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Unveiling the Metaverse: Paving the Way for Technological Providers

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Abstract

The Metaverse is set to be the next big thing after the advent of the Internet and is expected to have a major impact on society in the coming decades. The Metaverse converges the physical and digital worlds, enabling immersive experiences in both virtual and physical environments. This digital immersion offers users endless new opportunities by removing physical boundaries; people will have the opportunity to travel through time, explore the various worlds that constitute the Metaverse or enjoy unique experiences. Users will have access to immersive environments, enabling them to work, learn, shop, socialise and explore a wide range of interests. Although still in the experimental stage, the Metaverse is expected to revolutionise a multitude of industries and sectors.
This study provides a 360-degree view of the Metaverse, its characteristics, the underlying architecture, the current situation, and the challenges that will have to be addressed to enable its diffusion. By reviewing academic works and media articles, this paper defines the concepts of immersive experience, the technologies that enable its fruition, and the potential applications and opportunities for different sectors. This document provides a classification of platforms called 'Metaverse Platforms', which provide users with the opportunity to access three-dimensional virtual universes and live immersive experiences. Moreover, the technological providers of this sector have been mapped both at a global level and more in detail at an Italian one. In the last part of the study, through the information obtained from the interviews with Italian providers, guidelines are suggested for the realisation of immersive projects and an analysis of the most delicate phases that can cause bottlenecks within the process.

Keywords: Metaverse, immersive experience, immersive technology

Abstract in lingua italiana

Il Metaverso è destinato ad essere la prossima grande novità dopo l'avvento di Internet e si prevede che avrà un grande impatto sulla società nei prossimi decenni. Il Metaverso fa convergere il mondo fisico e quello digitale, consentendo esperienze immersive in ambienti sia virtuali che fisici. Questa immersione digitale offre agli utenti nuove e infinite opportunità, eliminando i confini fisici; le persone avranno la possibilità di viaggiare nel tempo, esplorare i vari mondi che costituiscono il Metaverso o vivere esperienze uniche. Gli utenti avranno accesso a ambienti immersivi, i quali consentiranno loro di svolgere attività lavorative, di apprendimento, di acquisto, di socializzazione nonché di esplorare una vasta gamma di interessi. Sebbene sia ancora in fase sperimentale, si prevede che il Metaverso rivoluzionerà una moltitudine di industrie e settori.
Questo articolo fornisce una visione a 360 gradi del Metaverso, delle sue caratteristiche, dell'architettura sottostante, della situazione attuale e delle sfide che dovranno essere affrontate per consentirne la diffusione. Attraverso l'analisi di opere accademiche e articoli dei media, lo studio definisce i concetti di esperienza immersiva, le tecnologie che ne consentono la fruizione e le potenziali applicazioni e opportunità per i diversi settori. Nel presente documento è riportata una classificazione delle piattaforme denominate "Metaverse Platforms", che garantiscono ai fruitori l'opportunità di accedere a universi virtuali tridimensionali e vivere esperienze immersive. Inoltre, sono stati mappati i fornitori tecnologici di questo settore sia a livello globale che, più in dettaglio, a livello italiano. Nell'ultima parte dello studio, attraverso le informazioni ottenute dalle interviste ai fornitori italiani, vengono suggerite delle linee guida per la realizzazione di progetti immersivi e un'analisi delle fasi più delicate che possono causare colli di bottiglia all'interno del processo.

Parole chiave: Metaverso, esperienza immersive, tecnologia immersive

Contents

Abstract **i**

Abstract in lingua italiana **iii**

Contents **v**

Introduction **1**

1 From the Metaverse to immersive experiences: an overview of emerging technologies **3**

1.1 Metaverse Origin and Definition 3
1.2 Metaverse Features 5
1.3 Metaverse Architecture 8
1.4 Immersive Experience 11
1.5 Immersive Technology 14
1.6 S-O-R Framework 21
1.7 Applications of Immersive Experiences 28
1.8 Challenges for the Metaverse 34

2 Analysis of the Metaverse world: classification of technology providers and Metaverse Platforms **37**

2.1 AS-IS Situation 37
2.2 Metaverse Platforms 41
2.3 Deepening of Metaverse Platform Decentraland 43
2.4 Mapping of Global Providers 46
2.5 Mapping of Italian Providers 49

3 A comprehensive guidelines and analysis for the realisation of an immersive project **51**

3.1 Methodology 51

3.2 Outcomes Description 53
3.3 Steps of an Immersive Project 60
3.4 Delicate Phase, Criticality and Bottlenecks 66

4 Conclusions and future developments **69**

Bibliography **71**

A Appendix A **79**

List of Figures **91**

List of Tables **93**

Introduction

The relationship between humans and technology has always been a prevalent theme in modern society, but it can also be traced back to earlier times in human history when innovation was a means of improving an individual's quality of life. The importance of this consideration highlights how technological progress and society are in a mutually influential relationship, generating periodically new needs and opportunities.

From a technological standpoint, we have witnessed rapid evolutions over the last few decades, with increasingly intelligent devices and computing power that have occurred at ever-faster cycles. This has led to the emergence of technologies and devices that can radically change even in a very short time. All these factors are making many technologies accessible on a large scale and the mass market, permeating people's daily activities. However, while technology continues to advance, we are now at the peak of a new era where the boundary between the physical and digital world is becoming blurred. This is where the concept of the Metaverse comes into play.

The purpose of this thesis is to provide a comprehensive overview of the Metaverse, immersive experiences, and their impact on a multitude of sectors. By exploring the concept of the Metaverse and the technologies that enable immersive experiences, this thesis aims to provide a clear understanding of their potential applications in different sectors. Additionally, this thesis will map out the various immersive platforms available as well as technology providers that enable these experiences. By identifying key industry players, this thesis will provide a complete understanding of the current state of immersive technology and how it is being applied in practical contexts.

Finally, this document will develop guidelines and steps for creating an immersive project, taking into account the critical issues encountered in implementation.

For a better understanding of the topic covered, the text has been divided into 4 sections, each of which focuses on a specific aspect of the topic.

Chapter 1 focuses on providing a comprehensive definition of the Metaverse, including its key characteristics and underlying architecture. This chapter also delves into the concept of immersive experience and explores the various aspects of immersiveness and sense of immersion. Additionally, the chapter provides an in-depth analysis of the various immersive

technologies that enable the fruition of these experiences, analysing through the S-O-R framework, the factors that can influence the success of immersive technology implementation. Finally, it seeks to understand the potential impact of immersive technology in various work sectors. By exploring ways in which these technologies can be leveraged, this chapter provides valuable insights into the practical applications of immersive experiences and the potential benefits they can offer to businesses and organizations.

The primary aim of Chapter 2 is to undertake a comprehensive analysis of the current state of the Metaverse. This includes identifying the existing platforms of virtual worlds that can be classified as immersive and categorizing the technological suppliers operating within the Metaverse sector, both at a global level and specifically within the Italian market.

Chapter 3 endeavours to achieve several objectives. Firstly, it aims to showcase the insights derived from the interviews conducted with technology providers operating within the Italian market. Additionally, it seeks to establish a comprehensive framework for the development of immersive projects, offering readers a roadmap to guide the creation of immersive experiences. Lastly, this chapter seeks to identify the most crucial and delicate phases within the production process, identifying any potential bottlenecks that may impede progress.

In conclusion, in Chapter 4, an overview of what has been done in the previous chapters is shown and the conclusions and consideration of this study are presented.

1 | From the Metaverse to immersive experiences: an overview of emerging technologies

This chapter aims to provide an in-depth exploration of the Metaverse, covering topics such as its origin and definition, its characteristics, and its architecture. Delving into immersive technologies and experiences, including the use of the S-O-R framework applied to immersive technologies. Additionally, examining the importance and applications of immersive experiences, as well as the challenges that must be faced to fully realize the potential of the Metaverse. By the end of this chapter, readers will have a comprehensive understanding of this emerging technology and its potential impact on society.

1.1. Metaverse Origin and Definition

The word "Metaverse" derives from the fusion of two terms, "meta" and "universe". "Meta" is a Greek prefix that means "beyond", while "universe" refers to the totality of everything that exists. The term Metaverse appeared for the first time in Neal Stephenson's Cyberpunk Novel "Snow Crash" in 1992, which describes the Metaverse as a three-dimensional space that people can access through a VR interface. In the novel, the Metaverse appears as a place of evasion from real life, where users can create personalized avatars, participate in games, explore virtual worlds and trade with other users. The Metaverse has become a kind of parallel universe to real life, with many people spending much of their time inside it.

In 2003, the American software house Linden Lab Inspired by Snow Crash creates "Second Life", the first multi-user virtual environment, in which users can create a custom avatar and move it in a digital parallel world interacting with other users. A common definition of Metaverse is given precisely by the founder of Second Life, Philip Rosedale, who defines

it as "a set of interconnected virtual worlds, in which users can create and live shared experiences". However, Second Life only offers a glimpse of what the Metaverse is today. According to what stated by Dwivedi et al. (2022)[1], there are four main differences between the current Metaverse and the previous Second Life:

- The current Metaverse offers a higher level of immersion, high performance, and uses deep learning.
- Unlike the previous Metaverse based solely on PCs, the current Metaverse uses mobile devices to increase accessibility and continuity.
- Economic efficiency and stability of Metaverse services have been improved through the use of security technologies such as blockchain and virtual currencies.
- During the period of social restrictions caused by the Covid-19 pandemic, interest in the virtual world has grown.

Although the term Metaverse dates back to 1992, there seems to be no agreement on its universal definition. In addition to the definitions of Stephenson and Rosedale there are several other ones present in literature. According to Gursoy et al. (2022)[2] the Metaverse is a digital space in which users interact socially using digital avatar, generating value and co-creating experiences. Mitchell et al. (2009)[3] define it as "an immersive three -dimensional virtual world in which people interact as avatar with each other and with software agents, using the metaphor of the real world but without its physical limits". Buhalis et al. (2022)[4] describe it as a convergence without continuity of digital and physical universes that use ambient intelligence to improve physical spaces, products and services. According to Ning et al. (2022)[5], the Metaverse is a completely immersive, hyper spatiotemporal, and self-sufficient shared virtual space that merges the physical, human, and digital ternary worlds. M. Ball[6] offers his definition of the term Metaverse: "The Metaverse is a massively scaled and interoperable network of real-time rendered 3D virtual worlds which can be experienced synchronously and persistently by an effectively unlimited number of users with an individual sense of presence and with continuity of data, such as identity, history, entitlements, objects, communications, and payments.".
According to different definitions of Metaverse, this concept represents a virtual world that imitates reality and offers an immersive environment for the interaction between users (Dwivedi et al., 2022)[1]. While some people limit the meaning of Metaverse to the virtual universe, most of the existing definitions conceive Metaverse as a convergence between virtual and physical universes (Buhalis et al., 2023)[7].
In the Metaverse, all individual users have their respective avatars, in analogy with the user's physical self, to experience an alternative life in a virtuality that is a metaphor

for the user's real worlds. Generally, the development of the Metaverse consists in three subsequent phases from a macro perspective (Lee et al., 2021)[8]: digital twins, digital natives and finally surreality. The first phase produces a mirror world consisting of large-scale and high-fidelity digital twins of human beings and things in virtual environments, aimed at a vivid digital representation of physical reality. At this stage, virtual activities and properties such as the emotion and movement of the user are imitations of their physical counterparts, where reality and virtuality are two parallel spaces. The creation of native material is the main objective of the second phase, in which digital natives who are represented by avatars can create innovations for the online world that can only exist in virtual environments. In this phase, the virtual world has the ability to transform and innovate the production process of the real world, resulting in a greater interaction between these two worlds. At this point, the contents created in the digital world are equivalent to their physical counterparts. The Metaverse grows until its maturity in the last phase and turns into a persistent and self-sufficient surreal world that assimilates reality whitin itself. In this phase, where the virtual world's scope will be greater than that of the real world and more scenes and lives that do not actually exist in reality can exist in virtual realms, the seamless integration and mutual symbiosis of the physical and virtual worlds will be realized.

To conclude and offer a final definition of the term Metaverse, since the attributes given today to the "perfect Metaverse" appear objectively distant from the present situation, the study by Shah & Barrera is taken into consideration. This study after reviewing academic research works on the Metaverse in various disciplines and analysing the content of 78 practitioners' opinions on the Metaverse, formally defines the Metaverse as "a technology-mediated network of scalable and potentially interoperable extended reality environments merging the physical and virtual realities to provide experiences characterised by their level of immersiveness, environmental fidelity, and sociability" (Shah & Barrera, 2023, 6 [9]).

1.2. Metaverse Features

In the Metaverse, you can be who you want to be, create what you want, where you want, for who you want, and how you want. Grey literature extensively pursued the goal of describing the key features of the Metaverse. Mark van Rijmenam[10] highlighted six main characteristics (i.e. Interoperability, decentralization, persistency, spatiality, community-driven, and self-sovereignty) while C. BasuMallick[11] and G. Weston[12] focused also on the experienced and immersiveness. After these first attempts, the topic is starting to be deepened by academia (Wang et al., 2022[13]; Ning et al., 2021[5]; Barrera & Shah,

2023[9]).
Therefore, the following features are now considered as the most representative of the Metaverse:

- *Immersiveness*: the Metaverse will provide people with a variety of experiences that we are currently unable to enjoy since physical boundaries do not exist in the digital realm. More specifically, the Metaverse promises to bring all physical and digital experiences together under one roof. The term immersiveness means that the virtual space generated by the computer is realistic enough to allow users to feel psychologically and emotionally immersed (Wang et al., 2022)[13] and technology-related factors may manipulate the degree of immersion (Barrera & Shah, 2023)[9]. This includes the ability to interact with other users and virtual objects as if they were physically present, as well as the ability to explore and experience new environments and activities that would not be possible in the real world. A clearer and more in-depth analysis of the concept of immersion and immersive experience is proposed later in the thesis. By providing a fully immersive experience, the Metaverse has the potential to revolutionize how we interact with each other and the world around us, providing endless possibilities for exploration, education, and entertainment.

- *Persistency*: the Metaverse will be a persistent, always-on internet where experiences, whether virtual or augmented, remain online for anyone with access to it to experience for however long the creator chooses. This persistency applies to virtual worlds and augmented reality encounters, enabling synchronous virtual experiences that could change over time and are always available for users to explore. A persistent Metaverse should endure when you depart, much like the real world. Similar to how buildings in the actual world are persistent and can only be removed with the owner's consent, the key to a persistent Metaverse is that content can only be destroyed by the author. This could potentially be dangerous since terrorists or criminals might use this technology. In order to prevent users from dumping any type of content, platforms that let users drop augmented experiences in the real world should have clear rules. For artists and content producers, a permanent Metaverse would open up endless monetization prospects, as their efforts may be recognized and money can be paid quickly without banks.
  Without the use of physical storage devices or centralized servers, individuals and organizations can store and access data more securely and effectively in a persistent online environment. This could significantly lessen the carbon footprint of data storage and retrieval while also improving the availability and longevity of crucial data. However, the persistency of the Metaverse also raises important questions

about privacy, security, and control, as individuals and organizations may need to consider the long-term implications of their actions in a virtual world that is always online and accessible.

- *Interoperability*: It is all about to what extent users can seamlessly move across virtual worlds without interruption of the immersive experience, and take out the value they created inside one platform, bring it to another platform, and vice versa without any barriers (Wang et al., 2022)[13]. Users would be able to win, acquire, or earn a digital asset in one environment and utilize it in another, whether that environment is real or digital, thanks to interoperability. Interoperability enables users to move their assets and data from one platform to another and sell them to other users for the open market price. The benefit that society will derive from the Metaverse will increase in direct proportion to how flawless the experience is.

- *Sustainability*: High levels of independence, a closed economic cycle, and a stable set of values in the Metaverse are all indicators of sustainability. It should be open, which implies constantly arousing people's interest in producing digital content and open inventions (Dwivedi et al., 2022)[1], and it must be designed using a decentralized architecture to be permanent, thus avoiding being governed by a small number of dominant institutions (Wang et al., 2022)[13]. Additionally, encryption is essential for maintaining sustainability because it renders data immutable, verifiable, and traceable. This not only helps to prevent corruption and manipulation but also ensures that the Metaverse is able to operate in a transparent and trustworthy manner. Ultimately, sustainability is essential for the long-term success and growth of the Metaverse, as it allows it to thrive independently and adapt to the changing needs and demands of its users

- *Hyper Spatiotemporality*: the boundaries of space and time in the real world are finite and unchangeable. The term "hyper spatiotemporality" describes the breaking of time and space constraints since the Metaverse is a virtual space-time continuum that exists side by side with the real one (Wang et al., 2022[13]; Ning et al., 2021[5]). Users will be able to engage with digital goods in the most natural way possible utilizing their five senses thanks to spatial data, whether they are positioned in the virtual or physical world. Physical activities (movements, words, gestures) would be translated into computer interactions in the virtual or augmented experience through spatial computing.

- *Self sovereignty*: it is the idea that people, as well as things, should be in charge of their own data, identity, reputation, and information online without having to

rely on any one business, government agency, or middleman for security. In the current situation, users are not in control of their digital identities because they are controlled by online companies, so if you want to achieve an open, decentralized, and interoperable Metaverse, self-sovereignty is a crucial feature. This means that people should be able to manage and control their own digital assets and data without depending on outside organizations. Furthermore, since his the user who decides what information is shared and with whom, there is a higher level of privacy and security possible.

- *Community driven*: since humans are social beings by nature, any experience in the Metaverse, itself being a new type of social form (Ning et al., 2021)[5], will be heavily dependent on community. In this regard, the Metaverse will be no different from the actual world, where people gather and establish communities around a variety of interests, as belonging to a group has always been essential to personal existence. The Metaverse can bring communities to a new level by providing community members with real-time, shared, immersive, and even owned experiences. The Metaverse can give people a place to meaningfully interact with others, despite distance or other obstacles, by promoting a sense of community and belonging. By acting as a centre for community-driven experiences and initiatives, the Metaverse can aid in the expansion and advancement of communities all over the world.

1.3. Metaverse Architecture

In order to gain a comprehensive understanding of the Metaverse architecture, an extensive research was conducted on literature from technology-based journals. It was discovered that the design of the contemporary Metaverse arises from the combination of several building blocks (Barrera & Shah, 2023[9]; Lee et al., 2021[8]; Wang et al., 2022[13]; Elmasry et al., 2022[14]). Therefore, the following technological components have been analysed:

- *Network*: it is a crucial component of the Metaverse that enables seamless communication and transfer of information between users in different locations and time zones. However, the network itself poses a number of challenges, specifically with regards to latency, throughput, and jitter, all of which are critical indicators of mobile network performance (Lee et al., 2021)[8]. The added complexity of user mobility and embodied sensing further complicates this task. Unlike traditional network architecture, where communication between layers is minimal, addressing the demanding requirements of the Metaverse will require a two-way flow of infor-

mation between layers. The networks, such as 5G and 6G will play a vital role in the Metaverse by providing ubiquitous access to real-time, persistent connections between the augmented and virtual worlds. They allow for the removal of limitations of time and space, and enable scalable services to users, making the Metaverse a reality (Wang et al., 2022)[13].

