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Physical and digital worlds: implications and opportunities of the metaverse

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Abstract

The Metaverse is revolutionizing the world of the internet. It is the new "virtual" universe capable of going beyond the pure three-dimensional and immersive dimension combining the physical and digital worlds. The metaverse, which until recently was an abstract concept, is now assuming great importance and attracting the attention of consumers, investors, brands, and large global players. Certainly, the first sector to adapt to this new immersive reality is e-commerce. Obviously, e-commerce is not the only sector affected by this digital revolution. Interoperability and interconnection will revolutionize current business models. Although the business opportunities seem endless, the scenario is still not entirely clear. Thus, the aim of the present research is to provide an overview on the state of the art, technologies, applications, and challenges of metaverse. Ethical and social implications are also analized. The result is a first detailed scenario analysis on the Metaverse.

Keywords: Metaverse; Immersive Internet, Multi-technology, Sociality, AR, VR

Nomenclature

AI	Artificial intelligence
AR	Augmented reality
B-o	Birthbath optics
C-m	Curved mirrors
D	Diagonal
F LCD	Fast LCD
F-l	Fresnel lenses
h	Horizontal
I-O	Inside-out
IoT	Internet of Things

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Le	Light engine
ML	Micro LED
MR	Mixed reality
PC-P VR	PC-powered VR
P-p VR	Phone-powered VR
QS	Qualcomm Snapdragon
S -VR	Standalone VR
V	Vertical
VR	Virtual reality
W	Waveguides
XR	Extended reality

1. Introduction

Metaverse is a term coined by Neal Stephenson in the cyberpunk novel "Snow Crash" (1992) to indicate a three-dimensional space (a parallel universe) to the real world within which individuals can move, share and interact through personalized. The etymology of the word derives from a Macedonian word modeled on the English metaverse, formed by the prefix meta- (inside) and the noun (uni) *verse* "universe" (abbrevietion of universe) [1]. However, it is important to specify that an early idea of the Metaverse began to develop towards the end of the 1960s, through the first novels centered on parallel and digital universes, one thinks of the novelist Philip K. Dick with the text "*The Game-Players of Titan*" or the short story "*We Can Remember It For You Wholesale*" [2]. Therefore, the Metaverse is not a new concept [3]. Since October 2021, the term has gained a lot of popularity with the announcement of Facebook, which has decided to name the Group's holding company "Meta" (which controls the Facebook, Whatsapp, Instagram and Oculos platforms) and to start a project with this name, project about which little is known yet. A few days later, Microsoft announced that from 2022 it will integrate the Metaverse into the *Teams platform* with a feature called Mash: users will be able to create an avatar with which to participate in business meetings. Several high-tech companies (Meta, Adobe, Microsoft, Huawei, Nvidia, Epic Games, World Wide Web Consortium (W3C), Qualcomm, Sony Interactive Entertainment) have invested billions of dollars and worked intensively on virtual reality since the early 2000s [4]. As highlighted by Bloomberg Intelligence, the global metaverse market could reach between $390 billion and $800 billion by 2025. But the possibility of virtual reality entering our daily lives had not been considered until the outbreak of the pandemic [5], [6], [7]. The development of the metaverse has been made possible by technologies such as artificial intelligence, IoT, AR, VR, 3D modeling, and space and edge computers. Users' cognition, emotions, and behaviors can be influenced by key technologies that enable multiple metaverses.

In this context, the present study aims to understand the development of the Metaverse since its origin, describing its characteristics and applications. The rest of paper is organized as follows: Section 2 analyzes the social and ethical implication of Metaverse; Section 3 describes the different platforms used for Metaverse; Section 4 discusses the main evidence and academic perspectives on Metaverse. Section 5 defines future developments in the field of the Metaverse with a focus on education and training. Finally, Section 6 draws the main conclusions from the discussed research.

2. Metaverse: social and ethical implications

The metaverse has ethical implications that are bound to impact society. At the same time, it will be necessary to ensure the security of such parallel worlds [8]. The ethical and social implications characterizing the metaverse are described below.

