is the role of fractal theory in quantum physics. The paper discusses how researchers have utilized fractal concepts to better understand the complexity of quantum wave functions and the behavior of quantum systems. Fractal dimensions have been employed to analyze the self-similar behavior of quantum systems at different scales. Additionally, the paper explores how fractals have been applied to study quantum chaos, where highly sensitive systems display behavior similar to chaotic systems in classical physics. This research contributes to a deeper comprehension of the intricate nature of quantum phenomena and their connection to classical physics. The paper also delves into the application of fractals in computer science. It discusses how fractals have been instrumental in image compression, where they capture self-similar patterns to represent images efficiently using fractal codes. This approach enables the storage and transmission of images with reduced space requirements. Additionally, the paper explores how fractals have been utilized in computer graphics to generate realistic and intricate images of natural objects like landscapes and trees. By applying fractal algorithms, computer graphics can achieve a level of detail and complexity that is challenging to attain using traditional methods.

Moreover, the integration of fractal concepts in algorithms and computational complexity has been described. It discusses how fractals offer insights into algorithm structures and the relationship between algorithm complexity and input size. By leveraging fractal principles, researchers can design more efficient algorithms and gain a deeper understanding of the boundaries of computation. The paper demonstrates how fractals have found applications in various problems within computer science, aiding in image compression, computer graphics, and the design of efficient computer networks and communication systems. The results emphasize the wide-ranging impact and practicality of fractals in scientific and technological domains. Fractals provide a powerful tool for understanding complex systems, optimizing algorithms, and enhancing the efficiency of various processes. The implications of these results extend to fields such as quantum physics, computer science, image processing, and algorithm design. The findings showcased in the paper highlight the versatility and potential of fractals as a valuable resource for advancing research and technology in multiple disciplines.

Despite its potential benefits, there are challenges and concerns to address. One limitation is the requirement for ubiquity, or the need to create a virtual environment that is as compelling and interactive as the physical world. Achieving this level of immersion and cultural richness in the Metaverse may be a complex task. Additionally, the integration of transportation systems within the Metaverse poses practical challenges. While systems like public transportation and sharing economy applications have potential benefits in terms of identity verification and payment processing, there may be technical and logistical hurdles to overcome in implementing these systems effectively. In the context of education, there are concerns about the potential loss of physical interaction between students and teachers. The adoption of Metaverse technology in education may raise questions about the balance between virtual and real-world interactions and the impact on learning outcomes. Furthermore, access to Metaverse technology may not be universal, potentially leading to unequal opportunities for educational institutions and students. Another limitation lies in the potential effects of the Metaverse on real-world relationships and culture. The introduction of new behaviors and reliance on filters and curated content in social media platforms may impact personal relationships and shape societal norms. It is crucial to consider the implications and potential consequences of adopting Metaverse technology on a broader scale. While fractal theory offers valuable insights and applications in quantum physics, computer science, and other fields, there may be limitations in its application. The complexity of quantum systems and the challenges of interpreting fractal-like behavior require further research and exploration to fully understand and utilize these concepts effectively.

7. Conclusions

In conclusion, this research has presented a groundbreaking approach to the development of Metaverse technology, aiming to address the limitations of current digitalization efforts and create a more immersive and realistic digital representation of various phenomena and assets. By interconnecting Metaverse platforms and utilizing digital twins within a multi-layered structure, the proposed Meta-Metaverse methodology offers a novel solution to enhance the capacity, scalability, and versatility of traditional Metaverse technology. This approach holds tremendous potential to revolutionize multiple aspects of our lives, spanning science, medicine, technology, and beyond. By bridging the gap between the physical and digital worlds, the Meta-Metaverse approach opens up new opportunities for scientific research, enabling the exploration of cause-and-effect relationships in a virtual environment. Moreover, this interconnected Metaverse has the power to spark innovation, facilitate collaboration, and inspire groundbreaking ideas that can shape a better future. As we continue to advance Metaverse technology, it is essential to embrace this new approach and its potential implications while ensuring ethical considerations and inclusivity. By harnessing the capabilities of the Meta-Metaverse methodology, we can unlock the transformative potential of the Metaverse and pave the way for a more interconnected and enriched digital reality.

Author Contributions: Conceptualization, M.J.; methodology, M.J.; software, M.J. and A.D.S.; validation, A.J. and O.M.; formal analysis, M.J.; investigation, A.D.S. and M.J.; resources, O.M.; data curation, M.J.; writing—original draft preparation, M.J.; writing—review and editing, A.J.; visualization, M.J.; supervision, O.M.; project administration, O.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Moztarzadeh, O.; Jamshidi, M.; Sargolzaei, S.; Keikhaee, F.; Jamshidi, A.; Shadroo, S.; Hauer, L. Metaverse and Medical Diagnosis: A Blockchain-Based Digital Twinning Approach Based on MobileNetV2 Algorithm for Cervical Vertebral Maturation. *Diagnostics* **2023**, *13*, 1485.
