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Human centric platforms for personalized value creation in metaverse

Dimitris Mourtzis [a,*], Nikos Panopoulos [a], John Angelopoulos [a], Baicun Wang [b], Lihui Wang [c]

[a] Laboratory for Manufacturing Systems and Automation, Department of Mechanical Engineering and Aeronautics, University of Patras, Patras 26504, Greece
[b] State Key Lab of Fluid Power and Mechatronic Systems, School of Mechanical Engineering, Zhejiang University, Hangzhou, China
[c] Department of Production Engineering, KTH Royal Institute of Technology, Stockholm, Sweden

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ABSTRACT

The term "Metaverse" first used in Neal Stephenson's sci-fi book Snow Crash in 1992, refers to a fusion of virtual and real existence. Nearly 30 years later, that definition is taking shape and promises to alter how people live and operate. This next evolution of Internet also known as Web3.0 will combine digital and physical elements. Multiple definitions can be found in the literature, with the most prevalent being the "new internet", among others such as "democratized virtual society", "persistent virtual spaces", "a digital twin of our own world for personalized value creation". Consequently, the common consensus dictates that Metaverse can be realized as a new form of the Internet, totally reshaped from what is already known. As we are heading towards the coexistence of Industry 5.0 and Society 5.0 (super smart and intelligent society), this paper attempts to present the definition of Metaverse, its evolution, the advantages and disadvantages, the pillars for the technological advancement which could be the fuel to spark future investigation and discussion as well as to accelerate the development of Metaverse towards the human centric and personalized society. Furthermore, in this manuscript, challenges and opportunities are presented (including Manufacturing), a brief comparison is performed versus Virtual Reality, and a conceptual framework for integrating Metaverse in Manufacturing is also presented.

1. Introduction

Metaverse was first coined and used as a term in the science fiction book Snow Crash by Neal Stephenson, which was published in 1992 [1]. The term "Metaverse" is derived from the combination of the English word "universe" which means "everything that exists" [2], and the Greek prefix meta (beyond). By extension, this term describes the coexistence of all elements of life and modern societies in a parallel yet virtual space. Since its inception, the Metaverse has attracted considerable attention and has proven to have enormous potential for promoting human society, as it is characterized as the "the ultimate form of the Internet" [3]. It represents a second, computer-generated eXtended Reality (XR) world that users from all over the world could connect to and access using goggles and earphones. Additionally, the backbone of Metaverse is the "Street" protocol, that connects various virtual communities and places, acting as an analogue to the information superhighway [4]. The massively multiplayer VR game OASIS is a representation of the Metaverse in contemporary literature, as seen in Ernest Cline's science fiction book Ready Player One from 2011 [5], grown to become the main online hub for work, learning, and entertainment.

The Metaverse or the post-reality universe is a perpetual and persistent multi-user environment that combines physical reality and digital virtuality. It is based on the convergence of technologies, such as XR (Virtual Reality (VR), Mixed Reality (MR), and Augmented Reality (AR)), Digital Twin, and Blockchain, that enable multisensory interactions with digital objects, virtual environments, and people. Further to that, the Metaverse is a persistent multi-user platform that connects a network of socially interactive, networked immersive environments [6]. From now-on most user interactions are taking place in this digital universe. After the advent of widespread broadband Internet access and the potential to acquire powerful home computers equipped to run such technology, the term is frequently used to describe a shared VR Platform for personalized services and experiences [7,8]. It allows for fluid, real-time user embodied communication as well as dynamic interactions with digital artifacts. Avatars could teleport between the various virtual worlds in its initial iteration. The current iteration of the Metaverse includes social, immersive VR platforms that work with open game worlds, massively multiplayer online role-playing games (MMORPGs), and AR collaborative spaces [9]. The development paths

* Corresponding author.
E-mail address: mourtzis@lms.mech.upatras.gr (D. Mourtzis).