2.1 Social implications

The consequences of the use of meta-vertical technologies are a matter of debate. The risks of using these technologies are twofold. Firstly, related to psychic well-being (i.e. physical exercise, concrete engagement in social relationships, and time spent in nature). Secondly, related of being what one wants to be, i.e., cultivating an idealization of oneself and of the world [9]. Attraction, fascination, suggestion, pleasure, exaltation, may be the seductive ingredients that capture a considerable slice of the market [10]. In digital contexts, thus also in the metaverse, social relationships are enhanced, giving the illusion of cancelling distances, while one is alone in one's own space. This condition can represent the illusion of resolving one's own, perhaps unconscious, condition of loneliness. The disconnection with reality is directly proportional to the connection in the virtual [11]. The metaverse is an illusory dimension supported by the brain's immediate adaptation process. It perceives virtual reality as real, permuting our perception so that everything becomes easier to understand. And so, it is possible to create in parallel a perfect reality, to create one's own avatar with the characteristics one prefers, perhaps corresponding to the improved self-image and mirroring of one's own limitations. The person can thus become the perfect model of what they desire. The freedom to create a new identity, a virtual self, that corresponds to an idealized version of oneself, because it is better, is therefore legitimate. Ensuring the health of consumers interacting with VR is important, because being ignored or minimized could have long-term psychological effects [12].

2.2 Ethical implications

The technology of the metaverse has ethical implications [13]. Below are four of the ethical aspects that need to be addressed to make it safe for users to use the Metaverse:

- **Biometric data and privacy:** Virtual and augmented reality devices are set to provide users with access to the metaverse, but these devices, together with Brain-Computer Interfaces (BCIs) will track brainwave patterns and infer users' thought processes. Many consumers today simply accept privacy policies. Also of concern is the compromise of hacker attacks or misuse of data. Therefore, cybersecurity and data protection must also be ensured in the metaverse.
- **Bullying, hate speech and other phenomena:** The Internet and social media have already shown us people express opinions they would never express in real life, resulting in bullying, hate speech, etc. It is very likely that the same will happen in the metaverse, where people will be able to hide behind their avatar or "digital twin"..
- **Identity:** The metaverse, using NFT (Non-Fungible Token, which relies on blockchain to embed unique codes in digital assets), will allow users to show their unique and authentic avatar. The question arises - given that in the real world everyone must accept their essence (i.e., appearance, social background, race, social status and so on) - whether in the metaverse users can be anything they want to be, i.e., whether identity could be something users can choose.
- **Protecting the vulnerable:** If users can be anything they want to be in the metaverse, this makes it difficult to protect the vulnerable. It has been shown that consumption or even virtual participation in violent virtual reality games desensitizes people to violence, which poses the risk that 'acceptable' actions in the metaverse will be replicated in real life. These hyper-reality experiences could also trigger sensory overload and induce convulsions in those users who suffer from epilepsy.

According to the previous considerations it emerges that a legislative and regulatory framework will be needed as soon as possible. EU activity on the ethical aspect is intense and currently focuses on specific proposals as follows:

- Proposal#1 for EU Regulation 112/2018 promoting fairness and transparency for business users of online intermediary services.
- Proposal#2 for Regulation 850/2020 on a single market for digital services; Proposal for Regulation 842/2020 on fair and contestable markets in the digital sector.
- Proposal#3 for Regulation 106/2020 on harmonized rules on artificial intelligence (AI) [14].

At the international level, The World Economic Forum has decided to launch *"Defining and Building the Metaverse', an initiative that aims to build a 'fair, interoperable and secure metaverse*" through the collaboration of the public and private sectors, including business, civil society, academia, and regulators. To date 60 companies are involved (i.e. Microsoft, Meta Platforms, Lego Group and Walmart among others), along with experts, academics,

and associations to accelerate the development of the metaverse's governance and policy framework [15]. This will help to ensure the inclusive, ethical, and transformative use of this vital medium for social and economic interconnectivity' by enhancing its growth opportunity. The plan will focus on **two key areas**. The first is the governance of the metaverse, through examining how the technologies and environments of the metaverse can be developed in safe, secure, interoperable, and inclusive ways. The second will focus on value creation and identify the incentives and risks that businesses, individuals, and society will encounter when the metaverse comes to life. An adequate system of safeguards must also be prepared for the workers of the Metaverse, i.e., those who will work in the economic system of the new dimension [16]. The Metaverse will thus allow people from all parts of the planet to come into contact in a comprehensive and immersive manner [17]. These new relational possibilities will presumably lead to the emergence of new interpersonal relationships and the exchange of ideas, thoughts, and opinions [18]. How will it be possible to guarantee freedom of thought and at the same time prevent the spread of forms of racism and discrimination? [19].