2. Wu, D.; Yang, Z.; Zhang, P.; Wang, R.; Yang, B.; Ma, X. Virtual-Reality Inter-Promotion Technology for Metaverse: A Survey. *IEEE Internet Things J.* **2023**. [CrossRef]
3. Koohang, A.; Nord, J.H.; Ooi, K.-B.; Tan, G.W.-H.; Al-Emran, M.; Aw, E.C.-X.; Baabdullah, A.M.; Buhalis, D.; Cham, T.-H.; Dennis, C. Shaping the metaverse into reality: A holistic multidisciplinary understanding of opportunities, challenges, and avenues for future investigation. *J. Comput. Inf. Syst.* **2023**, *63*, 735–765.
4. Zhou, Y.; Huang, H.; Yuan, S.; Zou, H.; Xie, L.; Yang, J. MetaFi++: WiFi-enabled Transformer-based Human Pose Estimation for Metaverse Avatar Simulation. *IEEE Internet Things J.* **2023**, *early access*.
5. Shafiei, A.; Jamshidi, M.; Khani, F.; Talla, J.; Peroutka, Z.; Gantassi, R.; Baz, M.; Cheikhrouhou, O.; Hamam, H. A hybrid technique based on a genetic algorithm for fuzzy multiobjective problems in 5G, internet of things, and mobile edge computing. *Math. Probl. Eng.* **2021**, *2021*, 9194578. [CrossRef]
6. Huynh-The, T.; Gadekallu, T.R.; Wang, W.; Yenduri, G.; Ranaweera, P.; Pham, Q.-V.; da Costa, D.B.; Liyanage, M. Blockchain for the metaverse: A Review. *Future Gener. Comput. Syst.* **2023**, *143*, 401–419. [CrossRef]
7. Szymanski, T. An Ultra-Reliable Quantum-Safe Software-Defined Deterministic Internet of Things (IoT) for Data-Centers, Cloud Computing and the Metaverse. *IEEE Commun. Mag.* **2023**, *preprint*. [CrossRef]
8. Jamshidi, M.; Moztarzadeh, O.; Jamshidi, A.; Abdelgawad, A.; El-Baz, A.S.; Hauer, L. Future of Drug Discovery: The Synergy of Edge Computing, Internet of Medical Things, and Deep Learning. *Future Internet* **2023**, *15*, 142.
9. Taoube, L.; Khanna, P.; Schneider, C.; Burgess, A.; Bleasel, J.; Haq, I.; Roberts, C. Situated learning in community environments (SLICE): Systems design of an immersive and integrated curriculum for community-based learning. *Med. Teach.* **2023**, *45*, 80–88.
10. Chengoden, R.; Victor, N.; Huynh-The, T.; Yenduri, G.; Jhaveri, R.H.; Alazab, M.; Bhattacharya, S.; Hegde, P.; Maddikunta, P.K.R.; Gadekallu, T.R. Metaverse for Healthcare: A Survey on Potential Applications, Challenges and Future Directions. *IEEE Access* **2023**, *11*, 12765–12795. [CrossRef]
11. Lv, Z.; Xie, S.; Li, Y.; Hossain, M.S.; El Saddik, A. Building the metaverse by digital twins at all scales, state, relation. *Virtual Real. Intell. Hardw.* **2022**, *4*, 459–470. [CrossRef]
12. Jamshidi, M.; Yahya, S.I.; Nouri, L.; Hashemi-Dezaki, H.; Rezaei, A.; Chaudhary, M.A. A Super-Efficient GSM Triplexer for 5G-Enabled IoT in Sustainable Smart Grid Edge Computing and the Metaverse. *Sensors* **2023**, *23*, 3775. [CrossRef]
13. Jamshidi, M.; Yahya, S.I.; Nouri, L.; Hashemi-Dezaki, H.; Rezaei, A.; Chaudhary, M.A. A High-Efficiency Diplexer for Sustainable 5G-Enabled IoT in Metaverse Transportation System and Smart Grids. *Symmetry* **2023**, *15*, 821. [CrossRef]
14. Gai, T.; Wu, J.; Cao, M.; Ji, F.; Sun, Q.; Zhou, M. Trust chain driven bidirectional feedback mechanism in social network group decision making and its application in Metaverse virtual community. *Expert Syst. Appl.* **2023**, *228*, 120369.
15. Cheng, S. Metaverse and Social View. In *Metaverse: Concept, Content and Context*; Springer: Berlin/Heidelberg, Germany, 2023; pp. 107–122.
16. Jauhiainen, J.S.; Krohn, C.; Junnila, J. Metaverse and Sustainability: Systematic Review of Scientific Publications until 2022 and Beyond. *Sustainability* **2023**, *15*, 346. [CrossRef]
17. Hastuti, T.D.; Sanjaya, R.; Koeswoyo, F. The Readiness of Lasem Batik Small and Medium Enterprises to Join the Metaverse. *Computers* **2022**, *12*, 5. [CrossRef]
18. Franco, A.A.; Loup-Escande, E.; Loiseaux, G.; Chotard, J.N.; Zapata-Dominguez, D.; Ciger, J.; Leclere, A.; Denisart, L.; Lelong, R. From Battery Manufacturing to Smart Grids: Towards a Metaverse for the Energy Sciences. *Batter. Supercaps* **2023**, *6*, e202200369.