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of Metaverse and the interconnection between real and virtual world [10] is presented in Fig. 1. More specifically, the two development directions for Metaverse can be realized as follows: i) Transitioning from real to virtual world, the latter will be an imitation of the real world, and the user perception of the physical experience will be enhanced by building immersive digital experiences. Consequently, the digitalization of real experiences, will be in the center of attention. The vision for Metaverse is based on the digital reconstruction of the physical world to form a digital replica of the real world. ii) On the other hand, transitioning from virtual to real self-creation based on the virtual world is required, which also influences the real world.

As a result, the metaverse represents a new era in internet connectivity, characterized by:

- **Interactivity**
  allows the user to interact with other users, real-world objects, and any appearing virtual scenario.
- **Simulation**
  The laws of physics are applied to the virtual environment as if it were real-world (physics-based simulations) [12]. The user is guaranteed first-person access and a multisensory experience (e.g., via VR).
- **Decentralized environment**
  where users can exchange their ownership of the virtual world assets and perform real transactions on a virtual environment.
- **Persistent reality**

Virtual activity continues even if you temporarily disconnect from the metaverse, following the principle of Digital Twins, which calls for constant communication of the physical twin with its digital counterpart.

Based on the above-mentioned key points, Metaverse is a wide technological topic, that is estimated to drive the social, industrial, and academic hype for the following reasons:

- It will be the future form of internet, linked with Web 3.0.
- It will be entirely democratized for all users, having access to the worldwide web.
- The principle of Metaverse is based on the provision of open-source services.
- It will reshape/transform the human-machine interface (HMI).
- It could transform every aspect of social and professional life.
- It will have major implications for accessibility.

Consequently, in order to realize its full potential, the Metaverse needs to overcome the following challenges:

- Internet penetration is still too low.
- VR headsets should become more ergonomic and lightweight.
- Remote collaboration is still in its infancy.
- Advanced VR gear, required for Metaverse implementation is not yet commercially available.

Therefore, this communication article attempts to share the authors' view on Metaverse towards the Human Center Society and Industry 5.0 [13,14] by answering the following questions:

- What is Metaverse?
- Which is the Evolution of Metaverse?
- What are the advantages and disadvantages of Metaverse?
- What are the technological pillars of Metaverse?
- What are the revolution directions of Metaverse?

2. Conception of metaverse

2.1. From Web 1.0 to Web 3.0

Historically, the term "Web3″ appeared for the first time in 2014, and was coined by Gavin Wood, who is the co-founder of Ethereum and founder of Polkadot. Wood's definition is built upon a decentralized online ecosystem which utilizes blockchain technology. A crucial point is the fact that there are many virtual worlds developed in order to enable people towards the deepening and extension of social interactions virtually. This is accomplished by enhancing the web with a three-dimensional, immersive layer to produce more authentic and natural/intuitive experiences. Even from the comfort of one's own home, the metaverse has the potential to democratize access to important products, services, and experiences by dismantling physical barriers. Based on the abovementioned, Metaverse can be conceived as a digital Artificial Intelligence (AI) platform which offers users an advanced immersive 3D user interface, which promotes coexistence in a virtual twin of the physical world and eliminates the need for physical interaction/interface. Features and personalized services such as conversational, AI-powered, and human-like avatars enable natural conversations across various modalities [15]. Thus, considered from this perspective, the Metaverse is a definite evolution of conversational AI like Alexa, which is fusing with the 3D world of video games and other convergent technologies like VR and blockchain. It is obvious that conversational AI will be crucial in accelerating Web3 and the metaverse's growth [16].