3. Technologies and digital platforms for the metaverse

3.1 Technological Devices for an immersive experience

From a structural point of view, the metaverse is composed of three levels: the *content*, what is inside the metaverse; the *software*, the programs that make the metaverse work [20], [21], [22]. Finally, the *hardware* i.e., the tools for accessing the metaverse. However, immersion in the metaverse occurs through hardware [23], [24]. The most attractive and widely adopted interfaces with the metaverse are mobile and wearable devices such as AR glasses, headsets, and smartphones [25], [26]. These allow the user comfortable mobility, an immersive experience and a tangible feeling. Smartphones, computers, headsets can be used to access the metaverse, but the devices considered to pioneer the immersive 3D experience in the metaverse are head-mounted displays (HMDs) of virtual and augmented reality [27], [28], [29]. The main factor that distinguishes access to the metaverse via HMDs from access via a desktop computer is the degree of immersion. Immersion is an objective measure of the vividness offered by a system and the extent to which the system can exclude the external world [30], [31], [32], [33]. The strong interest in the metaverse and the associated prospect for growth accelerates the technological innovation of these devices. To date, there are a fair number of both AR and VR devices available with different features. However, the main features that determine their performance are [34]:

- **FOV** and **frame rate**: The greater the field of view (FOV) and the higher the frame rate, the better the viewer.
- **Degrees of freedom**: the main difference is in the freedom of movement. We can have three or six degrees of freedom.
- **Movement tracking**: there is a distinction between outside-in tracking and inside-out tracking. In both cases we refer to the technologies that make it possible to enjoy the 6dof. In the case of outside-in tracking, sensors are placed inside the room where the virtual reality experience will be enjoyed. In contrast, with inside-out tracking, there is no need for external sensors.
- **Wired or standalone**: wired VR viewers are those that cannot operate on their own and need a computer to which the computational load of processing the virtual reality world is delegated. Standalone VR viewers possess all the computational power needed to run on their own.
- **Controllers**: each VR visor provides the user with one or two controllers through which to interact in the virtual scene. In addition to physical controllers, using cameras or infrared sensors, some VR viewers allow direct use of the hands (hand tracking) to interact with virtual reality.

Tables 1 and Table 2 show the most important devices with their respective characteristics [35].

Table 1: Major VR devices

Brand		Oculus Quest2	Pico Neo2	DPVR P1 Pro 4K	HP Reverb G2	Valve Index	Pico Neo3	Nolo Sonic	HTC Vivo Row	Huawei 6DoF	DPVR P1 Pro Light
Processor		QS XR2	QS 845	QS XR1			QS XR2	QS 845	QS XR2		QS 821
Type		S -VR	S-VR	S-VR	PC-P VR[2]	PC-P VR	S-VR	S-VR	S-VR	P-p VR	S-VR
Display	*Display type*	F LCD	F LCD	F LCD	2× F LCD	2× F LCD	F LCD	F LCD	2× F LCD	2× F LCD	F LCD
	Resolution	183×1920	2048×2160	1920×2160	2160×2160	1440×1600	1832×1920	1920×2160	1600×1600	1600×1600	1280×1440
	Refresh rate	120 Hz	75 Hz	72 Hz	90 Hz	144 Hz	90 Hz	72 Hz	75 Hz	90 Hz	90 Hz
Optics	*Optics*	F-l	F-l		F-l	F-l	F-l				F-l
	Fields of view	89° h 93° v	101° h 101° v	100° d	107° d	107° d	98° h 90° v	101° h 90° v	100° d	90° d	100° d
Tracking	*Controllers Solutions*	6 DoF I-O	6 DoF I-O	3 DoF	6 DoF I-O	6 DoF I-O	6 DoF I-O	6 DoF I-O	6 DoF I-O	6 DoF I-O	3 DoF
Weight		503g	670g	340g	498g	809g	620g	502g	189g	188g	410g

