Designing Immersion in Art and Culture

INSIGHTS FROM ARTCAST4D PROJECT

Edited by
Davide Spallazzo and Mauro Ceconello

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ABSTRACT

This chapter presents findings from a systematic literature review on immersion's evolving definition amidst recent advancements in immersive technologies. Following PRISMA guidelines, 33 studies (2013-2022) from Scopus were analyzed. The results offer a comprehensive conceptualization of immersion and introduce its constituent elements, termed keys of immersion.
The review explores immersion across disciplines, notably in Computer Science and Engineering, focusing on Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) under Extended Reality (XR). It aims to define immersion, examine technology's role, and identify critical elements for immersive experiences.
Central to immersion is technology-mediated illusion, emphasizing sensory stimulation and user engagement (cognitive, emotional, physical). The research identifies six keys: Presence (feeling inside the environment), Cognitive and Emotional Engagement, Sensory Involvement (aligning real and virtual environments), Embodiment (active participation), and Isolation (positive detachment).

This review provides a comprehensive overview of immersion's definition amid technological advances. The keys offer insights for researchers, practitioners, and developers in immersive technologies, shaping understanding of immersive experiences.

1.1 Introduction

The emergence of immersive technologies signs a profound shift in the landscape of human-computer interaction. Beginning with tentative experimentations into Virtual Reality (VR) during the 1960s and culminating in the widespread availability of consumer-grade immersive solutions today, the trajectory of immersion has been marked by a path characterised by innovation and rapid advancement.
Once confined to the domains of scientific research laboratories and military training simulations, these technologies have transcended these confines to permeate nearly every aspect of contemporary life. They seamlessly integrate into modern existence, offering transformative experiences ranging from simulated journeys to distant galaxies to the pedagogical training of aspiring medical professionals and even to the virtual attendance of live musical performances from the comfort of one's home. Immersive experiences have become deeply rooted within our digital environment, reshaping our perceptions, engagements, and interactions.

In the rapid expansion of immersive technologies, an imperative for precision in terminology emerges. *Immersion* has become increasingly ubiquitous, yet its precise definition remains elusive. Is immersion merely the sensation of being enveloped within a virtual environment, or does it encompass a broader spectrum of experiences, including a profound sense of presence, agency, and emotional resonance?

The notion of immersion has been a subject of scholarly inquiry within the academic community, with its definition and scope evolving according to various theoretical and disciplinary perspectives. In 1994, Milgram and Kishino introduced the seminal concept of a virtual continuum, positing that immersive experiences span a spectrum from the physical to the virtual realm. This framework laid the foundation for subsequent research and development activities in virtual

and Augmented Reality (Milgram & Kishino, 1994). Studies such as the seminal work conducted by Slater and Wilbur (1997) delved into the effects and perceptions of immersion within the context of Virtual Reality technologies. Additionally, Bailenson and Yee (2005) investigated the psychological ramifications of immersive virtual experiences, contributing to a deeper understanding of the applications and potential implications of this transformative technology.

Without a unified understanding of immersion, discussions about immersive art and cultural heritage, among others, risk being ambiguous, hindering the establishment of cohesive frameworks, standards, and best practices. At the heart of this discourse lies the necessity to delineate the nuances of immersion within the context of art and cultural heritage. Is immersion solely dependent on the technological medium employed, or does it extend beyond the digital realm to encompass physical and sensory engagement?

Clarifying the concept of immersion is paramount for stakeholders across diverse fields. Researchers require a solid theoretical foundation to underpin their investigations into the dimensions of immersion. Practitioners seek guidance in designing immersive experiences that resonate with audiences, evoke emotional responses, and convey narratives authentically. Enthusiasts yearn for a deeper appreciation of the transformative potential of immersive technologies, both as channels for artistic expression and as tools for cultural valorisation. By fostering a shared understanding of immersion, stakeholders can deal with the complexities of this rapidly evolving landscape.
This shared lexicon catalyses interdisciplinary collaboration, facilitating dialogue between technologists, artists, cultural heritage professionals, and scholars. Together, they can unlock new avenues for artistic exploration, reimagine traditional modes of cultural representation, and forge deeper connections between individuals and their cultural heritage.