However, it is vital to establish a connection between the features of

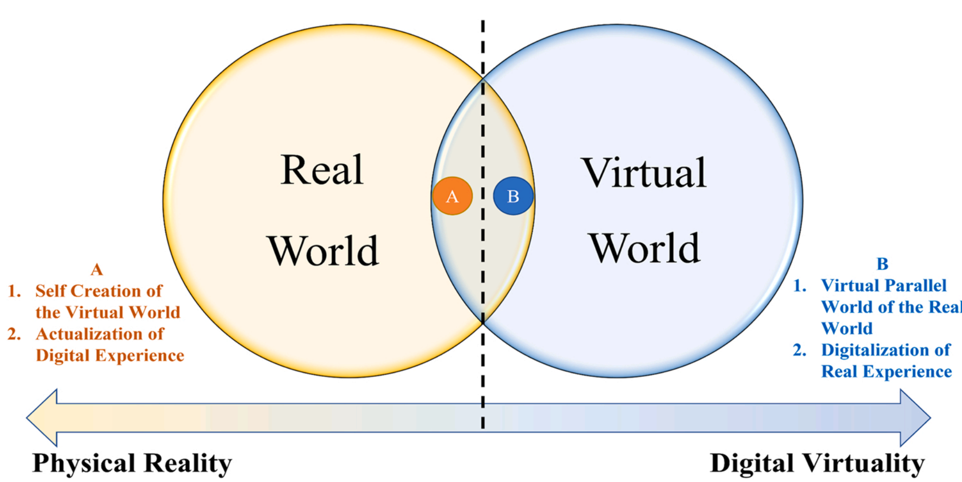

Fig. 1. Two Development Paths of Metaverse [11].

the past (Web 1.0), the current metaverse - Web 2.0 characteristics, and the upcoming Web 3.0 characteristics before delving further into the metaverse (Fig. 2). As more and more conventional virtual worlds incorporate elements of the blockchain-based worlds, the distinctions are becoming less clear [17].

In continuation to the previous discussion, Web 3.0 will rely on AI, ML, and blockchain technology. The basic concept of Web 3.0 is the creation of a decentralized internet with open, interconnected, intelligent websites and web applications. Web3 will give users more control over the data they produce online, whereas Web 2.0 focus is limited on interactive websites and user-generated content hosted on centralized websites [19]. The key benefits and drawbacks of Web3.0 are summarized in Table 1.

2.2. Market size of metaverse

The global metaverse market will be worth USD 426.9 billion by 2027, growing at a compound annual growth rate (CAGR) of 47.2%. Currently (mid-term 2022), the metaverse market is worth USD 61.8 billion [20]. Rising demand in the media and entertainment as well as the gaming industries, evolving opportunities from adjacent markets like XR, and digitalization in the art, fashion, and retail industries are some of the key factors anticipated to propel the growth of the metaverse market. These important factors greatly increase the scope, reach, and offerings of the metaverse to the various industries and end users. Additionally, the use of gamification and virtual world simulators by brands for their promotional campaigns has dramatically increased the demand for vendors in the metaverse market to redesign cutting-edge infrastructure, improve 3D environments, and provide a technologically driven ecosystem to provide end users with the best possible experiences and transactions.

2.3. Technological pillars of metaverse

The intelligent connection of people, processes, data, and objects is another simple definition of metaverse. Thus, the Metaverse is built on technologies that allow for multisensory interactions with digital people, objects, and environments. Stereoscopic displays that can convey the sense of depth enable the representational fidelity of the XR system [21]. The Metaverse is a description of a world where billions of objects are connected via public or private networks using both open and closed-source protocols and have sensors to measure, detect, and assess their status. The pillars of Metaverse are summarized as follows [22], and depicted in Fig. 3(i):

- **People**: Connecting people in more relevant, valuable ways (AI, 5 G/6 G networks, Digital Twins)

Table 1
Benefits versus Drawbacks of Web 3.0.

Benefits of Web 3.0	Drawbacks of Web 3.0
• Solve privacy, and plagiarism issues of older versions • Allow increased information linking • More accurate and efficient web browsing • Better and effective communication making the sharing of knowledge easier • New ways of human collaboration and interaction • Decentralization of data • Data Ownership • Better Marketing	• Those devices or gadgets which are not highly advanced will not be able to handle Web 3.0 • Previous versions of the web may seem to be outdated • Decentralization of data will lead to a lack of central control • Regulatory and enforcement difficulties in controlling cybercrime, hate speech and misinformation • Web 3.0 will not be easy for beginners to understand

- **Data**: Converting data into intelligence to make better decisions (AI, Blockchain)
- **Process**: Delivering the right information to the right person (or machine) at the right time (Expert Systems)
- **Things**: Physical and virtual devices and objects connected to the Internet and each other for intelligent decision making (Internet of Everything - IoE)

