

Handbook of Research on Implementing Digital Reality and Interactive Technologies to Achieve Society 5.0

Original

Handbook of Research on Implementing Digital Reality and Interactive Technologies to Achieve Society 5.0 / Ugliotti, Francesca Maria; Osello, Anna. - ELETTRONICO. - (2022), pp. 1-731. [10.4018/978-1-6684-4854-0]

Availability:

This version is available at: 11583/2971513 since: 2022-09-26T12:57:49Z

Publisher:

IGI Global

Published

DOI:10.4018/978-1-6684-4854-0

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Chapter 1

Haptic Interaction in Virtual Reality: Are We Ready for the Metaverse? Neuroscientific and Behavioral Considerations 1

Alberto Gallace, University of Milano Bicocca, Italy

Touch is fundamental to create our perception of reality and to allow fulfilling social experiences, such as those at the basis of metaverses. In order to be accurately reproduced, a number of scientific and technological aspects should be considered. In this chapter, the authors highlight the relevance of the tactile modality in eliciting ‘presence’ in virtual reality interactions. They also discuss the neuroscientific foundation of our bodily interactions and the fact that they are based on a number of receptors and neural circuits that contribute to the complexity of our perceptions. The available technological devices for the reproduction of touch in virtual environments and their limitations are also described. They suggest that virtual interactions should include more of this sensory modality and that attempts should be made to go beyond the actual approach to ‘mimicking reality’. In particular, future simulations should consider the perspective of creative ‘hyper-sensations’ including ‘hyper-touch’ on the basis of our psychological and neuroscientific knowledge.

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The chapter presents research on the relationship between the human body and the space implemented by data and digital interfaces. In this relationship, technology plays a mediating role. The research introduces the concept of a digital threshold to an interactive space that has the capacity to preserve the cognitive well-being of users and invite interaction. To do this, some characteristics are identified that can be used in the design with the aim of relating the body to the devices in the space. Pressure stimuli, rhythm, and body symmetry are the components of a natural language capable of activating a natural motorial reaction mechanism. The details of the experimentation carried out and the processing of the data collected through data visualisation are provided to support the argument.

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In terms of technological advantages, virtual reality or augmented reality remains less popular within the field of learning disabilities. Research shows that children with learning disabilities face various challenges in their day-to-day lives dealing with these disorders, demanding massive solutions. This chapter will address the pros and cons of virtual reality in learning disabilities across different age groups by combining theories of virtual worlds and learning disorders. Exciting research in virtual reality focuses on finding out how psychotherapies have benefits in learning and education. Upon review, it becomes evident that research in the virtual world along with learning disabilities has not yet been examined from a cohesive perspective, illustrating a lack of alliance that determines a more global understanding of the technological advantages of disabilities. Thus, this chapter aims to provide educators with an overview of explanations of the virtual world and to ensure appropriate development of VR/AR applications and special assistance for learning disabilities.

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The challenges of practicum learning for the vocational institute are increasingly prominent. Innovation is needed to utilize technology and learning media to support distance learning and adaptive learning. Phytochemistry Practicum, a course given in the third semester of the Pharmaceutical and Food Analysis Department of Poltekkes Kemenkes Jakarta II, provides knowledge and skills to analyze chemical compounds in plants. This study aimed to develop interactive learning media for remote practicum of phytochemical screening materials at the Pharmaceutical and Food Analysis Department of Poltekkes Kemenkes Jakarta II. The methods used in this study were descriptive exploratory for laboratory experiment, multi-media development life cycle (MDLC) for AR development, and game development life cycle (GDLC) for building the gamification system. The augmented reality application and education game have been published in Playstore under the name AR Fitokimia and Virtual Lab Fitokimia. Both of these products were able to be accessed easily through mobile devices.

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The purpose of this study was to explore the potential affordances and challenges of 3D virtual environments in psychoeducational group counseling. The research design was based on multiple case

study methodology. Face-to-face and 3D virtual psychoeducational counseling groups were formed that focused on procrastination, and multiple forms of data were collected from both groups' participants. The study's results revealed that perceived affordances of the 3D environment for group counseling were similar in both groups, with self-disclosure, anonymity, convenience, interactive environment, and accessible content as the emerged affordances. However, the study also revealed mixed results in terms of perceived challenges. While interaction issues, multitasking, lack of social interaction, and trust concerns emerged as common to both groups, factors such as technical issues and negative attitudes towards virtual intervention were revealed as divergent themes. Intervention outcome results revealed similar patterns in terms of procrastination behavior change in both groups.