The quest for clarity in defining immersion transcends mere semantics; it lays the foundation for a richer, more meaningful discourse surrounding immersive art and cultural heritage. Accordingly, in this chapter, we report the results of a systematic literature review to provide an updated definition of immersion. The scholarly approach aims to highlight the qualities of a system that should be considered

immersive, at least according to scholars. These are intended as operational insights that may guide practitioners involved in the design of such immersive solutions. Moving from these qualities, here named keys for immersion, the chapter further lists those technologies that may be considered enablers of immersive experiences.

1.2 Research approach

To achieve our objective, we conducted a systematic literature review following the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines (Page *et al*., 2021), which provide a standardised methodology for replicable literature reviews.

Our review began with defining search criteria through the creation of two distinct queries, incorporating the terms *immersive*, *immersive technology*, and *definition*. These queries were then executed in the SCOPUS online database, focusing on article titles, abstracts, and keywords. SCOPUS was chosen as the primary research database due to its extensive coverage across multiple scientific disciplines, including humanities and sciences.

The defined queries – (immersion AND definition) and (immersive AND technolog* AND definition) – yielded 636 and 240 papers, respectively. To refine the results, exclusion criteria were applied, including availability of full-text, English language, and publication between 2013 and 2022.

Although the concept of immersion has been prevalent in scientific literature since the 1980s and 1990s, particularly with the emergence of Virtual Reality, our systematic review focused on the past decade to provide a contemporary overview. Our aim was to explore and to clarify how technological advancements have influenced the definition of immersion and its current conceptualisation.

Following the initial exclusion process, 155 papers remained, predominantly from journals related to Computer Science and Engineering. These papers underwent further screening based on title and abstract, eliminating those not pertinent to our research objective. Specifically, studies unrelated to immersive technologies, such as discussions on chemical immersion, were excluded.

Subsequently, 33 papers were carefully reviewed to assess their relevance, during which it became apparent that seminal references in the field needed to be included. To address this, we employed snowball sampling, tracing significant references from the reviewed papers to expand our dataset to 46 studies, spanning various application domains and timeframes.

We conducted two coding cycles to analyse the selected papers using the MaxQDA software. Given the clarity of our research objectives, a preliminary set of categories was established to guide the initial coding cycle (Saldaña, 2009). These categories included *Immersion Definition* and *Immersive Technologies Definition*.

Moreover, after gathering data on the predefined categories, a second round of focused coding was conducted to identify thematic clusters and commonalities (Saldaña, 2009).

Subsequently, affinity maps were created to visualize the prominent topics, aiding discussions on pertinent research topics and guiding researchers towards a holistic definition of immersion. Keywords derived from the analysis were designated as *Keys of Immersion*.

Furthermore, the investigation facilitated the creation of detailed clusters and descriptions of immersive technologies, as outlined in the subsequent sections.

1.3 Immersion: a multifaceted definition

Numerous scholars have contributed to the discourse on immersion, offering diverse perspectives that range from delineating specific characteristics of the phenomenon to observing user behaviours within artificial environments. This section presents the outcomes of the systematic literature review aimed at examining definitions of immersion within artistic and cultural contexts. The review encompasses a spectrum of newly proposed and established definitions, offering an overview highlighting the commonalities observed among various definitions encountered.

The first part synthesises references that conceptualise immersion as the shift of human attention from the physical world to the artificial realm. Building upon this foundation, the second part

explores the notion of isolation, which is closely intertwined with and serves as a defining feature of immersion. Moving forward, the third part delves into the fundamental role of the human sensory system in experiencing immersion, elucidating the influence of stimuli from the surrounding artificial environment on human senses.

Finally, the last part examines the varying degrees of user engagement within immersive experiences, underscoring the nuanced levels of involvement contributing to the richness of immersive encounters. This comprehensive exploration aims to provide a holistic understanding of immersion within artistic and cultural domains, shedding light on its multifaceted nature and implications for user experience.

1.3.1 Immersion as a shift of human attention

Upon analysing the selected papers, it becomes apparent that discussions on immersion largely disregard the physical world, placing significant emphasis on the intricate relationship with an artificial dimension. This artificial realm is depicted as essential for crafting immersive environments, projecting the illusion of an alternate reality.