3. Elements of metaverse

Besides the current negligible percentage, 30% of global organizations would have goods and services prepared for the metaverse by 2026 [23]. Many businesses have been developing their own versions of the metaverse, including Meta Platforms, Microsoft, and NVIDIA among others. This technology, however, is still in the emergent stage of its evolution and is only available to a select group of early adopters. It will take the metaverse more than eight years to become widely used [24]. The solutions that are being currently positioned as metaverse may be compatible, but they do not meet the requirements of the true metaverse yet. Such solutions might have some of the characteristics of a complete metaverse such as persistence, decentralization, collaborativeness, and interoperability, but not all of the required yet. Some key early examples include gaming, virtual teamwork, navigation apps, social media, fungible tokens, and non-fungible tokens (NFTs). However, it is expected that the entire metaverse will not be controlled by a single vendor and will be independent of devices. Furthermore, it will have a virtual economy of its own, made possible by digital money or NFTs. The complete metaverse could consist of the elements depicted in Fig. 3 (ii). It can be divided into the following groups of technologies, i) application/interface, ii) content, and iii) infrastructure.

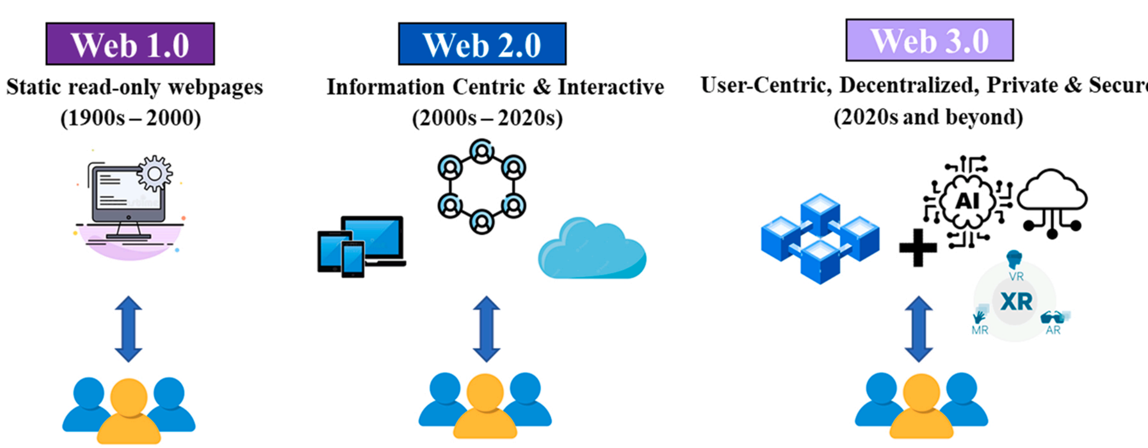

Fig. 2. Illustrative evolution of web communities [18].

