

The 4 Epochs of the Metaverse

Stelios A.K. Ioannidis

Department of Tourism Economics & Management
University of the Aegean
Chios, Greece

sioannidis@aegean.gr
0000-0002-9043-8895

(Corresponding Author)

Alexios - Patapios Kontis

Department of Tourism Economics & Management
University of the Aegean
Chios, Greece

apkontis@aegean.gr
0000-0003-0868-7612

Abstract — *The concept of the Metaverse has attracted considerable attention since 2021, primarily due to the rebranding of “Fakebook” to “Meta” and its promise of delivering a more immersive online experience. However, the origins of this term can be traced back to Neal Stephenson's sci-fi novel, “Snow Crash”, published in 1992. In the current study, an extensive articles review has been conducted, including academic sources, technology blogs, business reports, and social media posts. The main goal is to create a comprehensive timeline of the Metaverse and its underlying technologies. By categorizing 26 significant milestones into four distinct periods, the study introduces a framework called “4 Epochs of the Metaverse.” The suggested framework challenges previously established linear timelines found in literature by identifying time periods that are based on content, rather than on chronological order. The findings emphasize that the Metaverse is not a new phenomenon, but, rather, a concept that has evolved over time since 1905 and can be classified under 4 dynamic periods, which are named Epochs. The study provides an in-depth description of the origins and evolution of the Metaverse, serving a dual purpose for researchers and practitioners: it provides insights into the transformative potential and future possibilities of the metaverse, while it lays the groundwork for further exploration and innovation in this phygital (physical + digital) environment.*

Keywords — *Metaverse, blockchain, NFTs, timeline, digital twin*

I. INTRODUCTION

Over the past few years, there has been a notable explosion in interest surrounding the metaverse, especially following the rebranding of the social media giant “Facebook” to “Meta” [2], [8], [25], [45], [98], [112]. The company has made claims that the new platform will offer an even more immersive internet experience, where users will be able to actively participate in the virtual environment rather than simply observe it [75]. Following this announcement, a great number of people related the term “metaverse” with the social media company “Meta” and due to their lack of previous knowledge, it is widely believed, until the time of writing this study, that the metaverse is a new social medium. For this, it is important to note at this point that the term “metaverse” did not suddenly appear in 2021, nor should be associated with any particular company or platform. The origins of metaverse can be traced back to the year 1992 in Neal Stephenson's science fiction novel, “Snow Crash” [11], [27], [63], [78], [82]. In fact, the notion of metaverse extends even further into the past, as revealed by the current research. According to Stephenson, the metaverse is a virtual world that coexists alongside the physical realm. In his book, individuals interact with metaverse through digital representations called “avatars” [97]. Within the metaverse, people can engage in work, generate income, perform daily tasks, access information, socialize, join leisure activities, interact with others, and

explore diverse locations, as if they were in the physical world. Direct linkage and collaboration between the world of metaverse and the real-life world is of major importance, involving avatars controlled by human users and Artificial Intelligence (AI)-powered agents. These agents are avatars guided by lines of code, rather than human operators. They offer various services, such as information search and provision.

Stephenson's depiction of the metaverse in 1992 aligns with recent plans proposed by big corporations regarding its characteristics, way of use and potential benefits for its users. Nevertheless, there is a notable difference between the initial portrayal of the metaverse and how it is currently envisioned by developers, academics, and entrepreneurs. The difference lies in the technological advancements that have taken place from 1992 to the present day. These advancements involve the development of blockchain technology and its associated applications, such as smart contracts, decentralized applications (Dapps), cryptocurrencies, oracles, lifelogging, and Non-Fungible Tokens (NFTs), among others [56]. Apart from blockchain, other technologies including high-speed (5G-6G) connectivity, digital twins, mirror world, avatars, virtual reality (VR), augmented reality (AR), mixed reality (MR), and numerous others have furtherly fueled optimism among experts regarding metaverse's future capabilities and its widespread adoption [56], [57]. Some of the above technologies, such as VR, avatars, AI, high-speed connectivity, and fog computing to name some, were implied or directly mentioned in the initial concept of the metaverse by Neal Stephenson, while others have been later explored and incorporated, and now serve as essential components of it. An excellent illustration is the birth of NFTs: Although the first description of the metaverse in 1992 did not include any reference to NFTs or any assets with similar characteristics, nowadays, it is almost impossible to engage in discussions about the metaverse without acknowledging the significant role of NFTs in providing ownership rights. On the other hand, the collaboration between humans and AI-powered agents for rapid and accurate information access and critical discussions, as depicted in “Snow Crash”, has only recently appeared in the real world. It is more than characteristic the scene where *H. Protagonist* (the protagonist figure in the book) has long discussions with the *Librarian*. The latter is an AI entity that assists *H. Protagonist* in his research [58]. In fact, *Librarian* is a vast digital repository, while he possesses the ability to navigate through oceans of information within seconds [58], [97]. The emergence of human-AI collaboration today coincides with the boom of generative AI applications in late 2022 and the onset of 2023, with the widely known application “ChatGPT” playing the role of *Librarian*.



At present, the metaverse is predominantly a conceptual advancement or, better, a theoretical leap forward rather than a reality. Despite this, the gaming industry has enthusiastically embraced the idea of evolving multiplayer virtual worlds into metaverse environments. Moreover, gamers appear more than eager to follow this shift and immerse themselves in a novel experience. A study conducted by Ernst & Young indicates that the metaverse has the potential to revolutionize the gaming industry and introduce new business models to the real world [33], [61], [96]. Examples of such models are already emerging, such as Play-to-Earn (P2E) games or Run-to-Earn (R2E) mobile applications. P2E games or R2E applications use blockchain technology and reward users' performance with cryptocurrencies (tokens) that can be traded for other cryptocurrencies or exchanged for national currencies, in other words, they are games that can be a source of income for the user. Another potential of the metaverse lies in enabling hyper-realistic virtual conversations, experiences, and transactions. As the COVID-19 pandemic unveiled the benefits of digitization, with people having to meet [34], learn, have fun, socialize, seek consultation, and engage in online interactions [4], it is evident that the metaverse appears as a clear answer to how the future will look like.

To gain a deeper understanding of the ever-evolving concept of the metaverse and its ongoing development, it is imperative for researchers and practitioners to explore its origins, the historical progression of its components and the overall development of the metaverse as a cohesive entity up to the present. Understanding its roots and the path it has traversed over time is essential for harnessing its full potential and addressing the challenges it may present. In this regard, the current research makes a significant two-fold contribution. Firstly, it aims to uncover the roots of the metaverse by presenting a comprehensive and detailed timeline, shedding light on the milestones and key developments that shaped its evolution. This historical context not only highlights the metaverse's journey but, also, reveal the factors that have propelled its emergence. Secondly, this paper builds a dynamic framework that categorizes significant milestones of the metaverse's evolution into four distinct periods, referred to as "Epochs". By organizing the history of metaverse into these Epochs, researchers, developers, and enthusiasts can gain a clearer perspective on its continuous evolution.

II. METHODOLOGY

In addition to academic literature, the authors of the current study conducted an extensive articles review encompassing various sources such as technology blogs, business reports, social media posts, and webpages of tech corporations, all relevant to metaverse. For this purpose, two academic databases, namely "Research Gate" and "Google Scholar" were employed. From these two sources a sum of academic articles was collected, which were later screened for their relevance to the topic of metaverse. Irrelevant papers, along with duplications were excluded. Similarly, internet scraping was employed to gather business reports, social media posts and blog articles related to metaverse. For all the searches, the following keywords were utilized: "metaverse", "metaverse" AND "history", "history of metaverse", "metaverse" AND "timeline", "metaverse timeline",

"metaverse" AND "evolution", "metaverse evolution", "metaverse" AND "milestones" and "metaverse" AND "events".

Building upon the findings of previous researchers who identified VR, AR, blockchain (including cryptocurrencies, smart contracts, and NFTs), digital twins, mirror worlds, and edge computing as key underlying technologies of the metaverse [16], [25], [30], [57], the current research aims to examine the historical development of all these elements and their integration in shaping the concept of the metaverse. The collection of both academic and non-academic articles played a vital role in identifying events and inventions of great importance for the history of metaverse. Additionally, this approach not only aided in confirming and triangulating the inclusion of these milestones in the timeline of metaverse, but, also, enhanced our understanding of these events and their influence on the metaverse. Finally, the articles review method with academic and non-academic literature sufficiently facilitated the categorization of each event within the corresponding Epoch.

III. BUILDING THE METAVERSE TIMELINE

A. The History of Metaverse (1905-2000)

Although the concept of the metaverse was initially introduced in 1992, the idea of creating a virtual world that exists alongside and / or replaces the reality has roots that go long further back. The history of the metaverse can be traced back to the early 20th century, specifically in the science fiction short story "The Machine Stops" by E.M. Forster, published in 1909 [45], [70]. The story depicts a dystopian future, in which people live underground in cells, and rely on a machine (the "Machine") to fulfill their every need. "The Machine" allows them to control the temperature and lighting of their rooms, to virtually travel, to communicate with each other, to work, or search for information. However, this universal virtuality and dependence on technology ultimately influence the psychology and behavior of people in Forster's world. For example, a character all surprisingly expresses a desire for face-to-face interaction, complaining about the limitations of technology in truly connecting people [39] (p.2). It is worth noting that this story was written in response to E.G. Wells's work, "A Modern Utopia" [37], [48], [55], [90], which was published four years prior to "The Machine Stops", in 1905. Wells presented a parallel world, a second Earth, that was an idealized version of the real world, free from the flaws and limitations of reality. Wells aimed to describe an utopian society through his writing, focusing on designing an improved and desirable way of life [107] (p.8). E.M. Forster, in turn, sought to respond to Wells's vision by presenting his own version of a parallel virtual world, with technology leading to a dystopian future. In essence, Forster attempted to demonstrate how the machine-centered society, envisioned by Wells, would exacerbate pain, fear, and anxiety instead of alleviating them [37]. Thus, according to the current extensive articles review, the origins of the metaverse as a concept can be traced back to the science fiction literature of 1905 and 1909, where the ideas of a parallel world are presented in both utopian and dystopian forms, expressing expectations and fears for a world where technology defines reality. However, some researchers argued that the terms

"dystopian" and "utopian" cannot be used separately for these two works, as "...the effectiveness of dystopian fiction depends upon its invocation of utopia as its mirror image" [90] (p.56).