- *Computing*: it is a fundamental aspect of the Metaverse architecture, which refers to the main computer programs, algorithms, and instructions that provide the computational power necessary to support demanding functions such as visual rendering, data synchronization, motion tracking, and capturing, among others (Barrera & Shah, 2023)[9]. The large-scale multimedia systems of the Metaverse incur significant computational costs to provide these services. However, wearable and mobile devices, which are commonly used to access the Metaverse, often lack the necessary computational power. As a result, edge and cloud computing play a crucial role in providing the necessary computational power to support timely processing and responsive systems for Metaverse applications (Lee et al., 2021)[8].

- *Artificial Intelligence*: Artificial Intelligence (AI) encompasses a wide range of technologies that enable machines to mimic human-like learning, thinking, and behaviour. With the rapid advancement of AI technology, there are increasingly more applications that use it, such as language models like ChatGPT. In the Metaverse, AI has multiple potential uses, including the creation of non-player characters (NPCs) that learn and adapt their behaviour based on interactions with users, and the creation and rendering of massive metaverse scenes, as well as multilingual support (Wang et al., 2022)[13]. However, existing AI models are deep and require significant computational capabilities, which may not be suitable for resource-constrained mobile devices. Therefore, there is a need to design lightweight but efficient AI models to support the Metaverse (Lee et al., 2021)[8].

- *3D Modelling*: It is a crucial tool for creating a 3D virtual world in the Metaverse that is accurate and realistic. To make this a reality, several issues must be resolved, as claimed by Lee et al. (2021)[8]. First, more accurate and computationally effective spatial and scene understanding algorithms are needed for the integration of virtual objects and the real world. To ensure a seamless connection between the Metaverse and the real world, more trustworthy and effective body and pose-tracking algorithms are also required. Additionally, a lifelike 3D environment is made possible by colour correction, texture restoration, blur estimation, and super-resolution. Overall, 3D modelling is an important aspect of the Metaverse, as it allows users to experience virtual worlds that are as realistic as possible (Barrera &

Shah, 2023)[9].

- *Blockchain*: it is a digital technology that allows for the recording and verification of transactions in a decentralized, transparent and secure way. It's the foundation of many digital currencies and can also be used in various fields such as supply chain management, voting systems, and digital identity. It offers a tamper-proof and transparent record of transactions, and security through cryptography and it can't be altered once a block of transactions is added to the chain. Blockchain technology can facilitate huge data storage, sharing, and privacy in the Metaverse in a decentralized, secure, and interoperable manner (Lee et al., 2021)[8]. Additionally, blockchains have had a significant impact on the market for digital assets by enabling the creation of NFTs. These are digital records of ownership for unique, non-interchangeable digital media such as digital artwork or music that are stored within blockchain-based smart contracts. This allows for virtual assets to be securely transferred, traded, and tracked, providing a unique identity within the Metaverse environment (Wang et al., 2022)[13].

- *Internet of Things*: it refers to the network of physical objects, such as devices, vehicles, buildings and other items embedded with sensors, software, communication components, and internet connectivity, that enable these objects to collect and exchange data. The Internet of Things connects the physical world to the digital world through the use of interconnected smart devices, allowing for the seamless flow of information between the two realms. Within the context of the Metaverse, IoT sensors serve as an extension of human senses, providing additional data and insights to enhance the overall user experience (Wang et al., 2022)[13].

- *Interface devices*: experiences are available and delivered by the software, but nothing would happen without the physical technology, the hardware. This building block includes all interface devices that enable consumers and firms to access, interact, and have an identity in the Metaverse such as VR headsets, smart glasses, AR glasses as well as devices that allow access to platforms such as mobile phones, consoles, or pc.

  Interface devices play a role in determining the type of immersive experience that users have since they have the capacity to improve a user's sensory perception (Flavian et al., 2019)[15]. Utilizing any of the technology blocks mentioned in this section can allow a company to create its own Metaverse experiences and build a distinct virtual space where users can work together, create together, communicate and consume digital content and resources (Barrera & Shah, 2023)[9].

- *Extended Reality*: it is a term used to describe all forms of reality beyond the physical, including virtual reality (VR), augmented reality (AR), and mixed reality (MR). XR technology is used to create immersive experiences that blend the real world with digital elements such as images, sounds, and other sensory inputs. Users can fully immerse themselves in a virtual world thanks to XR, which produces experiences that are more realistic and precise and are comparable to those had in the real world. The physical world can be altered by MR and AR technology, thus linking the Metaverse and our real world together. In one of the next section of the work, we will focus on the detailed analysis of all major categories of immersive technologies, exploring their characteristics and functionalities, to provide a comprehensive view of this ever-changing world.

1.4. Immersive Experience

The purpose of this paragraph is to frame the concept of "immersive experience" by first analysing and understanding the two words that make it up and then providing a comprehensive definition. Among the academic works that define the concept of experience, the one by Buchenau & Suri (2000)[16] describes it as the set of sensations that people perceive during interaction with the environment and other people, which are subsequently processed and transformed into knowledge.
Possible human experiences can be categorized based on the mode in which they are experienced (sensory or non-sensory) and the nature of the perceived objects (real, imaginary, or virtual) (K. M. Lee, 2004)[17]. Based on these two categories, experiences can be divided into three types (see figure 1.1)

- real experience, which is the sensory experience of real objects;
- virtual experience, which is the sensory or non-sensory experience of virtual objects;
- hallucination, which is the sensory experience of imaginary objects.

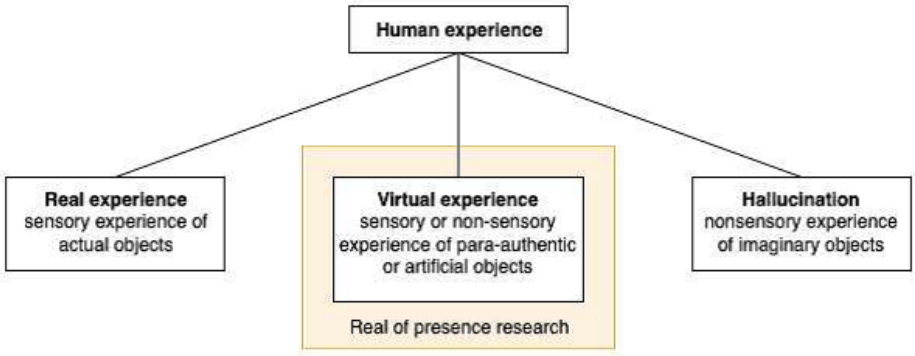

Figure 1.1: Typologies of human experience

The virtual experience is one of the three that is most closely related to the immersive experience. As we'll see, for a virtual experience to be fully appreciated, sensory stimulation is necessary in order to elicit a perceptual response.
To understand what is meant by "immersion," it is necessary to analyse the relationship between the concepts of immersiveness, sense of immersion, and presence (see figure 1.2).

Figure 1.2: Relationship immersiveness - immersion - presence

The term "immersiveness" refers to a system's potential to produce a "sense of immersion," emphasizing in particular that this capacity to immerse users in various environments by acting on their sensory perceptions is objective and quantifiable based on the expression of various distinct characteristics. From the user's perspective, this ability can be understood as being given the ability to perceive, feel, and cognitively process data that would not otherwise be available, thereby improving human cognition.
This "sense of immersion," which we will simply refer to as immersion from now on, refers, as stated by Slater et al. (1996)[18], to the objective ability of a system to produce immersiveness according to measures defined by the following concepts:

- extensive, associated with the extent to which more senses are engaged;
- surrounding, relating to the extent to which data can travel to a person's sense organs from any virtual direction and the participant's capacity to turn in that direction and appropriately receive directional sensory signals;

- vivid, a metric for the range and depth of sensory data that can be produced that takes into account aspects of the information's quality, resolution, and content as it is represented in the environment;
- matching, a metric that evaluates the consistency between actual motions and how well they are accurately reflected in the virtual world when combined with other data that is available.

As argued by Patrick et al. (2000)[19] different degrees of immersion depend on the system's technical ability to surround all users' senses and therefore on how much their minds can be deceived.
A perfect sense of immersion can be achieved when the immersive system is able to provide the same sensory perceptions that would be experienced in the real world, which leads to the conclusion that the ability to develop immersiveness can be considered a purely technical aspect directly related to the quality of the system being interacted with. In real life, this happens when the brain is unable to tell the difference between real and virtual things.
In academia, the concept of immersion, i.e. the sensation of involvement with the immersive environment, is further subdivided into two distinct dimensions (Sherman & Craig, 2003)[20]:

- mental immersion, which refers to the mental state in which a user feels completely absorbed in an immersive environment;
- physical immersion, which refers to the state in which a user feels both physically and mentally immersed in an immersive environment. This state is attained when the user interprets visual, acoustic, and tactile signals to learn about, navigate, and control objects in the synthetic environment.

The idea of immersion has also been developed using a hierarchical framework with three main components (Jennett et al., 2008)[21]:

- engagement, characterized by the interest in the artefact and the intention to use it;
- engrossment, characterised by escalating interest, a strong emotional connection, and seclusion from the external environments;
- total immersion, characterized by a maximum level of attention and total isolation given by the mental absorption generated by the interaction with the artefact.

A person's subjective perception of feeling in a place or environment, even when they are

physically located in another place, is described and acknowledged as presence (Witmer and Singer, 1998)[22].
As a result, presence is based on both the value of the content and a more subjective nature related to personal factors. These two factors are intertwined because the greater the degree of immersion and engagement a system can foster in a user, the greater the likelihood that the user will feel a strong sense of "presence" throughout use and interaction.
According to J. Löwgren (2007)[23], presence can be described as a psychological state or as having a subjective perception in which, even if the experience is produced by technology, some or all of the person's perception ignores the role of technology at the time of the virtual experience. It is useful to differentiate between the concepts of "presence" and "telepresence" or "virtual presence". The former refers to the natural perception of an environment, while the latter refers to the mediated perception of an environment that may be either real but distant in time or space, or a simulated virtual world generated by computer technology.
According to Turner et al. (2016)[24], an immersive experience is positively correlated with the level of sensory richness that is technologically mediated and encourages detachment from the outside world. Slater (2009)[25] defines the immersive experience as the extent to which a computerized system can provide the user with the illusion of a vivid reality.
Based on the gathered information, it is possible to define an immersive experience as the set of sensations that people perceive while interacting with an immersive system within a defined (social) context and which are transformed into knowledge.
Once the meaning of immersive experience has been defined, it is appropriate to examine the enabling technologies and tools that allow users to experience a sense of immersion.

1.5. Immersive Technology

In this paragraph the meaning of immersive technology will be defined and the different categories of immersive technology will be examined and explored.
Researchers have defined immersive technology from different perspectives by referring to the literature. Some of them have emphasized the role of sensory information as a distinctive feature of immersive technology.
For instance, Slater (2009)[25] characterizes immersive technology as a technology that provides users with a significant amount or quality of sensory input. On the other hand, other researchers have highlighted the immersive experience of users while utilizing the technology. Lee, Chung, et al. (2013)[26] define immersive technology as a technology

that blurs the boundaries between the physical and virtual worlds, resulting in a sense of immersion and amplifying the realism of virtual experiences (Soliman, Peetz, & Davydenko, 2017[27]; Suh & Prophet, 2018[28]).
Immersive technologies are associated with different types of realities such as virtual reality (VR), augmented reality (AR), and mixed reality (MR) (Palmas & Klinker, 2020)[29]. To avoid confusion and possible misunderstandings regarding the multiple definitions used to describe immersive technologies, a new term has been introduced: Extended reality (XR). This term fits perfectly with the various immersive technologies that will be presented in this section, as it encompasses all the real-virtual combined environments and human-machine interactions that can be generated by computer technologies and wearable devices. As stated by Palmas & Klinker (2020)[29], Extended Reality (XR), under a single term, brings together the three types of alternative realities (AR, VR, MR) mentioned and potential future ones (X), leading to an ever-increasing scope of realities. This convergence offers limitless possibilities for the future of XR.
In order to gain a better understanding of the most important immersive technologies, a brief analysis of each of them will be provided.

Augmented Reality is a first-person experience that involves virtual elements overlaid onto the physical environment in real-time, enabled by processing devices (Park & Kim, 2022)[30]. AR can overlay different types of content: images, videos, sounds, graphics, games, 3D models, and GPS information. Azuma (1997)[31] describes AR as a reality that combines the real and the virtual, interactive in real-time, and integrated in 3D into the user's visual field (see figure 1.3).

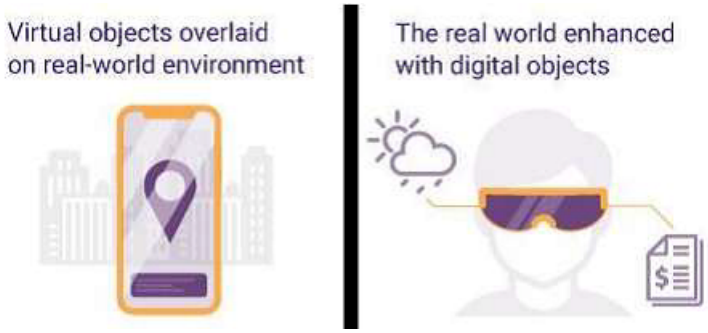

Figure 1.3: Augmented Reality properties

In the development of augmented reality applications, it is important to consider both the content visualization technique and the type of device used. Regarding the technical side, there are three main modes (see figure 1.4):

- optical see-through, it uses semi-transparent glasses to overlay virtual images onto reality, providing a natural experience for the user;
- video see-through, it allows manipulation of virtual images and synchronization with the recorded scene, which is not possible with optical see-through technology;
- projective, this technique has the advantage of not requiring special glasses to be worn by users and being able to cover large surfaces, thus offering a wide field of view. In addition, the projection surfaces can vary from simple flat or coloured walls to complex scaled models.

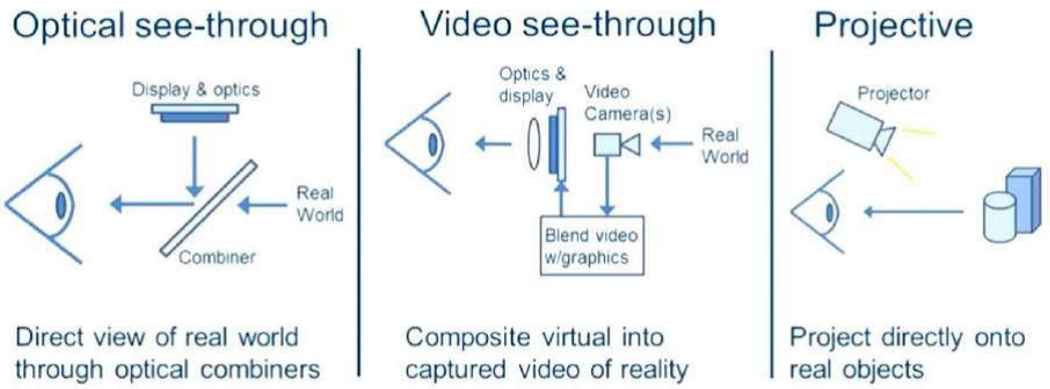

Figure 1.4: The modalities of AR systems

Regarding the types of devices, three categories are identified based on their position between the user and the real environment:

- head-worn;
- hand-held;
- spatial.

The primary category comprises devices consisting of head-mounted displays (HMDs) placed on the user's head through a helmet and can be monocular or binocular. These devices can use both visualization techniques, namely the use of transparent displays (optical see-through) or the use of completely generated real-world images through video (video see-through). Some of the most famous devices belonging to this category released over the years are Google Glass, Meta Vision, and Microsoft's Hololens.
The second category of augmented reality devices includes those based on video see-through techniques, such as smartphones and tablets that allow users to open a portal to the augmented world through the camera, as well as those that use optical see-through

displays such as wearable displays and portable projectors. The main characteristic of this category of devices is portability, and although they may sometimes be more cumbersome than the first category, they currently represent the best solution for introducing augmented reality into a mass market, thanks to their low production costs and ease of use. The third category of devices refers to static solutions positioned within an environment, such as video see-through displays, spatial optical see-through displays, and projectors. These devices are suitable for large-scale presentations and exhibitions where limited and direct interaction with the content is required.

Virtual Reality offers an immersive experience that simulates being in a specific location, unencumbered by physical limitations, allowing individuals to explore different environments and gain new insights and perspectives (Park & Kim, 2022)[30]. According to Lee, Chung et al. (2013)[26], VR refers to a technology that creates an interactive and immersive virtual environment, specifically designed to replicate a real-life experience.
The main objective of Virtual Reality is to offer an evocative experience, transporting the user to a special environment without physical limitations and developing in him the "sense of being there" (Coelho et al., 2022)[32]. As previously mentioned, in the literature, this sensation during an immersive experience has been described as "presence", or more specifically as "telepresence". The term VR is closely related to the concept of telepresence and represents the ultimate effort to make the immersive experience as similar as possible to that experienced within a real environment.
In evaluating the actual quality of virtual reality, many technological variables must be taken into consideration. Among these, the two most studied dimensions in academia are vividness and interactivity (see figure 1.5).

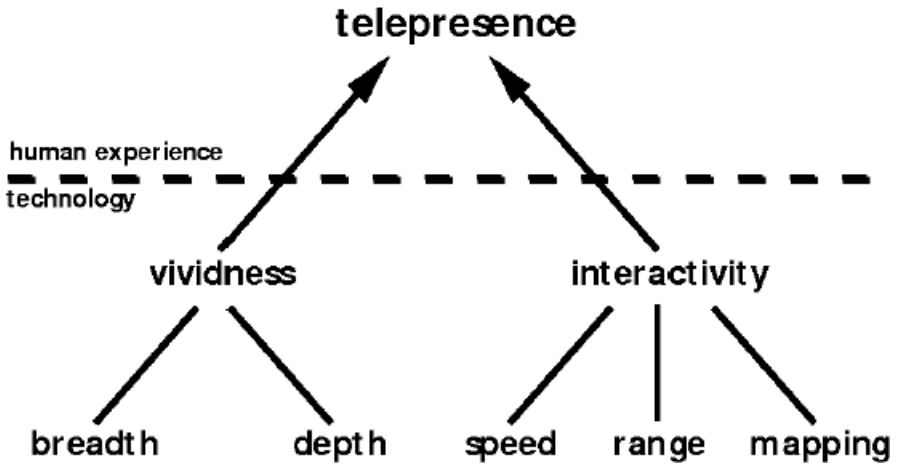

Figure 1.5: Quality dimensions of a VR system

The first dimension refers to the technology's ability to create a virtual environment that is sensorially rich and engaging, while the second dimension concerns the user's ability to manipulate shapes and content within that environment. Both dimensions are influenced by various properties that contribute to the overall quality of the experience. The vividness dimension is characterized by two main factors: breadth, which is the number of sensory channels presented simultaneously, and depth, which indicates the degree of resolution of each sensory channel. On the other hand, the interactivity dimension is linked to the concepts of speed, range, and mapping. Speed refers to the rapidity with which the user's input is assimilated by the virtual environment, while range indicates the number of actions available at any given moment. Finally, mapping refers to the system's ability to naturally and predictably map controls to any changes in the virtual environment.
Regarding VR systems, Ma & Zheng (2011)[33] classify them into three categories:

- fully immersive VR;
- semi-immersive VR;
- non-immersive VR.

