Digital Twin for Amyotrophic Lateral Sclerosis: a system for patient engagement

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

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Handbook of Research on Promoting Economic and Social Development Through Serious Games

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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.

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.

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.

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.

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

Section 2
Smart Environments and Systems

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

This chapter aims to describe the multidimensional virtual reality tools applied to healthcare: in particular the comparison between virtual reality traditional tolls 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.

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.

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 microservices 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 visual, can restore autonomy and quality of life to the frailest people.

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.

Chapter 26
Digital Twin for Amyotrophic Lateral Sclerosis:
A System for Patient Engagement

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ABSTRACT

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.

INTRODUCTION

In recent years, the adoption of innovative technologies for the development of Smart Cities and Smart Society has been studied by many researchers to refine the management of the built environment related to healthcare facilities. This goal achievement involves the use of interdisciplinary information considering both medical personnel for patient management and technical one for facility management. In this

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context, the concept of Digital Health can be defined as "*the cultural transformation of how disruptive technologies that provide digital and objective data accessible to both caregivers and patients leads to an equal level doctor-patient relationship with shared decision-making and the democratization of care*" (Meskó et al., 2017). This transformation involves the adoption of many technologies capable of handling large amounts of data that must then be interpreted by qualified personnel. The inclusion of such innovative methods and tools can often be counterproductive if not accompanied by an awareness of the goals to be achieved and the challenges to be met, such as the overcoming of digital divide.

The elaboration of virtual environments, able to provide scenarios of interaction between the user and the surrounding environment, poses several challenges related to technological innovation and human behavior. Gamification approach is one of the main strategies adopted. It can be defined as "*the use of game design elements in non-game contexts*" (Deterding et al., 2011). It is based on the use of technologies of the gaming world in contexts whose interest is to increase user involvement. The idea behind gamification is to exploit the motivational possibilities of entertainment games in other spheres (i.e., health sector, building sector) by leveraging the features of a certain application to make user engagement more motivating. Using a Gamification approach, it is possible to harness a predisposition to motivation in performing an action or a task. This is since games can put users in favorable conditions, stimulating them and increasing their involvement.

In the age of connection, the information society (society 4.0) needs to use technological advancement and ICTs to solve social problems and overcome the fragilities of people with disabilities through an integration of cyberspace and physical space. Through this paradigm shift, it is possible to speak of a Society 5.0 in which people are connected with cyberspace and, through artificial intelligence (AI) algorithms, can overcome the limitations of physical space to improve the quality of life for all citizens. Through an approach to gamification and Serious Games (SGs), it is possible to trigger this change by relating people with ICTs. (Narvaez Rojas, 2021).

Many researchers are investigating these arguments and a broad range of consumer applications for monitoring and managing one's own health and well-being are available on the market. One important sector is SGs for health (Wattanasoontorn et al., 2013), games used to drive health-related outcomes. The majority of these are "health behavior changes games" (Baranowski et al., 2008) or "health games" (Kharrazi et al., 2012) affecting the health behaviors of health care receivers (and not e.g., training health care providers) (Wattanasoontorn et al., 2013). The activities on which developed applications focus concern physical activity, nutrition, and stroke rehabilitation, with an about equal share of (a) "exergames" or "active video games" directly requiring physical activity as input, (b) behavioral games focusing specific behaviors, (c) rehabilitation games guiding rehabilitative movements, and (d) educational games targeting belief and attitude change as a precondition to behavior change (Kharrazi et al., 2012).