19. Deng, Y.; Weng, Z.; Zhang, T. Metaverse-driven remote management solution for scene-based energy storage power stations. *Evol. Intell.* **2022**, 1–12. [CrossRef]
20. Fang, G.; Sun, Y.; Almutiq, M.; Zhou, W.; Zhao, Y.; Ren, Y. Distributed Medical Data Storage Mechanism Based on Proof of Retrievability and Vector Commitment for Metaverse Services. *IEEE J. Biomed. Health Inform.* **2023**. [CrossRef] [PubMed]
21. Daneshfar, F.; Jamshidi, M.B. An octonion-based nonlinear echo state network for speech emotion recognition in Metaverse. *Neural Netw.* **2023**, *163*, 108–121. [CrossRef] [PubMed]
22. Knox, J. The metaverse, or the serious business of tech frontiers. *Postdigital Sci. Educ.* **2022**, *4*, 207–215. [CrossRef]
23. Anshari, M.; Syafrudin, M.; Fitriyani, N.L.; Razzaq, A. Ethical Responsibility and Sustainability (ERS) Development in a Metaverse Business Model. *Sustainability* **2022**, *14*, 15805. [CrossRef]

24. Arora, S.; Pathak, R.S. *Koch's Fractal Approach to Hiding Information in a Digital Cover to Achieve Imperceptibility*; SSRN—Elsevier: Rochester, NY, USA, 2023.
25. Li, X.; Wei, W.; Wang, L.; Ding, P.; Zhu, L.; Cai, J. A new method for evaluating the pore structure complexity of digital rocks based on the relative value of fractal dimension. *Mar. Pet. Geol.* **2022**, *141*, 105694.
26. Fang, H.; Sang, S.; Liu, S.; Liu, H.; Xu, H.; Huang, Y. Determination of representative elementary volume of digital coal based on fractal theory with X-ray CT data and its application in fractal permeability predication model. *Front. Earth Sci.* **2022**, *16*, 657–670.
27. Wu, W.; Lu, J.; Zhang, H. A fractal-theory-based multi-agent model of the cyber physical production system for customized products. *J. Manuf. Syst.* **2023**, *67*, 143–154. [CrossRef]
28. Hwang, G.-J.; Chien, S.-Y. Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective. *Comput. Educ. Artif. Intell.* **2022**, *3*, 100082.
29. Zhao, Y.; Jiang, J.; Chen, Y.; Liu, R.; Yang, Y.; Xue, X.; Chen, S. Metaverse: Perspectives from graphics, interactions and visualization. *Vis. Inform.* **2022**, *6*, 56–67.
30. Arpaci, I.; Karatas, K.; Kusci, I.; Al-Emran, M. Understanding the social sustainability of the Metaverse by integrating UTAUT2 and big five personality traits: A hybrid SEM-ANN approach. *Technol. Soc.* **2022**, *71*, 102120.
31. Contreras, G.S.; González, A.H.; Fernández, M.I.S.; Martínez, C.B.; Cepa, J.; Escobar, Z. The importance of the application of the metaverse in education. *Mod. Appl. Sci.* **2022**, *16*, 1–34. [CrossRef]
32. Moztarzadeh, O.; Jamshidi, M.; Sargolzaei, S.; Jamshidi, A.; Baghalipour, N.; Malekzadeh Moghani, M.; Hauer, L. Metaverse and Healthcare: Machine Learning-Enabled Digital Twins of Cancer. *Bioengineering* **2023**, *10*, 455. [CrossRef]
33. Karaca, Y.; Baleanu, D.; Zhang, Y.-D.; Gervasi, O.; Moonis, M. *Multi-Chaos, Fractal and Multi-Fractional Artificial Intelligence of Different Complex Systems*; Academic Press: Cambridge, MA, USA, 2022.
34. Jahanmiri, F.; Parker, D.C. An overview of fractal geometry applied to urban planning. *Land* **2022**, *11*, 475. [CrossRef]
35. You, M.; Guan, C.; Lai, R. Spatial Structure of an Urban Park System Based on Fractal Theory: A Case Study of Fuzhou, China. *Remote Sens.* **2022**, *14*, 2144.
36. Babič, M.; Marinković, D.; Kovačič, M.; Šter, B.; Calì, M. A new method of quantifying the complexity of fractal networks. *Fractal Fract.* **2022**, *6*, 282. [CrossRef]
37. Accou, B.; Carpinelli, F. Systematically investigating human and organisational factors in complex socio-technical systems by using the "SAfety FRactal ANalysis" method. *Appl. Ergon.* **2022**, *100*, 103662.
38. Han, S. Analysis of Digital Pattern Generation Technology Based on Fractal Graph. In Proceedings of the 2022 2nd International Conference on Computation, Communication and Engineering (ICCCE), Guangzhou, China, 4–6 November 2022; pp. 45–48.