For instance, Slater and Wilbur (1997) define immersion as «the extent to which computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality to the senses of a human participant». Similarly, Zhang (2020) characterises immersion as «the sensory and perceptual experience of being physically located in a non-physical, mediated, or simulated virtual environment».

In this context, the term *inclusive* signifies the extent to which the user's perception and engagement within the immersive environment transcend the confines of the physical world. It captures the degree to which the immersive experience envelops and absorbs the user, creating a sense of detachment from their immediate physical surroundings. As a result, the immersive environment becomes a self-contained reality that overtakes the influence of the external physical environment, fostering a deeper level of engagement and immersion for the user.

Similarly, Sas & O'Hare (2003) underscore the concept of the «shifting of focus of consciousness», whereby users move their attention from the physical environment to an alternative reality.

Murray (1997) describes immersion as «the pleasurable experience of being transported to an elaborately simulated place» and «the sensation of being surrounded by a completely other reality that takes over all of our attention and our whole perceptual apparatus». Additionally, Zhang (2020) highlights the notion of shifting attention by defining immersion as a «transcendental experience of being physically shifted into the virtual space». Zhang further asserts that «immersion in a virtual environment is a technology-mediated illusion that [...] leads to the alignment of one's attentional focus to a synthetic yet perceptually authentic reality». The author also emphasizes the critical role of the senses in redirecting focus from the physical to the artificial world.

The literature review reveals a compelling convergence between the virtual realm and contemporary efforts to define immersion, especially within contexts driven by technological advancements. This convergence indicates a remarkable shift in how immersion is conceptualized, with virtual environments increasingly shaping our understanding of immersive experiences.

While the evolution of immersion definitions is influenced by various factors, such as specific research domains and temporal constraints, the pervasive influence of recently popularised technologies is evident. These technologies, including virtual, augmented, and Mixed Reality, have revolutionised how we perceive and engage with immersive environments. This shift reflects society's growing reliance on digital interfaces and artificial environments to facilitate immersive experiences. Consequently, contemporary definitions of immersion prioritise technological aspects, emphasising the role of digital simulations and sensory stimuli in creating immersive encounters.

1.3.2 Immersion as isolation

Several papers examined in the analysis delve into transitioning attention from the physical realm to the artificial environment within immersive situations. This phenomenon introduces the concept of isolation, wherein individuals find themselves mentally and perceptually detached from their immediate physical surroundings. The concept of isolation within immersive experiences highlights the profound shift in cognitive focus when individuals engage with

virtual or simulated environments. As users immerse themselves in these artificial worlds, their attention becomes increasingly directed towards the digital stimuli and sensory inputs presented within the immersive space.

For instance, Lidwell *et al*. (2010) suggest that individuals lose their «awareness of the real world» when immersed in virtual environments. Similarly, Turner *et al*. (2016) establish a connection between the concept of isolation and the technological aspects of immersive systems. They define immersion as «the degree of technologically mediated sensory richness that facilitates isolation or decoupling from the real world». Additionally, Spence *et al*. (2017) conceptualise immersion as encompassing «a range of internally perceived states [...] that focuses the participant's attention to the exclusion of everyday concerns». The authors further explore related concepts such as involvement, multi-level treaty, participant attention, and detachment from the real world. Moreover, the experience of isolation in immersive environments can be characterised by a heightened sense of presence and engagement with the virtual content. As users become absorbed in the immersive experience, they may lose awareness of their physical surroundings, experiencing a state of cognitive and perceptual immersion within the artificial environment.

The sensation of detachment from the physical world, where users fully or partially concentrate on the artificial environment, is linked to the perceived level of immersion. This sense of isolation from tangible surroundings is crucial in amplifying the immersive environment and enhancing the user's feeling of presence within the virtual realm.