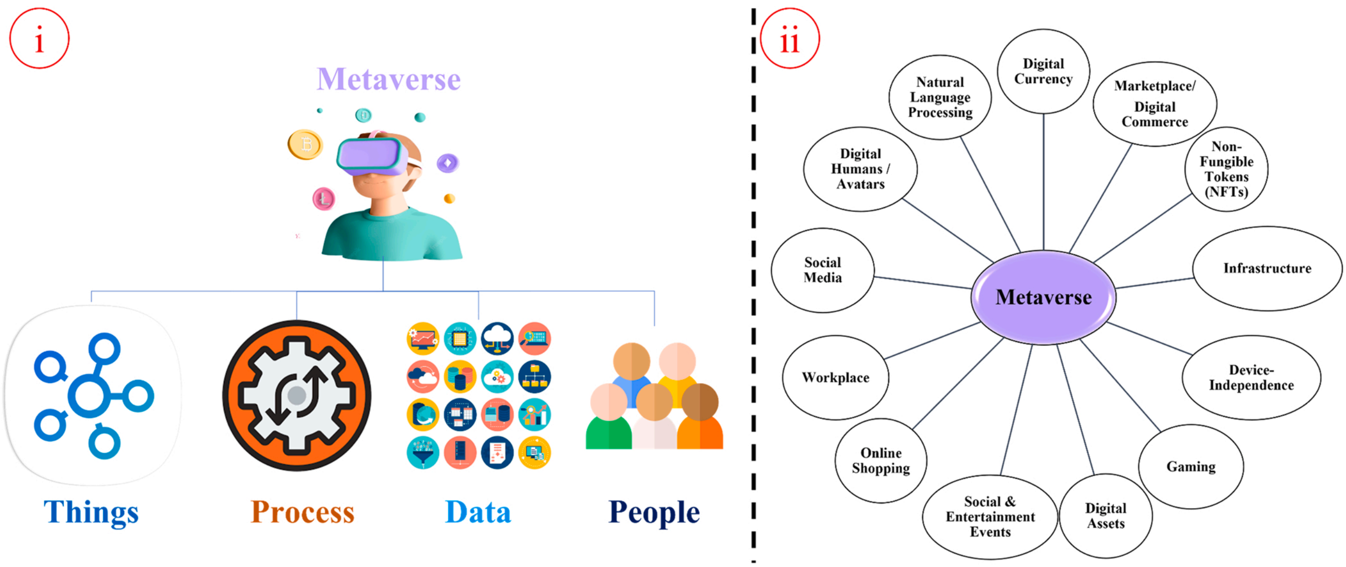

Fig. 3. i) Technological Pillars of the Metaverse; ii) Elements of Metaverse [10].

4. Hierarchical structure of metaverse

XR is the gateway to the metaverse, and XR devices are the essential tools for bridging the two worlds. Development and construction of equipment are top priorities during the early stages of development. Currently, the essential XR products have to be developed, and implemented on their fundamental features. The realization of the metaverse is said to be made up of seven layers of development and implementation (Fig. 4). The early development stage will concentrate on infrastructure and equipment as well as development tools according to the four metaverse development stages [9]. Seven tiers make up this conceptual framework, which describes the value chain of the metaverse market. Infrastructure serves as the base layer, without which none of the subsequent developments would be possible. This is why the metaverse is driven by technological processes. Experience, discovery, the creator economy, spatial computing, decentralization, and human interface make up the other tiers [23].

5. Metaverse in smart manufacturing

Industry 4.0 has created a world in which offline and online coexist. The Metaverse integrates various technologies (e.g., blockchain, industrial artificial intelligence, etc.) to generate augmented reality-based immersive experiences and to establish a connection between real and virtual worlds. This convergence is also occurring in the manufacturing business. The metaverse encapsulates a plethora of critical components that will totally reshape the manufacturing landscape. Users can quickly identify ways to make manufacturing safer, more efficient by dragging and dropping assets into a metaverse framework's physics-based simulation without undertaking significant physical testing, as well as to setup new collaboration channels. Consequently, metaverse serves as a communal space for exchanging ideas resulting in shorter product life cycles. Customers will gain a better understanding of the supply chain process as a result of 3D representations of how products and services are manufactured, delivered, supplied, and sold. Albeit the metaverse is still in its infancy in general and specifically in manufacturing, great potential for reforming and improving manufacturing as it is known, is emerging. The first step is to meet digital operations. Manufacturers should collect data from processes, aggregate it, and use interoperability protocols to connect it across the supply chain. Furthermore, it provides considerable benefits in Industry 4.0, particularly in terms of employee training and data access. Finally, Metaverse is undoubtedly the next

