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A proposal for an integrated framework for immersive technologies

Guillem Bacete (Culturalink & INNOPAC)
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1. Introduction: problems and objective

Recent years have witnessed a fast-growing interest in immersive technology among scholars and practitioners. The term immersive technology originates from the first prototype of human- computer interaction in the mid-20th century (Sutherland, 1964), and today it commonly represents any technology capable of providing computer-generated stimulations with physical, spatial and visual dimensions (Suh and Prophet, 2018), such as virtual reality (VR), augmented reality (AR), mixed reality (MR), and others that are considered to lie in the virtuality continuum (Milgram and Kishino, 1994). Today immersive technologies are being widely leveraged to enhance user experience and ultimately improve innovation and competitiveness in a range of sectors and fields, from education (Rodriguez-Ardura & Meseguer-Artola, 2019; Tang et al., 2020; Wu et al., 2013) and health care (Tang et al., 2022) to tourism (Beck et al., 2019; Guttentag, 2010; Pratisto et al., 2022) and video games (Jennett et al., 2008; Michailidis et al., 2018; Nilsson et al., 2016). While there is an increasing awareness and capacity for the use of immersive technologies, in practice, however, theoretical research in this area has relatively lagged. Three significant problems can be noticed as follows.

First of all, the definition of immersive technology remains vague and imprecise. Most definitions in current literature have operational features to fit specific research purposes, while any scientific definition is still missing, as evidenced by its frequent overlap with VR (Slater and Sanchez-Vives, 2016), its confusion with “presence”,

"engagement" and "involvement" (Nilsson et al., 2016) and its misuse in the creative field to represent interactive and inclusive technologies (Carrozzino & Bergamasco, 2010; Guttentag, 2010; Jung et al., 2016). Secondly, the interplay between technology and humans has been generally neglected in the existing literature. While the roots of immersive technology lie in computer-human interaction, and both technology and user factors have been well studied respectively, how technology and people interact to achieve immersive outcomes is often treated as a black box that is outside the focus of research. Last but not the least, the application of immersive technology in cultural and creative sectors is not fully explored, in spite of that cultural and creative sectors are largely characterised by an experience economy, in which immersive technologies can play a crucial role.

To address the aforementioned problems and bridge the existing gap, our research endeavours to develop an integrated conceptual framework that synthesises current technological and psychological approaches to immersive technology. This framework aims to enhance our understanding of immersive technologies and facilitate the observation and explanation of the dynamic interplay between technology and humans in immersive generative processes.

2. Methodology

To establish a solid foundation, a literature review will be first conducted to delve into the existing technological and psychological perspectives surrounding immersive technology, with the main aim of extracting a synthetic conceptual definition, which gives importance to the interactive process between the technology and the user as the fundamental basis for the framework to be proposed. By defining immersive technology as an intersection between immersion and technology, a knowledge-based approach will be employed to deconstruct a technology into three knowledge bases: hardware, software and know-how, which subsequently results in four cross-cutting technological domains: namely (1) interoperability (hardware + software), (2) optimisation (hardware + know-how), (3) environment (software + know-how) and (4) experience (hardware + software + know-how). Based on this, further efforts will be given to the analysis of

features and functions of these four domains, as well as the possible role of users (i.e., developer and audience) in each domain to enable immersion generation.

Table 1. Comparative analysis between the technological and psychological perspectives

	Technological perspective	Psychological perspective
Convergence		
Nature	Immersion is essentially a technology-human interaction	
Precondition	Immersion results from isolating the user from irrelevant stimuli	
Mechanism	Immersive outcome is based on fidelity stimulation and fluid response.	
Divergence		
Property	Objective	Subjective
Source	Sensory stimulus	Attentional state
Isolation technique	Physical isolation	Mental absorption
The role of user	Passive	Active
The role of technology	Generator	Enhancer
Content	Frame	Driver

Source: elaborated by authors.