1.3.3 Human sensory system and artificial stimuli

While immersion typically revolves around the virtual realm, scholars acknowledge the importance of reconnecting and interacting with the physical world. They highlight the crucial role human sensory and perceptual experiences play in this process. Despite the allure of immersive virtual environments, scholars recognise the inherent value of our physical senses in shaping our understanding and engagement with the world around us, focusing on how humans perceive the artificial environment. Perceiving the immersive environment can be effortlessly experienced. Sweetser and Wyeth's GameFlow model of

enjoyment in video games (2005) describes immersion as «a deep but effortless involvement that can often lead to a loss of concern for self, everyday life, and an altered sense of time».

Conversely, a physical sensation linked to perception and verbs like *feeling surrounded*, *enveloped*, and *immersed* are identified in literature as defining features of immersion, despite its occurrence within an artificial environment. Josephine Machon (2013) underscores this notion by defining immersive systems as «systems that generate a three-dimensional image that appears to surround the user».

The verbs *sensing* and *perceiving* appear frequently in the definition of immersion. Murray (1997) captures immersion as «the sensation of being surrounded by a completely other reality», emphasising the sense of being enveloped by an alternate world. Similarly, Biocca and Delanay (1995) delve into the perceptual dimension of immersion, characterizing it as «the degree to which a virtual environment submerges the user's perceptual system». It highlights the immersive experience's ability to deeply engage the user's senses, effectively transporting them into the virtual environment and blurring the boundaries between reality and simulation.

Enveloping stimuli and human perceptions also resonate with Palmer's studies (1995), where immersion is articulated as «the degree to which users of a virtual environment feel engaged, absorbed, and encompassed by the stimuli of the virtual environment».

This further underscores the immersive experience's ability to captivate users and create a profound sense of engagement and absorption within the virtual world.

Other scholars delve into the concept of enhancing human sensory capabilities. Zhang (2020) conceptualises immersion in a virtual environment as a technological system that «engulfs the senses», emphasising the comprehensive nature of sensory engagement within immersive experiences. Similarly, West *et al*. (2015) discuss a «sensory augmentation» phenomenon, particularly in the context of VR and AR technologies, which enhances the interaction between physical reality and digital data. This augmentation amplifies sensory experiences, blurring the boundaries between the physical and virtual worlds.

Human-environment interaction involves multiple senses, as highlighted by Sommer *et al*. (2020), who emphasise that «full

immersion addresses all human senses». By engaging all senses, immersive technologies aim to replicate the richness and complexity of real-world experiences, further enhancing the user's sense of presence and immersion within virtual environments.

The sensory environment encountered by users plays a pivotal role in shaping their perception of immersion. Stimuli received through various sensory channels, including visual, auditory, tactile, and others, significantly impact the user's sense of immersion. The quality and fidelity of these sensory inputs, as well as the relative importance of each (such as sight versus stance, sight versus acceleration, etc.), contribute to creating a more immersive and realistic experience. This enhances the overall sense of presence within the virtual environment while isolating users from the physical world, promoting engagement and embodiment. Literature includes case studies exploring the use of sensory stimulation in immersive environments, as evidenced by the work of Pietroni and Antinucci (2010).

While virtual immersion provides captivating experiences, scholars emphasize the importance of incorporating physical sensations and perceptions into immersive encounters. This recognition underscores the need for a balanced approach that integrates both virtual and physical dimensions to create truly immersive experiences.

By acknowledging the interplay between virtual and physical elements, scholars aim to enhance immersive encounters' overall richness and authenticity.

1.3.4 Different levels of engagement and embodiment

The analyzed papers illustrate varying levels of immersion that individuals can experience, depending on how effectively interactions within an immersive environment foster engagement. Spence *et al.* (2017) note that immersive engagement occurs on cognitive, emotional, and physical levels. Slater and colleagues focus on the physical aspect, describing immersion in terms of «sensorimotor contingencies», which Witmer and Singer (1998) define as the «physical actions required within a specific environment to perceive and interact with that environment».

Buttazzoni *et al.* (2022) present the concept of «place immersion», categorized into neuro-spatial, psycho-spatial, and socio-spa-

tial domains. They characterize immersion as an «embodied process of an effortless experience» influenced by «multiple factors including environmental context, cognitive elements, and social interactions». Witmer and Singer (1998) also describe immersion as a response to an environment that «envelops the participant and facilitates interaction with a continuous stream of virtual and haptic stimuli», highlighting the rich, ongoing nature of sensory input typical in immersive settings.