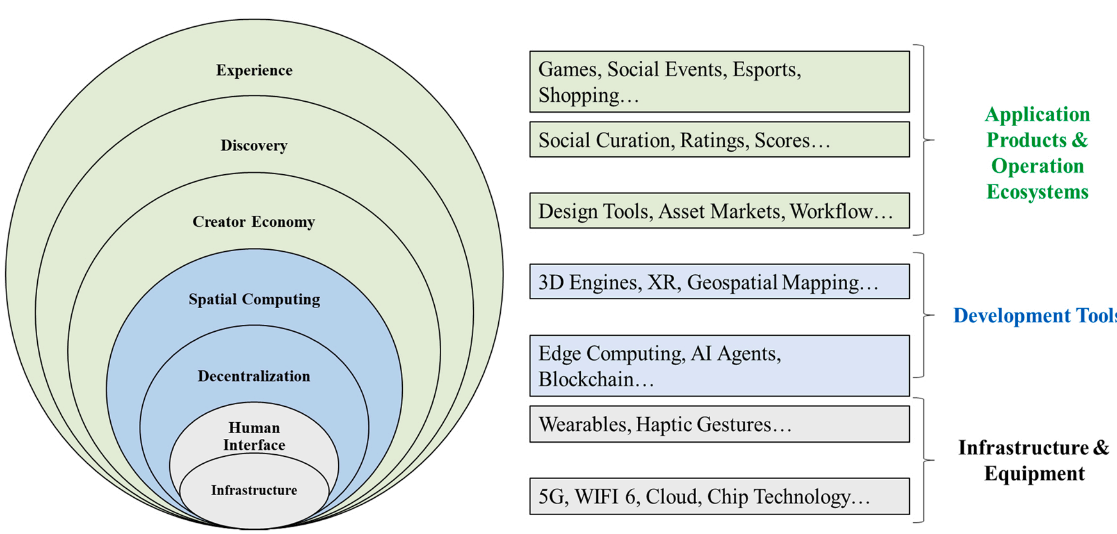

Fig. 4. Layers of Metaverse [11].

significant technological revolution in manufacturing. It will increase productivity and efficiency, reduce expenses, and assist firms in achieving better overall results. Thus, if decision-makers want to stay competitive, they need to invest on metaverse [25]. One key manufacturing aspect towards the investigation of environmental impact of manufacturing activities, as well as the issue of system sustainability is subject to Zero-Defect Manufacturing (ZDM) Technology [26]. To that end, the simulation and visualization functionalities of Metaverse should be exploited. It is also worth noting that several businesses have committed to take actions to reduce the environmental impact of the required data centers that power the metaverse. For example, Google has promised that all its data centers will run continuously on carbon-free energy by 2030 [27]. {{{Table 2}}}.

6. Challenges, opportunities and applications

6.1. Challenges

The key identified challenges for complete Metaverse implementation, are listed as follows [28]:

1. *Identity Management:* Current Web 2.0 apps struggle to verify ID, and as we use the products and services more widely in Metaverse, the issue will only get worse.
2. *Security, Safety, and Privacy (SSP):* Concerns about privacy, safety, and security will rise as devices and people become more interconnected and gather more data, which will speed up the expansion of the Metaverse to a rate close to that of the physical universe. Customers' trust in the Metaverse and any upcoming X-verse versions will depend on how businesses choose to strike a balance between customer SSP.
3. *Finance in Metaverse*: While using cryptocurrency is challenging and doing so in the Metaverse will complicate what is already an unregulated payment system. One solution to this is to use CBDC (Central Bank Digital Currency)
4. *Laws, regulations, and protections*: In order to protect the Metaverse users, including intellectual property, with the newly discovered businesses like NFTs, the law must explore this new world and this new territory.
5. *The emotional and mental impact of living in Metaverse*: The same problems caused by nonstop social media use and online gaming will spread to the Metaverse on a large scale with the addition of another dimension and interactions that happen in close to real-time, which could lead to a lot of mental health problems in the real world and cause the distinction between the real and imaginary worlds to become blurred.
6. *Standardization of the Metaverse*: This is one of the most challenging phases in the early lifecycle of any new technology because everyone wants to set the "standard" and control the market. Standards will cover all processes, protocols, hardware/software, and will make interoperability a key component of the Metaverse's design and implementation.
7. *Human Centricity:* In order to ensure sustainability and resilience in the future, human-centricity should be a central component of all Human Robot Collaboration (HRC) systems. Prof. Wang in [29], proposes a futuristic perspective of four Enhanced Human Abilities (EHAs) namely: augmented robot, cognitive system, mixed reality, and co-intelligence that can be used to energize, advise, support, and empower a human operator from a futuristic perspective.

Table 2
Categorical introduction of Metaverse in Smart Manufacturing.