BACKGROUND

Gamification in Building Sector

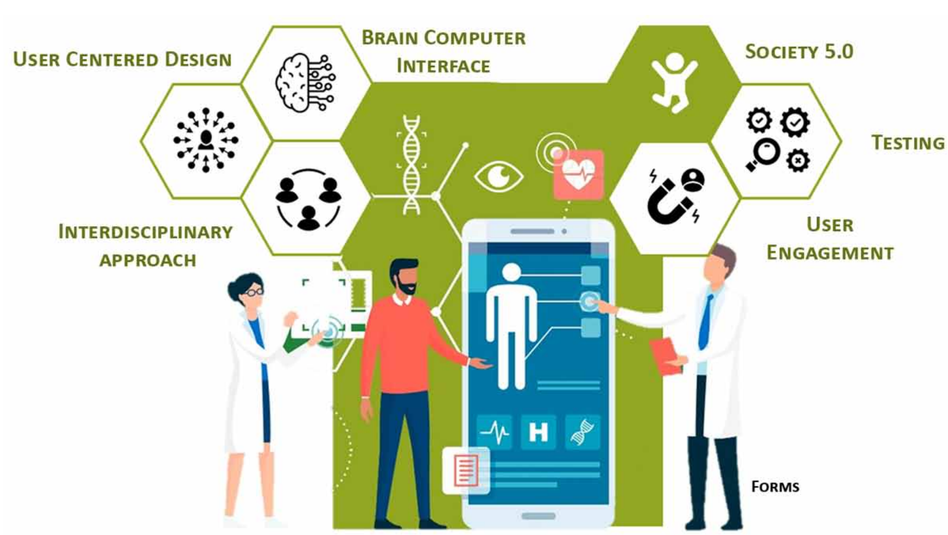
With the advancement of computer and information technologies in recent years, innovative methods such as Building Information Modelling (BIM) and visualization tools such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) have been applied widely across the Architecture, Engineering, Construction, and Operation (AECO) industry (Springer, 2022). In the context of the AECO sector, SGs have been applied to construction health and safety education, professional skill training, evacuation training, behavioral analysis, emergency studies, and decision-making processes

Game features and mechanisms have been integrated with these visualization applications, expanding their impact. Many analogies can be found between the building process and the role-playing game ecosystem in which there are various missions that can be performed by different actors who may use different tools. Each tool is needed to solve a certain task/activity in a certain time. Gamification associated with the world of construction therefore requires the development of a shared digital platform among the various actors involved to achieve a given project objective (Bottiglieri, M. A., 2019). While the development of a 3D information model is essential, it is also important that the information can reach the end user to enable him/her to perform a certain activity, thanks in part to interoperability.

Moving to Industry 4.0 and intelligence construction, Digital Twins (Grieves, 2014) is another evidence for improving the interactive experience between information models and end users. Therefore, the immersive visualization environment (VR and MR) can be made from the gathered data of existing buildings, thus, to develop a dynamic interactive gamificative BIM environment to enhance owners and end users experience by using various headsets.

The proposed innovation in this contribution takes part into the Smart Advanced Modelling for Care (SAM4Care) project (Osello, 2018), which aims to unite two souls: i) the management of heterogeneous data domains related to the building and urban scale; ii) the patients' care who, due to neurodegenerative diseases, are no longer able to please their personal needs through the body movement. For these reasons, the Proof of Concept (PoC) project was born related to the elaboration of an integrated and open-source system, based on a special algorithm for the connection of BIM models with Internet of Things (IoT) databases through VAR. The proposed innovation is based on the creation of a Digital Twin for Amyotrophic Lateral Sclerosis (DTALS) to identify its role and impact as a game changer in the disease management. The DTALS involves the development of a virtual replica related to physical reality. The development of this system is based on a user-centered approaches, increasing emphasis on engagement utilizing processes, increasing collaboration in program development, testing, and data sharing to achieve higher quality, more sustainable outcomes oriented to people welfare (Fleming et al, 2016).

Figure 1. Suggestive image of the investigated health monitoring system



For this contribution, the selected case study is a patient suffering from a neurodegenerative disease, placed in a residential environment converted to an inpatient room. In the latter, a network of sensors necessary for data acquisition is set up.

Human-Computer Interaction and Reality-Virtuality Continuum for Digital Health

E-health was born in 1990, then in 2010 with the digitisation of healthcare, following the pandemic emergency of 2019, the necessity of customising monitoring processes to better follow patients has emerged even more. Furthermore, the cost of treating patients with serious conditions has increased, along with the need to modernise hospitals and medical facilities (Meskó, Drobni, Bényei, Gergely, & Győrffy, 2017). As a result of this global event, the processing of medical data and an efficient system is simultaneously the subject of studies that have led to the coining of the term Digital Health (E-health). It can thus be defined as ”*the proper use of technology for improving the health and wellbeing of people at individual and population levels, as well as enhancing the care of patients through intelligent processing of clinical and genetic data”* (Fatehi, Samadbeik, & Azar, 2020). Thus, the concept of the Digital Twin in relation to the patient has been increasingly approached in order to improve treatment, monitoring and diagnostic methods. In this way, the patient, between the medical sector and digital technologies, becomes the focus of Digital Healthcare. Essential technologies in this development are Artificial Intelligence (AI), Machine Learning (ML) and the use of sensors, which combine ICT technologies to solve or alleviate patients' problems. The interest of Digital Healthcare is to provide a better administrative and clinical service, but also to help patients to better manage their health, especially in the most sensitive cases, by making them active participants in making decisions about their own health (Edirippulige & Senanayake, 2020) (Meskó, Drobni, Bényei, Gergely, & Győrffy, 2017). Obviously, patients need to be prepared to participate in the management of their medical conditions and it is only through collaboration that the success of these initiatives can be achieved.