Despite the diverse interpretations encountered, the overarching themes from the literature review converge on the comprehensive nature that defines immersion. The research group has identified engagement as a crucial factor in determining the user's level of focus within the immersive experience, encompassing both cognitive and emotional dimensions. Additionally, embodiment relates to the degree of interactivity experienced by the user within the immersive environment, involving them in various ways.

1.4 Immersion definition and Keys of Immersion

Based on the findings reported in the previous section, this segment offers a synthesized definition that encompasses the traits and characterizing elements recognized by various scholars over the past decade.

Immersion can thus be defined as «the sensory and perceptual experience of being surrounded by an environment perceived by the user as the real and prominent one: this artificial world is able to engage the user cognitively, emotionally, and physically, suspending attention from the concrete world».

This definition highlights the significance of human sensoriality and the stimuli provided by the artificial environment, which overshadow those from the physical realm. The user's attention is fully shifted, leading to complete cognitive, emotional, and physical engagement with the artificial dimension in which they are immersed.

From the literature analysis, as synthesized in the given definition, valuable elements can be extrapolated to identify the distinctive traits of immersion, referred to as Keys of Immersion.

The *Keys of Immersion* encompass recurring elements associated with the concept of immersion and include:

- Presence;
- Engagement:
  - Cognitive level;
  - Emotional level.
- Sensory involvement;
- Embodiment;
- Isolation.

The following section, structured as a glossary, delves deeper into and defines each *Key of Immersion*.

1.5 Keys of Immersion

1.5.1 Presence

Presence is frequently discussed in conjunction with the concept of immersion and is sometimes used synonymously. Slater *et al*. (2009) and Heeter (1992) describe it as the sensation of being within the environment where one is immersed. According to Cummings and Bailenson (2016), increased immersion typically enhances the sense of presence. There is a direct correlation between the perception of presence in a given environment and the level of immersion experienced by the user. When users feel a strong sense of presence, they become deeply absorbed in the artificial world, resulting in heightened immersion.

1.5.2 Engagement

According to O'Brien and Toms (2018), numerous studies have characterized engagement through various attributes, such as media presentation, perceived user control, choice, challenge, feedback, and variety. These attributes collectively highlight the physical, cognitive, and affective aspects of user experiences. They define engagement as «a quality of user experiences with technology that is characterized by challenge, aesthetic and sensory appeal, feedback, novelty, interactivity, perceived control and time, awareness, motivation, interest, and affects». Building on these definitions, a clear relationship emerges between user engagement and perceived

immersiveness. Cognitive engagement focuses on the conscious involvement of the user, where active participation and mental concentration enhance the immersive experience. In contrast, emotional engagement emphasizes the subconscious elements of the experience, exploring the user's emotional responses and feelings that may not be immediately evident or consciously recognized.

1.5.3 Sensory involvement

As demonstrated earlier, sensory involvement plays a crucial role in shaping an immersive encounter. According to Naef *et al*. (2022), heightened sensory immersion correlates with enhanced alignment between the real and virtual environments facilitated by advanced technologies. This alignment fosters a stronger sense of presence within the virtual environment. Sensory involvement, integral to immersion, involves the interaction between human sensory faculties and stimuli presented by the artificial environment. It encompasses the engagement of multiple sensory modalities including vision, auditory perception, tactile sensation, and even proprioception, thereby creating a comprehensive and immersive experience for the user.

1.5.4 Embodiment

Embodiment refers to the experience of being enveloped by simulated sensorimotor information in mediated environments, creating a personal sense of undergoing the experience firsthand (Ahn, 2011). It entails a deep engagement on an identity level, focusing more on internal human perception rather than on external interactions with the environment, influenced by the extent of interaction within the experience. Embodiment enables users not just to observe but also to actively participate in and manipulate the virtual environment, thereby significantly enhancing their overall sense of immersion. Through embodied interaction, users gain a sense of agency and control, which strengthens their emotional engagement and cognitive investment in the experience.