3. Results

3.1. Immersive technology based on the technology-human interaction

Immersive technology has its roots in the first prototype of computer-human interaction (Sutherland, 1964). Technology-centred and human-centred approaches have historically developed separately, often competing rather than merging, in an effort to gain a deeper understanding of immersive technology. While the technology-centred approach focuses on the technical features of immersive environments and requires the use of different sensory devices to make users interact with artificial information (Rubio-Tamayo et al., 2017), the human-centred approach concentrates on the psychological state and subjective state of individuals interacting with virtual environments, in terms of their mental investment and engagement in the activities(Agrawal et al., 2020). There are both differences and commonalities between the two approaches, as shown in Table 1. They converge in their understanding of the nature, prerequisite and mechanism of immersive technology, while diverging in their views on the property, source, isolation technique, the roles of users and technology and content of immersive technology. Based on their commonalities, it can be assumed that immersive technology is

essentially a technology-human interaction, where immersive outcomes result from the isolation of the users from irrelevant stimuli and the degree of immersion depend to some extent on the fidelity of the stimuli and fluid response. In other words, immersive technology can be understood as the collection of technical elements that mediate between the user and a virtual object or environment through the display of sensorial stimuli, which drives the user´s attention and elicit a sense of involvement in displayed contents.

3.2. Three knowledge bases of immersive technologies

Immersive technology is a special type of technology that contains both the essential characteristics of technology and the specificity given to it by immersion. Technology includes all the skills, knowledge, procedures, and contributions acquired for making, using and doing useful things (Chandra & Zulkieflimansyah, 2003). Knowledge exists in different forms, including tangible and intangible, hard and soft, codified and tacit, and explicit and implicit (Polanyi, 1997). From a knowledge-based perspective, immersive technology is composed of at least three bases of knowledge, as follows:

- Hardware. It is the tangible knowledge comprising the set of instruments and devices or equipment used in a system that enables its operation. In this sense, the different devices within the system determine its capabilities, in terms of storage, processing power, tracking (input data) and rendering (output data). Moreover, the different input/output devices allow the system to stimulate different senses. For example, a system equipped with stereoscopic vision displays, spatial audio or haptic interface has the ability to generate visual, auditory and tactile stimuli. Therefore, hardware characterizes the system's capacity, in terms of the array of supported actions and the available sensory stimulation possibilities or sensory-motor contingencies (Slater, 2009).

- Software. It refers to the intangible, technical artefacts such as programs, algorithms and other data structures embedded in a database that enable the system’s functionality. Software is at the intersection between the hardware and the user. On the one hand, the controller software regulates the hardware

through a set of instructions and routines to provide an appropriate response to user cues. On the other hand, programs and applications include the data that provide the interface, allowing the user to interact with the system. The software, therefore, carries the content represented in the immersive system, with which the user interacts, such as graphics or audio, and the instructions for the system to execute it in a way that is harmonious and comprehensible to the user. Thus, software features the system performance, in terms of effectiveness and efficiency.

● Know-how. It is a specific component that encompasses the skills and expertise from different domains used in the design, development and operation of a system to elicit immersion within the user. In other words, know-how enhances the immersive potential of the system and content. Know-how applies the understanding of how technology affects the user and what different pathways or mechanisms can be used by technology to elicit immersion. These mechanisms are essentially multi-sensory stimulation, which depends on the sensory-motor contingencies supported by the system, and mental absorption, resulting from the content's features and its narrative richness or the challenge it presents (Agrawal et al., 2020). Know-how can be sorted in terms of technical know- how (system's immersive potential) and creative know-how (content's immersive potential).

3.3. Four domains for technology-human interaction

There are four knowledge domains that can be identified in terms of different combinations of knowledge bases.

● Interoperability. The combination of hardware and software results in the interoperability between the different system components, an essential feature of immersive technology that describes the extent to which an immersive system works in a comprehensive and harmonic manner. This domain represents the configuration of the immersive system and its operational capabilities. A system is a heterogeneous set of hardware and software components whose purpose is

to establish the interaction between the user and the content. With this aim, the various components must communicate and coordinate effectively, ultimately working together to respond seamlessly and cohesively to user cues.

● Optimisation. It is the result of applying technical know-how to hardware with the aim of improving the performance of the equipment and subsequently its effectiveness in generating immersion. This domain involves the selection and configuration of equipment to maximise its performance at both device and equipment levels. At the device level, optimisation adjusts operating parameters to increase the efficiency of devices or to introduce improvements. At the equipment level, optimisation addresses the characteristics of the space where the immersive experience will take place to select an optimal composition of hardware (i.e. the type and a number of hardware components required for a given space of interaction) and its calibration (i.e. the fine-tuning of the input devices or sensors).