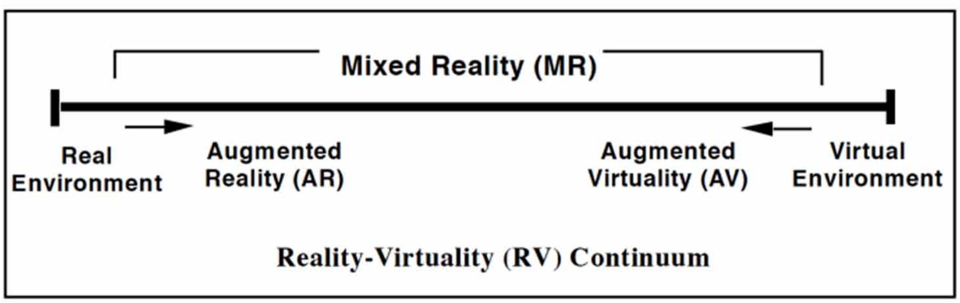
Several solutions have focused their attention on Human-Computer Interaction (HCI) to generate a final product to approach the growing adoption of Digital Health. Typically, HCI consists of a study phase, followed by a design phase, an implementation phase, and a hardware and software analysis phase. In order to bring a viable product to life, it is of primary importance that one first studies the intended audience. This is important because following a demand and/or need, a product can be designed to meets the needs of the end user. HCI has been shown to stimulate the human cognitive faculties, defined as the whole range of information that we are able to remember and process in order to use a system (Alonso-Valerdi, 2017). The simpler the stimuli are, the more they meet the end user's need, the easier the platform will be to use and the easier it will be to use. In the course of studies, different technologies that can stimulate the cognitive load of the end-user have been evaluated: sound synthesis, kinesthetic and tactile feedback and eye-tracking that captures the movement of the cornea. In particular, the latter method caters for a whole audience of people with illnesses or disabilities. Eye-tracking technologies capture images as a result of the optical reflection of the cornea: a pattern of infrared light is projected and it hits the eyes and locates the cornea, so its movements can be followed. This makes it easy to understand how eye movement tracking can control a computer as well as to understand, at least in terms of statistics, the degree of interest and attention of the user. Every eye-tracking technology requires an initial calibration process. Eye-tracking as a substitute for mouse pointing is the most widespread way of exploiting this technology (Björnsson et al, 2020).

The eye-gaze usage is often combined with the use of Virtual Reality (VR). VR is commonly understood as a technology that totally immerses the user in a ‘synthetic’ environment. It has been shown that patients who took an active part in research involving the use of Virtual Reality (VR) were able to actively experience the research, also providing positive feedback: the experience instilled in them a reduction in pain and anxiety (Meskó et al, 2017). The VR system can be distinguished into:

- *Non-immersive system*: uses a screen or computer on which the virtual environment is displayed.
- *Fully immersive system*: gives users a more realistic simulation experience because the person is totally immersed in the virtual environment and has to use a technological system consisting of sensors, visors and controllers.

VR is thus a technology that plays an active and effective part in the therapy of patients. VR - like Augmented Reality (AR) and Augmented Virtuality (AV), which together define the spectrum of Mixed Reality (MR) with the reality-virtuality continuum) - is reality in which the real and virtual worlds are represented together on a single screen (Cáceres, Carrasco, & Ríos, 2018).

Figure 2. Representation of Reality-Virtuality Continuum (Heliyon, 2018)



AR can be defined as “*augmenting natural feedback to the operator with simulated cues*” and is closer to the real world, whereas AV is closer to the virtual world (Cáceres, Carrasco, & Ríos, 2018). In AR, interactions in the virtual world are reflected in the physical world (Edirippulige & Senanayake, 2020). In the medical field, AR has been used for medical imaging, superimposing data via imaging techniques. Virtual Environments (VE) are very versatile especially for those with severe paralysis: they attempt to reconstruct circumstances and situations through which patients can gradually adapt to their condition, but at the same time can maintain and train the abilities they still own (Beaudouin-Lafon, 1993). While some studies have started to conceive the idea of creating a Digital Twin of the patient himself, with this work the authors want to conceive the Digital Twin of what surrounds the patient, the place where he/she lives to provide a virtual representation of it: so, he/she could communicate with physical reality (Meskó et al, 2017).