1.5.5 Isolation

In the literature, isolation from the physical world is viewed positively in the context of immersive experiences because it facilitates a shift

in the user's focus to a virtual environment. Turner *et al.* (2016) describe isolation as a natural outcome of immersion, defining it as «decoupling from the real world». This isolation is essential for reducing distractions and external influences, allowing users to become more mentally and emotionally engaged in the virtual environment. Embracing this isolation enables users to freely explore, interact with, and fully experience the artificial environment, detached from the constraints of the physical world.

1.6 Identifying Immersive Technologies

The term *technology* encompasses the broader technological domains identified and explored as facilitators of immersive experiences, such as Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), Extended Reality (XR), projections, lighting systems, and others. In contrast, *tools* specifically refers to the devices and equipment used to practically apply these technologies. This includes Head-Mounted Displays (HMDs), simulators, mobile devices, projectors, and other relevant tools employed to deliver immersive experiences to users.

Various technologies associated with the concept of immersion have been identified in the literature, each offering different levels of immersive capability. These technologies are collectively referred to as immersive technologies. Through systematic literature analysis, it became evident that in the last decade, particularly within the fields of Computer Science and Engineering, Virtual Reality (VR) and Augmented Reality (AR) are prominently recognized as immersive technologies. VR and AR technologies are typically positioned along the Virtual Continuum introduced by Milgram and Kishino (1994), which delineates a spectrum of Mixed Reality (MR) experiences.

Within the Virtual Continuum, Augmented Reality (AR) is situated near the Real Environment, as it overlays virtual objects onto the physical world, while Augmented Virtuality (AV) is closer to the Virtual Environment, integrating physical objects or content into a virtual substrate. According to Lohre *et al.* (2020), Virtual Reality (VR) offers fully virtual worlds, AR enhances real-world interactions with virtual overlays,

and Mixed Reality (MR) spans the spectrum between these two extremes. In recent years, AR, VR, and MR have been commonly grouped under the umbrella expression *Extended Reality* (*XR*) *technologies*. Zhang (2020) defines XR as technology encompassing VR, MR, and AR, creating simulated and augmented realities that extend beyond physical boundaries. Furthermore, researchers have explored the concept of the Metaverse in relation to XR technologies, which allows continuous access to online content using XR tools (Pimentel *et al*., 2022). Initially defined by Stephenson (1992) as a realm where human avatars interact with software agents in a 3D space mirroring reality, the Metaverse has evolved. Lee and Kim (2022) provide a comprehensive definition, describing it as a persistent mixed-reality world where people and objects interact synchronously across time and space, utilizing avatars, immersive devices, platforms, and infrastructure.

Building upon these insights into immersive technologies, the following sections present definitions of VR, MR, and AR derived from a systematic review of literature published in the past decade. Additionally, explicit connections to the Keys of Immersion defined in the preceding chapter are highlighted.

1.6.1 Virtual Reality

Jaron Lanier first coined the expression *Virtual Reality* in 1986, which has since evolved with advancements in technology. Various definitions of VR have emerged in the literature, often reflecting aspects associated with the previously identified Keys of Immersion. Presence, engagement, and sensory involvement are among the recurring terms found in these definitions.

Steuer (1992) associates VR with presence and telepresence, describing it as «the sensation of being in an environment generated by natural or mediated means». The Department of Defense (2018) emphasizes presence within virtual environments through the perception of objects. Benoit *et al*. (2015) suggest that VR «can evoke the sensation of physical presence in locations representing real or imagined worlds».

Engagement is highlighted in several studies focusing on interactivity and user experiences in VR environments. Bisson *et al*. (2007) define VR as «a real-time interactive simulation», while McCloy and

Stone (2001) describe it as enabling «real-time interaction with digital databases». Barbosa *et al.* (2019) compare VR to «an immersive individual experience driven by interactive stimuli». Optale *et al.* (2010) connect VR's interactivity with visual, tactile, and kinesthetic perception, and Hsieh *et al.* (2018) explore user interaction through multiple sensory modalities.