The next milestone in the realization of the metaverse can be found in the science fiction short story "Pygmalion's Spectacles" by S.G. Weinbaum, published in 1935. The story depicts virtual reality for the first time [89] and explores the idea of users escaping from the physical world to such an extent, that they question the nature of reality itself. The protagonist experiences a story with all senses engaged, where he becomes part of the narrative and interacts with the virtual environment to such a degree that he is left in doubt whether his encounter was a mere illusion or a real event [106] (p.3). According to [59], "Pygmalion's Spectacles" is considered the starting point of the metaverse. It not only presents the concept of virtual reality technology and user's full immersion, as it was imagined by S.G. Weinbaum, but, also, describes the impact of such an experience on the protagonist, who begins to question the boundaries between truth and illusion, between dreaming and reality [106]. Related to virtual reality, in 1939, the first non-digital virtual reality device, known as the "View-Master" [47], was introduced at the *New York World's Fair*. This device aimed to "travel" users far from their physical surroundings. It consisted of a pair of eyepieces that displayed a series of color images mounted on a rotating circular cardboard base. This invention marked an early attempt to create an immersive experience for users. Two decades later in the history of the metaverse, another notable advancement emerged in the technology industry. In 1962, Morton Heilig developed the simulator "Sensorama" [35], [53], [78], [94]. Users were offered a groundbreaking simulation of a motorbike ride through the streets of New York City, with 3D graphics, a vibrating seat, realistic sounds, and authentic odors. "Sensorama" could even create the feeling of wind on the rider's face, rendering it an immersive experience [10], [59], [78]. Later, in 1968, Ivan Sutherland developed the "Sword of Damocles", the first portable virtual reality device that resembled today's VR headsets. The name of the device was inspired by the mythological *Sword of Damocles*, as it was large, heavy, and hung from the ceiling before connecting to the user's head [78], [105]. The "Sword of Damocles" integrated the latest virtual reality advancements of its time, introducing the novel feature of portability.

In the 1970s, the gaming industry introduced the idea of users exploring and joining adventures in virtual worlds and presented the concept of self-representation within those environments to the public. This began with the popular tabletop role-playing game "Dungeons & Dragons", which was created by the American game designers E.G. Gyrax and D. Arneson in 1974 [27], [67]. This idea brought the world one step closer to metaverse, as it introduced the concept that fantasy worlds not only exist and can be visited (as it happened in the 1960s) but one can live and perform tasks and activities in there, same as in the real world. A few years later, proto-digital virtual worlds called "MUDs" (Multi-User Dungeons) and "MUSHs" (Multi-User Shared Hallucinations) emerged, with "MUD1" being the first digital virtual world in 1978 [26], [32], [72]. In the same year, the *Massachusetts Institute of Technology* (MIT) presented the

"Aspen Movie Map", a virtual navigation program that allowed users to explore the city of Aspen in Colorado [59], [71], [103]. This marked the first successful attempt of virtual reality transporting users to a real place. Conversely, the video game "MUD1" immersed users in non-real locations by presenting text-based scenarios and commands on a computer screen [27]. In the years to follow, several video games capable of hosting larger numbers of players followed "MUD1", including "AberMUD" in 1987, "tinyMUD" in 1988, "LPMUD" in 1989, and "DikuMUD" in 1990 [27].

Three years after the release of "MUD1", the publication of "Simulacra and Simulation" by the French sociologist and philosopher Jean Baudrillard, in 1981 [59], represents another significant milestone in the evolution history of the metaverse. Baudrillard identified and described the state where simulation replaces reality rather than merely reflecting it. In this way, simulation is perceived as reality [21]. This body of work by Baudrillard can be seen as the foundation of immersive experiences, a core characteristic of the metaverse. The author states, "*The territory no longer precedes the map, nor does it survive it. It is nevertheless the map that precedes the territory... it is no longer a question of imitation, nor duplication, nor even parody. It is a question of substituting the signs of the real for the real*" [36]. At the same time, in the film industry, "Tron" was released in 1982 and introduced viewers to the concept of becoming completely immersed in virtual reality [19], [35]. In essence, "Tron" visualized the work of J. Baudrillard and furtherly familiarized the audience with the idea that virtual worlds can entirely replace and define reality through full immersion. Two years later, in 1984, the science fiction novel "Neuromancer" by William Gibson introduced the term *cyberspace* for the first time. *Cyberspace* refers to any online digital environment directly linked to the real world, highly resembling metaverse [13], [26], [35], [100]. W. Gibson defines cyberspace as "*a consensual hallucination experienced daily by billions of legitimate operators, in every nation, by children being taught mathematical concepts... A graphic representation of data abstracted from banks of every computer in the human system*" [42] (p.56). This quote can perfectly describe the metaverse, as described so far, from a rather technical aspect. It is worth noting that three years prior, in 1981, Vernor Vinge's novel "True Names" had influenced both W. Gibson in writing "Neuromancer" and later Neal Stephenson in the creation of "Snow Crash" [13], [27]. "True Names" and "Neuromancer" introduced readers to the use of electronic computers for accessing virtual realms that were as real as the physical world. These virtual realms maintained a direct connection to the physical world, meaning that actions taken by users in the virtual environments had real-life consequences. It cannot be ignored the description of "Neuromancer" from [44] as "*a conceptual world where words, human relationships, data, wealth, and power are manifested by people using computer-mediated communication technology*" (p.313). The final milestone of the 1980s took place in 1986, with the release of the videogame "Habitat". The game built upon the concept of existing and acting within a virtual world enabling users to interact in real-time. It was the first multiplayer role-playing game with a graphical environment (not solely text-based like "MUDs") for Commodore 64 (8-bit) computer models. The

novel element brought by "Habitat" was the introduction of the term "avatar" [26]. The game made its users familiar for the first time with the idea of visually represent themselves in a virtual environment, a fundamental necessity for the metaverse.

The 1990s can be recognized as the pivotal decade in the timeline building of the metaverse, since the very term was established by the creator of "Snow Crash" in 1992. However, a year earlier, Dr. D. Gelernter, a computer science professor at Yale University, presented the theory of *Mirror Worlds* in his book of the same name [52]. The concept of *Mirror Worlds* revolves around creating accurate digital replicas of systems, whether they are small entities such as companies or larger entities such as cities or, even, destinations. *Mirror Worlds*, according to their creator, serve simulation, testing, and information gathering purposes [41]. The significance of this milestone is paramount for the evolution of metaverse, given that every physical destination can potentially be replicated as a *Mirror World* in the metaverse, granting users the ability to virtually visit it with their avatars. Apart from *Mirror Worlds*, during the same year, the internet took shape in its present form, offering users the ability to create content and engage in secure online transactions [26]. This evolution paved the way for the emergence of various virtual worlds in the form of websites. Some of these include "Cityspace" in 1993, "CyberTown", "Worlds", and "ActiveWorlds" in 1995, "Online Traveler" in 1996, and "There" in 1998 [3], [27], [60], [67], [80]. These platforms not only delivered gameplay experiences similar to multiplayer video games, but, also, offered opportunities for online socialization and interaction among users. Players of these games had the chance to interact with fellow internet users within the same virtual environment, initiating a new trend: socializing and making connections with both familiar and unfamiliar individuals in virtual worlds, mirroring real-world interactions. During the 1990s, strangers could build friendships in virtual realms through their avatars and meet as friends in the real world.

In 1996, the interconnection between real and virtual worlds was further illustrated in the sci-fi book series "Otherland" by Tad Williams [73], [88], [102]. This series of books insisted on the idea that actions taken in a virtual world could have irreversible consequences in the real life, which is a fact for the metaverse, as described by N. Stephenson. One year later, in 1997, following the trend of the time, the first social network on the Internet, called "Sixdegrees", was established [59]. This platform encouraged users to build online friendships and reconnect with old schoolmates, based on the idea that each person's group of friends could be utilized by others to find common acquaintances [91]. Online socialization has emerged as the predominant trend of this decade, encouraging individuals to make use of technology for their interactions, either for business or recreational purposes. Finally, 1999 the movies "The Matrix" and "The Thirteenth Floor" succeeded in popularizing the notion of virtual worlds to the extent of mainstream. These films reached a much broader audience beyond merely video game enthusiasts, challenging the imagination of viewers. In the same year, internet users experienced live voice chats within a virtual environment. It was achieved by the creators of the video game "SissyFight2000". Overall, the 1990s undeniably shaped the

vision of metaverse through the realm of gaming, the film industry, and the literature. The last decade of the previous century effectively acquainted the public with the fundamental essence of the metaverse: interactions through digital representation in real time, even with sound, which can have direct impact on real life. Consequently, it comes with no surprise that 1990's established all the core characteristics of the metaverse, as it is currently envisioned.

B. The History of Metaverse (2000-2023)

In the new millennium, the development of various platforms in the logic of metaverse took place, such as "Habbo Hotel" in 2002 [32], [92]. Two highly important platforms followed, "The Sims" [2], [12] and "Second Life" in 2003 [3], [11], [27], [64], [68], [80], [92], [105], with the latter being widely considered as the closest and most popular representation of the metaverse up to that date. Of course, myriads of online games with remarkable graphics and the ability to accommodate a great number of users are emerging at the same decade, such as "Lineage II", "World of Warcraft" [12], [15], or "League of Legends" [84]. What sets "Habbo Hotel", "The Sims" and "Second Life" apart from multiplayer online games of the same decade, is that the primary goal of online games focuses on accomplishing missions and following predefined storylines [17], [57]. In contrast, in the cases of "Habbo Hotel", "The Sims", and "Second Life", users were invited to live a parallel life in a virtual world, alongside their real one, without being confined to any predetermined scenario. *"The distinction lies in the focus on the social nature of virtual worlds, without the inclusion of 'game' elements as the primary defining rules of the space"* [95] (p.4). As a result, the present study delineates a substantial differentiation between online games and the metaverse. Due to this distinction, famous multiplayer online games that researchers may refer to as "metaverses" are omitted from the current metaverse timeline. It is important to emphasize that labeling a platform as a "metaverse" is based not only on its technical attributes but also on its intended purpose of use.