The first type is the most well-known and involves the use of a Head-Mounted Display (HMD), which tends to completely isolate the user from the outside world, although some devices use video see-through techniques. The second type includes systems that use large-screen monitors, projectors, or multiple concurrent projection systems to provide relatively high graphic performance. Finally, the last type refers to desktop solutions where virtual environments can be accessed via computers and where content manipulation occurs through conventional devices such as a keyboard and mouse.
To make virtual reality increasingly immersive, it is necessary to not only take care of the visual aspect but also other sensory perceptions. For this reason, many immersive systems include not only viewers but also devices such as data gloves, haptic feedback devices, and motion tracking devices. However, the high level of expertise and costs required to develop and implement these systems are important aspects to consider. Both content creation and rendering, as well as the hardware and software required, require advanced skills.

Mixed reality is a technology in which real and virtual content coexist and interact in real time, MR integrates the concepts of VR and AR creating a hybrid form of XR. As stated by Palmas & Klinker (2020)[29], it can be defined as the evolution of AR in which the user is able to interact and manipulate the digital content that is overlaid in the real world.

A Mixed Reality (MR) environment is a space where the real and virtual worlds coexist, where objects from both worlds are presented together in the same display (Milgram & Kishino, 1994)[34] (see figure 1.6).

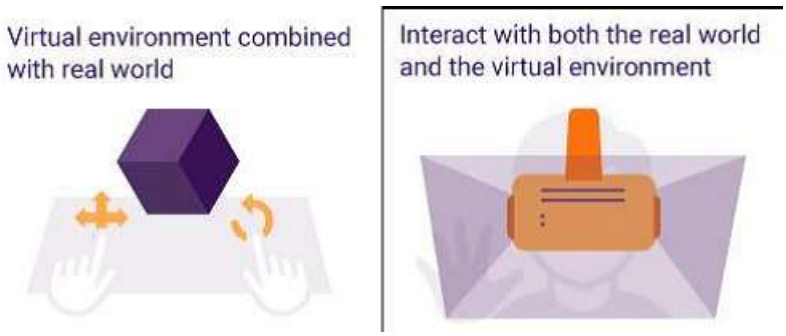

Figure 1.6: Mixed Reality properties

In an MR interface that uses an HMD, information can be presented in three different modes:

- head-stabilized;
- body-stabilized;
- world-stabilized.

In the first case, information is fixed to the user's point of view and does not change when the point of view orientation or position is changed. In the second case, information is fixed to the user's body position and varies when the user changes the point of view orientation, but not the position. Finally, in the third case, information is fixed to real-world positions and varies when the user changes both the point of view orientation and position. Each of these methods requires increasingly complex head-tracking technologies depending on the degree of externalization of the interface from the user.
In the context of a Mixed Reality system, the visual representation of spatial information can overcome limitations imposed by the limited field of view of HMDs, allowing for the addition of overlaid information directly onto the surrounding environment. This is particularly important because the information presented in an MR interface is usually strongly tied to the user's position and activity relative to the real world.

There is also another category of immersive technology that falls within the definition of XR seen previously, namely haptic technology which is increasingly being used alongside VR to offer an increasingly immersive and engaging experience.
Haptic feedback is a term that refers to a set of feedback modalities, including force

feedback, tactile feedback, and proprioceptive feedback (Burdea, 1996)[35]. Force feedback allows the perception of information related to the hardness, weight, and inertia of a virtual object, while tactile feedback is used to provide the user with a sensation of the geometry, smoothness, slipperiness, and temperature when in contact with the surface of the virtual object. Lastly, proprioceptive feedback is used to detect and control the user's body position and posture.

The purpose of haptic technology is to enable users to feel the characteristics of virtual objects like folds, textures, edges, temperature, and slipperiness (Chrysanthakopoulou et al., 2021)[36]. Academia long discussed the relationship between presence, immersion, and haptic feedback. As argued by Lee & Kim (2008)[37] haptic feedback significantly improved task performance and significantly enhanced presence, though the quality of the haptic feedback must also be taken into account (Sanchez-Vives & Slater, 2005)[38]. Overall, haptic feedback has been demonstrated to improve interaction, spatial guidance, and learning in VR environments and can improve overall task performance as well as the users' perceived sense of presence (Kreimer et al., 2019)[39]. An example of this technology is haptic gloves 1.7, similar to a normal glove but containing a system of flexible tendons and actuators that apply resistance to the hand so that you feel the weight and shape of the virtual object in addition to a system of microfluidic actuators placed inside the gloves that physically interact with the skin of the hand to recreate the sensation of touch, making the perception of virtual objects more and more real.

Figure 1.7: Structure of a haptic gloves

Another example of haptic technology is the VR haptic suit which immerses the user in a virtual reality world by isolating the body and providing haptic feedback.
In conclusion, the importance of immersive experiences cannot be overstated. Immersive technology is changing the way we consume media, learn new things, and interact with our environment. It allows to experience things that would otherwise be impossible or impractical, and it has the potential to revolutionize the way we understand and interact with the world around us.

1.6. S-O-R Framework

The purpose of this section is to show through the S-O-R framework how immersive technology (stimuli) influences participants' perceptions (organism), which in turn influence their satisfaction (response). In 1974 Mehrabian & Russell introduced the S-O-R framework to explain the relationship between stimulus, organism, and response. According to this approach, environmental cues act as stimuli that influence an individual's cognitive and affective reactions, eliciting positive or negative behavioural responses. This approach has been widely used in retail studies to investigate the effects of environmental cues on individuals' cognition and emotions, which in turn influence purchase and adoption behaviours. Within Suh and Prophet's (2018)[28] study, this framework is applied to other contexts involving the adoption of technology objects, including those concerning immersive technology. The study revealed the interplay between technological, content, psychological, cognitive and behavioural factors in relation to successful technology implementation and user adoption of immersive technology. The study's authors, using the scheme in figure 1.8, distinguish and categorize various elements for each of the three components (stimuli-organism-response) that may appear as a result of their application.

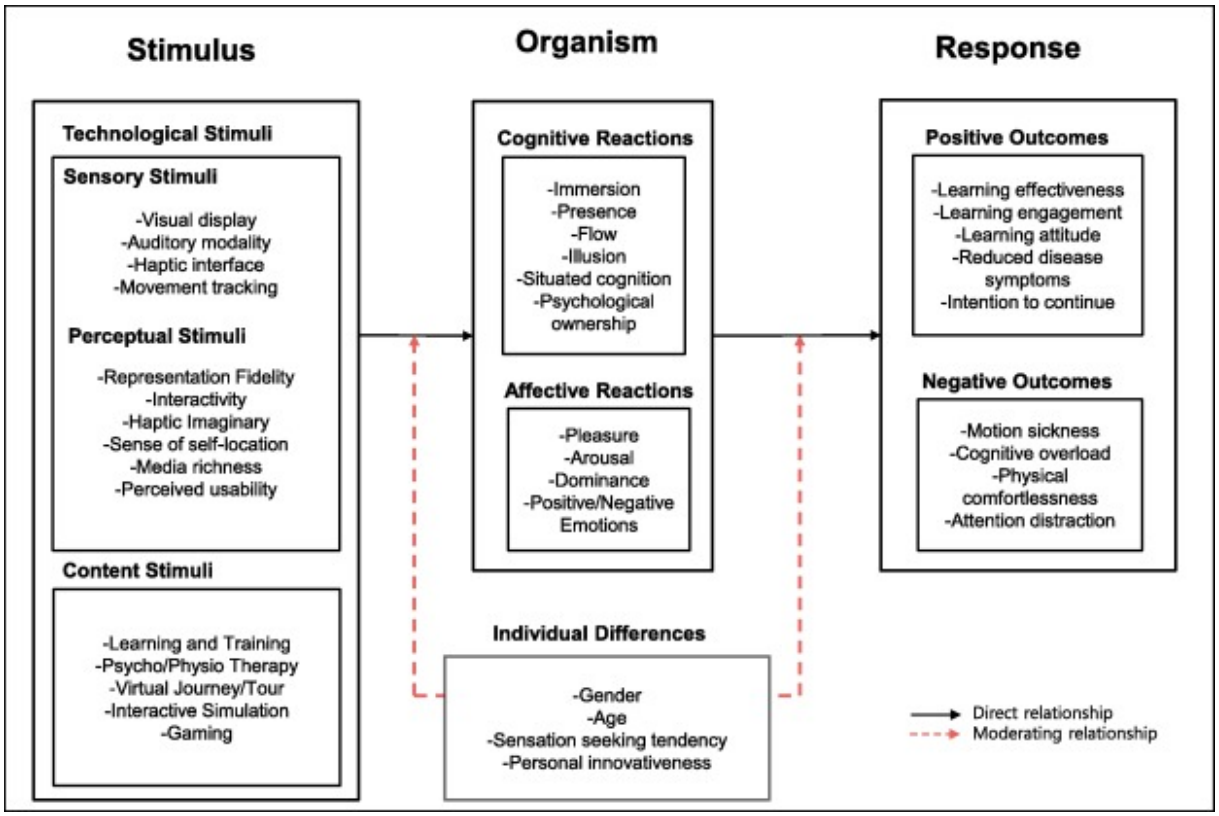

Figure 1.8: S-O-R framework applied to immersive technologies

Starting from the stimuli component, it is characterized by a dual nature, that is, technological and content-related. The first stream of studies encompasses two aspects, the sensory and the perceptual. The sensory aspect hypothesizes that sensory stimuli are crucial in enhancing the user experience in an immersive environment. Studies have examined the effects of visual displays, auditory modalities, haptic interfaces, and movement tracking (see table 1.1).

Factor	System Feature
Visual Display	Stationary display
	Head-based display
	Hand-based display
Auditory modality	Synthetic sound feedback:
	Stationary auditory modality (speaker-based 3D sound)
	Head position-based auditory modality (headphones)"
Haptic interface	Interface for tangible interaction, the means to interact physically with virtual objects
Movement tracking	Sensor-based tracking
	Vision-based tracking
	Marker-based tracking
	Hybrid tracking

Table 1.1: Summary of the sensory stimuli

The perceptual aspect, on the other hand, examines how the immersive system's functionalities are perceived by users and how perceptual stimuli influence the user experience (see table 1.2).

Factor	System Feature
Interactivity	A system features that can instantly detect a user's input, specifically their gestures, and respond to the new activity in real-time
Representation fidelity	The level of realism of the objects and scenarios represented. When objects are accurately rendered and have consistent behavior, users experience rich graphics and smooth transitions, making for a more immersive immersive experience
Imagination	A system feature that stimulates the human mind's creative capacity to perceive and imagine nonexistent things
Haptic imagery	The ability to accurately transfer information content through touch, in order to perceive the texture of an item of clothing and create a tactile sensation
Perceived sense of self-location	The sensation where an online consumer perceives their self to be located inside the body of their avatar
Media richness	The richness of media makes a simulation experience more authentic through various sensory stimulations and multiple cues
Perceived usability	A user's perception of a technology's system features refers to how easily, effectively, usefully, efficiently, and satisfactorily the technology can help them achieve their objectives

Table 1.2: Summary of the perceptual stimuli

The other area of research related to the content of the stimulus instead focuses on the objective and purpose of the interaction with an immersive system, which is summarized in a summary list (see table 1.3).

Content Topic	Content Feature
Learning and training	Users mentally process various information resources, and to maintain motivation by enabling conceptual fusion, content features that facilitate social interaction are highlighted, such as collaboration for problem solving and stimulation of motivation and performance. Providing various levels of difficulty increases the motivation of users to understand the subject matter
Psycho- and physiotherapy	Various psychological techniques using immersive environments are used to treat pain in the medical industry, as patients interact with virtual objects or characters that elicit emotional responses comparable to those produced by real stimuli, distracting their attention from pain, stress and anxiety
Virtual journeys tour	In a synthetic world, users are perceptually convinced that they are really "there". It has been proven that the immersive use of recreated environments is able to arouse coherent and expected sensations with the real equivalent
Interactive stimulation	Users thanks to the immersive environment interact with facial expressions, figures and simulated environments as they interact with objects. Content features that allow the creation and manipulation of objects evoke positive emotions for the user. To stimulate users' narrative experiences, interactive simulation content should incorporate chronological logic in terms of characters, events, images, and informational content
Gaming	Immersive game content varies depending on whether the game is designed for players to have a competitive or collaborative experience. In general, collaborative games in immersive settings have been found to be more effective in facilitating user cognitive engagement and spatial/social/temporal presence because they allow multiple participants to share the physical and virtual spaces around them and play together with opponents

Table 1.3: Summary of the content stimuli

Examining the second component of the S-O-R framework, i.e. that of the organism, it can be observed the presence of user reactions, which manifest themselves as effects resulting from the stimulus and which are differentiated based on their nature into two categories: cognitive and affective. Cognitive reactions (see table 1.4) represent the mental processes that occur during the user's interaction with an immersive system.

Factor	**Definition**
Immersion	**Mental immersion**, the mental state in which a user feels completely absorbed in an immersive environment; **physical immersion**, the state in which a user feels both physically and mentally immersed in an immersive environment
Presence	A psychological condition in which a user perceives themselves to be in a specific location, despite being physically situated elsewhere
Flow	Subjective psychological state of control, attention, curiosity, and intrinsic interest accompanied by a loss of self-awareness and self-reinforcement of the human-computer interactivity bond
Illusion	It identifies both the strong illusion of being in a place despite the certainty of knowing that you are not there (place illusion) and the fact that what is happening is real even though you know it is not real (plausibility illusion)
Situated cognition	In an immersive environment, users cognitively blend virtual information and real context, which gives them the feeling of being in authentic contexts, improving their performance
Psychological owernship	Users are concerned with controlling virtual objects that look similar to their real physical bodies so that they can align their virtual selves with their real physical selves

Table 1.4: Summary of cognitive reactions

Affective reactions (see table 1.5), on the other hand, are the emotional reactions that occur during interaction with technology and can influence performance.

Factor	Definition
Pleasure	The degree to which immersive technology evokes a pleasant (or unpleasant) emotion in users
Arousal	The degree of intensity of the pleasant or unpleasant emotion
Dominance	The control and dominating nature of emotion
Positive Emotions	Pleasure, fun, happiness, trust and hope
Negative Emotions	Boredom, anxiety, depression, tension, fear, anger and rage

Table 1.5: Summary of affective reactions

The use of immersive technologies has a direct impact on the last component of the framework, which is the response. This impact is related to the outcomes that can result from the use of these technologies and which can lead users to modify their behaviour over time. These outcomes can be positive in nature (See table 1.6), leading to real benefits in learning, understood as the acquisition or modification of knowledge and values, but also negative in nature (See table 1.7), causing discomfort and unpleasant sensations .

Factor	Definition
Learning effectiveness	Improving learning processes and outcomes, including content knowledge level, academic performance, performance, skills, abilities and others
Learning engagement	Increased amount of time spent with immersive systems, increased frequency of interactions
Learning attitude	Improved attitudes towards learning materials after experiencing immersion
Task performance	Improved efficiency (i.e. lower than average completion time for correct actions) and accuracy (i.e. lower average overall failure rate / higher success rate for tasks)
Reduced disease symptoms	Reduction of disease symptoms (e.g. pain, psychological stress and mental illness)
Intention to use	Intentionality in the use of immersive technologies

Table 1.6: Summary of response in immersive technology use (positive outcomes)

Factor	Definition
Motion sickness	Adverse sense of discomfort, disorientation, nausea and vomiting in users who experience immersive systems through HMDs
Physical discomfort	Feeling of physical discomfort reported for example in cases where objects had to be held at eye level for correct viewing in the immersive environment
Cognitive overload	A limited screen size can overwhelm the user by compressing the amount of information presented into a small space
Distracted attention	Immersive technology often fails to balance the distribution of a user's attention between virtual and physical spaces, causing them to interact excessively with virtual information and technology leading them to ignore the real environment and/or learning process

Table 1.7: Summary of response in immersive technology use (negative outcomes)

The study analyses how technological, content, psychological, cognitive, and behavioural factors influence the success of immersive technology implementation and user adoption. It offers practical guidance for system developers and managers seeking new ways to promote user engagement through immersive technologies. Furthermore, it is important to note, that immersive technologies do not always create positive user experiences. There are several factors that contribute to negative user experiences. For these reasons, system designers should consider how to minimise the negative effects of using immersive technology on user experiences.

1.7. Applications of Immersive Experiences

The advent of the Metaverse and immersive experiences represents a new phase of technological innovation. Over time, the internet has evolved significantly, going from simple emails to high-quality video calls, allowing people to communicate more immediately and engagingly.

However, with the introduction of the Metaverse and immersive experiences, we are witnessing an even more significant revolution in information and communication technology. These new technologies are transforming communication into something much more engaging and immersive, allowing people to have completely new experiences.

The Metaverse offers the possibility of interacting with virtual environments in a completely new way, thanks to immersive technologies. These technologies are and will continue to have an increasingly significant impact on people's lives. A seen in the previous section, immersive experiences offer new opportunities for different sectors, and more and more companies are using immersion to change the way they operate, which also affects their employees and customers. There are many uses for immersive experiences and currently, the main ones are:

- *Training and learning*, engaging employees is one of the biggest challenges for learning and development professionals. To overcome this obstacle, more and more companies are leveraging immersive learning, an experiential training methodology that uses immersive technology to simulate real-world scenarios and train employees in a safe and engaging training environment. A study by Stanford University and the Technical University Denmark has in fact found that students remember more when they use virtual teaching methods compared to traditional methods, with a 76% increase in learning effectiveness [40]. According to an Accenture report [41], immersive learning brings various benefits, first of all, it offers immersive environments that recreate real-life scenarios, which allows employees to attain a high level of experience in a short time. Moreover, immersive learning boosts engagement through gamification strategies that result in higher retention; studies suggest that learning through experiences enhances retention by up to 75% and raises the quality of learning. Another benefit of immersive learning technologies is the ability to reduce operational costs. While the cost of acquiring the technology needed to implement virtual immersive learning can be high, using it to train large numbers of people over multiple training cycles can be very cost-effective in the long run. One of the greatest benefits of immersive training is that within virtual learning environments, mistakes can be made and corrected without negative consequences for staff and without risking serious economic damage to equipment. Finally, immersive learning technologies offer advanced analysis tools, which allow detailed data collection on the performance of the participants and engagement levels. This data can be used to further enhance the learning experience by tailoring training to the specific needs of learning and development staff.
- *Art*, immersive experiences represent a revolution in art, allowing for the enjoyment of works in completely new ways. Through this type of visualization, art becomes a three-dimensional object in space, rather than a flat two-dimensional image. This type of experience offers a deeper involvement and allows the viewer to become an integral part of the work itself. Furthermore, immersive experiences allow cre-

ators to express their creativity in ever more innovative ways. Three-dimensional works of art can be created with a variety of materials and techniques, ranging from drawing to digital sculpting, virtual reality to augmented reality. This opens up new opportunities for artists to express their vision more comprehensively and engagingly. Another benefit is that the immersive space allows for greater interaction between the audience and the artwork. Thanks to the possibility of moving in three-dimensional space, visitors can explore the work of art from different angles and perspectives, interacting with it actively. This allows the audience to experience the art in a more personal and immersive way, creating a stronger emotional connection to the work.