Sensory involvement is another concept emphasized by scholars. Sommer *et al.* (2020) note the integration of visual, auditory, and haptic senses in VR applications. According to Merriam-Webster's online dictionary, VR is experienced through sensory stimuli such as sights and sounds. Kilmon *et al.* (2010) and Mantovani *et al.* (2003) describe visual and auditory feedback as pivotal for immersion in VR environments. Lohre *et al.* (2020) link head-mounted displays and controllers to visual, auditory, and haptic feedback. Dos Santos Mendes *et al.* (2012) define VR as a «computer-based technology providing a multisensorial environment».

Regarding the virtual environment itself, scholars highlight that VR is generated from a computer device to create a three-dimensional environment. Schroeder (1996) defines VR as a computer-generated display that enables users to interact within a distinct environment. Glännfjord *et al.* (2017) characterize VR as a computer-generated simulation producing a realistic-looking world, while Levy *et al.* (2016) depict it as an interactive, computer-generated three-dimensional environment. The INACSL Standards Committee (2016) defines VR as a «computer-generated reality» that facilitates auditory and visual stimuli for learners.

In summary, the definitions and perspectives on VR from various scholars underscore its capability to create immersive experiences through sensory engagement, interactive elements, and computer-generated environments. These aspects align closely with the multidimensional nature of immersion as delineated in the literature.

1.6.2 Augmented Reality

The expression *Augmented Reality* was first coined by Caudell and Mizell (1992) and discussed by many scholars over the years. In their study, Ardiny and Khanmirza (2018) analysed the Milgram and Kishino (1994) Virtual Continuum, previously cited, to provide a definition of AR.

Their proposal described it as «an interactive experience in the real-world environment where the computer-generated information and elements are linked to the real world».

The scholars also analysed the production of AR contents as divided into three steps:

1. all physical-world data is collected by various sensors;
2. this information is then analysed, and additional information from different information sources;
3. the gained information is displayed as digital elements.

Analysing the definitions of Augmented Reality selected from the literature analysis, the connection of this digital technology with the real world is stressed out. Parveau and Adda (2018) define AR as technology that superimposes virtual information upon the real world, for example, adding text or images to what the user sees. Lopreiato *et al.* (2016) report the verb «superimpose» as well, talking about AR as a technology connecting synthetic stimuli to real-world objects. For the Department of Defense (2018) of the United States of America, AR overlays digital computer-generated information in natural-world objects or places. Its scope is to enhance user experience. «Overlay» is a word that is also found in the definition of Berryman (2012) that positions AR as between reality and digital information and emphasizes its role in improving the learning process. Azuma *et al.* (2001) define the combination of reality and virtual objects in the natural environment as a property of AR systems. Virtual objects coexist with the natural world in the same space. The combination of virtual elements and concrete world objects/images is an item also reported by Botella *et al*. (2016) and Lohre *et al*. (2020).

Regenbrecht and Shubert (2021) have studied the sense of presence inside the AR contest. Their studies regarded how important is the recognition of the virtual object as a tangible object by the user experiencing AR content. This could be related to Lee's (2004) definition of presence, as a «psychological state in which virtual (para-authentic or artificial) objects are experienced as actual objects in either sensory or nonsensory ways». The analysis of their results showed that both realness and spatial presence contribute to the acceptance of an AR system by users. It is also interesting the way in which they underline different ways of having AR expe-

riences through head-mounted devices, hand-held devices, and projections on real-world objects. The sense of presence is also studied by Marto *et al.* (2020) related to the sensory involvement concept in AR. Indeed, in their study on AR experiences for Cultural Heritage, they define the integration of smell and audio as sensory stimuli enhancement of AR technology. The conclusion of their statistical analysis demonstrates how the involvement of a sensory part inside the AR experience does not directly enhance the sense of presence of users, but it influences the enjoyment of the experience and the acquired knowledge from the cultural visit. In their study, Arghashi and Yuksel (2022) investigated the level of engagement AR technologies bring to the consumer experience for brands strategy. They report other studies confirming that the engagement felt by customers enhances consumer satisfaction (Javornik, 2016; Hilken *et al*., 2017; Yim *et al*., 2017; Rauschnabel *et al*., 2019; Smink *et al*., 2019; Nikhashemi *et al*., 2021;). AR leads to great interaction (McLean & Wilson, 2019), immersion, novelty, enjoyment and usefulness (Yim *et al*., 2017) for consumers experiencing it. Moreover, other fields recognize this enhancement of engagement level. For example, in the application of AR technologies within circular economy activities and information, Katika *et al.* (2022) found a high level of user engagement, while Zuo *et al.* (2022) studied high engagement levels in the learning and gaming fields.