In search for more milestones in the new millennium, the current paper highlights the introduction of the concept of "Digital Twins" by Dr. M. Grieves in 2002. By 2003, the *University of Michigan* began offering lessons on this topic [9], [43], [49], [86]. The term "Digital Twin" refers to a precise digital representation of a physical object. Since the notion of "Digital Twin" closely aligns with that of "Mirror World" a further explanation is needed at this point: The concept of "Digital Twin" describes a single entity that can be digitally represented, while the latter refers to a group of digital twins operating as a system and collectively represented. For instance, the accurate depiction of a hotel in a virtual world can be termed as the digital twin of that specific hotel. The collective assembly of digital twins of every hotel or other infrastructure of the destination in the same platform, forms the *Mirror World* of the destination. As of the writing of this paper, digital twin technology has not yet been fully integrated into any metaverse platform, due to increased technological requirements, although it is considered a fundamental characteristic of the metaverse. With "fully integrated" the current research refers to seamless flow of information between the physical and digital

counterparts beyond just the graphical representation of the physical part. Therefore, in the previous example, if a user visits the physical hotel and makes a room reservation, the digital twin of the hotel will display that specific room as booked for users on the platform. The same applies to the Mirror World, but on a larger scale.

In 2006 “ABN AMRO” becomes the first European bank to appear on the metaverse-oriented platform “Second Life”, following the digital twin concept [85]. This move initiates the metamorphosis of the metaverse from a space primarily for gaming and social interaction to a space where users can discover a wider range of possibilities, closely related to their everyday lives. In that same year, the launch of the virtual space “Roblox” took place [51], [67], [69], [76], [111], allowing users not only to build a variety of games accessible to other users, but also to organize events, such as parties and concerts. Up to the present day, during these events, users have the opportunity, for instance, to attend real-time concerts of their favorite bands alongside their friends. For the first time “Roblox” fulfilled a major expectation about the metaverse, that it should have a dynamic nature. This means that users could interact not only with one another, but also with the virtual environment they immerse themselves in. It is noteworthy that the first concert in the metaverse was held in 2020 featuring the artist Travis Scott on the “Fortnite” platform, followed by pop singer Ariana Grande in 2021, also hosted on “Fortnite” [11], [27], [32], [84].

In addition, “Roblox” contributed to the use of metaverse as a means for users to generate income, thereby reinforcing the direction, initially introduced by “ABN AMRO”, that the metaverse should serve a variety of purposes beyond mere entertainment. At this point it is important to note that users’ earliest attempts to generate income through virtual worlds dates as far back as 1993, with the game “Cybercity”. In that game users could trade items in-game with other users. However, a great difference exists between the early attempts, such as “Cybercity”, and the modern approach of to income generation by “Roblox”: In the former case, virtual world did not organically support income generation; it was rather users’ ingenuity that allowed them to trade in-game items for real money. On the contrary, “Roblox” not only officially allows but, even, encourages its users to generate income by building applications within the platform. Following “Roblox”, similar virtual spaces emerged, such as “Sandbox” in 2011 [11], [27], “Decentraland” in 2015 [11], [100] and “Fortnite” in 2017 [2], [12], [32]. These platforms provided users with various ways to generate income, including cryptocurrency trading, digital assets trading, advertising products or services, earning rewards by participating in games or activities within the platforms, and numerous other avenues. In more detail, by adopting blockchain technology, “Decentraland” and “Sandbox” allow users to connect their digital wallets to their platforms and engage in transactions using the platform tokens (“MANA” and “Sand,” respectively). They also allow them to buy and sell pieces of digital land in the form of NFTs. This signifies the essential contribution of blockchain as an underlying technology of the metaverse. Beyond providing users with opportunities for income generation, “Second Life”, “Roblox”, “Sandbox”, and “Decentraland” have fostered a real-world economic

ecosystem: These platforms attracted the interest of well-known commercial firms, which have established a presence and initiated operations, focusing on addressing the needs of avatars rather than their operators. As a result, users can purchase accessories in the metaverse for their avatars [7], [12], [30], [62], [81], [87], on the base that avatars in a virtual world have the same needs as humans in the real world. The new norm introduced by these four pioneer platforms has, essentially, created a parallel economic sphere alongside the physical world, illustrating the ontology of the metaverse as a parallel reality, consistently with its original vision.

Regarding blockchain technology and its role as an underlying technology, it is important to recognize that a series of innovations in the field were utilized to expand the potentiality of the metaverse. The creation of *Bitcoin* in 2009 by Satoshi Nakamoto [6], [14], [23], the establishment of the *Ethereum* network in 2014 by Vitalik Buterin [23], the development of smart contracts on the blockchain by Vitalik Buterin in 2014 [50], and the creation of NFTs in 2015 [6] facilitated the realization of agreements, transactions and items trading within the metaverse. It needs to be clarified that smart contracts were initially conceptualized by cryptographer N. Szabo in 1994. Nonetheless, in the timeline presented in the current paper, smart contracts are chronologically positioned in 2014, referring to the initial practical implementation of this application on the blockchain. Adding to the diverse range of roles that the metaverse is anticipated to play, in 2007, the platform “Second Life” hosted the first university lecture, delivered by Dr. Rob Bloomfield, a renowned accounting professor from *Cornell University*. The lecture focused on *Economics in the Metaverse* [20], [29], [110]. Up to that time, “Second Life” was the first platform to showcase the ability of metaverse to revolutionize education, however, in the following years a variety of universities and colleges were represented on “Second Life” or other similar platforms for either educational or promotional reasons.

In 2009, the concept of “avatar”, the visual representation of a user in a virtual world, was introduced to the public through the widely popular movie “Avatar” [35], [88]. Before that movie, the term “avatar” was familiar only within gaming circles or among tech-savvy communities. Two years later, in 2011, Ernest Cline’s sci-fi novel “Ready Player One” further popularized the idea of interacting through avatars in a metaverse environment. This idea was later brought to the big screen by Steven Spielberg in 2018, when the novel adapted into a film under the same title [11], [22], [100]. The storyline portrays users living and interacting in the metaverse through their avatars, using computers and portable devices [105]. In fact, “Ready Player One” was the visualization of how N. Stephenson described the metaverse in “Snow Crash”.

Another significant milestone in the metaverse timeline is the creation of the first NFT in 2014, named *Quantum* by artists Jennifer and Kevin McCoy. Since then, NFTs became a prominent feature of the metaverse [46], primarily due to their tradeability in combination with their ability to grant ownership rights to their holders. “Sotheby’s” auctioned *Quantum* in June 2021 for \$1.472 billion, describing it as “universally regarded as the first NFT ever created” [104]. According to “Sotheby’s” website: “these prime movers

occupy a singular position in art history. They came first. Kevin McCoy's *Quantum is such a work*" [93]. Continuing with milestones that shaped our vision of metaverse, the speech of the President of France within a metaverse environment cannot be overlooked. In October 2022, Emmanuel Macron, delivered a real-time speech to an audience of avatars on the virtual world platform "Decentraland" [24]. Thus, the range of purposes that metaverse can cover expands even to nation-wide communication and delivery of political messages. In the same year, three reputable universities, namely *University of Nicosia* in Cyprus, *University of Nanjing*, and the *Hong Kong Polytechnic* in China—incorporated the concept of the metaverse into their curriculum, by offering master's programs focused on this subject. The recognition of the metaverse as a research-worthy topic was further evidenced in 2021 through the establishment of the *Journal of Metaverse*, the first academic journal dedicated to this field and the "AIRSI2022" scientific conference in 2022. "AIRSI2022" was the first academic conference to take place within a metaverse environment, where participants utilized avatars to present their research and interact with one another.

Finalizing the collection of milestones that shaped the metaverse to the present day, the year of writing this paper, 2023, includes two pivotal events: Firstly, AI-empowered avatars made their debut for public use, with the company "DeepBrainAI" creating *Prof. AI Human*, a digital twin of a university professor equipped with deep learning abilities. This allowed the digital replica of Prof. Kim to deliver lectures and respond to stimuli much like a real person. Secondly, the first court hearing on the metaverse occurred at the "Magdalena Administrative Court" in Colombia, where everyone involved was represented by their avatars. These two milestones expand even further the diverse range of applications of metaverse platforms. As already mentioned, since 2006 that metaverse has proved its capability of extending beyond its conventional use in gaming and socialization. The latest milestones reveal the almost limitless potential of applications in everyday life, on the condition that technology can efficiently support new ideas. In addition, the milestones presented in this paper emphatically confirm for once more that the metaverse can constitute a digital reflection of real life, in every aspect of it.

C. The Metaverse Timeline

The timeline proposed within the current research is illustrated in Figure 1. The *Metaverse Timeline* has included 26 milestones with great impact on bringing the metaverse closer to the envisioned concept of the past. The milestones are chronologically presented in Figure 1 as following: "A Modern Utopia" in 1905, "The Machine Stops" in 1909, "Pygmalion's Spectacles" in 1935, "Sensorama" in 1962, "Tron" in 1982, "Neuromancer" in 1984, "Habitat" in 1985, "Mirror Worlds" and "Snow Crash" in 1992, "Otherland" in 1996, "The Matrix" in 1999, "Habbo Hotel" and the theory of *Digital Twins* in 2002, the launch of "Second Life" in 2003, the launch of "Roblox" in 2006, the movie "Avatar" in 2009, the sci-fi novel "Ready Player One" in 2011, the first NFT in 2014, and the use of smart contracts in Ethereum network in 2015.

Furthermore, the timeline incorporates significant events, as the first ever concert on a metaverse-oriented platform and the launch of "Decentraland", both occurring in 2020. In the subsequent year, 2021, entries refer to the rebranding of "Facebook" to "Meta" and the establishment of the first academic journal *Journal of Metaverse*. In 2022, the timeline includes the first national leader's speech, the initiation of university masters' classes on the metaverse, and the hosting of "AIRSI2022". In the same year, the first attempt of a mirror world is highlighted: The digital representation of the entire city of Seoul. Finally, the year 2023 includes the first court hearing on the metaverse and the emergence of a virtual human professor. This AI-empowered avatar has been trained using the knowledge and personality traits of a human professor and is employed for educational purposes, effectively replacing the human professor.