- *Virtual tours*, immersive experiences are an innovative and effective way to offer virtual tours, allowing users to show your properties and business in an engaging and realistic way. The immersive experience allows for the creation of realistic and interactive three-dimensional environments, allowing users to explore spaces in a more immersive and detailed way. Virtual tours based on immersive experiences are also very convenient, as they do not require commuting, travel costs, or concerns about weather conditions that could ruin plans. This makes them ideal for showcasting real estate, museums, art galleries, and other venues that require a guided tour. Virtual reality allows for the creation of a realistic and immersive environment for the virtual tour, where users can explore spaces and interact with objects naturally. Furthermore, immersive technology allows for the customization of the experience according to the users' needs, making it possible to choose specific paths or objects to explore. In this way, business and property owners can present their spaces in an innovative and captivating way, attracting potential clients and increasing public interest.

- *Increase productivity*, immersive experiences, through the use of virtual technologies, offer a wide range of possibilities to increase productivity in companies. This technology can be used in various fields such as education, training, healthcare, and marketing, but also to improve work productivity and efficiency.
  Immersive technology is a powerful tool that can be used by companies to target specific groups, such as millennials, and improve concentration during work. Thanks to its interactive features, the immersive experience can help employees organize better and make the most of their time, offering the possibility to collaborate and communicate more effectively.

- *Product design*, immersive experiences have become an increasingly important tool in the product design process. With immersive technology, designers can interact

with the product more realistically, helping them better understand design concepts and how they might be implemented. With immersive experience, designers can see the product in a three-dimensional way and even walk inside it, allowing them to more effectively identify problems and make necessary modifications. The use of immersive technology can also allow designers to create virtual prototypes and test them before investing in expensive physical prototypes. This saves time and resources and allows designers to make changes quickly and efficiently. In addition, the immersive experience can be used to test products and collect customer feedback before releasing them to market.

- *Communication*, immersive communication is a multi-channel and multi-sensory experience: what you see and what you hear [42]. This type of communication allows visitors or audiences to explore and interact with content in a non-linear manner, choosing how they want to consume the content and taking control of their experience. Companies can use immersive communication in many different contexts, to create a more engaging and memorable experience for the audience, increasing the effectiveness of communication and audience engagement. Immersive communication adds an element of play and interaction to the experience, making it more interesting and engaging for the audience. Instead of relying on traditional communication channels, immersive communication focuses on experience and interaction, creating a more engaging and memorable experience for the audience.

- *Shopping and e-commerce*, immersive commerce represents an advanced version of traditional e-commerce that leverages immersive technologies to enhance the customer shopping experience. It is an evolution, rather than a replacement, of normal online commerce.
  The goal of immersive shopping is to offer an interactive and engaging experience for consumers, making them feel truly immersed in the shopping session, instead of a quick navigation. Thanks to this increased engagement, customers are more likely to make purchases and spend more time researching the product, while also developing a greater knowledge of the brand and the products themselves.
  Benefits of immersive commerce include improved purchase conversion, lower return rate, increased average cart value, and increased customer loyalty.
  In addition, virtual reality and augmented reality can be used to create unique shopping experiences, such as allowing customers to virtually try on clothing without physically wearing them. This type of experience can be particularly useful for companies operating in the clothing and fashion sector.

- *Event*, immersive experiences are changing the face of events around the world.

What was once considered a static, one-way event now becomes an engaging, interactive experience for guests.
One of the key advantages of immersive experiences during events is the ability to engage attendees more deeply. Additionally, they can help event organizers overcome geographic limitations. Attending events can be challenging for those in far-flung locations or who have difficulty traveling. Immersive technology can be used to create virtual events that allow attendees to join from anywhere in the world.
Immersive technology is used for a variety of tasks, including checking the identity of participants and monitoring their location in the event. In addition, virtual reality is taking concert experiences to a whole new level, allowing attendees to immerse themselves in live virtual concerts without needing to be physically present.
Immersive experiences can also help event planners reach a wider audience. Events can be streamed or recorded so that people can participate remotely. In this way, events can reach a global audience, increasing the visibility and effectiveness of the event itself.

- *Remote working*, immersive experiences are revolutionizing the world of remote working, providing new opportunities for workers to feel connected with their colleagues and to collaborate more efficiently.
  Immersive technology allows workers to immerse themselves in a virtual environment as if they were physically present in the office. These devices allow employees to enter a fully immersive experience, giving them the feeling of being present in the same work environment as their colleagues. This means they can participate in virtual meetings more effectively, work on shared projects in real-time, and collaborate more efficiently with their colleagues. This technology has been enthusiastically embraced by companies around the world, as it allows employees to feel less isolated and increase productivity. In addition to improving collaboration and productivity, immersive experiences can also help employees maintain a work-life balance. With immersive technology, workers can create a virtual workspace that meets their individual needs and helps them better focus on their work.

- *Customer experience*, immersive experiences are a natural extension of the customer experience. By using immersive technologies, companies can offer an engaging and personalized experience to their customers. Additionally, they can provide a more detailed presentation of their products or services, thus improving the customer's understanding and familiarity with the brand.
  Immersive experiences provide companies with the opportunity to create a stronger and more enduring bond with their clients, increasing customer loyalty and improv-

ing the likelihood of future purchases.

- *Gaming*, in recent years, the video game industry has seen a huge impact thanks to the introduction of immersive experiences. VR headset technology has allowed players to experience a new, more interactive, and engaging gaming experience. Immersive virtual reality has become particularly useful for games that require greater immersion in the game world, such as role-playing or simulation games. Players can fully immerse themselves in a virtual world, where they can interact with objects and characters, hear sounds and noises realistically, and even move within the virtual space. This makes the gaming experience much more exciting, engaging, and realistic. The introduction of VR immersive technology has transformed the gaming world, making it even more captivating, engaging, and exciting. The ability to experience a realistic gaming experience and play with friends in a virtual world has given new life to the gaming industry and opened up new possibilities for the future of gaming.

- *Marketing*, immersive marketing involve the consumer through a multichannel approach, distributing personalized content throughout the entire customer journey. The goal of immersive marketing campaigns and applied technologies is to involve the user in a unique experience, incorporating their lifestyle, and transforming the brand or product into a cult element. Immersive experiences in marketing refer to a total sensory perception that involves the viewer's senses and emotions. They are designed to immerse the viewer in the story, rather than simply showing photos or videos. This creates an engaging experience for the consumer, who can feel more involved and connect with the brand or product on a deeper level.
  Furthermore, immersive experiences can be used to create innovative marketing content, such as 360-degree videos and virtual tours, which allow potential customers to explore places and products in a more interactive and engaging way. This allows consumers to see the product or service in a realistic virtual environment, increasing their emotional and cognitive engagement. Immersive technology can also be used to create marketing experiences at events and trade shows. For example, a company could create a virtual reality experience to let participants take a virtual journey through the product they are promoting. This can increase the interest and curiosity of potential customers, attracting their attention to the product or service in a more engaging way.

1.8. Challenges for the Metaverse

Although the Metaverse appears to be a cutting-edge technology with a lot of potential, there are still several entry barriers since it is still in the early stages of development and its uses and potential are not yet clearly defined. As suggested by Park & Kim (2022)[30] the Metaverse will have several challenges to face; firstly the adoption of immersive tech, one of the main concerns is the cost of hardware and software, which can be a significant barrier to entry for small sized businesses and individuals because it represents a significant investment that can strain their limited resources. Most small companies operate on a tight budget and have limited financial resources to invest in expensive technology. Additionally, even though the sensor technology in the Metaverse closely matches that of the real world, some sensations are best perceived in the latter and there are also concerns about the impact of immersive technologies on users, such as the potential for motion sickness and the risk of addiction.

Another big challenge is reaching a critical mass of users, essential for the success of the Metaverse because it triggers a network effect that increases the value of the platform as more people use it. The network effect occurs when the value of a platform increases as more people use it, leading to a virtuous cycle of growth and adoption. When a critical mass of users is reached, the Metaverse becomes more attractive to new users, leading to further growth in its user base. There are several advantages to reaching a critical mass of users. One of the most significant benefits is that it allows for the formation of communities of practice. These communities are groups of users who share a common interest or goal and collaborate and share information using the Metaverse. Communities of practice can help to drive usage and engagement on the platform, as they provide a way for users to connect with like-minded individuals and collaborate on projects or ideas.

Another advantage of reaching a critical mass of users is that it can help to drive innovation on the platform. As more users use the Metaverse, they will come up with new ways to use it, leading to the development of new applications and use cases.

Reaching a critical mass of users also helps to ensure the sustainability of the Metaverse because it creates more business and investment opportunities. As the user base grows, the Metaverse becomes more attractive to advertisers, businesses, and investors, leading to increased revenue and funding opportunities.

Therefore, it is essential that the Metaverse platforms raise awareness and promote various applications and captivating experiences that encourage user participation. The user experience is undoubtedly the key to widespread adoption, and the first impression is crucial. If the user is not engaged and experiences frustration during the initial (login, account creation) or exploratory phases, he will quickly lose interest [43]. Hence, businesses

need to develop use cases, establish the proper culture, and provide people with the tools they need to form strong bonds with other users, creators, and the platform itself. As was stated, interoperability is a key property of the Metaverse, which enables seamless communication and exchange of data across various platforms and virtual environments. Interoperability can be attained by establishing standards, protocols, and frameworks for development that are accepted by all parties, similar to those that allow the application programming interfaces (APIs) to link different platforms easily. However, ensuring interoperability for the Metaverse is a complex challenge that requires more than just agreeing on standards and frameworks. To enable interoperable assets that can be used in various virtual worlds, it is crucial to come to a consensus on the functionalities and rules that will govern the Metaverse. This requires collaboration and cooperation among developers, businesses, and users to create a shared vision of the Metaverse's future and a common understanding of how it should function.

Another significant challenge will be maintaining privacy and security, as it will be possible to create avatars of any appearance and type within the Metaverse. This makes it relatively simple to impersonate someone by creating a digital replica of their avatar, emphasizing the importance of verifying one's identity and ensuring that they are who they claim to be. With the ability to create an exact duplicate of another person and use deep fake audio to control their actions and speech within any digital environment, there is a potential for individuals in the real world to commit crimes while hiding behind anonymous avatars within the Metaverse. It is necessary to establish norms and restrictions within the Metaverse that differ from those in the real world, as it is based on sharing and granting a high degree of freedom. To create a Metaverse in which various avatars can coexist harmoniously, it is crucial to design new levels of security and methods for protecting personal data and privacy that do not rely on invasive authentication or personal verification techniques.

2 | Analysis of the Metaverse world: classification of technology providers and Metaverse Platforms

The Metaverse lends itself to be the new technological paradigm, so it becomes imperative to analyze its construction and possible future directions and projections. The actors involved in the process will be many as well as opportunities, it will become normal to work in the Metaverse and more and more companies will want to enter it to exploit its resources, and expand their customer base, their communication channels, and their portfolio. To date, however, it is difficult for companies to understand which solutions are best suited to their business model and how to integrate them since there are no guidelines for accessing the Metaverse, for these reasons the providers of platforms and technologies become key players. Each platform is different from the other and contains its own distinctive features, characteristics, and services while the technology providers develop tailor-made virtual experiences or environments. One of the aims of this thesis is to map software/hardware suppliers and platforms with particular regard to the Italian territory.

2.1. AS-IS Situation

To gain a better understanding of the current state and future projections of the Metaverse, it is helpful to examine the details. Currently, the Metaverse has approximately 400 million active users and this growth trend is expected to continue [44]. However, the majority of users are concentrated on a few platforms, as shown in table 2.1[45], preventing the Metaverse from being considered a true multiverse.

Virtual world	Users
Roblox	230M
Minecrafat	165M
Fortnite	85M
Zepeto	2M
Avakin Life	10M
IMVU	7M
Rec Room	7M

Table 2.1: Users presence in virtual Metaverse worlds

There are, however, other digital universes that are expanding, as shown in the Vincos graph (See figure 2.1)[46], which only considers platforms that meet these characteristics:

- 3D Worlds;
- Shared: multiple people;
- Social;
- Identity: people can create their own avatars and use them to move freely in space or to interact with the virtual environment.

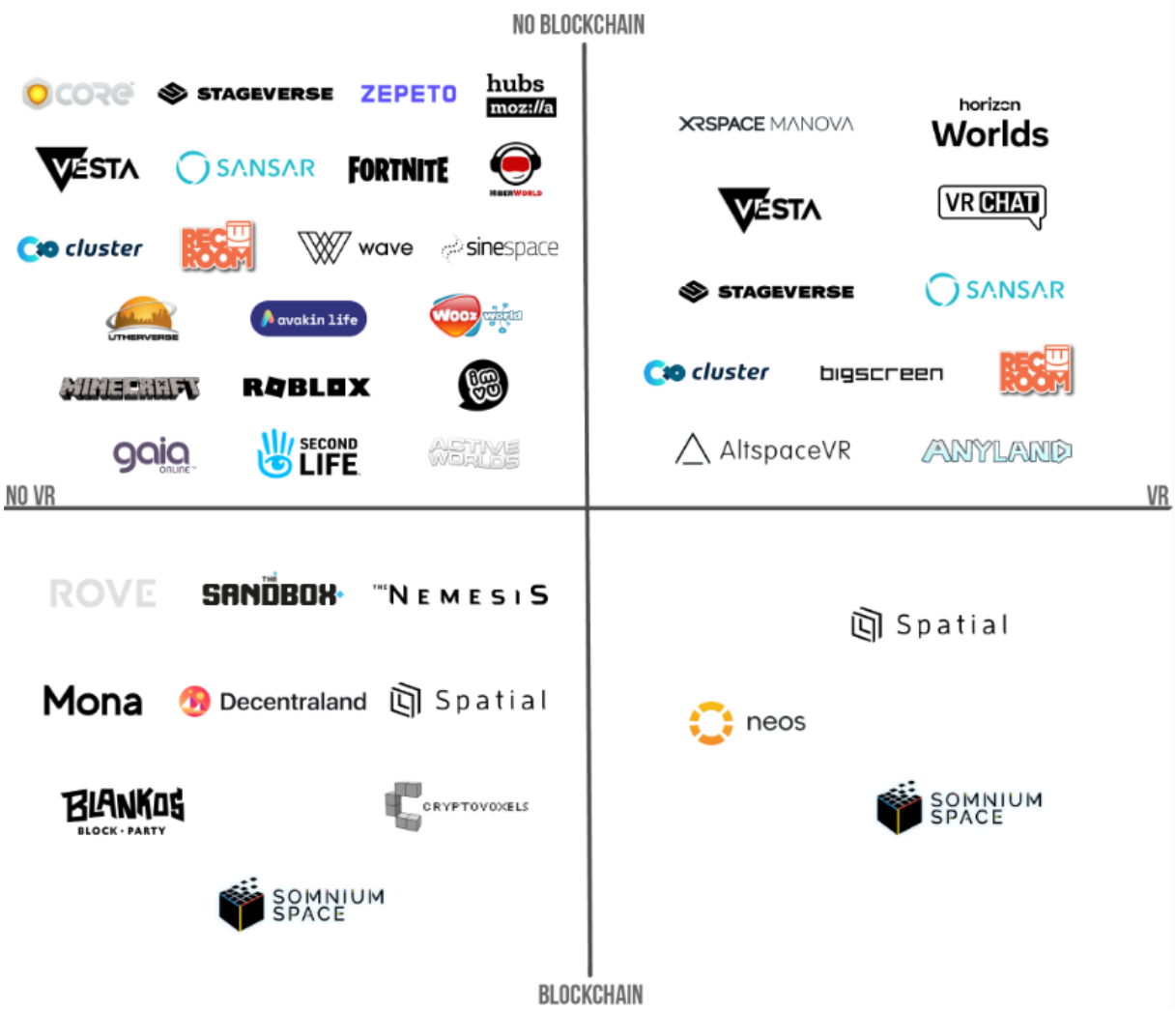

Figure 2.1: Vincos graph

In the chart, platforms are divided into centralized and decentralized on the ordinate axis and between VR contents and not on the abscissa axis. The most well-known and popular platforms are centralized and without VR, which account for almost all active monthly users, the most used are Roblox, Minecraft, and Fortnite. This is because centralized platforms are more efficient; most centralized systems have a well-defined hierarchy with a transparent chain of command, which reduces redundancy and leads to better performance. Decentralized systems, on the other hand, are currently less efficient and may sometimes face governance conflicts. The fact that they have anonymous users has a cost (crime problem), but they have several advantages and solve the major problems of centralized platforms [47]:

- Control: the shift from fully controlled by a central authority to community-governed decentralized autonomous organizations (DAOs), where decisions are made by user

consensus. A centralized organization's primary objective is most often to maximize profits, which results in a misalignment of the interests of the user and the company. This issue is resolved by decentralized control, which raises user confidence in the platform.

- Security: centralized systems, such as those used by many organizations, are vulnerable to a single point of failure. This means that all user data is stored on a single server, which is at high risk of being hacked or leaked if the business does not implement the strongest security protocols. On the other hand, decentralized systems distribute the decision-making process among network participants, reducing the risk of a single point of failure. This makes decentralized systems more secure and less vulnerable to attacks.

The greater adoption of platforms that do not generate content in VR is mainly due to a technological factor. As already addressed above, headsets and VR content have limits; therefore time is needed for development. It should also be taken into consideration that the quality of immersive experiences is constantly improving as is the public's interest in this technology. According to a report published by McKinsey in June 2022 [14], about 79% of active users in the Metaverse have made at least one purchase, mainly to improve their online gaming experience. Only a small percentage of purchases were dedicated to the purchase of assets. In an article published by Gartner in February 2022 [48], it is predicted that by 2026, 25% of people will spend at least one hour a day in the Metaverse, taking advantage of the new opportunities offered by this new technology, such as experiences not possible in physical reality, new ways of connectivity and social interaction, escape from reality and change of their own identity, as well as possible educational opportunities.

In economic terms, the global Metaverse market was estimated at 38.85 billion US dollars in 2021 [49]. In 2022, this figure should rise to 47.48 billion US dollars, before reaching 678.8 billion US dollars by 2030, with a CAGR (compound annual growth rate) of 39.4% expected during the forecast period due to the increase in demand from various sectors [50]. According to an analysis by McKinsey [14], the Metaverse could generate between 4 and 5 trillion US dollars for the consumer and the enterprise by 2030, while in 2022 it generated between 200 and 300 billion US dollars.

In order to try to seize these opportunities and not risk being left behind, more and more companies are entering or getting ready to enter the virtual goods industry. Several brands have already heavily invested and announced incursions into the Metaverse through virtual games, products, or NFTs (non-fungible tokens).

For example, JP Morgan, one of the largest US banks, recently announced its entry into

the world of the Metaverse [51][52]. JP Morgan has decided to invest in this sector to take advantage of the opportunities offered by virtual reality technology and increase its presence in the digital space, has indeed chosen to open a venue called Onyx Lounge on Decentraland and has also founded its own cryptocurrency. The bank is working on projects that aim to create unique experiences for customers, such as the ability to explore financial markets in an interactive and immersive way. In addition, JP Morgan hopes to use the Metaverse to provide innovative financial services to customers and to promote collaboration and training within the company. Also, Hyundai has recently entered the world of the Metaverse with the Hyundai Mobility Adventure initiative [53][54], an experience on the online gaming platform Roblox. This initiative is structured as a game journey that sees players facing various challenges and puzzles, using Hyundai vehicles as a means of transport.