1.6.3 Other technologies and tools for immersive experience

Some technologies are discussed solely within specific application case studies, complicating the retrieval of prior research and literature on these technologies. However, we found it valuable to incorporate them into the chapter to present a broader view of available immersive technologies and tools. Below, concise definitions of each technology are provided.

Head-mounted display (HMD)

HMDs are wearable devices resembling goggles that users wear directly on their heads. These devices project digital or virtual information onto screens that cover the user's normal field of vision (Milgram & Colquhoun, 1999). HMDs can be utilized in both VR and AR technol-

ogies: in VR, the content is displayed to the user through lenses inside the visor, creating an immersive virtual environment. In AR, the HMD functions as a transparent lens through which users perceive the real world enhanced with AR projections displayed on the lens itself.

Cave Automatic Virtual Environment (CAVE)

It is described by Manjrekar *et al*. as a completely immersive Virtual Reality setting designed to replicate controlled environments (Manjrekar *et al*., 2014). Typically, a CAVE consists of a cubic room with rear-projection screens on its walls (Muhanna, 2015). Users are immersed within this cubic space and can interact with the virtual content presented. This system was first developed in 1992 by researchers at the Electronic Visualization Laboratory at the University of Illinois (Cruz-Neira *et al*., 1992).

Projections

The technology of projection for immersive installations and experiences holds significant practical implications. Drawing insights from grey literature and examining various technological aspects highlighted in case studies (Maldovan *et al*., 2006), it is observed that projection for immersive environments involves using projectors to display digital audio-visual content onto surfaces or objects within the physical environment. Some studios and artists also employ 3D mapping technology to project video or images onto buildings, specific environments, or three-dimensional geometries, ensuring a precise alignment of audio-visual content with the physical space, even when an audio system is not necessarily integrated.

Video 360º

Li *et al*. (2019) define the 360º video/image, also referred to as panoramic, spherical, or omnidirectional, as a novel multimedia format that delivers an immersive user experience. This content surrounds the viewer, providing a panoramic view distinct from traditional 2D representations, which are limited to flat planar surfaces. Apple Inc.'s QuickTime VR serves as a commercial example, enhancing this approach by transitioning from still images to video clips, initially branded as QT-VR 3.0. The immersive effect is achieved through

audio-visual content projected onto a sphere, covering the viewers' entire 360°×180° field of view.

Body tracking tools

As reported by Watada *et al*. (2010), tracking can be broadly defined as estimating an object's trajectory within a scene's image plane. Huang and Huang (2002) further emphasize that visual tracking of human body movement is now a pivotal technology across various domains. Body tracking technology plays a crucial role in immersive environments and installations by capturing and transmitting users' position and movements to the digital/virtual system, thereby enhancing interaction through multiple modalities.

Haptic devices.

According to Sreelakshmi and Subash (2017), haptic technologies are «the science of integrating touch sensation and control into computer-generated applications». Steinbach *et al*. (2019) define haptic devices as mechatronic systems that provide force feedback to users. These devices enable users to perceive the tactile sensation (e.g., velvet) and the physical presence or force of virtual objects (e.g., surgical instruments for operations, manipulation of delicate or soft objects), thereby ensuring enhanced control and interaction through tactile feedback.

Audio systems

Valbom and Marcos (2005) identified sound as a crucial element in establishing atmosphere and emotion. Their research underscores the importance of integrating sound with emerging interaction methods like gesture-based actions and 3D visual content within immersive environments.Significant advancements in this domain include the THX audio specifications, primarily designed for movie theatres and IMAX, alongside holophonic audio systems. According to literature findings, the primary role of immersive audio systems is to synthesize, manipulate, and render sound fields in real-time (Kyriakakis, 1998).

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