IV. AN OVERVIEW OF METAVERSE TIMELINES

Despite its relatively recent emergence in academic literature, the metaverse has already become a subject of interest with researchers aiming to identify crucial milestones and establish robust timelines. The metaverse timeline suggested in this paper sheds light on the metaverse journey over the past 118 years, commencing with its initial conceptualization in 1905 and progressing to the present day. The significance of every milestone included in this timeline has been extensively discussed in the previous chapter. It is worth noting that, at the time of writing this paper, the metaverse has not been fully realized as envisioned by N. Stephenson, nor has it fully met modern expectations [27], [31], [38], [109], [111]. "However, although there is no perfect example that meets all of the requirements of an ideal metaverse, various existing works possess several features that are worthy of summary" [27] (p.157). The root of this inconsistency primarily stems from existing technological constraints in integrating the underlying technologies into a unified system. Moreover, each of these technologies is still separately advancing to reach the requisite level of advancement to fully support the metaverse in its final form [5]. Wiederhold states characteristically on this issue that "Right now, there are several obstacles standing in the way of this fully immersive vision, and even metaverse supporters are not expecting it to be fully realized any time soon. For the metaverse to truly replicate the real world, there will need to be significant upgrades to existing computer systems and technology" [108] (p.1). In summary, the metaverse's evolution is a complex narrative spanning over a century, which makes imperative the need for a systematic examination. To this end, the *4 Epochs of the Metaverse* framework is proposed after the analysis of all the existing timelines sourced in literature.

A. Previous metaverse timelines

- The American digital marketing agency "Jack Morton" in its *metaverse timeline project*, classifies the historical trajectory of the metaverse into 4 periods: the fantasy period (1935-1978), the foundation period (1978-2009), the experimentation period (2011-2019), and the adoption period (2019-present) [59].

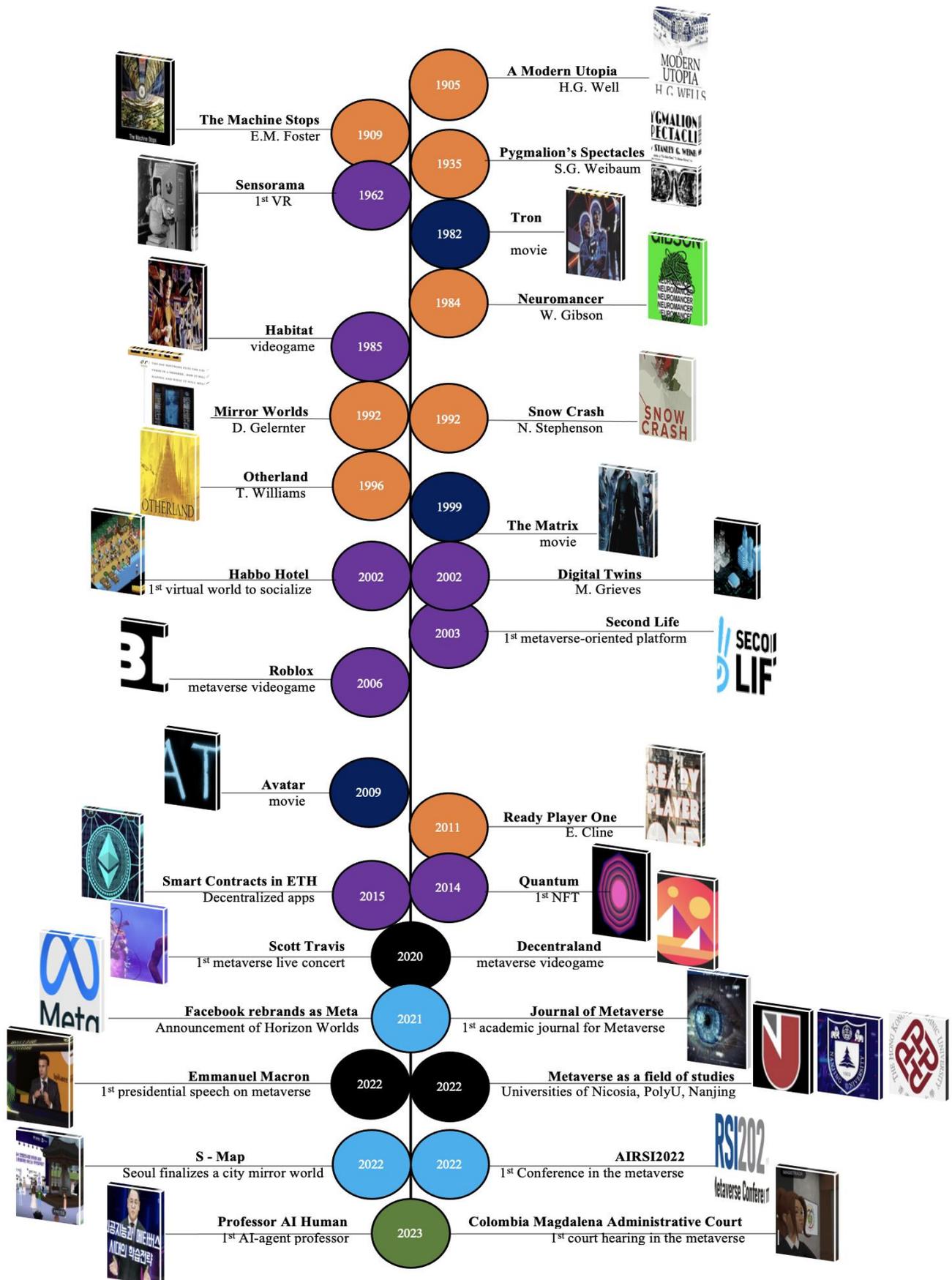


FIGURE I. The Metaverse and its components timeline (1905 – 2023)

- [27] attempt a similar demonstration of the underlying technologies of the metaverse by defining 4 periods: first period, called *Text-based Interactive Game* period spans from 1974 to mid-1990s and can be divided into two categories, *Prehistory* (before the web) and the *Main Period*. The second period, from 1994 until the early 2000s, belongs to the *Open Virtual Worlds*. The third period starts from 2003 with “Second Life” until 2018 and belongs to Massively Multiplayer Online Games, while the fourth period commences from 2018 and the incorporation of Blockchain into virtual worlds until today.
- According to [54] there are specific events related to the components of the metaverse, from its presentation in literature as an idea, to the involvement of giant companies, such as “Meta” and “Microsoft”. The authors present 20 significant events in their timeline, starting from the birth of the internet in 1991 and reaching to “Facebook”’s renaming to “Meta” in 2021.
- The American investment bank “JP Morgan” entered the metaverse through its blockchain platform, "Onyx", and released a report in 2022 including a metaverse timeline exclusively focused on gaming. The report highlights 13 key events in the history of the metaverse, stating that "*The metaverse is evolving from two decades of gaming and will be built upon gaming infrastructure*" [84] (p.6). The report's historical overview starts from 2003 with the release of “Second Life” and ends with Microsoft’s announcement in January 2022 of its intention to acquire the company "Activision Blizzard", a company that is one of the pioneers in producing video games and virtual worlds.
- An interesting approach is presented by [81], who view the metaverse as an evolution of people’s communication, creating a different perspective from that of other researchers. This overview starts with the discovery of speech and language as a means of communication 300,000 years ago and presents 13 events until 2021, where it ends with the rebrand of “Facebook” to “Meta”.
- [67] based on the review and classification from [27], present a similar historical trajectory of the metaverse grouped into 5 periods, namely the period of *Literature* (1974-1984), the period of *Interactive Text-Based Games* (1984-1992), the period of *Virtual Worlds* and *Multi-User Online Games* (1995-2011), the period of *Mobile-based Virtual Environments* (2015-2017), and finally, the *New Era of the Metaverse* (2017-2020). The authors showcase 21 events starting from the year 1974 and the release of the tabletop role-playing game *Dungeon & Dragons*, up to the year 2020 and the release of the virtual world-game *Alien Worlds*, which is a P2E game. The authors categorize the events into 3 categories: events related to the evolution of the metaverse, representative narratives of science fiction, and technological discoveries in the market.
- [26] are the only researchers who choose not to employ the term "metaverse" in their article "3D Virtual Worlds and the Metaverse: Current status and Future Possibilities", published in 2013. Instead, they opt for the term "virtual worlds". Their article provides a detailed historical overview of virtual worlds through five periods: the first period, in the 1970s, is characterized by virtual worlds based on tabletop role-playing games, such as *Dungeons & Dragons*. The second period begins in 1984 with the video game “Habitat” and includes virtual worlds with two-dimensional or three-dimensional graphics. The third period is placed in the mid-1990s and is characterized by progress in graphics and computing power. The fourth period begins in the dawn of the new millennium and includes the use of virtual reality for commercial and advertising purposes, and its adoption by institutional players. The authors mention “Second Life” in 2003 as a great example of the fourth period. Finally, the fifth period begins in 2007 and includes open-source and decentralized architecture in the creation of virtual worlds.
- [66] in his historical retrospective on the website *Tech Target Network*, in November 2022, recognizes the ongoing evolution of the metaverse, while pointing out that it has not reached its full potential. His timeline is composed of milestones related to the metaverse’s underlying technologies. He presents 24 events, spanning from 1938, with the coining of the term "virtual reality", to 2022 where it culminates with the collaboration between “Siemens” and “Nvidia”. That collaboration signified the entry of the German technology giant into the metaverse.
- [8] based on *CNBC*’s timeline [18], choose to start their historical overview with the inception of the internet, in 1989. They present 12 events up to 2021, where the renaming of “Facebook” to “Meta” took place. There are no distinct periods in their overview, while they emphasize on the creation of the *Mesh* platform by “Microsoft” in 2021.
- [83] commence their historical review in 1992 with the release of “Snow Crash” and mention 12 events up to 2021, including the development of “Horizon Worlds” in pilot form from “Meta”. The authors describe three eras in the evolution of the metaverse: 1) the era of *science fiction* works, the *gradual implementation of the metaverse* 2) through virtual worlds and then 3) through online interactive video games.