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After introducing the topic of education in immersive virtual reality (iVR), the authors describe the methodology and procedure used to test an educational game in virtual reality. The objective of this chapter is to contribute to the definition of a format for the evaluation of educational experiences in VR by describing the methodology adopted in the mentioned case study. A group of 30 students completed a lesson in virtual reality, and their experience was evaluated through qualitative (questionnaires, thinking aloud, interviews) and quantitative (task completion and time) tools. The results show some need for improvement of the simulation, but subjects were immersed in the experience and scored highly on the final assessment on understanding the educational content.

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Is digital innovation helping towards achieving a higher level of education or not? Since the impact of technologies is affecting more of our society, it is also true that its use in education is still limited, even in university education, where it could have the real added value of experimenting with new approaches to didactics. Within this context, the chapter briefly presents digital innovation and the enabling technologies currently in use that are also producing new opportunities for the architectural, engineering, construction, and operation (AECO) sector. Furthermore, the chapter provides two examples of master and bachelor courses related to BIM and algorithmic parametric modelling that integrates several tools and technologies, such as cloud-computing, big data, and machine learning to add value to harnessing technologies so that digital innovation could truly improve the efficiency of the AECO sector.

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The research is based on the hypothesis that integrating site-specific and global data into the design process requires a methodological design approach, which connects local to global systems and extends the application of available predefined algorithmic scripts and singular solutions. These tools allow the designer to apprehend and simulate possible future scenarios with unparalleled precision and speed. Computational design thinking will help us master increasingly complex design challenges as well as build a profound theoretical knowledge base to meaningfully integrate current and future technologies. After re-evaluating the principles of the computational pioneers, computationally driven methods for pressing urban challenges through data-informed design speculations are discussed. Cutting-edge design speculations aim to open up new immersive design simulation and participatory processes in environmental design and urban development and give sustainable answers to societal and environmental challenges, ultimately shaping our future world.

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This research experiments the theme of cultural heritage (CH) in architectural/engineering fields, located in urban space. Primary sources and new tactics for digital reconstruction allow interactive contextualization-access to often inaccessible data creating pedagogical apps for spreading. Digital efforts are central, in recent years based on new technological opportunities that emerged from big data, Semantic Web technologies, and exponential growth of data accessible through digital libraries – EUROPEANA. Also, the use of data-based BIM allowed the gaining of high-level semantic concepts. Then, interdisciplinary collaborations between ICT and humanities disciplines are crucial for the advance of workflows that allow research on CH to exploit machine learning approaches. This chapter traces the visualizing cities progress, involving Duke and Padua University. This initiative embraces the analysis of urban systems to reveal with diverse methods how documentation/understanding of cultural sites complexities is part of a multimedia process that includes digital visualization of CH.

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The methods, processes, and tools adopted according to the needs of the transition based on the Industry 4.0 should be based on the level of digitization of the companies, checking and monitoring their digitization over time, and considering the relation within the society. The study presented in this chapter starts from the work of the European community, directed to the assessment of the digital maturity of companies in the context of the European network of digital innovation hubs. Assessment that takes place through the compilation of questionnaires assessing the digital maturity of companies. Starting from what has been developed by the European community, the authors believe it is essential to develop specific focal points according to the peculiarities of the different sectors and in particular considering the construction one. This approach will open a new key to promote the digitalisation of the construction sector that is still lagging compared to the other industrial sectors.

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The information data that can be included in models can also relate to the different dimensional domains of BIM depending on the purpose of the model itself. On this premise, the POR-FESR eBIM project “Existing Building Information Modeling for the Management of the Intervention on the Built Environment” has developed skills, models, and solutions related to the conservation and enhancement of the built heritage using the BIM methodology implemented on dedicated IT platforms, identifying and characterizing the materials that compose it (from the shell to the structure to the covering). Among the various building materials, particular attention has been devoted to ceramic tiles and to their role and uses in the building industry for their digitization and use in BIM models on an open standard platform.

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The international fire safety framework defines the characteristics of an escape system that can communicate information to allow occupants to make the optimal decision to reach a safe place. Fire safety engineering is the subject that helps the designer to carry out analyses for the study of fire through the use of CFD (computational fluid dynamics) tools and escape modelling. The interaction between the escape system and the occupants is a factor that controls the effectiveness of the design solution. This factor is difficult to assess in the absence of specific tools. An analysis methodology based on numerical simulation models, aided by virtual reality tools, improves the interpretation of results. The authors set out to develop a method capable of exporting fire simulation in a virtual environment and visualising the results within a virtual reality environment. The methodology is able to improve the knowledge of the emergency dynamics within the fire scenario.