The Reality-Virtuality continuum offers the opportunity to establish an ideal connection between the physical world and the virtual world, but as virtual information overlaps with reality and vice versa, it becomes increasingly complex to establish the boundary between AR and AV. In fact, each environment becomes contaminated with information from different domains that increase the quality of the developed Digital Twin. The study initially considered AV as the main area of investigation of the gaming environment, exploiting the virtual model as a graphical interface connecting the two worlds. Promising as gamification for health and well-being may be, the essential question remains whether gamified interventions are effective in driving behavior change, health, and well-being, and more specifically, whether they manage to do so via intrinsic motivation (Johnson et al, 2016).

Having defined a precise target group to be addressed, the demand arises from the patients' need to acquire more autonomy, but at the same time there is a demand to shorten the distance between medium and patient. For patients with motor neuron deficiency, the use of eye-gaze or eye-detection technology is vital, and it is the best solution to make them communicate (Björnsson et al, 2020). Popular technologies include *Tobii*, *EagleEyes* and so on; making full use of eye-detection technology to control a computer. The greatest benefit of this kind of technology lies in the possibility of interacting with Graphic Computer Interfaces (GUIs), being able, for example, to take advantage of keyboards to communicate. The wink is the most widely used way to replace the mouse click. An important factor not to be forgotten and to be evaluated with the daily use of such a technology, such as the one proposed here, is eye fatigue, followed by cognitive fatigue. With this in mind, one must try to optimise the quality of navigation as much as possible and make sure that they are used in such a way that the experience is not frustrating. One can assess this through Fittz's Law, which measures the time it takes to perform an action on the screen in a given area over a given period of time (Björnsson et al, 2020).

In this sense, HCI has been used as a means of expanding the senses for those who are deprived of them due to pathologies, by stimulating each person's cognitive perception. In the construction of the platform, medical and engineering disciplines were united, so as to create strong communication between professionals who could mutually bring points of discussion to light in order to build a valid platform for the doctors themselves, but above all for patients. In this case, a technology was studied that would be able to meet a specific target population: people with total body paralysis, i.e., ALS patients. The main symptoms are asymmetry and spasticity of movements, atrophy of muscles, speech disorders that later lead to dysphagia and failure to breathe, the main cause of death for these patients. Consequent to the onset of primary symptoms is the development of depressive states (in 4 – 56% of cases) that arise because of the inability to perform most of the daily life actions. The combination of these issues contributes to the progressive decrease in patients' quality of life. For these reasons, research focused on the need to define a specific technology for neuro-degenerative diseases, on the optimization of life quality and on maintaining patients' autonomy as much as possible (Zarei et al, 2015). The crucial point is the strong social impact they have, degrading the freedom of action (Alotto et al, 2019) (Eid et al, 2016). This condition makes the patient conscious from one side, but on the other side he/she cannot make movements or communicate verbally due to a complete paralysis of almost all voluntary muscles in the body, except for the eye muscles. Patients suffering from neurodegenerative diseases or unable to move can try to keep their minds and cognitive abilities active. The technology, however, can be aimed at a broader audience including all those who cannot move their limbs or part of them, so as to provide them with an alternative that allows them to perform certain actions of daily living independently. With this in mind, we wanted to focus on an adaptive interface - personal health as intuitive and simple as possible. This was achieved by translating operations with objects into a 'language' that could interface with VR and physical reality in order to bring the actions requested as input to the interface back to reality. More appropriately, then, it will speak of AV.

The conceptual and structural model thus conceived was submitted to the attention of healthcare professionals in order to better understand what might interest them in the care of patients on the one hand, but also to interface between professionals working together to provide an innovative technology useful to patients. At the same time, 20 ALS patients were interviewed by *ad hoc* forms to better understand their needs and wishes. In this way, the two end-users were involved in the design of the platform.