B. The proposed framework

A strong commonality among all the historical trajectories presented above is the association of the metaverse with the gaming industry. Except for the timeline presented by “Jack Morton”, all the previous attempts to build a metaverse timeline were closely related to gaming. The timelines presented highlight the existence of several Web3 gaming platforms and acknowledge their significance as milestones for the metaverse. Another common point among previous works is that most of the researchers label their timelines as *history of the metaverse*, implying that all these gaming platforms can be characterized as metaverses. On the contrary, [26] provides a historical retrospective using the term "virtual worlds" instead of "metaverse". The current research paper after having reviewed in detail all previous

works, introduces a novel approach of examining the evolution of the metaverse. It traces the metaverse journey from the roots of its component parts to its full fruition in the future. The proposed framework, as illustrated in **Table 1**, consists of 4 time periods, referred to as *Epochs*. The *4 Epochs of the Metaverse* effectively covers the metaverse’s journey from 1905 to its eventual full realization in the future. The proposed framework not only allows for the inclusion of more milestones in the future, but also offers a better understanding of each milestone’s impact on the metaverse’s evolution by categorizing them in the corresponding epoch. The *4 Epochs of the Metaverse* is described below in detail:

The first period, known as the *Epoch of Ideas*, spans from the initial idea of a parallel world to the release of the movie “Avatar” in 2009. It begins with the publication of “A Modern Utopia” in 1905 and is characterized by science fiction narratives. Those works introduced the public to the concept of parallel worlds, virtual worlds, and the interconnectedness of virtual with real world. During the *Epoch of Ideas* the technologies required to create such worlds were envisioned and illustrated in the novels and movies of that Epoch. These visions may have cast light on different facets of the metaverse, yet without providing a complete description of it. The *Epoch of Ideas* include the novels “A Modern Utopia”, “The Machine Stops”, “Pygmalion’s Spectacles” and “Otherland”. It also involves the publication of “Mirror Worlds”, and the theory of “Digital Twins”. The early videogame “Habitat” and the movie “Avatar” complete the list of the milestones that introduced all the fundamental components constituting a metaverse.

TABLE I. The 4 Epochs of The Metaverse Framework

The 4 Epochs of the Metaverse		
Epochs’ Order	Epochs’ Names	Chronological Period
1 st Epoch	<i>Epoch of Ideas</i>	1905 - 2009
2 nd Epoch	<i>Epoch of Definitions</i>	1982 - 2011
3 rd Epoch	<i>Epoch of Foundation & Experimentation</i>	1962 - present
Sub-Epoch 3.1	<i>Epoch of Foundation</i>	1962 - present
Sub-Epoch 3.2	<i>Epoch of Experimentation</i>	1993 - present
4 th Epoch	<i>Metaverse Epoch</i>	Undefined

The second period is called the *Epoch of Definition* and ranges from 1982 to 2011. It is characterized by pieces of literature that showcase fully integrated metaverses and describe in detail their capabilities and benefits for users. Throughout this period, the public becomes familiar with the idea and the characteristics of a fully integrated metaverse, in contrast to the first period, where the focus was on peoples’ familiarization with the underlying technologies and the notion of virtual worlds. The Epoch begins with the movie “Tron” in 1982 and continues with the publication of “Neuromancer” in 1984. “Snow Crash” and “The Matrix” are undoubtedly included in the *Epoch of Definition*. The Epoch extends until 2011 when “Ready Player One” portrayed a modern, vibrant, and complete metaverse. In all these pieces

of work, fully realized metaverse worlds are presented, making use of all the elements unveiled during the *Epoch of Ideas*.

The third period, the *Epoch of Foundation & Experimentation* signals the practical implementation of the previous two Epochs, by realizing the ideas of the 1st Epoch and the launch of platforms, as described in the 2nd Epoch. The *Epoch of Foundation and Experimentation* succeeds in bringing to life the underlying technologies of the metaverse, while progressively leans towards the realization of a full metaverse, as described in the works of the *Epoch of Definition*. Since a complete metaverse has not been fully realized yet, the 3rd period is an ongoing Epoch that continues to the present day and will reach its conclusion when a fully integrated metaverse becomes accessible. This Epoch is further divided into two sub-Epochs: The *Epoch of Foundation* and the *Epoch of Experimentation*.

- The former includes all the significant achievements that succeeded in making real and available to people the ideas expressed in 1st Epoch. The *Epoch of Foundation* began in 1962 with the creation of the first simulator called “Sensorama” and continues to the present day, including the game “Habbo Hotel”, the genesis of the first NFT “Quantum”, the implementation of smart contracts, the launch of cryptocurrencies and blockchain networks, the progress in reaching 5G speed and the widespread adoption of avatars for both gaming and social interactions. The recent advancements in AI applications have made this technology readily available and user-friendly, and led to its widespread popularity, having as starting point the launch of generative AI application “ChatGPT” in November 2022. The progress in AI research can be also classified within the *Epoch of Foundation*.
- The *Epoch of Experimentation* combines different underlying technologies from the *Epoch of Foundation*, in an effort to reach to a fully developed metaverse. This period began in 1993 with the launch of metaverse-oriented videogames, such as “CitySpace”, “CyberTown”, “Worlds” and “Active Worlds”. These games constituted innovations in the field of multiplayer virtual worlds, as they seamlessly combined 3D graphics, internet connectivity, user communication, VR elements, avatars, in-platform monetary systems and the potential for users to generate income with real life value. It becomes evident that that the *Epoch of Experimentation* not only synthesizes the achievements of the *Epoch of Foundation*, but also realizes the interconnection of virtual worlds with the real world. Users can establish relationships through virtual worlds that extend into the real world. Additionally, they have the capacity to generate in-game income with value in the real world, by converting in-platform earnings into real-world currencies, such as USD or EUR. The *Epoch of Experimentation* and the continuous effort to combine and incorporate advanced technologies is still ongoing and will persist until the arrival of *Metaverse Epoch*.

The 4th period, known as the *Metaverse Epoch*, lies in the future and has not been reached as of the time of writing this

paper in 2023. This period will inaugurate the implementation of a complete, practical, and user-friendly metaverse that is accessible to the public. The term "user-friendly" refers to the size and the ease of use of portable devices required for accessing the metaverse. The term "complete" encompasses the integration of all underlying technologies to support the use of metaverse for every aspect of our daily life. The term "practical" refers to a fully functional space designed to provide users with an easy, flawless, and enjoyable experience while navigating in it. The *Metaverse Epoch* differs from the *Epoch of Foundation & Experimentation* on several aspects: Firstly, the 4th Epoch is expected to offer fully operational and mature metaverses, all incorporating the elements described in the *Epoch of Definition*. On the contrary, in the 3rd Epoch, only some of the underlying technologies are present in the current platforms, limiting down the potential of these platforms. In the *Metaverse Epoch* interoperability will become a reality, allowing users for rapid and seamless navigation among metaverses owned by different companies, similarly to the case today where users can easily navigate across different webpages. Currently, interoperability remains a major and rather unsolved problem for metaverse platforms.

Moreover, metaverses of the 4th Epoch will serve a greater multitude of purposes than today. This includes innovative approaches to generating income, emergence of novel professions, new methods of work attendance or task execution, super realistic representation of users through their avatars, capturing even facial expressions, and a myriad of other applications beyond recreational purposes that is the common case today. It needs to be clarified that previous attempts have already proved metaverse capable of serving this wide spectrum of purposes, as already mentioned in this paper. However, what differentiates the *Metaverse Epoch* from today is the comprehensive integration of these features across all metaverse platforms, accompanied by improvements in user friendliness and reduced access costs. For instance, users would no longer need to create a new avatar upon entering a new metaverse (similarly to modern internet users do not need to sign up a new account every time they navigate across various webpages) or connect their e-wallet every time they jump from one metaverse to another, since the wallet will be linked with their avatar. Thus, users of the *Metaverse Epoch* will be able to make use of their money or NFTs across all metaverse platforms in a convenient way. Most importantly, people will find strong reasons to use metaverse for every aspect of their daily life. The absence of these features in current metaverse-oriented platforms is a result of technological limitations, which serves as a strong signal that the *Metaverse Epoch* is not here yet. Based on this, the present paper characterizes as "metaverse-oriented" all the current platforms, diverging from the dominant characterization "metaverse", used by most members in academia and the business community.

V. DISCUSSION

The 4 Epochs framework offers a fresh perspective on studying the development of the metaverse, diverging from the traditional linear timelines used in previous studies. Instead of defining the Epochs as strict sequential phases based on chronological order, this framework focuses on

content. It treats Epochs as overlapping and dynamic periods of time, which include events of similar impact on metaverse's evolution. As a result, the *4 Epochs of the Metaverse* effectively manages the complexity of metaverse development: From opaque theoretical concepts to well-shaped ideas and, finally, the launch of metaverse-oriented platforms today, the history of metaverse is a multifaceted and complex journey. This journey could be hardly understood and analyzed if it was approached only on a temporal basis. The analysis based on the content of the events assisted by the dynamic and overlapping nature of the Epochs can efficiently tackle this challenge.

According to the present study, since 1905 emerging ideas and approaches have continuously surfaced, forming the basis for defining the metaverse and its societal benefits. As these definitions evolved, new approaches and conceptual frameworks emerged, underscoring the need for an overlapping categorization, as the two first Epochs were ongoing in parallel. Meanwhile, developers and entrepreneurs began experimenting on the content of the first two epochs, leading to the realization of metaverse-oriented platforms. The creators of these platforms capitalized on technological advancements and managed to integrate several elements that aligned with the metaverse envisioned characteristics, as described by the ideas and definitions available by that time. Due to those creators and their works, the 3rd epoch of the metaverse has been already a reality since 1962, while, not surprisingly, new ideas and new definitions of the metaverse continued to emerge, concurrently with experimentation. This overlapping series of events, as addressed in the current research, cannot be adequately depicted by chronological based timelines, and constitutes the main gap that the 4 Epochs framework aims to fill. Considering the dynamic nature of the framework, at first it categorizes milestones into three groups: i) initial and raw visions and ideas of particular elements related to virtual worlds, ii) complete and well-shaped descriptions of the metaverse, and iii) technological realizations of all the above. It further allows for new entries of events in the future, as new technological advancements and ideas continuously emerge. The dynamic nature of the *4 Epochs of the Metaverse* enables the temporal adjustment of the boundaries for each Epoch. The current temporal boundaries, as presented in this paper are based on the events up to the time of writing this study. With the evolution of the technological landscape, the framework exhibits flexibility to accommodate shifts and future progress within the metaverse realm.