The purpose of this initiative is to advance "Metamobility," or to open the door for a connection between an intelligent device and the Metaverse that seeks to extend the function of mobility to virtual reality (VR), ultimately allowing people to overcome physical limitations of movement in time and space. Hyundai hopes to engage a youthful and interested audience with these themes by leveraging Roblox's massive popularity. In addition, Hyundai Mobility Adventure also offers players the opportunity to experience first-hand the technology of zero-emission vehicles, through a realistic simulation of the performance and features of these vehicles. In summary, Hyundai's entry into the Metaverse through the Hyundai Mobility Adventure initiative represents a new opportunity to promote Metamobility and build innovative relationships with young people.

2.2. Metaverse Platforms

The scope of this paragraph is to delve deeper into the platforms depicted in the table A.1 contained within Appendix A, which constitute the surface of the Metaverse, that is, what is currently most tangible for the user. Indeed, the user can already enter and experience these virtual worlds, thus better understanding what the Metaverse is and the trends for its future evolution. Some of the platforms listed in table A.1 have already achieved a high level of popularity, this is because they are already in a maturity phase, compared to others that are more recent or that target users residing in other continents and are therefore popular only in some countries. As previously mentioned, most of these virtual worlds rely on a centralized system and do not support 3D headsets, but an increasing number of digital platforms are working to offer their users the possibility of using virtual reality content in the future. Looking at the release year of the platforms, it is evident that most of them have less than ten years and some, in particular, the decentralized ones

are very recent. This is due to a progressive improvement and development of technology, and it can be reasonably expected that more virtual worlds will be created in the future as technology continues to improve. The "older" platforms, except for "Second Life" which still has a significant number of loyal users, "Active Worlds" and "Gaia Online" are now almost disused, as newer virtual worlds have been able to take advantage of newer 3D technology and increased bandwidth availability to offer a superior user experience. In terms of compatible operating systems, platforms generally aim to include as many as possible, to facilitate their diffusion and reach as many users as possible. The degree of interaction is high in all the different virtual worlds, in fact, one of the keys to their functioning and continued expansion is the formation of communities, as in every digital platform there is the possibility of adding other people to one's friends list, chatting, interacting and participating in events with other users. Voice chat is a feature that arouses contrasting opinions, there are those who prefer to use it and those who instead prefer to play without it and consider it only a disturbance. Most platforms have an in-game voice chat but offer their users the possibility to disable it or block annoying users as needed. Other digital worlds do not have the option of voice chat, so gamer communities have organized themselves by creating dedicated rooms on Discord, a free communication application that now counts millions of users and that allows you to use voice, text, and video chats to communicate.

In terms of graphic style, each of these worlds has its particularities and characteristics, making each one different from the others. The realistic graphic style as well as the surreal one cannot yet afford a high level of detail, this is due to a problem of bandwidth and connection speed. It is possible to create a highly realistic and high-detail scenario, but if every time you had to wait 5 minutes to load a room, no one would use that platform. However, it should be remembered that the infrastructure has made giant strides in recent years, both bandwidth and latency have improved significantly and will continue to improve in the coming years. As for the ability to monetize, digital platforms have implemented similar strategies to try to increase the user base, they are all free access and most offer the possibility to make purchases in the store to improve the in-game experience. Some of them offer monthly or seasonal subscriptions that grant access to exclusive content or an upgrade of the account with more features. A slightly different discourse for digital worlds that rely on decentralized systems, in whose store it is possible to buy wearables and lands in the form of NFTs, and therefore the ownership of them resides in the user who made the purchase and who can decide in the future to resell the object or put it up for auction.

2.3. Deepening of Metaverse Platform Decentraland

Figure 2.2: Image of Decentraland virtual world

Decentraland is a decentralized virtual world that allows people to possess their own virtual land in a unique way. Its development began in 2015 with a 2D proof of concept called Stone Age, and it opened to the public in early 2020 after significant progress was made.

One of the best features of Decentraland is that it is completely decentralized, which means that there is no central authority that controls the world. This is what distinguishes it from other centralized digital worlds like Minecraft for example, where a single entity has the power to censor or ban users, or even shut down resulting in the loss of everything built on the platform. Decentraland is community-owned, and governed by a Decentralized Autonomous Organization (DAO), which means that all community members can participate in voting on proposals, including smart contracts that control land, property, wearables, and the market.

This freedom allows users to create a wide range of content, from simple 3D scenes to interactive objects, buildings, artworks, games, and even large events that can attract thousands of users.

Decentraland land ownership is divided into small fragments called parcels, each parcel measuring 16 meters by 16 meters, (52 ft by 52 ft) and is the smallest piece of land you can own. Each parcel is represented by an X and Y coordinate on the virtual map, and by a land token deployed on the Ethereum blockchain. LAND is an ERC 721 token, classified as non-fungible token (NFT), it's scarce and it's a collectible. As a result, LAND

token holds the information of the land location in Decentraland and the XY coordinates, along with the decentralized servers run by the community holding the content needed to render it in 3D graphics.

In the event that an individual possesses multiple adjacent land parcels in Decentraland, they have the option of merging them to form an estate. Additionally, there are designated regions in the virtual world with a particular theme, resulting in the creation of specialized districts.

Decentraland's economy is based on three native tokens: LAND, Estate, and MANA. LAND is an ERC-721 token that represents individual parcels of digital land, while Estate is an ERC-721 token that represents merged parcels of digital land. On the other hand, MANA is an ERC-20 token and serves as Decentraland's in-world currency.

All of these tokens' characteristics are defined by three smart contracts: the MANA token contract, the LAND registry contract, and the Estate registry contract. The main difference between these types of tokens is that LAND and Estate are non-fungible while MANA is a fungible token, which means that it is interchangeable with other ERC-20 tokens. Likewise, each MANA token is identical and lacks unique properties, making it an ideal currency for Decentraland.

In the Decentraland Marketplace, you can buy LAND, wearables, and other digital assets with MANA. Owning LAND grants users the freedom to create digital environments and applications, which can be monetized. To participate in Decentraland's ecosystem, users need to hold MANA within an Ethereum wallet. Because of the relatively small pool of MANA, its value can be volatile. Additionally, all transactions are settled between Ethereum wallets, and therefore, they are verified by Ethereum's network and logged on its blockchain. The MANA token currently benefits from excellent liquidity and can be purchased, traded, or sold on around a hundred different exchange platforms. Decentraland has created a unique economy based on the ownership of digital assets, and its tokens and smart contracts ensure secure and transparent transactions.

Decentraland functions as a public infrastructure, it is wholly owned by its users and is governed by the Decentraland DAO, as previously mentioned. To participate in the Decentraland DAO, users need to hold wrapped MANA (wMANA), LAND, and Estate tokens. The voting power is calculated based on the number of tokens held, with one unit of voting power given for each wMANA token and 2000 units of voting power per parcel of LAND or Estate. In Decentraland, "wrapping" MANA refers to locking it up in the DAO, preventing any further spending or transfers. To spend or transfer it, you must first unwrap it. On the other hand, registering LAND and Estate tokens for voting does not lock them up, and users can still use them normally when registered.

In addition to the DAO, Decentraland has a Security Advisory Board (SAB) responsi-

ble for overseeing the platform's smart contract security, reviewing governance proposals, and addressing bug reports. The SAB has the authority to delay or reject governance proposals that could have a negative impact on the platform.

Decentraland offers a plethora of in-game experiences for its users. Upon entering the virtual world, users can customize their avatars with unique wearables, adding to the fun and immersive experience. Building and developing one's land is another aspect of the game, which can be achieved through the Visual Builder tool or the Software Development Kit (SDK). With some basic programming skills, users can further enhance their participation in the world by interacting with other users through the built-in chat tool or inviting friends to virtual social gatherings.

Once in the world, Decentraland's gameplay is expansive and engaging. The virtual world is vast and traversable, with colourful and dynamic landscapes. Currently, the total world size of Decentraland is more than 90,000 LANDs, representing a total area of about 1,440,000 square meters. Users can easily navigate the world with their mouse and arrow keys, entering buildings and interacting with objects. Alternatively, users can open the map and quickly jump to any location that catches their interest. From clubs and museums to casinos and parks, there is something for everyone in Decentraland. Users can explore digital art installations, take a ride on a Ferris wheel, listen to music or the sounds of nature, and even play games.

Despite a large number of possible activities, Decentraland turns out to be a bit empty. In fact, according to Coindesk and Yahoo!finance, on average it registers less than a thousand users a day [55][56]. The best way to socialize on Decentraland is through the events that take place on the platform and attract a greater number of users.

For example, from March 28th to March 31st, 2023, the second edition of the "Metaverse Fashion Week" (MVFW) was held in the virtual universe of Decentraland, marking a significant milestone in the rise of the virtual fashion market. With the participation of over sixty brands, artists, and designers, including notable names such as Dolce & Gabbana, Tommy Hilfiger, and Diesel, MVFW23 confirmed itself as a significant event in the global fashion industry. On one side, Decentraland was able to gain greater media coverage compared to its competing virtual universes, while on the other side, brands are taking this new world seriously, far removed from the snobbery they once held towards emerging online sales.

2.4. Mapping of Global Providers

The proliferation of applications utilizing immersive experiences, coupled with the constant advancement of immersive technologies, has resulted in an increased emphasis on the role of technology providers. To gain a clearer understanding of the key players in this field, a comprehensive list has been compiled and presented in Table A.2, which can be found in the Appendix A for reference. The presented table comprises not only established and sizable corporations boasting thousands of employees, but also emerging and comparatively smaller firms, typically comprising a few dozen employees. Despite their smaller size, these emerging companies have made noteworthy contributions towards the development of the Metaverse. Given the extensive and diverse fields involved in the development of the Metaverse, I have chosen to categorize companies according to their respective areas of expertise, as many specialize solely in one of these specific domains. These fields are:

- *Avatars & Digital Identities*: encompasses all aspects relating to the creation of distinct digital avatars or the design of custom-made clothing to ensure that the digital avatar accurately reflects the user's identity, thus enabling them to feel more immersed in the virtual world. A prime example of this category is Ready Player Me, a European company that provides users with the ability to generate a fully customizable 3D avatar by utilizing a simple selfie, which can later be seamlessly integrated into a vast range of applications and games.

- *Social*: comprises companies that have an established presence in the social sector and are seeking new opportunities in the Metaverse to stay relevant and adaptive to evolving trends. This category encompasses prominent entities such as Meta, ByteDance, and YouTube, among others.

- *Virtual Retail & Showroom*: pertains to the development of virtual shops and showrooms that offer users a novel and immersive shopping experience. A representative of this category is Byondxr, a platform on which brands and retailers rely to create virtual fashion stores and related experiences.

- *Meta Marketing*: encompasses companies that are pioneering innovative advertising methods by leveraging the immersive features of virtual environments.

- *Virtual work*: refers to the utilization of virtual reality (VR) technology by companies to create virtual workspaces and environments. These virtual workplaces are fully equipped with tools that enable teams and customers to host events, workshops, and training sessions in the Metaverse. An example of this is Cavrnus, a US-based

company established in 2019, which enables all kinds of businesses, brands, and creators to design, construct, and distribute customized virtual platforms that embody their unique vision of the Metaverse.

- *Industrial work*: encompasses the advancement and utilization of all immersive technologies to enhance work efficiency. This also involves the use of immersive technologies for targeted purposes, such as professional training or product design.
- *Economy creator*: pertains to a wide range of companies involved in the development of Metaverse platforms, content creation, and audience engagement. An exemplary illustration of this category is the Roblox Corporation, which is the firm responsible for creating Roblox.
- *Spatial computing*: refers to the enterprises that are engaged in the creation of advanced technologies, which facilitate the mapping and processing of physical spaces into digital representations. Such technologies enable real-time interactions between users and digital objects or information superimposed onto the physical world. Spatial computing encompasses the development of various cutting-edge technologies such as extended reality, computer vision, volumetric video, spatial audio, and 3D engines.
- *Decentralization*: encompasses a range of enterprises that specialize in the development of blockchain, cryptocurrency, and non-fungible tokens (NFTs). Prominent examples of such companies include Ethereum, OpenSea, and Gemini, among others. These entities are involved in creating innovative solutions that enable the distribution of power and control away from a central authority, thereby fostering a more equitable and transparent ecosystem. Through the use of decentralized technologies, these companies are seeking to transform a variety of industries, including finance, healthcare, supply chain management, and digital art, among others.
- *Interface*: includes enterprises that are engaged in the development of technologies aimed at facilitating the connection between users and virtual worlds. These technologies include devices such as virtual reality headsets, smart glasses, and other related hardware and software components.
- *Infrastracture*: comprises companies primarily engaged in the telecommunications industry, focused on enhancing and modernizing existing infrastructure to enable more robust and reliable connectivity, expedited processing capabilities, and superior cloud-based services in the times ahead.

Due to the vastness of the discussed fields and the presence of numerous companies op-

erating within them, it was not feasible to compile all entities within Table A.2. Rather, only those deemed already well-established or those demonstrating promising potential were included.

It is important to differentiate between the two distinct types of companies, namely, established and emerging entities, as they approach the sector in divergent ways. The former refers to companies that have been in existence for several years, boasting a sizable workforce and a profitable enterprise. Their objective is to expand their business prospects by investing in the Metaverse and adapting to new generational trends to avoid being excluded from the market. Conversely, the latter refers to nascent companies, established in recent years, that operate within these novel sectors and do not necessitate the reconfiguration of their competencies and business models.

Regarding the geographical locations of enterprises, it is noteworthy that most of them maintain multiple offices across the globe. However, for the purposes of the present table, only their primary headquarters are considered. As depicted in the graph 2.3, over 60% of companies are situated in the United States, with the state of California being the most prominent. This is primarily due to Silicon Valley, which has facilitated the growth of numerous distinguished and startup technology companies, alongside a favourable business environment.

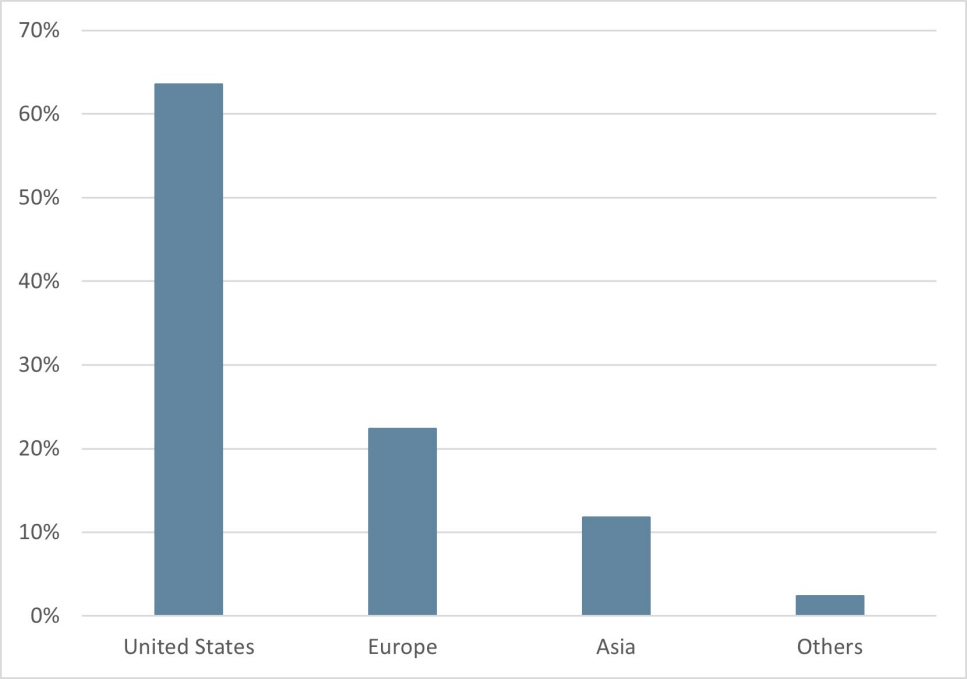

Figure 2.3: Headquarters of global technological providers in percentage

2.5. Mapping of Italian Providers

As already mentioned, the Metaverse is an emerging sector that is attracting the attention of many companies, especially those that are innovative and open to innovation. However, information on Italian companies operating in this sector is still limited. In fact, the mapping of Italian technology providers operating in the Metaverse sector, which can be found in Table A.3 in Appendix A, only shows a part of the companies present in the market, as there are many emerging realities that are not yet known.
One of the main reasons is that in Italy only in recent years there has been an increase in media interest and public interest in these technologies, thanks also to the advent of advanced hardware devices that allow for increasingly immersive experiences. Consequently, demand for these services has begun to grow and this has led to the birth of many new companies in recent years.
Among those mapped in Table A.3, as shown in graph 2.4 only a few have existed for more than 10 years; most of the others were founded in the last 5-8 years.

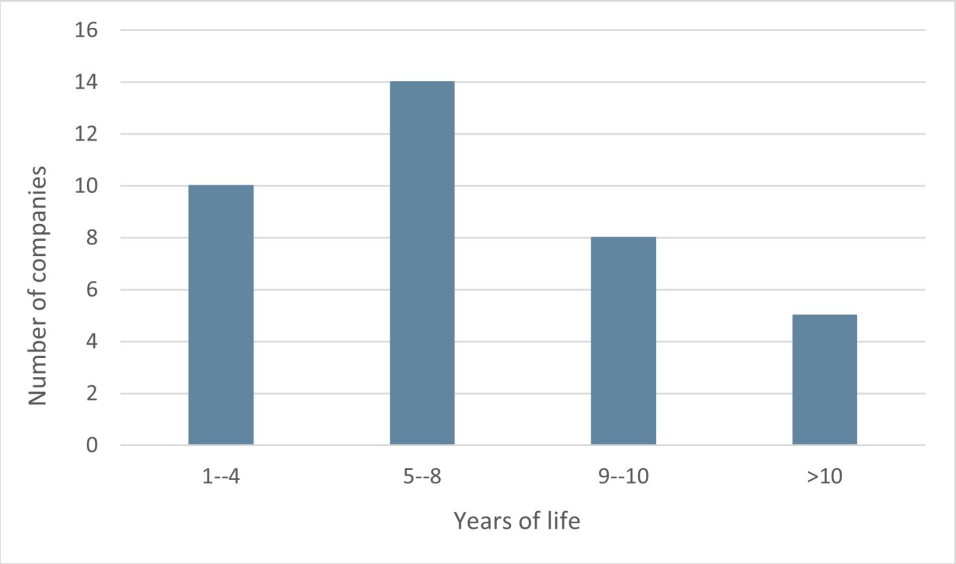

Figure 2.4: Life years of Italian technological providers

The companies identified in the table have been categorized based on the sectors they operate in. Most of them work in developing augmented and virtual reality technologies and creating immersive experiences. Graph 2.5 shows how many of these companies work in the AR sector, how many in the VR sector, how many in both, and how many in neither. It is worth noting that most of them focus on both AR and VR.