39. Gogins, M. Metamathematics of Algorithmic Composition. *arXiv* **2023**, arXiv:2305.15601.
40. Rani, M.; Kumar, V. Superior julia set. *Res. Math. Educ.* **2004**, *8*, 261–277.
41. Martinez, F.; Manriquez, H.; Ojeda, A.; Olea, G. Organization patterns of complex river networks in Chile: A fractal morphology. *Mathematics* **2022**, *10*, 1806.
42. Bunde, A.; Havlin, S. *Fractals in Science*; Springer: Berlin/Heidelberg, Germany, 2013.
43. Tran, N.H.; Rahman, M.; Rahman, S.S. A nested neuro-fractal-stochastic technique for modeling naturally fractured reservoirs. In Proceedings of the SPE Asia Pacific Oil and Gas Conference and Exhibition, Melbourne, Australia, 8–10 October 2002; p. SPE-77877-MS.
44. Kargar, S.; Mohammad-Khanli, L. Fractal: An advanced multidimensional range query lookup protocol on nested rings for distributed systems. *J. Netw. Comput. Appl.* **2017**, *87*, 147–168.
45. Havlin, S.; Buldyrev, S.; Goldberger, A.; Mantegna, R.; Ossadnik, S.; Peng, C.-K.; Simons, M.; Stanley, H. Fractals in biology and medicine. *Chaos Solitons Fractals* **1995**, *6*, 171–201. [CrossRef]
46. Cross, S.S. Fractals in pathology. *J. Pathol.* **1997**, *182*, 1–8. [CrossRef]
47. Löchel, H.F.; Welzel, M.; Hattab, G.; Hauschild, A.-C.; Heider, D. Fractal construction of constrained code words for DNA storage systems. *Nucleic Acids Res.* **2022**, *50*, e30. [CrossRef]
48. Adhikari, N.; Logeshwaran, J.; Kiruthiga, T. The Artificially Intelligent Switching Framework for Terminal Access Provides Smart Routing in Modern Computer Networks. *BOHR Int. J. Smart Comput. Inf. Technol.* **2022**, *3*, 45–50.
49. Kumar, A.; Sharma, K.; Singh, H.; Naugriya, S.G.; Gill, S.S.; Buyya, R. A drone-based networked system and methods for combating coronavirus disease (COVID-19) pandemic. *Future Gener. Comput. Syst.* **2021**, *115*, 1–19. [CrossRef]
50. Visconti, R.M. From physical reality to the Metaverse: A Multilayer Network Valuation. *J. Metaverse* **2022**, *2*, 16–22.
51. Sivasankar, G. Study of blockchain technology, AI and digital networking in metaverse. *IRE J.* **2022**, *5*, 110–115.
52. Jamshidi, M.B.; Ebadpour, M.; Moghani, M.M. Cancer Digital Twins in Metaverse. In Proceedings of the 2022 20th International Conference on Mechatronics-Mechatronika (ME), Pilsen, Czech Republic, 7–9 December 2022; pp. 1–6.
53. Gupta, O.J.; Yadav, S.; Srivastava, M.K.; Darda, P.; Mishra, V. Understanding the intention to use metaverse in healthcare utilizing a mix method approach. *Int. J. Healthc. Manag.* **2023**, *in press*. [CrossRef]
54. Kerdvibulvech, C.; Chang, C.-C. A New Study of Integration between Social Robotic Systems and the Metaverse for Dealing with Healthcare in the Post-COVID-19 Situations. In Proceedings of the International Conference on Social Robotics, Florence, Italy, 13–16 December 2022; pp. 392–401.

55. Jamshidi, M.B.; Talla, J.; Lalbakhsh, A.; Sharifi-Atashgah, M.S.; Sabet, A.; Peroutka, Z. A conceptual deep learning framework for COVID-19 drug discovery. In Proceedings of the 2021 IEEE 12th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), New York, NY, USA, 1–4 December 2021; pp. 00030–00034.
56. Ali, S.; Abdullah; Armand, T.P.T.; Athar, A.; Hussain, A.; Ali, M.; Yaseen, M.; Joo, M.-I.; Kim, H.-C. Metaverse in healthcare integrated with explainable ai and blockchain: Enabling immersiveness, ensuring trust, and providing patient data security. *Sensors* **2023**, *23*, 565.
57. Huynh-The, T.; Pham, Q.-V.; Pham, X.-Q.; Nguyen, T.T.; Han, Z.; Kim, D.-S. Artificial intelligence for the metaverse: A survey. *Eng. Appl. Artif. Intell.* **2023**, *117*, 105581.
58. Marzaleh, M.A.; Peyravi, M.; Shaygani, F. A revolution in health: Opportunities and challenges of the Metaverse. *Excli J.* **2022**, *21*, 791–792.