Manufacturing Aspect	Description
Customers	Metaverse will enable better customer interactions, and consequently, they can co-create and give real-time feedback in all stages of the production processes of a product
Layout design	Layout design of factories and manufacturing networks, can be more responsive and agile by simulating different manufacturing and production scenarios
Logistics	With Digital Twin in Metaverse, logistics supported by blockchain facilitate processes such as product traceability, smart contracts, payments, etc., by enhancing transparency, and visibility of the stakeholders
Maintenance	Improved maintenance quality and speed supported by interactive augmented and virtual reality (including maintenance training and education)
Personnel allocation	Promotion of remote work and upskilling models in manufacturing and operations management
Prototyping	Increased agility in the production and responsiveness to the market can be achieved with AR/VR and 3D printing, through Metaverse, for rapid prototyping
Resource allocation	The Metaverse in conjunction with Simulation technologies, will unlock new capabilities and facilitate the selections of better configurations of resource allocation, considering product characteristics
Zero-Defect Manufacturing	Studies exploring the gains (e.g., minimization of the pollution, carbon reduction, traffic congestion, delivery times) enabled by remote work/telework for improved sustainability

6.2. Opportunities and applications

Although the advantages and opportunities provided by the metaverse are not yet immediately viable, emerging metaverse solutions provide a hint as to possible use cases. It is expected that the shift to the metaverse will be just as important as the shift from analog to digital. The metaverse will provide real-time, intriguing, and useful information across scenarios for interactions in the physical world. Examples include augmented social networking filters, guidance for industrial repair tasks, interactive museum exhibits, dynamic information overlays for knowledge workers, and wayfinding for both business and consumer use. Another example of a digital interaction is the capacity to move between various virtual worlds. Although the current metaverse experiences will not completely replace the way we interact with applications, websites, and other digital platforms, they will probably pave the way to new kinds of interactions and business models that can be tailored to these new use cases. Other sectors that will be directly impacted by the metaverse include banking, electronics, semiconductors, semiconductor manufacturing, communications and media, retail, and engineering, marketing of organizations, branding, and sales roles for goods and services. Furthermore, product leaders have to look beyond the immediate contextual use of their products to identify opportunities that cut across applications. The metaverse may enable brand-new Supply Chain experiences in the digital world that we have never had before.

Modern tools like 5 G, the Industrial IoT, and VR are used in the metaverse to give users a fully immersive, multi-sensory experience. By providing 3D representations of how businesses produce, deliver, and advertise their goods, the metaverse will improve supply chain transparency. Those who are interested will gain visibility to: 1) lead times, 2) real-time shipping costs, 3) transit time and 4) delays [30].

6.3. Metaverse software platforms ecosystem – a conceptual framework

The year 2020 was a milestone in the evolution of spatial computing during the pandemic. Software platforms can be considered as the backbone technology for the development and execution of application programs. In Fig. 5 the XR software platforms for Metaverse are divided into five different layers: 1) Enabling Platforms, 2) Content Platforms, 3) Human Centered Platforms, 4) Utility Platforms and 5) Application Platforms. The metaverse will require capabilities such as AR, VR, and enable legacy devices to operate within it. These layers can be considered as logic software layers, moving from the core computing power to real use cases and technological applications [31].