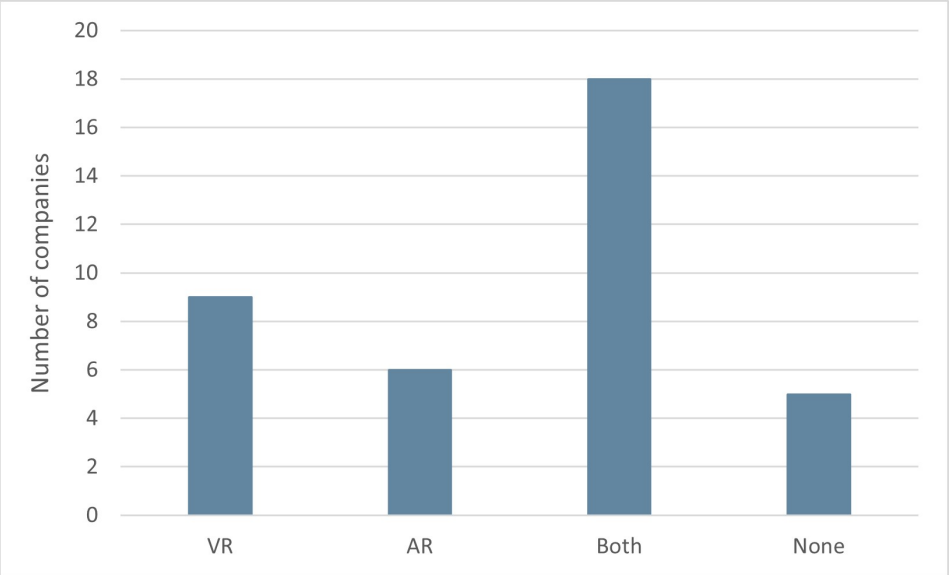

Figure 2.5: Italian technology providers and sectors of interest

As regards the geographical location, companies are spread throughout the country but with a greater concentration in Milan. In fact, 12 out of 38 enterprises have their main headquarters there.
Focusing instead on the number of employees, it is worth noting that none of them have more than fifty employees. This is due to the fact that the Metaverse is still an emerging sector and in a development phase. In addition, many companies that are entering the Metaverse are startups that are still trying to find their place in the market and develop their product and service offerings. For these reasons, many of the mapped companies are made up of a single team with fewer than ten employees.
Although expectations around the world of the Metaverse and these companies are sometimes immature and unrealistic, it is possible in the future, thanks to training and experience, to build a solid Made in Italy culture of the Metaverse.

3 | A comprehensive guidelines and analysis for the realisation of an immersive project

This chapter aims to provide an overview of the companies interviewed by examining the main insights that emerged from the analysis of the data collected through the interviews. In particular, the guidelines for the realization of a successful immersive project will be presented.

3.1. Methodology

To better and more deeply understand the Italian technology providers in the immersive experiences sector, I decided to interview them. The goal is to learn about their activities and products and gain a deeper understanding of their development and production processes. Additionally, the main focus of these interviews has been to obtain valuable insights into the design phases. Thus managing to better understand how technology providers design and develop their technological solutions and in general to know in detail the technological development process. Another reason I have decided to conduct these interviews is to discover the main factors that influence the success of technological projects and the challenges that technology providers must face in terms of project criticality and bottlenecks.
In summary, I decided to interview Italian technology providers to acquire greater awareness of the world of immersive technology, gather insights, and have their perspectives on the Metaverse topic.
All the companies listed in Table A.3, available in the appendix A, were contacted through various communication channels, including LinkedIn through the company's page or by contacting the CEO directly, via the company's e-mail, or through an interview request sent through the website. The most effective method for getting in touch with these companies has turned out to be LinkedIn, a platform that allows you to relate to various

professionals in a more direct and faster way than traditional e-mails.
For each company my request was the same, to have the opportunity to do a brief 15-minute interview via video call, thus giving me the opportunity to ask a series of questions and to be able to establish a direct relationship with industry professionals.
I managed to get in touch and had the opportunity to interview seven of these organizations and I was able to talk to people who play a fundamental role in their business and who have a 360-degree view of what is happening in their company. The people I interviewed are respectively: Manuel Bazzanella founder and CEO of Digital Mosaic, Alessandro Lorica CEO of Oniride Srl., Niccolò Gallo co-founder of Periodico Studio, Gualtiero Carraro owner and founder of Carraro Lab, Enrico Degrassi co-founder and CEO of IKON Digital Farm, Matteo Esposito co-founder and CEO of InVRsion and Matteo Valoriani CEO of FifthIngenium.
The methodology used for the interviews was the same for all companies, that is, a semi-structured one, which combines a predetermined set of open-ended questions (questions that stimulate discussion) with the opportunity for the interviewer to further explore particular themes or answers.
In each interview, I presented the following questions:

- What is the company's core business?
- What is the core industry served?
- What kind of graphic style do you create?
- Do you use AI? If so, for what purpose?
- What are the main project phases that need to be implemented once a client is acquired?
- Which are the most decisive for the success of the project?
- What are the bottlenecks? Which are the most delicate in terms of required effort?
- What is the pricing of the services offered?
- Do you have any partnerships?
- Describe a significant use case.

3.2. Outcomes Description

This section aims to present the results obtained from the interview. To build an effective scheme, it is essential to fully understand the context in which the project is conceived and will be implemented. In particular, the analysis of the interviewed companies is a fundamental step in acquiring a complete vision of the context in which the immersive project fits. For this reason, a brief description of each interviewed company has been included in this section.

Digital Mosaik

Figure 3.1: Digital Mosaik Logo

It is an innovative company founded in 2016 in Trento by Manuel Bazzanella with the ambitious goal of making virtual reality an accessible, efficient, and easily usable technology for businesses. With a team of less than twenty highly skilled and passionate employees, the company operates in the constantly evolving fields of the Metaverse, virtual reality, and blockchain, providing customized solutions for immersive and engaging experiences.
Digital Mosaik's mission is to simplify access to virtual reality technologies for businesses and help them fully harness the potential of these technologies. To achieve this goal, the company offers a wide range of services, including immersive experience projects and virtual worlds tailored to enhance different sectors such as marketing, training, industrial design, tourism, and gaming. Additionally, it offers consulting services to help clients select the most suitable solutions to develop and successfully integrate into their business, as well as an academy open to companies, professionals, and students that offers training courses to bring people closer to immersive and blockchain technologies that will constitute the new technological paradigm.
Digital Mosaic has already worked on several important cases in the area such as the Muse Adventures project carried out in 2021 together with MUSE, the Science Museum of Trento, which aims to study how virtual reality can contribute, through a new language, to the valorisation of science and the dissemination of scientific knowledge [57]. Furthermore, in 2021 the company carried out an important project for the training of surgeons,

doctors, instrument operators, and nurses. Through the Metchannel VR platform [58], created with Olympus Italia, medical personnel can simply wear a virtual reality headset to simulate an operation, learn correct procedures, or learn how to use equipment properly. This technology has made it possible to lower training costs, reduce risks and errors, accelerate learning, and simplify training moreover it can be used anywhere in the world without the need to travel or use operating rooms.

FifthIngenium

Figure 3.2: FifthIngenium Logo

It is a company founded in Marcianise, a municipality in the province of Caserta in 2014 by Antimo Musone, Matteo Valoriani and Domenico Letizia and which boasts a team of around thirty employees distributed between the two offices in Milan and Marcianise. The company is committed to providing highly innovative software solutions to help customers create new business architectures and realize their business objectives.
The company operates in the field of software development, immersive reality, artificial intelligence and cloud computing and offers solutions such as Software Development, System Integration, Mixed Reality, Machine Learning as well as a series of products already on the market. FifthIngenium's mission is to identify the most suitable options for customers and define with them the transformation plans aimed at achieving the objectives. FifthIngenium is committed to serving a diverse range of industries including Industry 4.0, Education, Healthcare, Tourism and Advertising. With their expertise and innovative solutions, the company is able to help clients turn their business into a success.
The firm also works with some of the biggest names in IT, such as Microsoft Mixed Reality, and has many high-profile clients, including Coca Cola, Ferrari, Iveco, Unicredit and Vodafone. This demonstrates their ability to deliver high quality solutions and their experience. In addition, FifthIngenium in 2021 won the third edition of "Action for 5G" [59], the Vodafone call for startups, SMEs and social enterprises, presenting TINALP, an innovative web platform for the rapid, secure and fast creation and management of forms of learning. The platform uses next-generation virtual and augmented reality environments to deliver immersive and challenging learning. With TINALP, students can

interact with the learning environment in an intuitive way, without using a controller, and have an active role during the training process. The platform allows you to create lessons intuitively, with the ability to import 2D and 3D content, access personalized training paths, and view unique content such as volumetric videos. The solution supports shared training experiences open to multiple users simultaneously, both locally and remotely, offering a new way of experiencing training that is more stimulating and engaging.
FifthIngenium closed the last round of financing in 2021 for a total of 880,800 USD [60], this allowed it to be competitive and explore new business opportunities.

Periodico Studio

Figure 3.3: Periodico Studio Logo

It is an innovative augmented reality communication and marketing company based in Livorno, founded in 2021 by Leonardo Pezzini, Christian Guidi, and Niccolò Gallo. It is a small company made up of a team of fewer than ten employees with the ambitious goal of revolutionizing the conventional approach to communication. Although born very recently, the company stands out for its ability to create customized solutions for corporate communication, offering services such as AR content creation, 3D modeling, branding, web design, communication strategies, and digital marketing.
Being a creative hub, Periodico Studio's corporate mission is to create immersive experiences in Augmented Reality out of the ordinary, firmly believing in creative contaminations and in the use of the most advanced technologies to offer innovative and creative marketing and communication solutions. The Periodico Studio team works closely with its clients to understand their unique needs and provide customized solutions that best suit them. Furthermore, the company serves a wide range of industries, including luxury, architecture, design, and hospitality, and focuses on providing innovative solutions that help its customers communicate effectively and differently.
Periodico Studio solutions take advantage of WebAR technology which allows access to AR experiences by scanning a QR code or via a URL link. Although it is a very young company, it has recently managed to enter the communication and marketing of the yachting world by participating in important exhibitions such as the Monaco Yacht Show S.A.M. and the Cannes Yachting Festival presenting their Web AR solutions dedicated to

the sector [61][62].

Oniride Srl

Figure 3.4: Oniride Logo

It is a software development company based in Rome, founded in 2014 by Andrea Giansanti. With a team of around ten highly skilled employees, Oniride focuses on creating a new language through immersive platforms. The company was founded with the aim of telling, teaching, and captivating its audience through innovative and engaging solutions. In 2020, Oniride was acquired by DM Cultura, a leading company in the design of software for the cultural sector. This union has made it possible to combine the consolidated experience of DM Cultura with the innovative vocation of Oniride, focused on the research and development of multimedia technologies.

Oniride's mission is to use the innovative technology of virtual reality to digitally revitalize, enhance and preserve cultural heritage. Through virtual reality and mixed reality projects, the company wishes to tell the stories of our historical heritage. Oniride offers a wide range of solutions for the cultural sector, including VR and AR experiences, virtual tours, gaming apps, and metaverse creation. The company has collaborated with important partners such as Nissan, Tim, BNP Paribas, and Warner Bros proving to be able to provide world-class solutions for its customers.

The "The secrets of Pyrgi" project, developed by Oniride for LazioCrea and the Lazio Region, offers an immersive experience in virtual reality that allows users to immerse themselves in the Castle of Santa Severa, discovering its history, the landscapes, and the mysterious secrets of Etruscans through a VR viewer [63].

Carraro LAB

Figure 3.5: Carraro LAB Logo

It is an innovative and cutting-edge company in the field of software development and immersive technologies. Founded in 1999 by the twins Gualtiero Carraro and Roberto Carraro in Palazzolo sull'Oglio, in the province of Brescia, the company is made up of a team of around ten employees.

Carraro LAB's mission is to bring immersive technologies within the reach of companies and public bodies, to be able to transform and innovate their communication and their way of working. The company offers a wide range of solutions for various industries, including public administration, tourism, culture, marketing, and training. Solutions include immersive experiences in virtual and augmented reality, 3D simulators, games, immersive installations, 360° video, and metaverses.

The founders, Gualtiero Carraro and Roberto Carraro, have a long experience in the digital sector, dating back to the 80s. Their expertise and dedication to creating innovative solutions have attracted the attention of the international community, which has recognized their work with awards and accolades. Among the most significant achievements of Carraro LAB is the first tourist metaverse for Procida 2022 [64], the immersive APP for iPad "Roma Virtual History" presented by Steve Jobs [65], the first virtual reality mass experience during Expo 2015 [66], the first applications for Oculus and GEAR VR and the street view technology introduced in 2006 which anticipated Google [67].

The company also has a large base of high-level customers, which includes Italian and foreign public bodies, as well as world-renowned companies such as Unicredit, Sky, Samsung, Enel, Mercedes-Benz, Hermes, and Pwc to name a few. This demonstrates the level of competence and reliability of Carraro LAB and its ability to offer innovative and quality solutions to its customers.

Carraro LAB has obtained 11 international awards for digital culture in Europe and the United States, testifying to its exceptional reputation at a global level.

IKON Digital Farm

Figure 3.6: IKON Logo

It is a company operating in the field of IT services, software development, and immersive technologies. Founded in 1997 by Enrico Degrassi in Staranzano, in the province of Gorizia, the company has grown to become a team of approximately thirty employees, professionals with heterogeneous experiences and skills, who share a passion for research, creativity, and technology.
IKON's corporate mission is to create a creative space where innovative technologies and nature come together to create unique experiences for its customers. IKON offers complete solutions, from design to implementation, for virtual and augmented reality experiences, gaming, 3D, IoT, mobile, video, web, and interactive and immersive installations.
The company primarily serves the tourism, culture, retail, and restaurant industries, but is open to partnering with any industry looking to enhance its digital presence. IKON has two operational headquarters in Italy, the main one in Staranzano and the other in Udine, and has established partnerships with leading technology companies such as Samsung Italy and Microsoft. The headquarters in Staranzano, immersed in greenery and surrounded by vineyards, olive groves, and a forest with over 1500 trees, is further evidence of the company's commitment to sustainability and the reduction of environmental impact.
IKON has received numerous awards and recognitions both nationally and internationally, including the World Summit Award for the Monte San Michele Museum in 2019. The company is committed to optimizing business processes and improving the quality of its products and services, and since 2009 it has been certified ISO 9001, a guarantee of professionalism and efficiency.
IKON's clients include some of the most important names, such as IKEA, Gucci, Prada, Emirates, Illy, and Fincantieri, who have chosen to rely on the company's experience and expertise.
In 2020, IKON developed a project, called CollioXR, for Fondazione Carigo and Banca Intesa with the aim of promoting social and economic development in the territory of the province of Gorizia. This has led to the creation of a mobile app based on extended

reality, which combines geo-referenced storytelling, virtual reality, and augmented reality, providing an immersive and engaging experience [68][69].

InVRsion

Figure 3.7: InVRsion Logo

It is an IT company founded in 2015 in Milan by Matteo Esposito, Flora Caroli, Paolo Pascolo, and Luca Ferrari Trecate. With a team of approximately thirty employees, InVRsion is dedicated to providing its B2B customers with the best possible experience through Full Reality.
InVRsion's corporate mission is to become the benchmark for VR and AR retail experiences. The company operates in the sector of IT services, software development, and immersive technologies, offering innovative and cutting-edge solutions such as 3D commerce, retail store virtualization, virtual showroom, Shelfzone, and digital twins. InVRsion serves a wide range of industries, from Consumer Packaged Goods (CPGs) and Retail to Fashion, Real Estate, Interior Design, and much more. With its expertise in simulating retail spaces using immersive virtual reality technologies, the company boasts a list of prominent clients, including Pepsico, Nestlé, Ferrero, Accenture, Auchan, and Esselunga. InVRsion also deals with the development of customized immersive applications for the digitization of 3D products (digital twins) of which it owns patents to scale industrially on the production of the latter.
Shelfzone, the Software as a Service produced by InVRsion, is now a successful solution and is a unique tool that allows customers to build their store from scratch, manage categories, do commercial marketing and brand research, enhance collaboration between teams, organizations, and customers, and save time and costs. Shelfzone gives brands and retailers full control over their designs as they can create, test and showcase their work autonomously, anywhere, anytime [70].
InVRsion raised a total of €6.5 million in funding in 4 rounds, proving to be a fast-growing company and a leader in its category [71].

After having presented and described the interview methodology in detail and understood the context in which interviewees operate, the results obtained are shown in Table A.4, which can be consulted in Appendix A.
Thanks to all the elements collected, it was possible to reprocess the data and extrapolate their implications, which will be explained in detail in sections 3.3 and 3.4.

3.3. Steps of an Immersive Project

A technological process represents a series of interconnected activities aimed at creating technological products or services, such as mobile applications, software, video game, website, virtual or augmented reality products, and so on. These activities are generally organized in a logical sequence of steps, each of which corresponds to a specific phase of the process. Knowing the stages of a technological process is important to understand how technological products are developed and what skills are needed to successfully complete the project.
In this section, we will focus on the steps of an immersive project, examining the activities that compose them and their role in completing the project. An immersive project is a technological experience that uses virtual reality, augmented reality, or other immersive technologies to create an engaging and interactive experience for the user. These projects can be used in a variety of contexts, such as education, entertainment, professional training, tourism, health, and so on. Creating an immersive project requires a specific technological process, which often relies on an iterative and collaborative development methodology. The process involves five steps:

The first step is that of **Assessment**, it is a critical component of any technological process and allows for understanding and addressing the specific needs of the customer. During this phase it is important to be able to "break the ice", a team of experts works closely with the customer to better identify his needs and understand how to provide a suitable customized solution. This phase consists of three main components: the initial client discovery phase, the workshop, and the actual training. The phase of getting to know the customer is crucial for understanding their needs and expectations, but also for establishing a solid working relationship.
During the interviews, it emerged that the various customers approach these new technologies in different ways, with some completely relying on the company's abilities and others seeking to have control over the project. For this reason, it is important to create the right dynamics in the company-customer relationship. The fundamental component of this very first phase turns out to be the human one and consequently, the ability to

convey trust and build a relationship of understanding with the customer.
Following the client discovery phase there is that of workshops, which also involves the final operators, those who will then use the solution. This is an important moment to involve the customer and the operators in the technological solution that will be implemented. A team of experts provides an overview of the technologies and immersive experiences available, explaining the benefits and how they can be used within the client's business. During the workshop, the end operators have the opportunity to ask questions and better understand the technological solution that will be implemented. In this phase, the activities that will be carried out in the following months are described in detail to ensure the correct implementation of the chosen technological solution.
Finally, the specific training phase is paired with the workshop phase. The purpose of this activity is to teach the end customer how to use the tools and various usage methods. This is an important step to ensure that the chosen solution is suitable and that operators are able to use it correctly once implemented. Although this phase may seem superficial, in reality, it is not, as these are new technologies that are constantly and rapidly evolving. It is important to provide the customer with information and skills to interact with these technologies both currently and in the future.
In summary, Assessment is a critical step that starts the immersive project. The client discovery phase makes it possible to identify his needs and establish a solid working understanding. The workshop involves both the customer and the operators in the technological solution, while the training phase provides the necessary skills to guarantee the effective and appropriate use of the chosen technological solution.