The forthcoming 4th Epoch is anticipated to become a reality when technological progress enables smooth integration of all distinct components of the metaverse onto a unified platform. This will ensure seamless flow of information and interconnection among different metaverses, enhanced user experience, usefulness, and ease of use. Creators will persist in combining different elements and technologies, as they currently do, until we reach the point of achieving a fully integrated metaverse. This will mark the transition from the 3rd Epoch to the *Metaverse Epoch*. Of course, it would not be a surprise if novel ideas or theoretical concepts emerge and reshape the current vision of metaverse. In fact, this seems to be the most likely scenario. Such a case

will eventually prolong the duration of the first three Epochs in the framework. Shifts or alterations in human needs and the emergence of fresh ideas or perspectives in future societies might lead to new approaches on how the metaverse should cater people's needs.

Although this paper extensively discusses the technological struggles and the journey to efficiently support a complete metaverse, it must be noted that its realization, and consequently the *Metaverse Epoch*, is not solely dependent on the technological development. The overall usefulness is an equally major condition for the initiation of the last Epoch. At present, most individuals miss to find significant value in the existing metaverse-oriented platforms, which are mainly visited by young users out of curiosity or for gaming. This is partially related to technology limitations, as the use of these platforms for purposes other than gaming exceeds our current technological capabilities. Furthermore, existing tools for social interaction (such as social media websites), online shopping (e-shops platforms) or attending meetings and performing tasks (online meeting platforms) are more user-friendly and effective. Current metaverse-oriented platforms are struggling to provide added value in comparison to the already established tools, leading people to reject metaverse as a means to simplify their lives.

A fully integrated metaverse could add value in areas such as work, social life, and entertainment, as well as a more user-friendly nature. In the *Metaverse Epoch* people will not only use these platforms for playing games or socializing but for everyday tasks. In this frame, the *4 Epochs of the Metaverse* can also be applied across diverse sectors that recently began embracing metaverse technology, including but not limited to, tourism [30], [45], [63], [81], education [1], [3], [22], [77], healthcare [9], [27], [40], [54], [65], [74], [77], [79], [99], [101], [109], construction [1], [9], [77], entertainment and gaming [3], [22], [77], [79], real estate [27], [30], [77], [84], [112], and the banking sector [28], [85], [92]. The implementation of the 4 Epochs framework to any economic sector that has adopted a metaverse focus will offer a better understanding of the sector's evolution in the future.

FUNDING

The research work was supported by the Hellenic Foundation for Research and Innovation (HFRI) under the 4th Call for HFRI PhD Fellowships (Fellowship Number: 9449).

AUTHORS' CONTRIBUTIONS

All authors have participated in drafting the manuscript. All authors read and approved the final version of the manuscript. All authors contributed equally to the manuscript and read and approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare that they have no actual or potential conflict of interest as it concerns the publication of this paper.

ACKNOWLEDGMENT

We thank the Hellenic Foundation for Research and Innovation (HFRI) for their support.

REFERENCES

- [1] Akour, I. A., Al-Marouf, R. S., Alfaisal, R., Salloum, S. A. (2022) A conceptual framework for determining metaverse adoption in higher institutions of gulf area: An empirical study using hybrid SEM-ANN approach. *Computers and Education: Artificial Intelligence*, 3, 100052. Doi:10.1016/j.caeai.2022.100052
- [2] Allam, Z., Sharifi, A., Bibri, S. E., Jones, D. S., Krogstie, J. (2022) The Metaverse as a Virtual Form of Smart Cities: Opportunities and Challenges for Environmental, Economic, and Social Sustainability in Urban Futures. *Smart Cities*, 5(3), 771–801. Doi:10.3390/smartcities5030040
- [3] Almoqbel, M. Y., Naderi, A., Wohn, D. Y., Goyal, N. (2022) The Metaverse: A Systematic Literature Review to Map Scholarly Definitions. *Companion Computer Supported Cooperative Work and Social Computing*, 80–84. Doi:10.1145/3500868.3559448
- [4] Alvarez-Risco, A., Del-Aguila-Arcentales, S., Rosen, M. A., & Yáñez, J. A. (2022). Social Cognitive Theory to Assess the Intention to Participate in the Facebook Metaverse by Citizens in Peru during the COVID-19 Pandemic. *Journal of Open Innovation: Technology, Market, and Complexity*, 8(3), 142. Doi:10.3390/joitmc8030142
- [5] Anderson, J., & Rainie, L. (2022) The Metaverse in 2040. Pew Research Org Report. https://www.pewresearch.org/internet/wp-content/uploads/sites/9/2022/06/PL_2022.06.30_Metaverse-Predictions_FINAL.pdf Accessed 10 November 2022
- [6] Ante, L. (2021) Smart contracts on the blockchain – A bibliometric analysis and review. *Telematics and Informatics*, 57.101519. Doi:10.1016/j.tele.2020.101519
- [7] Aurigi, A (2022) Smart cities, metaverses, and the relevance of place. *IET Smart Cities*, 4(3), 157–159. Doi:10.1049/smc2.12030
- [8] Bale, A. S., Ghorpade, N., Hashim, M. F., Vaishnav, J., Almaspoor, Z. (2022) A Comprehensive Study on Metaverse and Its Impacts on Humans. *Advances in Human-Computer Interaction*, 2022, e3247060. Doi:10.1155/2022/3247060
- [9] Barricelli, B. R., Casiraghi, E., Fogli, D. (2019) A Survey on Digital Twin: Definitions, Characteristics, Applications, and Design Implications. *IEEE Access*, 7, 167653–167671. Doi:10.1109/ACCESS.2019.2953499
- [10] Basso, A. (2017) Advantages, Critics and Paradoxes of Virtual Reality Applied to Digital Systems of Architectural Prefiguration, the Phenomenon of Virtual Migration. *Proceedings*, 1, 915. Doi:10.3390/proceedings1090915
- [11] Bayram, A. (2022) Metaleisure: Leisure Time Habits to be Changed with Metaverse. *Journal of Metaverse*, 2(1), 1-7. <https://dergipark.org.tr/en/pub/jmv/issue/67967/1065227> Accessed 11 November 2022
- [12] Belk, R., Humayun, M., Brouard, M. (2022) Money, possessions, and ownership in the Metaverse: NFTs, cryptocurrencies, Web3 and Wild Markets. *Journal of Business Research*, 153, 198–205. Doi:10.1016/j.jbusres.2022.08.031
- [13] Bibri, S. E. (2022) 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*, 5(3), 832–874. Doi:10.3390/smartcities5030043
- [14] Bouraga, S. (2021) A taxonomy of blockchain consensus protocols: A survey and classification framework. *Expert Systems with Applications*, 168, 114384. Doi:10.1016/j.eswa.2020.114384
- [15] Bourlakis, M., Papagiannidis, S., Li, F. (2009). Retail spatial evolution: Paving the way from traditional to metaverse retailing. *Electronic Commerce Research*, 9(1), 135–148. Doi:10.1007/s10660-009-9030-8
- [16] Buhalis, D., Lin, M. & Leung, D. (2023). Metaverse as a Driver for Customer Experience and Value Co-Creation: Implications for Hospitality and Tourism Management and Marketing. *International Journal of Contemporary Hospitality Management*, 35(2), 701-716. Doi:10.1108/IJCHM-05-2022-0631