METHODOLOGY

In the present work, the authors focused their attention on patients suffering from Amyotrophic Lateral Sclerosis (ALS) that mainly affects subjects between 50 and 65 years old (Zarei et al., 2015). This type of Disease limits the actions of daily life since it affects Motor Neurons (MND), preventing more and more that the patient movements, breathe and speak independently. Different technologies have been created over the years to overcome the deficits of this category and they have turned their gaze on possible solutions that would allow patients to communicate. Among these, Eye-Tracking is the most widespread technology: it allows to track the Pupil Corneal Center (PCC) movement providing a method to interact with electronic devices.

This paper defines the essential features of an interface for the development of a communication medium (based on Human-Computer Interaction) for this type of patients, to help them overcome the barriers of their disease. Visualization, interaction, and analysis of the person's behavior in the developed digital environment are the requirements for improving the healthcare system through the development of digital assistants, reducing the distance between doctor and patient. Leveraging the Digital Health phenomenon, the aim is to develop an interface that allows the virtual navigation within patient's home (and beyond) to perform simple actions that are reflected in physical reality. There is precisely where a subject suffering from ALS in the more advanced stages of the disease has no control. Through this innovation, patients regain a new autonomy by becoming an active part of the proposed technological system. The invention implements a novel algorithm that, starting from the information contained in a BIM model, integrates IoT technology to control indoor automation. The 3D model exploration allows the navigation of virtual environments to patients suffering from motor neuron degradation (e.g., ALS) and enables interaction with common objects such as electrical systems, doors and windows.

Figure 3. Adopted workflow for the development of a DTALS platform

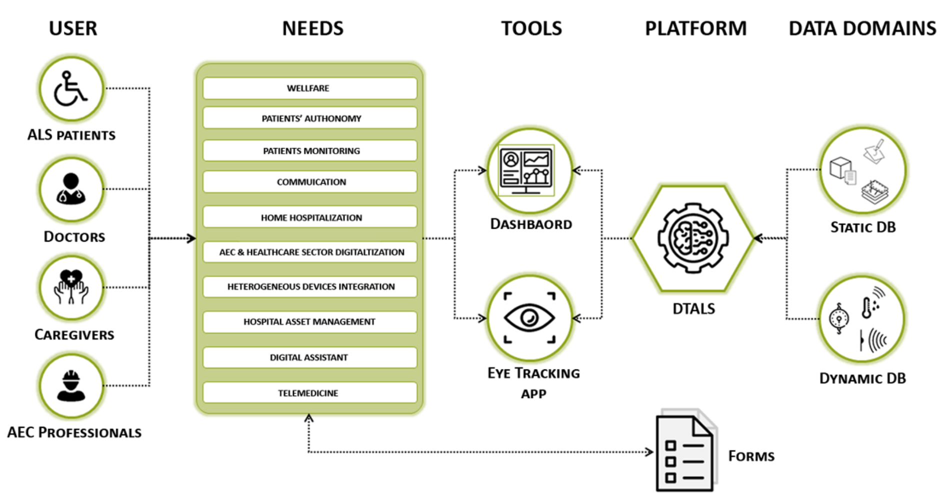


Figure 3 shows the relationships between users' needs and the tools hypothesized to fulfill them by interacting with the DTALS platform.

In the healthcare sector, in addition to ALS patients, many actors (e.g., doctors, caregivers, AEC professionals, owners) are involved in their management aimed at either improving the quality of life of patients in healthcare or home environments. For this reason, the development of an interactive digital platform can be used for multiple purposes, encompassing both healthcare and also real estate management aspects. Clearly, each user explicits different needs that therefore involve the development of different tools that can leverage the heterogeneous information collected in the data domains.

The elaboration of the DT prototype of a home or of a health facility, in which the patient resides, stems from information requirements identified from a census based on the drafting of specific questionnaires. The final users (e.g., patients, doctors) contribute to outline the characteristics of the proposed innovative system, defining their desires and needs that the PoC intends to fulfill. In this way end users become an integral part of the proposed system achieving the concept of Society 5.0. The DT of the selected home or healthcare facility provides an AV experience and establishes a link between virtual and real. In this way, the concept of DT expands from the building model to the patient, who through his avatar regains some skills lost due to his/her condition.

The concept model of the DTALS, characterized by three main parts "*physical products in Real Space, virtual products in Virtual Space, and the connections of data and information that ties the virtual and real products together*" (Grieves, 2014). Therefore, the development of the DTALS platform has to:

- Enable the collection of static data (BIM domain) and dynamic data (IoT database);
- Allow the data interchange and the connection between the BIM and IoT devices using gamification engine (e.g., Unity 3D);
- Provide the necessary services to patients for improving their quality of life;
- Facilitate their monitoring and the useful applications for medical équipe.