59. Ramu, S.P.; Srivastava, G.; Chengoden, R.; Victor, N.; Maddikunta, P.K.R.; Gadekallu, T.R. The Metaverse for Cognitive Health: A Paradigm Shift. *IEEE Consum. Electron. Mag.* **2023**. [CrossRef]
60. Al-Zyoud, I.; Laamarti, F.; Ma, X.; Tobón, D.; El Saddik, A. Towards a machine learning-based digital twin for non-invasive human bio-signal fusion. *Sensors* **2022**, *22*, 9747.
61. Liu, Y.X.; Chen, T.; Li, D.; Fu, J.; Liu, S.J. iMeta: Integrated meta-omics for biology and environments. *iMeta* **2022**, *1*, e15. [CrossRef]
62. Kim, A.; Yoo, B.; Huh, J.; So, M.-K.; Jeong, T.-D.; Moon, B.-I.; Lee, K.E.; Moon, H.S. P393: Effectiveness of group genetic counseling session via metaverse. *Genet. Med. Open* **2023**, *1*, 393–395.
63. Lee, C.-S.; Wang, M.-H.; Chen, C.-Y.; Yang, F.-J.; Dockhorn, A. Genetic Assessment Agent for High-School Student and Machine Co-Learning Model Construction on Computational Intelligence Experience. In Proceedings of the 2023 IEEE Congress on Evolutionary Computation (IEEE CEC 2023), Chicago, IL, USA, 2–5 July 2023.
64. Zhou, X.; Tang, L.; Lin, D.; Han, W. Virtual & augmented reality for biological microscope in experiment education. *Virtual Real. Intell. Hardw.* **2020**, *2*, 316–329.
65. Garcia-Bonete, M.J.; Jensen, M.; Katona, G. A practical guide to developing virtual and augmented reality exercises for teaching structural biology. *Biochem. Mol. Biol. Educ.* **2019**, *47*, 16–24.
66. Lippert, K.; Khan, M.N.R.; Rabbi, M.M.; Dutta, A.; Cloutier, R. A framework of metaverse for systems engineering. In Proceedings of the 2021 IEEE International Conference on Signal Processing, Information, Communication & Systems (SPICSCON), Dhaka, Bangladesh, 3–4 December 2021; pp. 50–54.
67. Palak; Sangeeta; Gulia, P.; Gill, N.S.; Chatterjee, J.M. Metaverse and Its Impact on Climate Change. In *The Future of Metaverse in the Virtual Era and Physical World*; Springer: Berlin/Heidelberg, Germany, 2023; pp. 211–222.
68. Stoll, C.; Gallersdörfer, U.; Klaaßen, L. Climate impacts of the metaverse. *Joule* **2022**, *6*, 2668–2673. [CrossRef]
69. Hatrote, H. Climate Change and Its Metacognitions in the Metaverse. Master's Thesis, Fashion Institute of Technology, State University of New York, New York, NY, USA, 2022.
70. Huang, H.; Zhang, Q.; Li, T.; Yang, Q.; Yin, Z.; Wu, J.; Xiong, Z.; Zhu, J.; Wu, J.; Zheng, Z. Economic Systems in Metaverse: Basics, State of the Art, and Challenges. *arXiv* **2022**, arXiv:2212.05803.
71. Cheng, X.; Zhang, S.; Fu, S.; Liu, W.; Guan, C.; Mou, J.; Ye, Q.; Huang, C. Exploring the metaverse in the digital economy: An overview and research framework. *J. Electron. Bus. Digit. Econ.* **2022**, *1*, 206–224.
72. Vidal-Tomás, D. The illusion of the metaverse and meta-economy. *Int. Rev. Financ. Anal.* **2023**, *86*, 102560. [CrossRef]
73. Ahmed, Y.; Reddy, M.; Mederos, J.; McDermott, K.C.; Varma, D.K.; Ludwig, C.A.; Khaderi, K.R. Democratizing healthcare in the Metaverse. How video games can monitor eye conditions using the Vision Performance Index: A pilot study. *Ophthalmol. Sci.* **2023**, 100349. [CrossRef]
74. McGregor, I. Video Game Audio in the Metaverse and Beyond. *ACM Games Res. Pract.* **2023**, *1*, 15. [CrossRef]
75. Bellenger, D.; Chen, M.; Xu, Z. Facial emotion recognition with a reduced feature set for video game and metaverse avatars. *Authorea Prepr.* **2023**, *preprint*.
76. Wei, S. Toward a Convergent Metaverse: Video Games and the Transformation of the Digital Body. *Theor. Stud. Lit. Art* **2023**, *43*, 52–60.
77. Hassan, T. Genetic and environmental influences on playing video games. *Media Psychol.* **2023**, 1–21. [CrossRef]
78. Montalvo, J.; García-Martín, Á.; Bescós, J. Exploiting semantic segmentation to boost reinforcement learning in video game environments. *Multimed. Tools Appl.* **2023**, *82*, 10961–10979. [CrossRef]
79. Venugopal, J.P.; Subramanian, A.A.V.; Peatchimuthu, J. The realm of metaverse: A survey. *Comput. Animat. Virtual Worlds* **2023**, e2150. [CrossRef]
80. Wan, X.; Zhang, G.; Yuan, Y.; Chai, S. Can metaverse technology drive digital transformation of manufacturers? Selection of evolutionary stability strategy based on supply chain perspective. *Appl. Soft Comput.* **2023**, *145*, 110611.