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Let us imagine a large sports facility and an integrated system to control its maintenance (structures, facilities, furnishings, communication systems), pre-configure temporary set-ups, procurement of goods and materials, check compliance with technical regulations concerning the safety and regularity of sports and recreational events, contracts with sponsors and suppliers, and the work of technical staff. Then, let's imagine that this mass of data is supplemented by tracking the flows of people attending events, recording their behaviour through the looks they make, the stops they make, the actions they take. This is the theme of the contribution proposed, an experimental application involving a sports facility of international importance and integrating BIM processes for design and maintenance, social and commercial information systems open to the public, marketing and usage analyses based on sensors and big data, and artificial intelligence capable of prefiguring the safest and most comfortable solutions.

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The new directions that digital reality is currently taking include an ever-greater involvement and interaction with the human being. In the field of cultural heritage, there is a need to find new ways to visit, enjoy, understand, and preserve cultural assets, also through digital fruition. The social value of cultural heritage and citizens' participation became crucial to increase quality of life, public services, creative activities, public engagement, new understanding, and education through technology development. Digital technologies can also contribute to safeguarding endangered cultural heritage preventive interventions, as well as ensuring equal and wide access to cultural assets and heritage sites. The aim is to find positive interconnections between physical and virtual spaces by applying digital systems to find additional knowledge and supporting the access to our common heritage through new technologies. The chapter explores more in detail these topics through the description of methodological approaches, applications of Semantic Web technologies, and latest projects.

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Preservation and dissemination of cultural heritage symbolizes a problem already present before the pandemic period and amplified during the COVID-19 crisis. As a result, the dematerialisation of architecture by digital technologies is the approach to connect Society 5.0 and architecture in cyberspace. The ambition of this chapter is to achieve an approach aimed to explain the impact of ICT during the pandemic and post-pandemic period, using HBIM technology, an essential tool for the approximation of Society 5.0 to the tangible smart heritage. On the other hand, the creation of a virtual tour breaks down architectural barriers (physical and spatial) allowing access to all users as a benefit of the dematerialisation of the asset. The work represents the use of technologies to create new knowledge and values, generating connections between people and tangible and non-tangible things.

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Heritage accessibility has been highlighted as a fundamental condition to convey multi-sphere values (social, artistic, economic, territorial), necessary for assigning the label of cultural heritage. Similarly, it permits to include new frontiers of educational processes for smart communities within digital data and VR systems developed from 3D survey actions. In this way, digital technologies can convey the societal challenge to evaluate the efficacy of cultural heritage communication beyond the in-situ physical experience, assessing the learning impact of virtual heritage environments. The scientific research on the production of effective heritage learning objects, from the EU project PROMETHEUS, is presented, enhancing opportunities of communication and virtual smart-fruition for sites along cultural heritage routes. Sites' virtual models are joined to physical prototypes to increase awareness and sustainable knowledge from the users' interactions with digital heritage.

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Starting from a recognition of the progressive settlement of the conception of cultural heritage through years, and the role that digital technologies have played, the contribution analyses how ICT (information communication technology) solutions, altogether intended, could provide a new human centrality in interpretation and presentation of cultural heritage. This opportunity is provided from the experience of INCIPICT project (INnovating CIty Planning through Information and Communications Technology), developed in L'Aquila since 2012. Within its framework, several reflections and applications on the field of cultural heritage have been developed to achieve results in terms of theory and praxis on the route toward a culture-based smart society.

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Cultural heritage represents the identity of people and, as such, is a fundamental element of our lives. The numerous projects carried out in recent years in the field of CH digitization have shown that the operation of dematerialization may be considered an essential tool for its preservation, conservation, and enhancement. Since advanced technology allows to valorize artifacts and bring a positive impact on the people's life to whom they belong, in the context of Society 5.0 it can be considered as a key tool. Starting from the analysis of the state of the art in the field of digitization, the main goal of the present study is to investigate the role that this process can take on within the complex process of valorization of monuments. To this aim, a research carried out on the Farnese Theatre will be illustrated. Particular attention will be paid to the methodological choices made for the creation of an extremely versatile three-dimensional model and for its possible uses.

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Society 5.0 has implemented the use of new digital technologies, overcoming traditional active learning systems with means and methodologies that extend the involvement of the digitized user. This trend has revolutionized how organizations and companies deliver their services through interconnected and interoperable platforms. The prevalence of new media has led to the adoption of applications that exploit gamification techniques and serious games to transfer reality into new virtuality. The contribution analyses procedures and methodologies that can be adapted to digitalize cultural heritage, focusing on the theatrical and musical entertainment sector (i.e., opera and theatre). During the COVID-19 pandemic, cultural organizations received significant containment measures to cancel events and openings. Therefore, investing inaccessible and reality-like digital applications through advanced participatory techniques reduced financial and target losses. In this way, the shift from the digital model to the interactive service model for sensory experiences skills the Citizen 5.0.