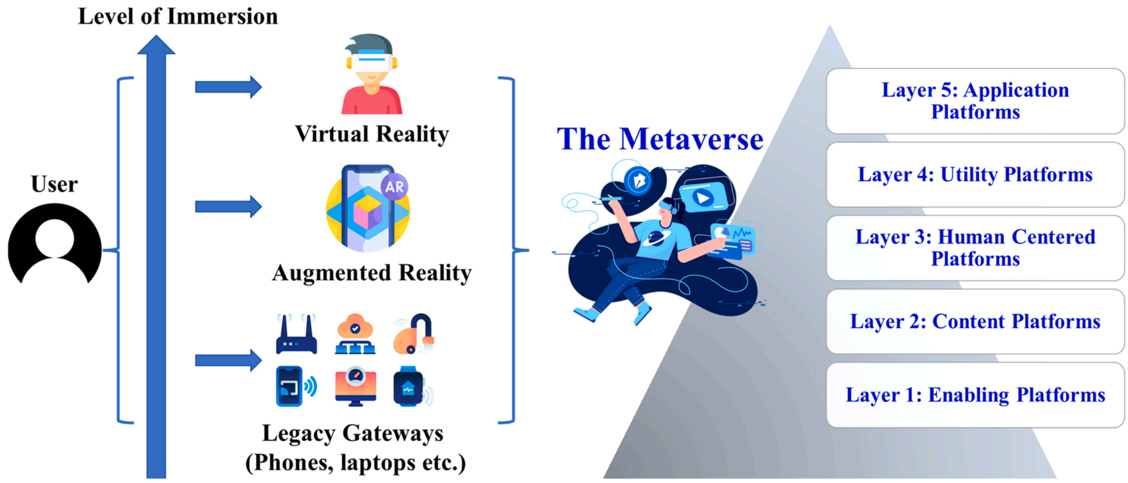

Fig. 5. Metaverse Software Platforms Ecosystem.

1. Enabling platforms refer to core software platforms or general-purpose software applications, that augment the XR software ecosystem by adding functionalities, such as operating systems, digital stores, real-time engines and frameworks, world mapping and tracking, and cloud rendering.
2. Content platforms enable the acquisition, creation, and management of the 3D content required in order to populate the metaverse, such as digital twins or virtual environments.
3. The third layer referred to as Human-centered platforms, includes operations relevant to the management of content related to human representations and virtual beings.
4. Utility platforms are specific platforms focusing on populating the metaverse with applications and utility related use cases, such as new search engines and new low code application platforms.
5. The fifth layer, entitled Application platforms focuses on a specific application field. Concretely this layer is composed of all experiences that the user of a headset can enjoy for personal or professional use.

6.4. Interoperability in the metaverse

Interoperability in Metaverse can be defined as the ability to unify economies, avatars and systems across worlds, extending its definition as one of the defining properties of the metaverse. However, achieving a sufficient level of interoperability in Metaverse is one of the major challenges along with composability. The latter refers to the users' ability in creatively combine interoperable Metaverse components together. It limits users' access to the Metaverse by preventing them from freely navigating across various virtual worlds integrated within the 3D horizon of Metaverse, but instead restricting their navigation to a single digital entity. Users within Metaverse seek the same consistency and interoperability as in the real world. Their participation in the Metaverse is intended to provide them with an immersive digital environment with a variety of interconnected virtual worlds where they can easily switch between any digital entity and take advantage of the benefits. All these perceptions become reality thanks to interoperability, which also creates a system called Interconnected Decentralized Metaverse [32]. The key domains of interoperability within the Metaverse can be summarized to i) Connectivity, ii) Persistence, iii) Presentation, iv) Meaning, v) Behavior. By extension, cutting-edge digital technologies, such as Artificial Intelligence, Digital Twins, Extended Reality, among others developed under the framework of Industry 4.0 will lay the foundations for the realization of Metaverse. On top of these technologies, new technologies will also be developed to facilitate the development of the abovementioned domains.

In principle, a semantic web could be very powerful since users could be capable to search and compare content according to a database of agreed-upon attributes. The concept behind the integration of semantic web would be to allow everyone to publish web pages that add new knowledge to the internet. Based on the abovementioned principle, ontologies could provide an opportunity to tackle the interoperability challenge in Metaverse. However, in order to achieve a widespread adoption and implementation of ontologies, more systematic and coordinated efforts are needed [33]. Furthermore, an ontological framework could be integrated in Metaverse in an attempt to assess interoperability of Metaverse for revealing the weak points as per the work presented in [34].

7. Conclusions

This paper aimed to present the definition of Metaverse, its evolution, the advantages and disadvantages, the pillars for the technological advancement which could be the fuel to spark future investigation and discussion as well as to accelerate the development of Metaverse towards the human centric and personalized society (Society 5.0). Additionally, challenges and opportunities in the Manufacturing and Industrial section as well as a brief comparison versus Virtual Reality, and a conceptual framework for integrating Metaverse in Manufacturing is also presented.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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