81. Wylde, V.; Prakash, E.; Hewage, C.; Platts, J. Post-Covid-19 Metaverse Cybersecurity and Data Privacy: Present and Future Challenges. In *Data Protection in a Post-Pandemic Society: Laws, Regulations, Best Practices and Recent Solutions*; Springer: Berlin/Heidelberg, Germany, 2023; pp. 1–48.
82. Cheah, I.; Shimul, A.S. Marketing in the metaverse: Moving forward–What's next? *J. Glob. Sch. Mark. Sci.* **2023**, *33*, 1–10.
83. De Giovanni, P. Sustainability of the Metaverse: A transition to Industry 5.0. *Sustainability* **2023**, *15*, 6079.
84. Cui, Y.; Idota, H.; Ota, M. Reforming Supply Chain Systems in Metaverse. In Proceedings of the 9th Multidisciplinary International Social Networks Conference, Matsuyama, Japan, 29–31 October 2022; pp. 39–43.

85. Periyasami, S.; Periyasamy, A.P. Metaverse as future promising platform business model: Case study on fashion value chain. *Businesses* **2022**, *2*, 527–545.
86. Khalaj, O.; Jamshidi, M.; Hassas, P.; Hosseininezhad, M.; Mašek, B.; Štadler, C.; Svoboda, J. Metaverse and AI Digital Twinning of 42SiCr Steel Alloys. *Mathematics* **2022**, *11*, 4. [CrossRef]
87. Gao, Y.; Lu, Y.; Zhu, X. Mateverse, the future materials science computation platform based on metaverse. *J. Phys. Chem. Lett.* **2022**, *14*, 148–157. [CrossRef]
88. Sutopo, A.H. *Developing Teaching Materials Based on Metaverse*; Topazart: Miami, FL, USA, 2022.
89. Zvarikova, K.; Michalikova, K.F.; Rowland, M. Retail data measurement tools, cognitive artificial intelligence algorithms, and metaverse live shopping analytics in immersive hyper-connected virtual spaces. *Linguist. Philos. Investig.* **2022**, *21*, 9–24.
90. Hawkins, M. Metaverse live shopping analytics: Retail data measurement tools, computer vision and deep learning algorithms, and decision intelligence and modeling. *J. Self-Gov. Manag. Econ.* **2022**, *10*, 22–36.
91. Popescu, G.H.; Valaskova, K.; Horak, J. Augmented reality shopping experiences, retail business analytics, and machine vision algorithms in the virtual economy of the metaverse. *J. Self-Gov. Manag. Econ.* **2022**, *10*, 67–81.
92. Zhang, L.; Anjum, M.A.; Wang, Y. The Impact of Trust-Building Mechanisms on Purchase Intention towards Metaverse Shopping: The Moderating Role of Age. *Int. J. Hum. Comput. Interact.* **2023**, 1–19. [CrossRef]
93. Ahmed, E.; Darwish, A.; Hassanien, A.E. A Framework for Shopping Based on Digital Twinning in the Metaverse World. In *The Future of Metaverse in the Virtual Era and Physical World*; Springer: Berlin/Heidelberg, Germany, 2023; pp. 155–168.
94. Barta, S.; Gurrea, R.; Flavián, C. Telepresence in live-stream shopping: An experimental study comparing Instagram and the metaverse. *Electron. Mark.* **2023**, *33*, 29.
95. Jayathilaka, R.; Samarasinghe, S.; Jayasekara, P.; Batawala, R.; De Silva, D.; Cooray, D. Effects of Metaverse Technology and Drone Delivery: Online Mobile Accessories Shopping in a Virtual Shop. *Int. J. Eng. Manag. Res.* **2022**, *12*, 370–378.
96. Patil, S.; Gaikwad, G.; Hiran, S.; Ikhar, A.; Jadhav, H. metaAR–AR/XR Shopping App using Unity. In Proceedings of the 2023 International Conference for Advancement in Technology (ICONAT), Goa, India, 24–26 January 2023; pp. 1–11.
97. Zvarikova, K.; Machova, V.; Nica, E. Cognitive Artificial Intelligence Algorithms, Movement and Behavior Tracking Tools, and Customer Identification Technology in the Metaverse Commerce. *Rev. Contemp. Philos.* **2022**, *21*, 171–187.
98. Valaskova, K.; Popp, J.; Balica, R.-Ş. Visual and Spatial Analytics, Immersive Virtual Simulation Technologies, and Motion Planning and Object Recognition Algorithms in the Retail Metaverse. *Econ. Manag. Financ. Mark.* **2022**, *17*, 58–74.