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The knowledge-intensive society paradigm fosters relationships between technology and human actors with data, values, and knowledge that become mutual drivers for social innovation. The cultural heritage sector is naturally influenced by this vision, and museums and cultural institutions have a prominent role in dissemination of cultural values. This chapter focuses on a method developed to combine the power of the computer visualization technology with the cultural elements spread across collections, introducing some notes and remarks on how digital replicas of drawings, manuscripts, and museum objects can be successfully employed to spread knowledge. Through a custom application called ISLe, aimed at visualizing 3D models that accurately replicate the original items, some experiences in the production of digital replicas are introduced, highlighting opportunities and criticalities to be considered in the adoption of technology that can be potentially shared and exploited by many possible figures involved in cultural heritage.

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Starlight Vattano, Università Iuav di Venezia, Italy

The chapter shows some of the outcomes of a research project begun in 2021 in collaboration with the Archivio Progetti Iuav of Venice, with the aim of disseminating the drawings, documents, and projects preserved. On the basis of the documentary collection including pieces, projects, models, together with a conspicuous repository of photographs and reproductions, the research deepens a little-explored aspect of an unbuilt Venice, circumscribing the investigation scope to the 20th century masters of architecture who contributed in rethinking the urban form of the lagoon city, such as Luciano Semerani's project for the sestiere of Cannaregio Ovest in 1978. The discussion on the Venetian structural system, the urban trace, and the architectural configuration is re-established in a dialogue between its history and its contemporaneity. This is achieved starting from the digital models and virtual tours with in-depth texts that integrate the information actions with respect to the qualities of the architectures and urban spaces activated and consulted with the exploration of the model.

Section 4

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The advent of mixed reality (MR) has revolutionized human activities on a daily basis, striving for augmenting professional and social interactions at all levels. In medicine, MR tools have been developed and tested at an increasing rate over the years, playing a promising role in assisting physicians while improving patient care. In this chapter, the authors present their initial experience in introducing different MR algorithms in routine clinical practice from their implementation in several neurosurgical procedures to their use during the COVID-19 pandemic. A general summary of the current literature on MR in medicine has also been reported.

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From Virtual Reality to 360° Videos: Upgrade or Downgrade? The Multidimensional Healthcare VR Technology 549

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This chapter aims to describe the multidimensional virtual reality tools applied to healthcare: in particular the comparison between virtual reality traditional tools and the 360° videos. The VR traditional devices could differ in terms of specific graphics (2D/3D), display devices (head mounted display), and tracking/sensing tools. Although they are ecological tools, they have several problems such as cybersickness, high-cost software, and psychometric issues. Instead, the 360° videos can be described as an extension of virtual reality technology: they are immersive videos or spherical videos that give the opportunity to immerse the subject in authentic natural environments, being viewed via an ordinary web browser in that a user can pan around by clicking and dragging. The comparison between those two technologies stems from the question if 360° videos could solve and overcome the problems related to virtual reality and be an effective and more ecological alternative.

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Francesca Maria Ugliotti, Politecnico di Torino, Italy

The development of serious games has enabled new challenges for the healthcare sector in psychological, cognitive, and motor rehabilitation. Thanks to virtual reality, stimulating and interactive experiences can be reproduced in a safe and controlled environment. This chapter illustrates the experimentation conducted in the hospital setting for the non-pharmacological treatment of cognitive disorders associated with dementia. The therapy aims to relax patients of the agitation cluster through a gaming approach through the immersion in multisensory and natural settings in which sound and visual stimuli are provided. The study is supported by a technological architecture including the virtual wall system for stereoscopic wall projection and rigid body tracking.

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Technological progress must aim at creating Society 5.0 by developing tools to support people. This contribution aims to show how modern technologies and their integration into society can support people with fragility. In particular, the authors present the prototype of a technology that the Turin Polytechnic has developed to provide an IoT device control tool for people with motor neuron degeneration. This, through the use of eye-trackers and building information models (BIM), allows the navigation of models in virtual reality and interaction with different devices and services. Furthermore, the use of micro-

services and the use of standard exchange formats allow easy integration with different services. The authors want to show how it is possible to build applications that, by bridging the real and the virtual, can restore autonomy and quality of life to the frailest people.

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This chapter focuses on the context in which patients such as those with Amyotrophic Lateral Sclerosis (ALS) are placed and what possibilities information and communication technologies (ICTs) offer to keep them in touch with the world to reach Society 5.0. In particular, the authors intend to show how the healthcare sector can use digital twin (DT) through elements of augmented virtuality (AR) and building information modelling (BIM) to create interactive interfaces that can solve, in part, problems involving frail patients but at the same time allowing their monitoring. Interconnection is possible through a gamification approach. In addition, a solution that considers the user (patient) involvement and that aims at its increase through interaction with alternative places to their home so as to stimulate them to keep an active mind and the degree of fun in a limiting condition is proposed.

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