Table 2: Major AR devices

Brand		MAD Gaze Glow Plus	Rokid Glass2	Magic Leap1	Microsoft HoloLens2	Vuzix 4000	Xiaomi Smart Glasses	Dream Glass 4K	Nreal Light	Lenovo ThinkReality A3	IMO air
Processor			Amlogic S905D3	NVIDIA Parker SOC	QS 850	QS XR1	Quad-core ARM CPU	Rockchip Mali T864		QS XR1	Quad-core ARM CPU
Type		P-p VR	S-VR	S-VR	S-VR	S-VR	S-VR	S-VR	P-p AR	PC-p AR	S-VR
Display	*Display type*	2 x OLED	LCOS		2× Le	DLP	2 x ML		2× OLED		
	Resolution	1920 x 1080	1280 x 720	1280 x 960	1440 x 936	854 x 480	640 x 480	1920 x 1080	1920 x 1080	1920 x 1080	
	Refresh rate			122 Hz	60 Hz		50 Hz	60 Hz	60 Hz		
Optics	*Optics*	B-o	W	W	W	W	W	C-m	B-o	B-o	W
	Fields of view	53° d	40° d	50° d	52° d	28° d	29° d	46° d	52° d		
Tracking	*Controllers*	6 DoF I-O	3 DoF	6 DoF I-O	6 DoF I-O	3 DoF	6 DoF	3 DoF	6 DoF I-O	6 DoF I-O	3 DoF
	Solutions	I-O	I-O		I-O	I-O	I-O	I-O	I-O		I-O
Weight (with headstrap)		80g	96g	316g	556g		51g	185g	41g	130g	78g

To provide as immersive an experience as possible and to make sure that the involvement is maximized, several companies are investing in developing various accessories [36]. Some of these are described below and shown in the Figure 1.

Fig. 1. Accessories for metaverse. A- Wristband; B-Gloves; C-Bodysuit (Tesla bodysuit); D-Treadmill.

3.2 Platforms for accessing the metaverse

Access to the metaverse is through various platforms that allow us to immerse ourselves in parallel worlds to

make this virtual world increasingly real [37]. The metaverse platform that has become popular in the global market is Second Life. It was invented by physicist Philip Roserdale and made available online by the production company Linden Lab in 2003. The virtual world of Second Life consists of an environment in which user avatars can create their own space in which they can share sounds, images and various types of messages, or explore the various environments and spaces of other users, with whom they can entertain and chat. Second Life users can also use a currency, the Linden for the purpose of exchanging goods within the virtual world. Since the first Second Life experiment, other types of metaverse have been created and made public. Today, many platforms with different features and functionality are available. The main features of the current platforms are: three-dimensionality of environments; shareability of spaces simultaneously by several people and sociality (pure games without prevalent social elements are excluded). The results of the analysis were reorganized and reported in Table 3 in which virtual worlds are classified according to the mode of access (virtual reality devices or desktop/web browser) and the technology that powers their internal economy (blockchain or other) [38].

Table 3: Classification of metaverse platforms

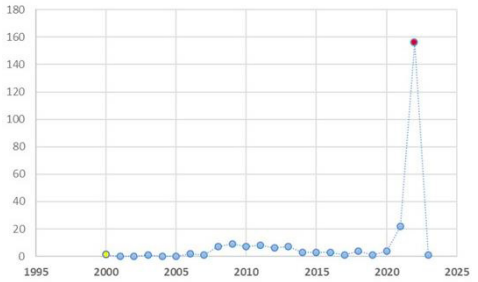
Platform	VR	Blockchain	desktop/web browser	Other technology
CoRE	✗	✗	✓	✓
STRAGEVERSE	✓	✗	✓	✓
ZEPETO	✗	✗	✓	✓
Hubs moz://a	✗	✗	✓	✓
VESTA	✓	✗	✓	✓
SANSAR	✓	✗	✓	✓
FORTNITE	✗	✗	✓	✓
Hiberworld	✗	✗	✓	✓
Cluster	✓	✗	✓	✓
REC ROOM	✓	✗	✓	✓
Wave	✗	✗	✓	✓
Sinespace	✗	✗	✓	✓
UTHERVERSE	✗	✗	✓	✓
Avakin life	✗	✗	✓	✓
Wooz world	✗	✗	✓	✓
MINECFRAFT	✗	✗	✓	✓
ROBLOX	✗	✗	✓	✓
SECOND LIFE	✗	✗	✓	✓
ACTIVE WORLDS	✗	✗	✓	✓
XRSPACE MANOVA	✓	✗	✗	✓
Horizon Worlds	✓	✗	✗	✓
VR CHAT	✓	✗	✗	✓
bigscreen	✓	✗	✗	✓
AltspaceVR	✓	✗	✗	✓
ANYLAND	✓	✗	✗	✓
ROVE	✗	✓	✓	✗
THE SANDBOX	✗	✓	✓	✗
NEMESIS	✗	✓	✓	✗
Mona	✗	✓	✓	✗
Decentaland	✗	✓	✓	✗
Spatial	✓	✓	✓	✗
BLANKOS	✗	✓	✓	✗
CRYPTOVOXELS	✗	✓	✓	✗