The **Discover** phase is the second step in the development of an immersive project and has the purpose of formalizing the idea and preparing the ground for the implementation of the solution. In this phase, some fundamental activities are carried out to ensure the success of the project.
Firstly, the formalization of the idea is a fundamental activity that enables the development of a clear and coherent framework for the project, defining the boundaries of the solution and the criteria for its validation. This activity helps define the feasibility of the project and identify any challenges that may arise during implementation. Furthermore, formalizing the idea helps to define the long-term goals of the project and to create a road map for the realisation of the solution. This is crucial to ensure that the project is well-defined and that the work teams have the information and tools necessary to carry it out successfully.
Subsequently, the choice of the most suitable work team in terms of skills is another important activity carried out during the Discover phase. The work team is in fact the

engine that drives the project, and its composition can significantly influence the final result. Furthermore, the team will have to work closely with the customer to ensure that the solution meets their needs. Choosing the right team means choosing people who have the skills, experience, and attitudes necessary to complete the project successfully. This team could be composed of developers, 3D artists, 3D coders, sales representatives, project managers, technical artists, programmers, designers, and other professional profiles who can contribute to the realization of the project. In the case of the small and medium-sized enterprises interviewed, it is common for the various professional profiles to cover multiple roles. For example, a programmer could also be a designer and participate in different project phases. In some cases, depending on the specific needs of the company, it may be necessary to use technology partners to support the project.
The Discover step also includes an experience definition phase. This activity allows to define the context in which the experience will be used and defines the key points that must be achieved and satisfied in the subsequent steps of Design and Develop. After the definition activity, a detailed analysis of the desired experience is carried out. This analysis includes the evaluation of the requirements necessary to realize the experience and the identification of the limits in terms of budget and quality of the final experience. The goal of this stage is to provide a solid foundation for the next steps in the process, ensuring that the final experience meets all established quality and budget criteria.
In summary, formalizing the idea and choosing the work team ensure that the project is well-defined and that the teams have the information and tools necessary to implement it successfully while the definition of the experience and the detailed analysis provide a solid foundation to ensure that the final experience meets all established quality and budget criteria. The Discover phase turns out to be an important step in the development of an immersive project, providing a solid foundation for the subsequent phases.

The **Design** phase is the next step after the Discover phase, and is a critical component of an immersive process that transforms ideas and concepts into a customized solution that meets specific customer needs. It is a phase that requires a rigorous decision-making process because the choices made during this phase will influence the final success of the product.
The Design phase begins with the definition of performance objectives, which are the requirements that the product must meet.
This is followed by the generation of as many conceptual solutions and ideas as possible, which will then be evaluated and selected to identify the preferred solution. This idea generation activity is important because, through brainstorming techniques, it allows to explore and creatively define possible solutions. Additionally, it allows to reduce the risks

of failure and to optimize the production process, avoiding investing resources in ineffective solutions or those that are not appreciated by users.
Subsequently, the most appropriate development platform is identified for the implementation of the chosen solution. This is followed by the construction of the narrative, i.e., what the flow of the immersive experience will be, the stages, the settings, the theme, and the soul of the experience itself. Another important activity related to the latter is the design of the User Experience (UX), which consists in designing an experience for users that is as intuitive, simple, and enjoyable as possible. UX design is important because it directly affects user satisfaction, loyalty, and use of the product or service. A good UX can improve the client company's brand reputation, increase conversion and profitability, and reduce assistance and support costs.
Finally, we move on to the detailed design phase, which involves defining the most technical aspects and the details that make up the final solution. This process includes defining elements such as content layout, colour choice, typography, character choice, iconography, and animation, as well as defining interactive features and transition animations between screens. The goal of detailed design is to design a consistent, high-quality user experience by improving the usability of the product or service, reducing user friction, and maximizing the effectiveness of features. To summarize, during the Design phase, the performance objectives are defined, ideas are generated and solutions evaluated, the most appropriate development platform is identified, the narrative is built, the User Experience is designed, and the technical aspects and details of the final solution are defined. The choices made during this step significantly influence the success of the product, which is why expertise and good practices are necessary.

The **Develop** phase represents the moment in which all the ideas and concepts generated in the Design phase materialize. During this phase, technical development of the solution takes place, from the creation of assets and 3D animations to the development of the User Interface (UI), sound design, implementation of interactions, and complex logic, ending with the testing, revision, and optimization.
The technical coding development constitutes one of the fundamental pillars of this phase and is composed of a series of activities such as the programming of the source code, the creation of data structures, assets, 3D animations, the management of files and libraries, the integration of functionalities and if necessary the development of artificial intelligence systems and other technical functionalities. Furthermore, it is important to ensure that the final product meets the requirements specified in the Design phase and that it is reliable and stable.
In parallel with the development of the code, the User Interface (UI) is also developed,

which is the visual aspect of the experience. The user interface is a fundamental aspect of the experience and must be developed to provide an intuitive and engaging user experience. The developers in this phase focus on the creation of the graphical interface, usability, accessibility, and compatibility with the various target platforms. The UI must be designed to provide a quality user experience that is intuitive and easy to use and must integrate seamlessly with the experience features. Additionally, in this phase, the sound design and voice-over recording are developed. The immersive experience can involve the reproduction of sounds and the recording of voices, which must be developed in order to create an immersive and realistic atmosphere. Complex logic and interactions are developed to ensure a smooth and interesting gaming experience.
The final phase of testing, revision, and optimization is equally important in this step. During testing, all aspects of the experience are checked, from functionality to stability, to identify any bugs or issues that need to be fixed. Afterwards, the necessary revisions are made and finally, the experience is optimized to ensure the best possible performance, such as fluidity and immediate response to user input. The Develop phase is therefore a fundamental phase of the technological process, in which the experience is translated into a concrete product, ready to be distributed to the public.

The **Distribute** step represents the final step of a technological process and follows the Develop phase. This step is focused on the distribution and use of the experience, once it has been developed and tested. The main purpose of this stage is to ensure that the experience is made available to the target audience in an easy and usable way. The first activity of this step consists in configuring the supports and platforms necessary for the distribution of the content. Depending on the product's characteristics and its final destination, different platforms may be required, such as websites, mobile applications, virtual or augmented reality platforms, and so on. This activity, therefore, involves the selection and configuration of the tools and resources necessary to distribute the product efficiently and effectively. During this phase, developers will ensure that the product functions correctly on each target platform and is optimized for each one.
The final review with the client represents another fundamental activity in this phase. During this stage, the development team will show the finished product to the customer and provide them with an opportunity to review it carefully and provide feedback. This feedback may concern the user experience, functionality, graphics, and any other aspect that the customer thinks is important. The development team will take these feedback into account to make any final corrections and improvements. It is important that the product is carefully inspected and any problems resolved before final delivery.
The third activity, the last of this process, concerns the delivery of the product. In this

phase, the product or technological experience will be delivered to the client, who can use and enjoy it as they please. It is important to ensure that the product is distributed correctly and that the instructions for use are clear and easy to follow. At this stage, the development team may provide technical assistance to ensure that the customer can use the product correctly and resolve any technical issues that may arise.
In addition, the distribution phase can also involve gathering feedback post-launch of the solution. This can help identify any problems or areas for improvement in the product and make subsequent corrections and improvements. Finally, it is important to track product performance after deployment. This can be done through the use of analytics metrics, such as usage rate, average usage duration, usage frequency, user reviews, and so on. This data can help understand the product's impact on the audience and evaluate its success.
In summary, the Distribute step represents the last fundamental step in a technological process and guarantees that the product or technological experience created is correctly distributed and usable by the end customer.

In conclusion, the steps of a technological process are essential for the realization of a successful immersive project. Each step is fundamental and requires specific skills to carry out the job efficiently and effectively.
Following a structured methodology, such as the five-step methodology described, helps to ensure that every aspect of the project is managed appropriately and that the set objectives are achieved. Furthermore, it is important to emphasize that technology is constantly evolving and that the technological process must be flexible and adapt to changes and market needs. The ability to adapt and innovate is critical to success in the technological field.
Finally, it's important to remember that every immersive project is unique and requires a personalized approach. The important thing is to follow a structured and flexible methodology that allows the project to be completed efficiently and effectively, to guarantee customer satisfaction and the success of the final product. A further consideration to be made is that the technological process can be adapted to the specific needs of each project. There is no single winning formula for creating a successful technological experience, but rather a series of techniques and strategies that can be used flexibly and adapted to the specific needs of each project.
Furthermore, the technological process is not static, but rather a dynamic process that requires constant adaptation and improvement according to the project's needs. In summary, the technological process shown represents a structured and systematic approach to the realization of successful immersive projects. Through its various steps, the technolog-

ical process helps to manage the complexity and multiplicity of aspects to consider during the implementation of an immersive project, ensuring greater efficiency and quality of the final result.

3.4. Delicate Phase, Criticality and Bottlenecks

During my research on Italian technology providers in the immersive experiences sector, I had the opportunity to ask the interviewed companies which is the most important and delicate phase within the technological process described earlier. In particular, I asked the companies to indicate the phase which, according to their experience, can have the greatest influence on the effectiveness of the final product or service and on the development timing. As highlighted in the previous section, each of the phases represents an essential part of the process itself and each phase is important. However, some steps may be more critical than others, especially considering the risk of possible problems, delays, or errors.

The identification of the most delicate phase of the technological process is of particular importance because it allows to concentrate more on that specific area, dedicating more resources, time, and attention. In this way, it is possible to minimize the risks of potential problems and ensure the maximum efficiency and quality of the process.

The initial phase of the technological process, known as Assessment, was identified as the most important and delicate by the companies in the immersive experience sector interviewed. In particular, the operators of the sector have underlined the importance of the workshop and training activities during this phase. This phase is the one that starts the project and involves the customer and the operators in the technological process. One of the major obstacles during this phase is the need to make the customer understand both the limits and the potential of immersive technologies. Most companies have reported the confusion of clients regarding these technologies and the need to clarify the picture by showing concrete examples of immersive projects that often differ from the client's initial expectations.

Although it may seem like a simple phase, the Assessment plays a fundamental role in the technological process, as it allows establishing the foundations for the creation of a feasible immersive project. Furthermore, the client's decision to entrust the project to the company largely depends on the quality of the activities carried out during this initial phase.

Some companies, in particular Carraro Lab, attach great importance to the creative phase of ideation of the immersive experience. In this phase, they try to create a work of art by developing something unique and never seen before. The standards of quality and

originality are high and represent a fundamental objective for the success of the project.

After examining the crucial stages in the process of creating immersive experiences, it is essential to identify the critical stages and possible bottlenecks that can slow down the workflow and affect the overall productivity of the process. A bottleneck is a point of congestion in a system where the capacity of a component fails to meet the demand of subsequent activities, causing delays, errors, and additional costs. The term "bottleneck" refers to the typical shape of a bottle and the fact that the neck of the bottle is the narrowest point, which is the most likely place for congestion, slowing the flow of liquid out of the bottle. Bottlenecks are a common factor within technological processes and occur when a specific stage or activity within the process slows down the entire process and hinders its flow. Identifying the bottlenecks within a technological process is of fundamental importance to ensure maximum efficiency and productivity of the process itself. Recognizing the point of suffering allows operators to focus more on that specific area, dedicating more resources, time, and attention to solving the problem. An additional advantage of identifying bottlenecks is the possibility of planning more effective process management. Knowing the points of suffering allows for the prediction of any interruptions or delays in the process and planning accordingly. The companies interviewed, specialized in the creation of immersive experiences, agree that one of the biggest problems encountered concerns the digitization of 3D assets, with high costs and long processing times. This represents a bottleneck within the technological process which hampers the flow and productivity of the entire process. However, the use of technologies such as Artificial Intelligence could represent a solution to overcome this difficulty. The introduction of AI within technological processes represents a great opportunity for companies that wish to increase efficiency, reduce costs and improve the quality of work. Thanks to the AI's automatic learning ability, machines can analyze large amounts of data and identify patterns and anomalies more efficiently than humans. This means businesses can use AI to perform predictive analytics and identify potential issues in advance, enabling them to take proactive action to mitigate negative impacts. Only some of the interviewed companies currently use AI because the implementation of AI requires careful planning and secure integration, but companies that have started using it within their processes have experienced significant benefits, with the prevalent use of technologies such as Data Analysis and Machine Learning.

In conclusion, the companies analysed agree that the Assessment step represents the most important and delicate phase of the technological process. Active customer involvement and clarity of ideas in this initial phase are essential for the success of the project and for the customer's decision to entrust the work to the company while identifying bottlenecks

within technological processes is crucial to ensure maximum efficiency and productivity. Currently, the major problem encountered by companies operating in the sector of immersive experiences seems to be represented by the difficult activity of digitizing 3D assets, however, the use of Artificial Intelligence seems to be the solution to overcome this obstacle.

4 | Conclusions and future developments

This project began with the goal of offering an analysis of the Metaverse and the influence of immersive experiences in the marketplace. To address this endeavour, the term 'Metaverse' was initially defined as a network of collaborative and immersive virtual worlds in which an unlimited number of users can use avatars to interact, work, shop and participate in various activities. Next, the characteristics considered to be the most representative of the Metaverse were defined, which are: Immersiveness; Persistency, Interoperability, Sustainability, Hyper Spatiotemporality, Self sovereignty, Community driven. Subsequently, the underlying architecture of the Metaverse was explained, consisting of the following building blocks: Network, Computing, Artificial Intelligence, 3D Modelling, Blockchain, Internet of Things, Interface devices, Extended Reality.

Once the structure of the Metaverse was analyzed, the concept of immersive experience was defined. The discussion has then enabled the identification of several different but related key terms such as immersiveness, sense of immersion annd presence. According to this relation, the first term identifies the objective ability of a system to elicit a sense of immersion, that is, the feeling of feeling involved with the system with which one interacts, and culminating in the stimulation of presence, that is, the subjective feeling of proximity and perception of the virtual environment as real. The analysis of these concepts gave rise to a possible classification of types of immersive technologies based on the different sensory perceptions that may be involved during the immersive experience. The proposed classification saw the identification of four possible alternatives consisting of: Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR) and Haptic Technology. Each of these technologies was then described in its main characteristics so that it could be understood how each of them can affect the generation of sense of immersion, increasing the immersiveness of a system.

Then, linking to Suh and Prophet's (2018)[28] study in which the S-O-R framework is applied to immersive technology, it was examined how technological, content, psychological, cognitive and behavioural factors influence the successful implementation of immersive

technology and user adoption.
Afterwards, to meet the first objective of the thesis, applications of immersive experiences in different contexts were discussed, presented what are the most common uses to date. The discussion thus made it possible to corroborate the importance of immersive experiences in both present and future contexts. The second thesis objective, i.e. mapping the software/hardware providers in the sector and the platforms considered immersive, was addressed by first presenting an analysis of the as-is context to better understand the current state and future projections of the Metaverse. Subsequently, platforms that fulfil these characteristics were classified: they are 3D Worlds, host a multiplicity of people, allow social interaction and users can create customised avatars. Platforms were classified according to the mode of access (virtual reality devices or desktop/web browser) and the technology that powers their internal economy (blockchain or not). Global technology providers were classified according to the Metaverse sector in which they operate, the fields considered were: Avatars & Digital identities, Social, Virtual Retail & Showroom, Meta marketing, Virtual work, Industrial work, Economy creator, Spatial computing, Decentralisation, Interface, Infrastracture.
In conclusion, the Italian providers were classified and valuable insights into the generalities of the companies were generated. The last objective of the work includes identifying project development phases, time, and bottlenecks related to the Metaverse. To succeed in this work, it was essential to be able to interview Italian companies in the sector. With the data generated from the collaboration with them, it was possible to identify a sequence of steps necessary for the realisation of the immersive project. In addition, the steps that were critical and could generate a bottleneck were analysed.
In the final analysis, having come to the conclusion of the document, it is thought that what is described in this study may constitute a useful piece of literature to provide a survey and overview of the issues related to the Metaverse and the potential application of immersive technologies that are progressively contaminating our daily lives. Furthermore, the mapping of technology providers offers a guideline for companies aiming to enter the Metaverse.

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A | Appendix A

In this Appendix the following tables are reported:

- Metaverse platforms table
- Global providers table
- Italian providers table

Metaverse platforms table

Company	VR\No VR	Centr\Decentr	Release year	Operating systems	Degree of interaction	Monetization
Active Worlds	No VR	Centralized	Initial release: 1995 Stable release: 2022	Windows, Mac OS, Linux	Chat, group chat, voice chat	Monthly subscriptions to unlock premium benefits, selling virtual worlds
AltspaceVR	VR	Centralized	Founded in 2013 Initial release: 2015	Oculus Rift/Quest/Go, Windows Mixed Reality, HTC Vive, Windows Mac OS	Chat, group chat, voice chat, selfie	No monetization at the moment
Anyland	VR	Centralized	2016	Oculus Rift/Quest/Go, Windows Mixed Reality, HTC Vive, Windows	Chat, group chat, voice chat	Patreon
Avakin life	No VR	Centralized	2013	Android, iOS, ChromeOS	Chat, group chat	VIP Monthly Subscriptions (multiple packages available) In app purchases
Bigscreen	VR	Centralized	2014	Oculus Rift/Quest/Go, Valve Index, HTC Vive, Windows Mixed Reality	Chat, group chat, voice chat	Movie rental
Blankos	No VR	Decentralized	2020	Windows, Mac OS	Chat, group chat	NFT shops, NFT marketplace
Cluster	Both	Centralized	2015	Oculus Rift/Quest/Go, HTC Vive, Windows Mixed Reality, Windows, Mac OS Android, iOS	Chat, group chat, voice chat	In-app purchases
Core	VR	Centralized	2020	Windows	Chat, group chat, voice chat	In-app purchases
Criptovoxels	No VR	Decentralized	2020	Windows, Oculus Quest Mac OS, Android	Chat, group chat, voice chat	Land and wearable purchases, auction
Decentraland	No VR	Decentralized	2020	Windows, Oculus Quest Mac OS	Chat, group chat, voice chat	NFT shops, NFT marketplace
Fortnite	No VR	Centralized	2017	Windows, Mac OS, PlayStation, Xbox, Nintendo, iOS, Android	Chat, group chat, voice chat	In-app purchases, vip subscriptions
Gaia online	No VR	Centralized	2003	Windows, Mac OS	Chat, group chat	In-app purchases
HiberWorld	No VR	Centralized	2019	Windows, Mac OS, Linux, Android, iOS	Chat, group chat, voice chat	No monetization at the moment

Hubs Mozilla	Both	Centralized	2018	Oculus Rift/Quest/Go, HTC Vive, Windows Mixed Reality, Windows, Mac OS, Android, iOS	Chat, group chat, voice chat	Monthly subscriptions
IMVU	No VR	Centralized	2014	Windows, Mac OS, Android, iOS	Chat, group chat, voice chat	In-app purchases
Minecraft	No VR	Centralized	2011	PlayStation, Xbox, Windows, Wii, Nintendo, macOS, Linux, Android, iOS	Chat, group chat, voice chat	Game sales, in-app purchases
Mona	No VR	Decentralized	2021	Windows, Mac OS, Linux	Chat, group chat, voice chat	NFT shops, NFT marketplace, land purchases
Neos	VR	Decentralized	2018	Oculus Rift/Quest/Go, HTC Vive, Windows Mixed Reality, Windows, Mac OS, Linux	Chat, group chat, voice chat	NFT shops, NFT marketplace
Rec Room	Both	Centralized	2016	Windows, Mac OS, Xbox, PlayStation, Oculus Quest, Meta Quest, Pico, iOS, Android	Chat, group chat, voice chat	In-app purchases
Roblox	No VR	Centralized	2006	Windows, macOS, iOS, Android, Fire OS	Chat, group chat, voice chat	In-app purchases
Rove	No VR	Decentralized	2022	Windows, macOS, iOS, Android	Chat, group chat, voice chat	NFT shops, NFT marketplace
Sansar	Both	Centralized	2017	Oculus Rift, HTC Vive, Windows, Xbox	Chat, group chat, voice chat	In-app purchases, subscription plans
Second Life	No VR	Centralized	2003	Windows, Mac OS, Linux	Chat, group chat, voice chat	Marketplace, in-app purchase