- [17] Castronova, E. (2001). Virtual Worlds: A First-Hand Account of Market and Society on the Cyberian Frontier. SSRN Electronic Journal. Doi:10.2139/ssrn.294828
- [18] CNBCTV18. (2022). Explained: The history of Metaverse. cnbctv18.com. Retrieved on 28/11/2022 from <https://www.cnbctv18.com/technology/explained-the-history-of-metaverse-12015212.htm>
- [19] Collins, C. (2008) Looking to the Future: Higher Education in the Metaverse. EDUCAUSE Review. <https://er.educause.edu/articles/2008/9/looking-to-the-future-higher-education-in-the-metaverse> Accessed 16 November 2022
- [20] Cornell.edu. (2007). Cornell Chronicle. News.cornell.edu. <https://news.cornell.edu/stories/2007/10/johnson-school-professor-uses-virtual-reality-class> Accessed 03 December 2022
- [21] Cultural Reader. (2012) Simulacra and Simulation by Jean Baudrillard – Summary. Cultural Reader. <https://culturalstudiesnow.blogspot.com/2012/10/simulacra-and-simulation-by-jean.html> Accessed 19 November 2022
- [22] Damar, M. (2021) Metaverse Shape of Your Life for Future: A bibliometric snapshot. Journal of Metaverse, 1(1), 1-8. <https://dergipark.org.tr/en/pub/jmv/issue/67581/1051371> Accessed 14 November 2022
- [23] Daskalakis, N., Georgitseas, P. (2020) An Introduction to cryptocurrencies: The crypto market ecosystem. London: Routledge.
- [24] Decentraland. (2022). Twitter post on 06/11/2022, 15:00. https://twitter.com/RLTY_Live/status/1577992293147185152?ref_src=twsrc%5Etfw%7Ctwcamp%5Etwetembed%7Ctwterm%5E1578007954049191938%7Ctwgr%5E736124a63b93f7d4d5305dd858dddfe5b75e711f%7Ctwcon%5Es3_&ref_url=https%3A%2F%2Fdailycoin.com%2Fmacro-shows-up-on-decentraland-first-presidential-speech-in-the-metaverse%2F Accessed 11 December 2022
- [25] Dhelim, S., Kechadi, T., Chen, L., Aung, N., Ning, H., Atzori, L. (2022) Edge-enabled Metaverse: The Convergence of Metaverse and Mobile Edge Computing. TechRxiv. Doi:10.36227/techrxiv.19606954.v1
- [26] Dionisio, J. D. N., Iii, W. G. B., Gilbert, R. (2013) 3D Virtual worlds and the metaverse: Current status and future possibilities. ACM Computing Surveys, 45(3), 1–38. Doi:10.1145/2480741.2480751
- [27] Duan, H., Li, J., Fan, S., Lin, Z., Wu, X., Cai, W. (2021) Metaverse for Social Good: A University Campus Prototype. Proceedings of the 29th ACM International Conference on Multimedia, 153–161. Doi:10.1145/3474085.3479238
- [28] Dubey, V., Mokashi, A., Pradhan, R., Gupta, P., Walimbe, R. (2022) Metaverse and Banking Industry – 2023 The Year of Metaverse Adoption. Technium: Romanian Journal of Applied Sciences and Technology, 4(10), Article 10. Doi:10.47577/technium.v4i10.7774
- [29] Duranske, B. (2007) Metanomics launches, Announces 2007 speakers. Virtuallyblind.com. <http://virtuallyblind.com/2007/09/13/metanomics-07-speakers/> Accessed 11 November 2022
- [30] Dwivedi, Y. K., Hughes, L., Baabdullah, A. M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M. M., Dennehy, D., Metri, B., Buhalis, D., Cheung, ... Wamba, S. F. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. International Journal of Information Management, 66, 102542. Doi:10.1016/j.ijinfomgt.2022.102542
- [31] Edwards, B. (2022) There is no Metaverse (yet). HowtoGeek.com. <https://www.howtogeek.com/777037/there-is-no-metaverse-yet/> Accessed 04 December 2022
- [32] EUBlockchain. (2022) Metaverse. European Union Blockchain Observatory & Forum. https://www.eublockchainforum.eu/sites/default/files/reports/Metaverse_Report_Final_1.pdf Accessed 11 November 2022
- [33] EY webpage. (2023). What’s possible for the gaming industry in the next dimension? Ey.com. Retrieved on 02/-5/2023 from https://www.ey.com/en_us/tmt/what-s-possible-for-the-gaming-industry-in-the-next-dimension
- [34] Fan, Z., Chen, C., & Huang, H. (2022). Immersive cultural heritage digital documentation and information service for historical figure metaverse: A case of Zhu Xi, Song Dynasty, China. Heritage Science, 10(1), 148. Doi:10.1186/s40494-022-00749-8
- [35] Faraboschi, P., Frachtenberg, E., Laplante, P., Milojicic, D., Saracco, R. (2022) Virtual Worlds (Metaverse): From Skepticism, to Fear, to Immersive Opportunities. Computer, 55(10), 100–106. Doi:10.1109/MC.2022.3192702
- [36] Felluga, D. (2002) Modules on Baudrillard: On Simulation. Introductory Guide to Critical Theory. <https://cla.purdue.edu/academic/english/theory/postmodernism/modules/baudrillardsimulation.html> Accessed 16 November 2022
- [37] Flaherty, S. (2020) ‘The Machine Stops’: E.M. Forster’s Esoteric critique of H.G. Wells ‘A Modern Utopia’. History, 105(366), 422–445. Doi:10.1111/1468-229X.13022
- [38] Forbes (2022) There is no Metaverse today, but be prepared. Forbes.com. <https://www.forbes.com/sites/forrester/2022/03/31/there-is-no-metaverse-today-but-be-prepared/?sh=1dbb639b236b> Accessed 14 November 2022
- [39] Forster, E.M. (2015). *The Machine Stops*. New Delhi: Prabhat Prakashan, kindle version.
- [40] Gadekallu, T. R., Yenduri, G., Ranaweera, P., Pham, Q.-V., Huynh-The, T., Wang, W., da Costa, D. B., Liyanage, M. (2022) Blockchain for the Metaverse: A Review. arXiv2203.09738 Doi:10.48550/arXiv.2203.09738
- [41] Gelernter, D. (1992). Mirror worlds: Or the day software puts the universe in a shoebox... How it will happen and what it will mean. New York: Oxford University Press.
- [42] Gibson, W. (1984) Neuromancer. New York, ACE
- [43] Grieves, M., & Vickers, J. (2017) Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems. In: Kahlen, J., Flumerfelt, S., Alves, A. (eds) Transdisciplinary Perspectives on Complex Systems. Cha, Springer Doi:10.1007/978-3-319-38756-7_4
- [44] Guo, J., Chow, A., Wigand, R. T. (2011) Virtual wealth protection through virtual money exchange. Electronic Commerce Research and Applications, 10(3), 313–330. Doi:10.1016/j.elerap.2010.10.003
- [45] Gursoy, D., Malodia, S., Dhir, A. (2022) The metaverse in the hospitality and tourism industry: An overview of current trends and future research directions. Journal of Hospitality Marketing & Management, 31(5), 527–534. Doi:10.1080/19368623.2022.2072504
- [46] Hannekes, B. (2022) A brief history of NFTs. Web3 University webpage. Retrieved on 27/11/2022 from <https://www.web3.university/tracks/build-your-first-nft/brief-history-of-nfts>
- [47] Harley, D. (2022) ‘‘This would be sweet in VR’’: On the discursive newness of virtual reality. New Media & Society, (ahead-of-print). Doi:10.1177/14614448221084655
- [48] Harris, J.W. (2021) When did E.M. Forster’s ‘The Machine Stops’ become science fiction?. Classics of Science Fiction. <https://classicsofsciencefiction.com/2020/08/21/when-did-e-m-forsters-the-machine-stops-become-science-fiction/> Accessed 21 November 2022
- [49] Hartmann, D., & Van der Auweraer, H. (2021) Digital Twins. In: Cruz, M., Parés, C., Quintela, P. (eds) Progress in Industrial Mathematics: Success Stories. Cham, Springer. Doi:10.1007/978-3-030-61844-5_1
- [50] Hewa, T., Ylianttila, M., Liyanage, M. (2021) Survey on blockchain based smart contracts: Applications, opportunities and challenges. Journal of Network and Computer Applications, 177, 102857. Doi:10.1016/j.jnca.2020.102857
- [51] Hollensen, S., Kotler, P., Opresnik, M. O. (2022) Metaverse – the new marketing universe. Journal of Business Strategy. 44(3), 119-125. Doi:10.1108/JBS-01-2022-0014

- [52] Hudson-Smith, A., & Batty, M. (2022) Ubiquitous geographic information in the emergent Metaverse. *Transactions in GIS*, 26(3), 1147–1157. Doi:10.1111/tgis.12932
- [53] Huggett, J. (2020). Virtually real or really virtual: Towards a heritage metaverse. *Studies in digital heritage*, 4(1), 1-15. <http://orcid.org/0000-0002-7535-9312>
- [54] Huynh-The, T., Pham, Q.-V., Pham, X.-Q., Nguyen, T. T., Han, Z., Kim, D.-S. (2022) Artificial Intelligence for the Metaverse: A Survey (arXiv:2202.10336). arXiv. <http://arxiv.org/abs/2202.10336>
- [55] Interesting Literature (2021) A summary and analysis of E.M. Forster's 'The Machine Stops'. [InterestingLiterature.com](https://interestingliterature.com/2021/02/em-forster-the-machine-stops-summary-analysis/). <https://interestingliterature.com/2021/02/em-forster-the-machine-stops-summary-analysis/> Accessed 21 November 2022
- [56] Ioannidis, S. A. (2023). A Blockchain-Based Tourism Industry: How Promising Can It Be?. In G. Kurubacak, R. Sharma, & H. Yıldırım (Eds.), *Glocal Policy and Strategies for Blockchain: Building Ecosystems and Sustainability* (pp. 27-50). IGI Global. <https://doi.org/10.4018/978-1-6684-4153-4.ch002>
- [57] Ioannidis, S. and Kontis, A.P. (2023). The Emergence of Metaverse in Tourism Literature: A Mixed Content Analysis. *Proceedings MTCON2023*. 15-18 March, Istanbul. (ahead-of-print)
- [58] Ioannidis, S. and Kontis, A.P. (2023). Metaverse for tourists and tourism destinations. *Information Technology & Tourism*. (ahead-of-print) Doi:10.1007/s40558-023-00271-y
- [59] Jack Morton WorldWide (2021) The Metaverse Creation. *Metaverse timeline*. <https://metaverse-timeline.com/> Accessed 01 December 2022
- [60] Jones, M.S (2022) Virtual World History. Part I. [matthewscottjones.com](https://matthewscottjones.com/history-of-virtual-worlds). <https://matthewscottjones.com/history-of-virtual-worlds> Accessed 11 November 2022
- [61] Katz, J. (2022). Gaming in the Metaverse: online safety in another dimension. *Public.io*. Retrieved on 02/05/2023 from <https://www.public.io/blog-post/gaming-in-the-metaverse-online-safety-in-another-dimension>
- [62] Kim, J. (2021) Advertising in the Metaverse: Research Agenda. *Journal of Interactive Advertising*, 21(3), 141–144. Doi:10.1080/15252019.2021.2001273
- [63] Koo, C., Kwon, J., Chung, N., Kim, J. (2022) Metaverse tourism: Conceptual framework and research propositions. *Current Issues in Tourism*, 1-7. Doi:10.1080/13683500.2022.2122781
- [64] Kumar, S., Chhugani, J., Kim, C., Kim, D., Nguyen, A., Dubey, P., Bienia, C., Kim, Y. (2008) Second Life and the New Generation of Virtual Worlds. *Computer*, 41(9), 46–53. Doi:10.1109/MC.2008.398
- [65] Lacity, M., Mullins, J.K., Kuai, L. (2022) What type of metaverse will we create? BcoE Whitepaper of Metaverse. 1-32, University of Arkansas. https://cpb-us-e1.wpmucdn.com/wordpressua.ark.edu/dist/5/444/files/2022/10/2022_02_BCoEWhitePaperMetaverse5493.pdf
- [66] Lawton, G. (2022) History of the Metaverse Explained. *TechTarget website*. <https://www.techtarget.com/searchcio/tip/History-of-the-metaverse-explained> Accessed 21 November 2022
- [67] Lee, L.-H., Braud, T., Zhou, P., Wang, L., Xu, D., Lin, Z., Kumar, A., Bermejo, C., Hui, P. (2021) All One Needs to Know about Metaverse: A Complete Survey on Technological Singularity, Virtual Ecosystem, and Research Agenda. *Journal of Latex Class Files*, 14(8), 1-66. <http://arxiv.org/abs/2110.05352>
- [68] Lee, S.-G., Trimi, S., Byun, W. K., Kang, M. (2011) Innovation and imitation effects in Metaverse service adoption. *Service Business*, 5(2), 155–172. Doi:10.1007/s11628-011-0108-8
- [69] Lim, W. Y. B., Xiong, Z., Niyato, D., Cao, X., Miao, C., Sun, S., Yang, Q. (2022) Realizing the Metaverse with Edge Intelligence: A Match Made in Heaven. *IEEE Wireless Communications*, (arXiv:2201.01634). <http://arxiv.org/abs/2201.01634>
- [70] MacNeil, J. (2019) The Machine Stops is Published, November 1, 1909. *EDN webpage*. <https://www.edn.com/the-machine-stops-is-published-november-1-1909/> Accessed 14 November 2022
- [71] Marr, B. (2022) A Short History of the Metaverse. *Bernardmarr.com*. <https://bernardmarr.com/a-short-history-of-the-metaverse/> Accessed 14 November 2022
- [72] Martin, E. (2022). ‘‘When was Dungeons and Dragons invented? A history of D&D’’. *Bookriot.com*. Accessed 02/02/2023 from <https://bookriot.com/when-was-dungeons-and-dragons-invented/>
- [73] Melcher, J. (2022) 5 novels that predicted the metaverse. *Exodus.com*. <https://www.exodus.com/news/novels-that-predicted-the-metaverse> Accessed 11 November 2022
- [74] Messinger, P.R., Stroulia, E., Lyons, K., Bone, M., Niu, R.H., Smirnov, K., Perelgut, S. (2009) Virtual worlds — past, present, and future: New directions in social computing. *Decision Support Systems*, 47(3), 204–228. Doi:10.1016/j.dss.2009.02.014
- [75] Meta (2021) Founder’s Letter. *Meta.com*. <https://about.fb.com/news/2021/10/founders-letter> Accessed 21 November 2022
- [76] Moro-Visconti, R. (2022) From physical reality to the Metaverse: A Multilayer Network Valuation. *Journal of Metaverse*, 2(1), 16–22. <https://dergipark.org.tr/en/download/article-file/2247581> Accessed 04 December 2022
- [77] Mozumder, M. A. I., Sheeraz, M. M., Athar, A., Aich, S., Kim, H.-C. (2022) Overview: Technology Roadmap of the Future Trend of Metaverse based on IoT, Blockchain, AI Technique, and Medical Domain Metaverse Activity. 2022 24th International Conference on Advanced Communication Technology (ICACT), 256–261. Doi:10.23919/ICACT53585.2022.9728808
- [78] Mystakidis, S. (2022) Metaverse. *Encyclopedia*, 2(1), 486–497. Doi:10.3390/encyclopedia2010031
- [79] Nair, V., Garrido, G. M., Song, D. (2022) Exploring the Unprecedented Privacy Risks of the Metaverse (arXiv:2207.13176). arXiv. <http://arxiv.org/abs/2207.13176>
- [80] Narin, N.G. (2021) A Content Analysis of the Metaverse Articles. *Journal of Metaverse*, 1(1), 17-24. <https://dergipark.org.tr/en/pub/jmv/issue/67581/1051382> Accessed 14 November 2022
- [81] Ning, H., Wang, H., Lin, Y., Wang, W., Dhelim, S., Farha, F., Ding, J., Daneshmand, M. (2021) A Survey on Metaverse: The State-of-the-art, Technologies, Applications, and Challenges (arXiv:2111.09673). arXiv. <http://arxiv.org/abs/2111.09673>
- [82] Niu, X., & Feng, W. (2022) Immersive Entertainment Environments—From Theme Parks to Metaverse. In N. A. Streitz, S. Konomi (eds.) *Distributed, Ambient and Pervasive Interactions. Smart Environments, Ecosystems, and Cities* (pp. 392–403). Springer International Publishing. Doi:10.1007/978-3-031-05463-1_27
- [83] Njoku, J. N., Nwakanma, C. I., Amaizu, G. C., Kim, D.-S. (2022) Prospects and challenges of Metaverse application in data-driven intelligent transportation systems. *IET Intelligent Transport Systems*, n/a(n/a). Doi:10.1049/itr2.12252
- [84] Onyx (2022) Opportunities in the metaverse. *JPMorgan.com*. <https://www.jpmorgan.com/content/dam/jpm/treasury-services/documents/opportunities-in-the-metaverse.pdf> Accessed 02 December 2022
- [85] Papagiannidis, S., Boulakis, M., Vafopoulos, M.N. (2008) Banking in Second Life: Marketing Opportunities and Repercussions. 1st Biannual International Conference ‘Strategic Developments in Services Marketing’. Doi:10.2139/ssm.1887570
- [86] Pokhrel, A., Katta, V., Colomo-Palacios, R. (2020) Digital Twin for Cybersecurity Incident Prediction: A Multivocal Literature Review. *Proceedings of the IEEE/ACM 42nd International Conference on Software Engineering Workshops*, 671–678. Doi:10.1145/3387940.3392199
- [87] Pookulangara, S., Kim, J., Josiam, B., Thombre, A. (2014) Intent to purchase from 3-D virtual environments: An exploratory study. *Journal of Global Fashion Marketing*, 5(4), 269–282. Doi:10.1080/20932685.2014.927659