SOMNIUM SPACE	✓	✓	✓	✗
Neos	✓	✓	✗	✗

However, despite the large number of platforms available, the market is dominated by two platforms, such as: **Decentraland** and **Sandbox**. Decentraland in December 2021 led the platform ranking with 8.5 million users. Sandbox, as of March 2022, registered 2 million users [39]. Decentraland is a decentralized platform built on the Ethereum blockchain where users can experiment, create and monetize assets, content and applications. It is not controlled by any centralized organization. This implies that no single agent has permission to change the rules of software, content and the cryptocurrency economy, or to prevent others from accessing the world, exchanging digital products and experimenting with services. Decentraland's architecture consists of three layers: a consensus layer to keep track of ownership and terrain content, a terrain content layer to distribute materials for rendering through a decentralized storage system, and a real-time layer to establish peer-to-peer connections for visualizing the world. Sandbox is a decentralized virtual world based on the Ethereum blockchain. Users can play, share, collect and exchange virtual goods and services without central control. ERC-20 blockchain technology is used to generate the token and ERC-1155 to exchange digital goods. Creators can earn tokens by selling their creations on a marketplace with secure copyright ownership that is associated and guaranteed through NFT, i.e. every object in the metaverse will be authenticated by a unique and immutable blockchain mechanism. Table 5 shows similarities and differences of the two platforms.

4. Evidence and academic perspectives: best practices and case studies

To fully understand the phenomenon of the metaverse and to understand how the scientific community is moving forward, a literature review was conducted. The Scopus database was used. An initial query was conducted. Only documents where the word "Metaverse" appears in the TITLE (metaverse) were considered. The search returned **247** documents. Figure 2 shows documents by years (a) and documents by type (b).



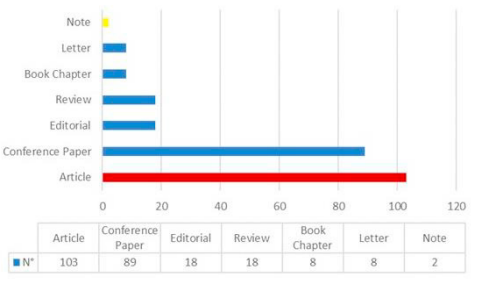


Fig. 2. (a) documents by years; (b) documents by type (sources: Scopus).

Although the metaverse was born in the 1990s, the first scientific articles were only registered in 2000. The number of articles increased considerably in 2020, probably due to the COVID19 pandemic that accelerated the transition to the digital world. More than 50% of the articles were published in 4 countries. The United States is the most productive country with 51 publications (20%), followed by China and South Korea with both 36 publications (15%). Following United Kingdom (30; 12%) and Japan (21; 8%). The results pointed out that the subject area in which the metaverse is most frequently addressed is computer science (31.6%). Therefore, the research was further refined. The search string used is as follows (TITLE (metaverse) AND TITLE-ABS-KEY (social) OR TITLE-ABS-KEY (healthcare) OR TITLE-ABS-KEY (gaming) OR TITLE-ABS-KEY (smart AND cities) OR TITLE-ABS-KEY (manufacturing) OR TITLE-ABS-KEY (e-commerce) OR TITLE-ABS-KEY (smart AND working) OR TITLE-ABS-KEY (education)). A total of **94** documents were obtained. Table 4 summarises the results of the research. More in detail, Table 5 summarizes the most interesting publications from our point of view.