Figure A.1

Sinespace	Both	Centralized	2016	Windows, Mac OS, Linux, iOS, Android, Oculus Rift, HTC Vive, Windows Mixed Reality	Chat, group chat, voice chat	In-app purchases, subscription plans
Somnium Space	Both	Decentralized	2017	Oculus Rift/Quest/Go, HTC Vive, Windows Mixed Reality, Windows, Mac OS, Linux	Chat, group chat, voice chat	NFT shops, NFT marketplace, land purchases
Spatial	Both	Decentralized	2016	Oculus Quest, Windows, Mac OS, Android, iOS	Chat, group chat, voice chat	NFT shops, NFT marketplace, land purchases, monthly subscriptions
Stageverse	Both	Centralized	2017	Oculus Quest, Windows, macOS, iOS, Android	Chat, group chat, voice chat	NFT shops, NFT marketplace
The Nemesis	No VR	Decentralized	2019	Windows, Mac OS, Android, iOS	Chat, group chat, voice chat	NFT shops, NFT marketplace, land purchases
The Sandbox	No VR	Decentralized	2012	Windows, Mac OS, Android, iOS	Chat, group chat, voice chat	NFT shops, NFT marketplace, land purchases
Utherverse	No VR	Centralized	2005	Windows	Chat, group chat, voice chat	In-app purchases
Vesta	Both	Centralized	2018	Oculus Rift/Quest, HTC Vive, Windows, Mac OS, Android, iOS	Chat, group chat	In-app purchase, monthly subscriptions
VR chat	VR	Centralized	2014	Windows, Oculus Quest/Rift, HTC Vive	Chat, group chat, voice chat	Mechandising, monthly subscriptions, in-app purchase
Wave	No VR	Centralized	2016	Windows, Oculus Quest Mac OS	Chat, group chat, voice chat	In-app purchases
Wooz world	No VR	Centralized	2010	Android, iOS	Chat, group chat	In-app purchase, monthly subscriptions
XRspace manova	VR	Centralized	2020	Android, iOS iOS	Chat, group chat, voice chat	VR headsets selling, in-app purchases
Zepeto	No VR	Centralized	2018	Android, iOS	Chat, group chat, voice chat	In-app purchases

Global providers table

Company	Main Sector	Metaverse Field	Foundation Year	Number of employees	Main Location
Genies	Avatar & digital identities	avatars & identities	2017	<200	Los Angeles, CA (US)
RTFKT	Avatar & digital identities, virtual fashion, collectibles	avatars & identities	2020	<100	London (UK)
Didimo	Avatar & digital identities	avatars & identities	2016	<50	Porto (PT)
Ready player me	Avatar & digital identities	avatars & identities	2014	<200	Tallinn (EE)
Cryptoavatars	Avatar & digital identities	avatars & identities	2021	<50	Zaragoza (ES)
Avatar sdk	Avatar, realistic character creation	avatars & identities	2014	<50	Santa Clara, CA (US)
Tafi	Avatar & digital identities	avatars & identities	2019	<100	Salt Lake City, UT (US)
Meta	Software development, connectivity	social	2004	>100K	Menlo Park, CA (US)
Snap inc.	Software development	social	2011	<10K	Santa Monica, CA (US)
Youtube	Internet, entertainment	social	2005	>100K	San Bruno, CA (US)
ByteDance	Internet, entertainment	social	2012	<50K	Pechino (CN)
Gather	Software development	social	2020	<100	San Bruno, CA (US)
Wechat	Software development	social	2011	<5K	Shenzhen (CN)
Amazon	E-commerce, internet, technology	virtual retail & showrooms	1994	>1M	Seattle, WA (US)
Walmart	Retail, technology, logistic	virtual retail & showrooms	1962	2M	Bentonville, AR (US)
Shopify	E-commerce, software development	virtual retail & showrooms, economy creator	2006	<50K	Ottawa, CA (US)
Etsy	E-commerce	virtual retail & showrooms	2005	<10K	Brooklyn, NY (US)
Tencent	Conglomerate, multimedia	virtual retail & showrooms	1998	>100K	Shenzhen (CN)
Alibaba	E-commerce, software development	virtual retail & showrooms, spatial computing	1999	<300K	Hangzhou (CN)
Rooom	Digital shoowroom, AR, VR	virtual retail & showrooms	2016	<200	Jena (DE)
Byondxr	Digital shoowroom, AR, VR	virtual retail & showrooms	2016	<100	New York, NY (US)
TAR (takeaway reality	AR, VR, consultancy	meta marketing	2020	<10	London (UK)

Subnation	Marketing	meta marketing	2018	<100	Los Angeles, CA (US)
Ocean Outdoor	Media, advertising	meta marketing	2007	<200	London (UK)
Geeiq	Marketing, Metaverse strategies	meta marketing	2018	<50	London (UK)
Publicis poke	Marketing, advertising	meta marketing	2019	<200	London (UK)
Rumfoords	Media, advertising, consultancy	meta marketing	2020	<50	New York, NY (US)
vSpatial	Software development	virtual work	2016	<50	Provo, UT (US)
Adobe	Software development, digital media	virtual work, economy creator	1982	<50K	San Jose, CA (US)
Iris	Software development, accountancy	virtual work	1978	<2K	Sloug (UK)
Microsoft	Information technology, software development, computer hardware, videogames	virtual work, industrial work, economy creator, decentralization, interface, infrastracture	1975	<200K	Redmond, WA (US)
Cavrnus	Metaverse platform	virtual work	2019	<50	Carlsbad, CA (US)
Vibe	IT services and IT consultancy	virtual work	2017	<200	Bellevue, WA (US)
MeetinVR	Softwre development, VR	virtual work	2016	<50	Copenhagen (DK)
Oracle	Information technology, software development, consultancy, cloud	industrial work	1977	<200K	Austin, Texas (US)
Nvidia	Computer hardware, AI, VR, gaming, robotics, supercomputing	industrial work, spatial computing, infrastracture	1993	<30K	Santa Clara, CA (US)
Sap	Information technology, ERP, CRM	industrial work	1972	>100K	Walldorf (DE)
Siemens	Conglomerate, eletrification, automation, technology	industrial work	1847	300K	Munich (DE)
Unity	Software development, 3D	virtual work, creator economy, spatial computing	2004	<10K	San Francisco, CA (US)

Sight machine	Software development, industry 4.0, big data, manufacturing analytics	industrial work	2011	<100	San Francisco, CA (US)
Autodesk	Software development	industrial work, spatial computing	1982	>10K	San Rafael, CA (US)
Roblox Corporation	Videogames, software development	economy creator	2004	<10K	San Mateo, CA (US)
Epic games	Videogames, software development	economy creator, spatial computing	1991	<10K	Cary, NC (US)
The Sandbox	Videogames, software development	economy creator	2018	<1K	Hong Kong, (HK)
RecRoom	Software development, VR	economy creator	2016	<300	Seattle, WA (US)
Genvid technologies	Software development, live streaming technology	economy creator	2016	<200	New York, NY (US)
Skillz	Mobile games	economy creator	2012	<300	San Francisco, CA (US)
Decentraland	Software development, connectivity, VR, blockchain	economy creator	2017	<200	New York, NY (US)
Buildbox	Software development, videogames	economy creator	2015	<50	Los Angeles, CA (US)
OpenAI	AI	spatial computing	2015	<1K	San Francisco, CA (US)
Niantic	Software development, AR, mobile games	spatial computing, interface	2011	<1K	San Francisco, CA (US)
Mozilla	Internet, software development	spatial computing	2005	<2K	San Francisco, CA (US)
Occipital	Mobile computer vision, software development	spatial computing	2008	<100	Boulder, CO (US)
O3DE	3D engine	spatial computing	2021	<50	San Francisco, CA (US)
Ethereum	Financial services, blockchain	decetralization	2014	<1K	Bern (CH)
Gemini	Financial services, blockchain	decetralization	2015	<1K	New York, NY (US)

Consensys	Software development, blockchain, fintech	decetralization	2015	<1K	Brooklyn, NY (US)
Tezos	Internet, blockchain	decetralization	2018	<50	Zug (CH)
IBM	IT services, IT consultancy	decetralization, infrastracture	1911	<300K	Armonk, NY (US)
Ava Labs	Financial services, blockchain	decetralization	2018	<300	Brooklyn, NY (US)
Dapper Labs	Blockchain, NFTs	decetralization	2018	<1K	Vancouver (CA)
OpenSea	Blockchain, NFTs	decetralization	2017	<1K	New York, NY (US)
Iota	Internet, blockchain	decetralization	2017	<200	Berlin (DE)
Immutable	Blockchain, NFTs	decetralization	2018	<400	Sydney (AU)
Solana Labs	Internet, blockchain	decetralization	2018	<300	San Francisco, CA (US)
Oculus	VR, computer hardware, software development	interface	2012	<1K	Menlo Park, CA (US)
Manus	VR, computer hardware, motion capture	interface	2014	<100	Geldrop (NL)
Haptx	Haptic technology, VR, AR, computer hardware	interface	2012	<50	San Luis Obsipo, CA (US)
Lofelt	Haptic technology, VR, AR, sofware development, computer hardware	interface	2014	<50	Berlin (DE)
Pimax	VR, computer hardware	interface	2015	<50	Shanghai (CN)
Magic Leap	AR, computer hardware	interface	2011	>1K	Plantation, FL (US)
PlayStation	Videogames, entertainment, computer hardware	interface	1994	>10K	San Mateo, CA (US)
Samsung	Conglomerate, computer hardware, smartphone, technology	interface, infrastructure	1938	<300K	Suwon-Si (KR)

Figure A.2

Apple	Computer hardware, smartphone, software development	interface, infrastructure	1976	<200K	Cupertino, CA (US)
Huawei	Computer hardware, smartphone, ICT infrastracture	interface	1987	<200K	Shenzhen (CN)
Neuralink	Biotechnology	interface	2016	<500	Fremont, CA (US)
DPVR	VR, computer hardware	interface	2014	<50	Shanghai (CN)
Google	Technology, information, internet	infrastructure	1998	<200K	Mountain View, CA (US)
Intel Corporation	Semiconductors	infrastructure	1968	>100K	Santa Clara, CA (US)
DFINITY Foundation	Internet, blockchain	infrastructure	2016	<500	Zurich (CH)
AT&T	Telecommunications, internet	infrastructure	1893	<300K	Dallas (US)
Verizon	Telecommunications, IT services , IT consultancy	infrastructure	1983	>100K	Basking Ridge, NJ (US)
Sony	Conglomerate, entertainment, computer hardwre, electronics, financial services	infrastructure	1946	>100K	Tokyo (JP)
Qualcomm	Semiconductors	infrastructure	1985	>50K	San Diego, CA (US)
AMD	Semiconductors	infrastructure	1969	<20K	Santa Clara, CA (US)

Italian providers table

Company	Sector	AR	VR	Foundation year	Main Location	Number of employees
AR Market	Immersive virtual experiences, AR, VR	X	X	2018	Roma (RM)	<50
Arte amica SC	Mobile app development, software, VR		X	2015	Lecce (LE)	<10
Aryel	AR, AR marketing	X		2020	Milano (MI)	<30
BadPug	App development, AR&VR solutions	X	X	2016	Milano (MI)	<10
Carraro LAB	AR,VR, platforms for web 3.0	X	X	1999	Palazzolo sull'Oglio (BS)	<10
Coderblock	Immersive Virtual Collabration, Metaverse	X		2016	Palermo (Pa)	<50
Digital mosaik	Immersive virtual experiences , VR, NFT, Blockchain		X	2016	Trento (TN)	<20
D-service Italia	VR, AR, AI	X	X	2013	Palermo (Pa)	<10
ElseCorp	Virtual retail, Fashion Retail, 3D design, 3D commerce	X	X	2014	Milano (MI)	<50
Fifthingenium	VR, AR, Cloud Computing, AI	X	X	2014	Milano (MI)	<50
Future Fashion	Fashion, Augmented Reality, 3D marketing	X		2017	Civitanova Marche (MC)	<50
Hevolus Innovation	VR, AR, AI, Metaverse	X	X	2000	Molfetta (BA)	<50
IKON Digital Farm	Digital experiences, Software solutions, VR, AR, IoT	X	X	1997	Staranzano (GO)	<50
Impersive	Virtual Immersive Experiences, VR		X	2014	Milano (MI)	<10
Innova	VR, AR, Immersive video, IoT, AI, Blockchain, NFT, Cybersecurity, Big Data, Web Agency	X	X	2017	Millazzo (ME)	<50
InVrsion	VR & AR retail experiences	X	X	2015	Milano (MI)	<30
KNOBS	Blockchain, software			2014	Milano (MI)	<60
LD multimedia	VR, Video360		X	2003	Moncalieri (TO)	<10
Oniride	VR, AR, 3D immersive environment	X	X	2014	Roma (RM)	<10
Ooniverse	Metaverse, VR, AR, NFTs,	X	X	\	Olbia (OT)	<10

OpenMall	Metaverse, AI, Big Data, NFT, AR		X	2019	Milano (MI)	<50
OVR (Over The Reality)	Metaverse,VR,AR, 3D Assets Production, NFTs	X	X	2018	Udine (UD)	<50
Periodico Studio	AR, AR marketing	X		2021	Livorno (LI)	<10
Pikkart	AR, Software development, Mobile App	X		2014	Modena (MO)	<50
Realmore	AR, VR, 3D holographic	X	X	2018	Milano (MI)	<50
Reasoned Art	NFT, crypto art, digital collectables, tourism			2019	Genova (GE)	<50
Revibe	NFT, metaverse, 3D Assets Production		X	2022	Torino (TO)	<50
Saysoon	NFT, crypto art, digital collectables, blockchain			2021	Milano (MI)	<10
Smiling	Blockchain, NFT, MarTech, AdTech			2017	Milano (MI)	<20
SoNi Srl	AR, VR, 3D service	X	X	2014	Udine (UD)	<10
Staragraph	NFT, digital collectables, entertainment			2017	Roma (RM)	<10
Superresolution srl	VR, AR, 3D immersive environment	X	X	2015	Empoli (FI)	<10
TechNova	AR, digital humans, consultancy	X		2022	Monza (MB)	<10
Tresessanta studio	VR, video marketing		X	2012	Rimini (RN)	\
Versy	Immersive Virtual Collabration, Metaverse		X	2022	Dubai	<10
VirtuItaly	Immersive Experiences, Immersive Virtual Exhibitions, VR		X	2015	Firenze (FI)	<10
XRIT	VR, AR, Gaming	X	X	2020	Sassari (SS)	<10
VRtualize	VR, AR, 3D experience	X	X	2021	Milano (MI)	<10

Figure A.3

Table of interviews with Italian providers

Figure A.4

Company	Core business	Core industry served	AI? For what purpose?	Main planning phases	Bottlenecks and most important st	Actors involved	Pricing	Partnership
Digital Mosaik	VR, Immersive experiences for existing platform	Multisector	No	Assesment, Discover, Design, Develop, Distribuite	Cost of 3D asset digitization activities, often high and linked to long processing times (AI to remedy the problem). Delicate phase of customer training	Developers, 3D artists, Technical Artists, Marketers, Art Director, Producer and Project	From 30k€ per project	No
Fifthingenium	XR, VR, AR experiences	Tourism, Industry 4.0, Training, Medical	Data analysis, 3D modeling, conversational agents	Workshop, Training, Project Running, Review, Deployment	Workshop to break the ice	Business developers, Tech experts, Project managers	Training and installation: from €10k Deployment: from €40-50k	Technological partners especially hardware, the most important: Microsoft,
Periodico Studio	Communication agency, AR experiences	Multisector, in particular: Luxury, Architecture, Design, Hospitality	No	Public relations, Design and Development (from the idea to the solution), Technical	Transform the idea into something feasible, assessment and training.	Project manager, Operations team	About 20k per year per project	AR developers, technical assistance,
Carraro Lab	Immersive experiences	Public administration (bodies-regions-ministries) Tourism and Culture, Marketing, Training sectors	For the Metamirror app that uses computer vision to create digital avatars	Experience Definition, Narrative Construction, Content Production, Editing, Rendering, Optimization and Software Editing	Involving the customer to make them understand what the potential of AR experiences is and why it can be important for a marketing campaign. Work platform limitations	Commercial, Production manager, Director, Operators, 3D technicians, 3D coders	From €10k to hundreds of thousands of euros	Amazon web services for cloud, system integrators for greater capability and
Oniride Srl.	Immersive experiences, metaverses	Culture	To personalize the experience based on customer preferences	Brief (formalization of the idea), Analysis of requirements, Detailed design, Implementation and	Formalization of the idea, making the customer understand what is feasible and what is not	Business developer, Commercials, Digital producer, Testing technicians	From €30-40k to €1M	Research, production of technology, increase capabilities
IKON Digital Farm	VR, AR, immersive experiences	Tourism, Culture, Retail, Restaurants	Data analysis, machine learning, feature recognition	Collection of requirements-briefing with the customer, Functional analysis, UX design, Execution of the graphic part, Development of	Initial phase, collection of requirements and UX design	Account, Sales, Analysts, Developers, 3D artists, Animators, Project managers,	From €10k to €300k	Technological partners such as samsung or microsoft, technicians
InVRsion	VR, 3D	Consumer Packaged Goods brands (Coca Cola, Nestlé, Ferrero), Retail	Machine Learning to transform photos into 3D digital twins	Assesment, Discover, Design, Develop, Distribuite	Cost of 3D asset digitization activities, often high and linked to long processing times (AI to remedy the problem). Delicate phase of customer training	C-level manager (marketing, research), Project manager, 3D artist, Engineers	license 20k€ per year, virtual environment 15k-90k€, 3D representation 65€-1000€	Partner per marketing (es. IPSOS), gruppi retail (RetailHub e Retail Institute o NRF).

List of Figures

1.1 Typologies of human experience 12
1.2 Relationship immersiveness - immersion - presence 12
1.3 Augmented Reality properties 15
1.4 The modalities of AR systems 16
1.5 Quality dimensions of a VR system 17
1.6 Mixed Reality properties 19
1.7 Structure of a haptic gloves 20
1.8 S-O-R framework applied to immersive technologies 22

2.1 Vincos graph 39
2.2 Image of Decentraland virtual world 43
2.3 Headquarters of global technological providers in percentage 48
2.4 Life years of Italian technological providers 49
2.5 Italian technology providers and sectors of interest 50

3.1 Digital Mosaik Logo 53
3.2 FifthIngenium Logo 54
3.3 Periodico Studio Logo 55
3.4 Oniride Logo 56
3.5 Carraro LAB Logo 57
3.6 IKON Logo 58
3.7 InVRsion Logo 59

A.1 82
A.2 87
A.3 89
A.4 90

List of Tables

1.1 Summary of the sensory stimuli 23
1.2 Summary of the perceptual stimuli 24
1.3 Summary of the content stimuli 25
1.4 Summary of cognitive reactions 26
1.5 Summary of affective reactions 27
1.6 Summary of response in immersive technology use (positive outcomes) . . . 27
1.7 Summary of response in immersive technology use (negative outcomes) . . 28

2.1 Users presence in virtual Metaverse worlds 38