● Environment. Applying creative know-how to software aims to generate an interactive virtual environment that contains virtual elements with which the user can interact. The environment integrates a technical dimension and a content dimension. The technical dimension involves the characteristics of the database in terms of language, programs, and operations that generate the virtual environment, which affects how the user interacts within the virtual environment, as the software represents in the virtual environment the data it receives from sensors. The content dimension addresses content in terms of its typology, such as the plot and events that unfold during the interaction, or the level of challenge presented by the activities in which the user is involved. The results are not uniform, as they depend on the user's characteristics to generate immersion. The content may have richness in the narrative aspect and yet fail to engage the user in the plot if it is not of interest to the user.

● Experience. The combination of the three components of immersive technology is

designed to provide an immersive user experience. To do this, these technology components have to be combined synergistically to maximise the immersive potential of the system and content. The fluidity and naturalness of interaction, the ability of the system to isolate the user from irrelevant stimuli, the intuitive use of the system and the way in which content is presented to the users are features of the system that facilitate the user immersion. However, achieving user immersion during the experience is complex and depends on multiple factors, over which technology does not have direct control, as part of it relies on the user.

3.4. The role of users

The use of immersive technology is twofold: one the one hand, it is used by producers to generate immersive outcomes; on the other hand, it leads to immersive experience consumed by end-users. Producers are users who use their technical and creative skills to develop immersive experiences, based on their area of expertise, while end-users are consumers and recipients of the immersive experience, although this depends on the target persona, in the cultural sphere they are usually the visitors to a facility such as a museum. Producers and end-users contribute to immersive generative processes from producing and demand perspectives respectively.

- In the interoperability domain, producers enable an optimal operational capacity by setting up communication protocols and compatibility among these components in advance; end-users often need play a role as external device accessor with their equipment like smartphone, which can affect the final experience.

- In the optimisation domain, producers need utilise their expertise and skills to ensure an optimal combination of hardware by considering (1) the features of the space where the immersive experience will take place to decide the equipment composition and (2) parameter adjust for an accurate tracking. End-users have not a specific role in the optimisation, as they may not have the necessary skills to adjust hardware, but their feedback is critical for hardware

development, especially in terms of ergonomics and design features aiming to reduce physical discomfort.

• In the virtual environment domain, producers create the virtual environment by integrating the technical and creative dimensions of immersion, based on both software development and programming and arts and creativity. End-users explore the possibilities and limits of the virtual content, helping to identify bottlenecks and glitches.

• In the experience domain, producers conceive the immersive experience from a holistic perspective, in terms of the capabilities offered by the immersive system, how the content is integrated into the system, and what mechanisms are employed to facilitate consumer immersion. End-users, therefore, have the role of a testers, interacting with the content. Through their actions during the interaction, immersion is progressively generated.

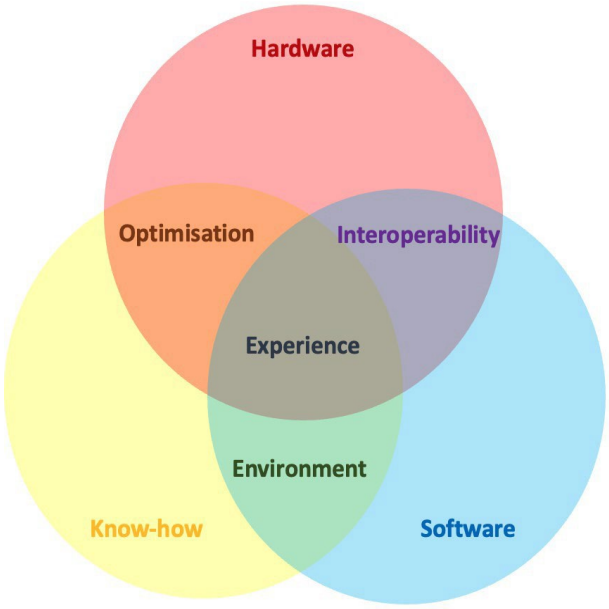

Figure 1. Four interaction domains of immersive technologies in terms of three knowledge bases.

4. Final remark and future work

Our research intends to propose an integrated framework for better understanding immersive technology by synthesising existing technological and psychological

perspectives while emphasising the interplay between technology and user in the immersive generative processes. By adopting a knowledge-based approach, we consider immersive technologies as collections of tangible and intangible knowledge carried by both producers and users, thus creating a theoretical space that makes possible the interaction of technology with humans. This framework can benefit the analysis and evaluation of the use of immersive technologies in experience-based sectors, such as cultural and creative sectors. However, the proposed framework is largely theory- driven and needs to be further tested and validated with empirical cases, which is the focus of our further work.

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