- [88] Radoff, J. (2021) Books about the Metaverse. Medium.com. <https://medium.com/building-the-metaverse/books-about-the-metaverse-b73f033f98f4> Accessed 21 November 2022
- [89] Rubio-Tamayo, J., Gertrudix Barrio, M., García García, F. (2017) Immersive Environments and Virtual Reality: Systematic Review and Advances in Communication, Interaction and Simulation. *Multimodal Technologies and Interaction*, 1(4), 21. Doi:10.3390/mti1040021
- [90] Russell, P.M. (2005) 'IMAGINE, IF YOU CAN': Love, Time and the impossibility of utopia in E.M. Forster's 'The Machine Stops'. *Critical Survey*, 17(1), 56-71. <https://www.jstor.org/stable/41556094>
- [91] Sixdegrees (2020) Homepage. <http://sixdegrees.com/> Accessed 19 November 2022
- [92] Smart, J., Cascio, J., Paffendorf, J. (2007) Metaverse Roadmap Overview. Metaverseroadmap.org. <https://www.metaverseroadmap.org/overview> Accessed 14 November 2022
- [93] Sotheby's (2022) Quantum. Sotheby's Website. <https://www.sothebys.com/en/buy/auction/2021/natively-digital-a-curved-nft-sale-2/quantum> Accessed 19 November 2022
- [94] Spence, C. (2020). Senses of place: architectural design for the multisensory mind. *Cognitive Research: Principles and Implications*, 5(1), 46. Doi:10.1186/s41235-020-00243-4
- [95] Spence, J. (2008) Demographics of Virtual Worlds. *Journal For Virtual Worlds Research*, 1(2). <https://jvwr-ojs-utexas.tdl.org/jvwr/article/view/360>
- [96] Srivastava, S. (2023). How could metaverse be a game changer for the virtual gaming industry? *Appinventiv.com*. Retrieved on 02/05/2023 from <https://appinventiv.com/blog/metaverse-gaming/>
- [97] Stephenson, N. (1992) *Snow Crash*. New York, Bantam Books
- [98] Taylor, C. R. (2022). Research on advertising in the metaverse: A call to action. *International Journal of Advertising*, 41(3), 383-384. Doi:10.1080/02650487.2022.2058786
- [99] Thomason, J. (2021) Metahealth – How Will the Metaverse Change Health Care? *Journal of Metaverse*, 1(1), 13-16. <https://dergipark.org.tr/en/pub/jmv/issue/67581/1051379> Accessed 19 November 2022
- [100] van der Merwe, D. F. (2021) The metaverse as virtual heterotopia. *Proceedings of The 3rd World Conference on Research in Social Sciences*. 3rd World Conference on Research in Social Sciences. Doi:10.33422/3rd.socialsciencesconf.2021.10.61
- [101] van Rijmenam, M. (2022) Step into the Metaverse. New Jersey, Wiley
- [102] verdict.co.uk (2022). Metaverse: A recent history in popular literature. Verdict webpage. Accessed 02/01/2021 from <https://www.verdict.co.uk/metaverse-literature-fiction>
- [103] Viveiros, L.C., Aikes Junior, J. (2018) Augmented Reality and its aspects: a case study for heating systems. *Research Gate*. https://www.researchgate.net/publication/340144636_Augmented_Reality_and_its_aspects_a_case_study_for_heating_systems Accessed 21 November 2022
- [104] Wang, D. (2022) Kevin McCoy: The metaverse is going to be powered by game engines. *Coindesk* Webpage. <https://www.coindesk.com/layer2/metaverseweek/2022/05/26/kevin-mccoy-the-metaverse-is-going-to-be-powered-by-game-engines/> Accessed 28 November 2022
- [105] Wang, Y., Su, Z., Zhang, N., Xing, R., Liu, D., Luan, T. H., Shen, X. (2022) A Survey on Metaverse: Fundamentals, Security, and Privacy. *IEEE Communications Surveys & Tutorials*, 1-32. Doi:10.1109/COMST.2022.3202047
- [106] Weinbaum, S.G. (1935) *Pygmalion's Spectacles*. New York, Stellar Publishing
- [107] Wells, H.G. (2022) *A Modern Utopia*. New York: Sheba Blake Publications Co, kindle version.
- [108] Wiederhold, B. K. (2022). Ready (or Not) player one: Initial musings on the metaverse. *Cyberpsychology, Behavior, and Social Networking*, 25(1), 1-2. Doi:10.1089/cyber.2021.29234.editorial
- [109] Wiederhold, B., & Riva, G. (2022) Metaverse Creates New Opportunities In Healthcare. In (eds) Wiederhold, B., Riva, G *Annals Review of Cybertherapy and Telemedicine*, 20, 3-7. San Diego, Interactive Media Institute.
- [110] Witt, L., Kperogi, F.A., Sinclair, G.W., Bohrer, C., & Negash, S. (2016). Journalism: How One University Used Virtual Worlds to Tell True Stories. *International Symposium On Online Journalism*, 6(1), 5-32.
- [111] Xu, M., Ng, W. C., Lim, W. Y. B., Kang, J., Xiong, Z., Niyato, D., Yang, Q., Shen, X. S., Miao, C. (2022) A Full Dive into Realizing the Edge-enabled Metaverse: Visions, Enabling Technologies, and Challenges. (arXiv:2203.05471), 1-44. <http://arxiv.org/abs/2203.05471>
- [112] Yang, Q., Zhao, Y., Huang, H., Xiong, Z., Kang, J., Zheng, Z. (2022) Fusing Blockchain and AI With Metaverse: A Survey. *IEEE Open Journal of the Computer Society*, 3, 122-136. Doi:10.1109/OJCS.2022.3188249