99. Rawat, D.B.; El Alami, H. Metaverse: Requirements, architecture, standards, status, challenges, and perspectives. *IEEE Internet Things Mag.* **2023**, *6*, 14–18. [CrossRef]
100. Wu, T.; Hao, F. Edu-Metaverse: Concept, architecture, and applications. *Interact. Learn. Environ.* **2023**, 1–28.
101. Al-Ghaili, A.M.; Kasim, H.; Al-Hada, N.M.; Hassan, Z.; Othman, M.; Hussain, T.J.; Kasmani, R.M.; Shayea, I. A review of metaverse's definitions, architecture, applications, challenges, issues, solutions, and future trends. *IEEE Access* **2022**, *10*, 125835–125866. [CrossRef]
102. Schumacher, P. The metaverse as opportunity for architecture and society: Design drivers, core competencies. *Archit. Intell.* **2022**, *1*, 11. [PubMed]
103. Haristianti, V.; Murdowo, D. The development of the virtual environment and its impact on interior designers and architects. Case study: Zaha Hadid Architects. In *Sustainable Development in Creative Industries: Embracing Digital Culture for Humanities*; Routledge: Milton Park, UK, 2023; pp. 296–301.
104. Izani, M.; Mustaffa, F.; Razak, A.; Alkhalidi, A. Metaverse: A Platform for Designers. In Proceedings of the 2nd International Conference on Creative Multimedia 2022 (ICCM 2022), Virtual, 26–28 July 2023; pp. 134–143.
105. Astanto, S.B. *Art in Metaverse Era Sustainable Interior Design Perspektif*; SSRN—Elsevier: Rochester, NY, USA, 2023. [CrossRef]
106. Wiederhold, B.K. Sexual harassment in the Metaverse. *Cyberpsychology Behav. Soc. Netw.* **2022**, *25*, 479–480. [CrossRef]
107. Kim, K.; Lee, A. Metaverse Buzz in the Fashion Industry: Social Network Analysis with Twitter Data Introduction. Available online: https://www.iastatedigitalpress.com/itaa/article/id/16028/ (accessed on 24 July 2023).
108. Deng, R.; Matthes, J. Utopian or dystopian? The portrayal of the metaverse in popular news on social media. *Heliyon* **2023**, *9*, e14509. [CrossRef]
109. Moro-Visconti, R. Metaverse: A Digital Network Valuation. In *The Valuation of Digital Intangibles: Technology, Marketing, and the Metaverse*; Springer: Berlin/Heidelberg, Germany, 2022; pp. 515–559.
110. Wang, Y.; Su, Z.; Yan, M. Social Metaverse: Challenges and Solutions. *arXiv* **2023**, arXiv:2301.10221.
111. Lee, H.-W.; Chang, K.; Uhm, J.-P.; Owiro, E. How Avatar Identification Affects Enjoyment in the Metaverse: The Roles of Avatar Customization and Social Engagement. *Cyberpsychol. Behav. Soc. Netw.* **2023**, *26*, 255–262.
112. Kshetri, N. Policy, ethical, social, and environmental considerations of Web3 and the metaverse. *IT Prof.* **2022**, *24*, 4–8. [CrossRef]
113. Egliston, B.; Carter, M. 'The metaverse and how we'll build it': The political economy of Meta's Reality Labs. *New Media Soc.* **2022**, 14614448221119785. [CrossRef]
114. Ricoy-Casas, R.M. The Metaverse as a New Space for Political Communication. In *Communication and Applied Technologies: Proceedings of ICOMTA 2022*; Springer: Berlin/Heidelberg, Germany, 2022; pp. 325–334.
115. Anderson, J.; Rainie, L. The Metaverse in 2040. Available online: https://www.pewresearch.org/internet/wp-content/uploads/sites/9/2022/06/PI_2022.06.30_Metaverse-Predictions_FINAL.pdf (accessed on 24 July 2023).

116. Dolata, M.; Schwabe, G. What is the Metaverse and who seeks to define it? Mapping the site of social construction. *J. Inf. Technol.* **2023**, 02683962231159927. [CrossRef]
117. Hine, E. Content Moderation in the Metaverse Could Be a New Frontier to Attack Freedom of Expression. *Philos. Technol.* **2023**, *36*, 43. [CrossRef]
118. Bibri, S.E. The social shaping of the metaverse as an alternative to the imaginaries of data-driven smart Cities: A study in science, technology, and society. *Smart Cities* **2022**, *5*, 832–874.
119. Yang, J.; Wang, X.; Zhao, Y. Parallel manufacturing for industrial metaverses: A new paradigm in smart manufacturing. *IEEE/CAA J. Autom. Sin.* **2022**, *9*, 2063–2070. [CrossRef]
120. Yao, X.; Ma, N.; Zhang, J.; Wang, K.; Yang, E.; Faccio, M. Enhancing wisdom manufacturing as industrial metaverse for industry and society 5.0. *J. Intell. Manuf.* **2022**, 1–21.
121. Lee, J.; Kundu, P. Integrated cyber-physical systems and industrial metaverse for remote manufacturing. *Manuf. Lett.* **2022**, *34*, 12–15. [CrossRef]
122. Nguyen, H.D.; Tran, K.P. Artificial Intelligence for Smart Manufacturing in Industry 5.0: Methods, Applications, and Challenges. In *Artificial Intelligence for Smart Manufacturing*; Springer: Cham, Switzerland, 2023; pp. 5–33.