Table 4: Documents for fields

Fields	n	Application advantages	Main references
Social	50	Metaverse is the evolution of social networks. It breaks the boundaries of time and space by erasing the distance between people and allowing total involvement.	Xu, J. [40], Duan, H. [41], Hendaoui, A. [42],
Gaming	6	Metaverse transforms the gaming experience by offering positive qualities, high realism, freedom, sharing and sociability. Game platforms are enhanced by the metaverse, allowing the player to embody and move or create additional power-ups available to other users.	Jungherr, A. [43], Baía Reis, A [44]
Smart city	1	Metaverse allows the physical world to be digitally mapped. it allows urban data such as people, vehicles, objects and space to be fully captured and form a visible, controllable and manageable digital twin city.	Kwon, C. [45]
Manufacturing	7	Metaverse supports the production process at different stages, from design to customer interaction. It enables rapid design of the production process and improves operational efficiency.	Lee, J.[46], Lin, Z.[47]
Education	20	Meta-education can enable hybrid, formal and informal active learning experiences. In 3D virtual campuses, students are co-owners of virtual spaces and co-creators of customized curricula. Total immersion enables accurate education to a mass audience about unknown circumstances and events in remote locations.	Jovanović, A. [48], Lee, H.[49], Hwang, G-J.[50]
Healhtcare	5	It can provide various healthcare services, such as patient care, digital education, diagnostics and therapy. The metaverse cancels the distance between doctor and patient, facilitating and reducing the time for diagnosis and access to treatment.	Wiederhold, B K. [51], Kerdvibulvech, C. [52]
E-commerce	4	Metaverse enables the creation of digital shops that combine the best of offline and online shopping without any difference in user experience.	Jeong, H.[53], Shen, B. [54]
Smart working	1	Metaverse brings new levels of social connection, mobility and collaboration, introducing a definitive solution to the problems of employee disconnection and isolation. Employees can log in and out of conference rooms and virtual offices in real time, present a project live, network with colleagues from around the world, or go to a virtual help desk.	Alpala, L -O. [55]

What lesson learned from the analysis of literature? It emerged that the development of the metaverse will pursuit to achieve increasingly "material" interaction [56]. One factor that is set to make a major contribution to the growth of the metaverse is the **field of education**. In this context, the metaverse is not a new concept: several researchers and educators have discussed its implications for learning. In fact, scientific studies evaluate the benefits of using the metaverse to improve the learning process [57], [58]. According to Collins [59], since the Metaverse is a place where individuals can meet and interact socially, its use would contribute to great educational and learning benefits. The opportunities seem fascinating. It is interesting to mention that after Zuckerberg, Microsoft's Nadella also talked about the metaverse showing a video of a meeting on Teams between two Accenture managers: one in physical version, the other in its avatar version (Figure 3).

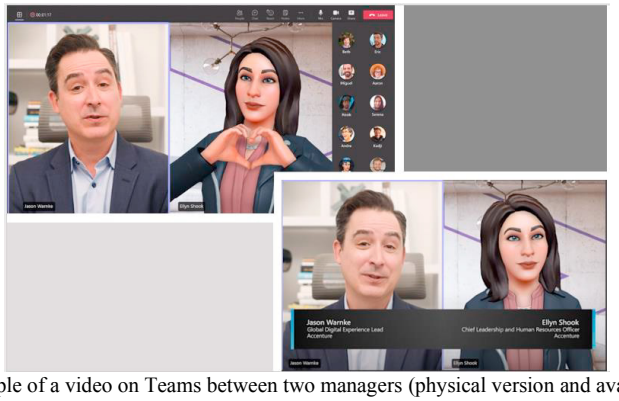


Fig. 3. Example of a video on Teams between two managers (physical version and avatar version).

Another area where the metaverse could be revolutionary is the **industrial metaverse** to accelerate processes such as repair/maintenance, start-up of new production lines, remote monitoring/troubleshooting, remote control, and training of new users/managers through simulation.

6. Conclusions

This study analyzed the implications and opportunities offered by the Metaverse, the latest evolution of the Internet. It is possible to conclude virtual reality does not replace the world wide web. Interoperability between worlds and platforms is one of the most important bets of the Metaverse. The Metaverse is the implementation not only of a space, but of society itself. A virtual world without real interactions between people, as current social media has accustomed us, is out of date, and it is no coincidence that the pandemic, which has socially isolated us, has made the need to develop a more coherent and integrated reality re-emerge. digital social. The Metaverse must be the evolution of this experience.

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