123. Kusuma, A.T.; Supangkat, S.H. Metaverse fundamental technologies for smart city: A literature review. In Proceedings of the 2022 International Conference on ICT for Smart Society (ICISS), Bandung, Indonesia, 10–11 August 2022; pp. 1–7.
124. Keshmiri Neghab, H.; Jamshidi, M.; Keshmiri Neghab, H. Digital twin of a magnetic medical microrobot with stochastic model predictive controller boosted by machine learning in cyber-physical healthcare systems. *Information* **2022**, *13*, 321.
125. Khalaj, O.; Jamshidi, M.; Hassas, P.; Mašek, B.; Štadler, C.; Svoboda, J. Digital Twinning of a Magnetic Forging Holder to Enhance Productivity for Industry 4.0 and Metaverse. *Processes* **2023**, *11*, 1703. [CrossRef]
126. Chaudhuri, A.; Anand, A. Enable the metaverse and smart society with trustworthy and sustainable 'things'. *J. Data Prot. Priv.* **2023**, *5*, 363–373.
127. Alpala, L.O.; Quiroga-Parra, D.J.; Torres, J.C.; Peluffo-Ordóñez, D.H. Smart factory using virtual reality and online multi-user: Towards a metaverse for experimental frameworks. *Appl. Sci.* **2022**, *12*, 6258.
128. Wang, F.-Y.; Qin, R.; Wang, X.; Hu, B. Metasocieties in metaverse: Metaeconomics and metamanagement for metaenterprises and metacities. *IEEE Trans. Comput. Soc. Syst.* **2022**, *9*, 2–7.
129. Kerdvibulvech, C. Exploring the impacts of COVID-19 on digital and metaverse games. In Proceedings of the International Conference on Human-Computer Interaction, Virtual Event, 26 June–1 July 2022; pp. 561–565.
130. Dubey, V.; Mokashi, A.; Pradhan, R.; Gupta, P.; Walimbe, R. Metaverse and Banking Industry–2023 The Year of Metaverse Adoption. *Tech. Romanian J. Appl. Sci. Technol.* **2022**, *4*, 62–73.
131. Dionisio, J.D.N.; III, W.G.B.; Gilbert, R. 3D virtual worlds and the metaverse: Current status and future possibilities. *ACM Comput. Surv. (CSUR)* **2013**, *45*, 34.
132. Chen, C.; Yao, M.Z. Strategic use of immersive media and narrative message in virtual marketing: Understanding the roles of telepresence and transportation. *Psychol. Mark.* **2022**, *39*, 524–542.
133. Buhalis, D.; Leung, D.; Lin, M. Metaverse as a disruptive technology revolutionising tourism management and marketing. *Tour. Manag.* **2023**, *97*, 104724. [CrossRef]
134. Ning, H.; Wang, H.; Lin, Y.; Wang, W.; Dhelim, S.; Farha, F.; Ding, J.; Daneshmand, M. A Survey on the Metaverse: The State-of-the-Art, Technologies, Applications, and Challenges. *arXiv* **2021**, arXiv:2111.09673.
135. Zhang, H.; Luo, G.; Li, Y.; Wang, F.Y. Parallel Vision for Intelligent Transportation Systems in Metaverse: Challenges, Solutions, and Potential Applications. *IEEE Trans. Syst. Man Cybern. Syst.* **2022**, *53*, 3400–3413.
136. Mwema, F.M.; Jen, T.-C.; Kaspar, P. Fractal Theory in Thin Films: Literature Review and Bibliometric Evidence on Applications and Trends. *Fractal Fract.* **2022**, *6*, 489.
137. Grosu, G.F.; Hopp, A.V.; Moca, V.V.; Bârzan, H.; Ciuparu, A.; Ercsey-Ravasz, M.; Winkel, M.; Linde, H.; Mureșan, R.C. The fractal brain: Scale-invariance in structure and dynamics. *Cereb. Cortex* **2023**, *33*, 4574–4605.
138. El-Nabulsi, R.A.; Anukool, W. Fractal MHD wind in the solar atmosphere. *Adv. Space Res.* **2022**, *69*, 3525–3539. [CrossRef]
139. El-Nabulsi, R.A.; Anukool, W. Ocean–atmosphere dynamics and Rossby waves in fractal anisotropic media. *Meteorol. Atmos. Phys.* **2022**, *134*, 33.
140. Michallek, F.; Nakamura, S.; Ota, H.; Ogawa, R.; Shizuka, T.; Nakashima, H.; Wang, Y.-N.; Ito, T.; Sakuma, H.; Dewey, M. Fractal analysis of 4D dynamic myocardial stress-CT perfusion imaging differentiates micro-and macrovascular ischemia in a multi-center proof-of-concept study. *Sci. Rep.* **2022**, *12*, 5085. [PubMed]