In particular two applications were selected and investigated for the DTALS: the Patiet App and the Medical App.

Patient App

The application aims to increase autonomy to patients by allowing them, through non-immersive virtual reality, to perform many tasks independently in the home and/or hospital environment. This app allows users to:

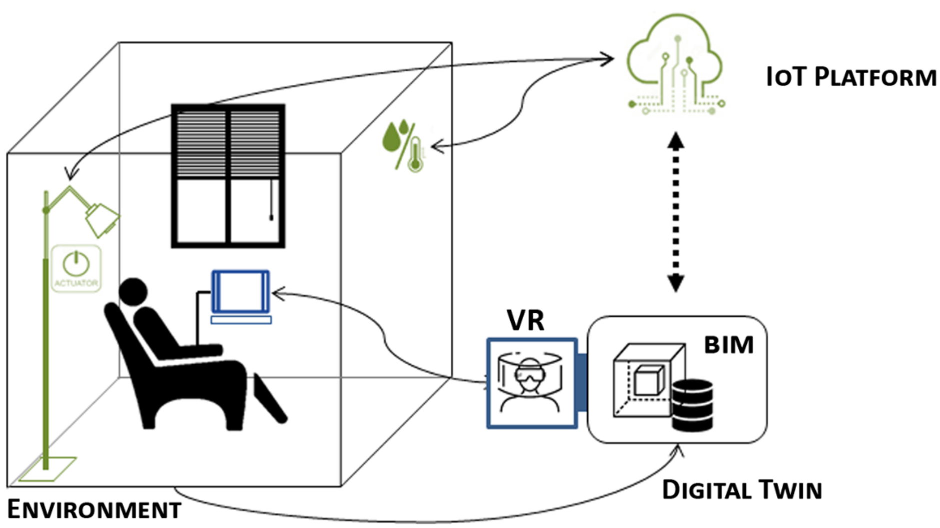
- Navigate within a virtual space to patients suffering from motor neuron impairment (they are incapacitated in limb movement, while having intact cognition and control of eye movements);
- Interact with common objects such as electrical systems, doors, windows by users;

The BIM model, 3D graphic building database, is enriched with specific information for the subsequent application in Unity aimed for the interaction of the patient with the surrounding environment.

Thanks to the parametric approach of the BIM methodology, 3D parametric models have been developed by using the BIM authoring platform *Autodesk Revit*®. As the DTALS platform was conceived as a scalable web open-source platform, the BIM model were initially exported in the *.ifc* OpenBIM format and the uploaded in the BIM domain using a BIM based server that is essential to manage models in the correct way and it allows to modify, replace and implement models, check files versions to understand what changes have been made and to approve or not such changes. The model navigation in a VR environment was developed in Unity3D engine. As it unfortunately does not support *.ifc* data-format, BIM models have been converted in *.obj* format and *.glb* format. Through this interoperability process, a GUI was developed for enabling the model uploading process in the BIM Domain and for produce a reliable, updatable BIM model.

In designing the platform for patients, the idea was to exploit the power of the icon model, launched on the market by Mackintosh Finder, so as to make familiarisation with it more immediate (Alonso-Valerdi et al., 2017). But, again, attention was paid to trying to make the gap between medium and patient smaller, which is often important. In this way, the interaction between the two actors is shorter, as the patient can directly call the doctor or nurse, while the doctor himself can independently access the real-time patient data

Figure 4. Sample of the proposed DTALS infrastructure for patient use in the indoor environment



Medical App

The application aims to visualize patients' health parameters, collecting and transmitting environmental/medical data in compliance with current regulations through IoT with plug and play integration of new services. Figure 4 show a sample of the GUIs proposed for the DTALS.

A Web platform is being developed for physicians and caregivers where the patient's history, diagnosis and treatment can be placed. In addition, a track is kept of the interactions between the patient and the environment to allow to understand, for example, his activity, his progress in the pathology and his rehabilitation process, in a broad sense. This is not merely about consulting users on drafts but also about a deep understanding of user needs and preferences, and actively involving users in design processes from the outset. By contrast, a user-centered design would begin with users, to understand issues such as how and when they would be willing to use the internet for mental wellbeing, and to explore their current behavior, needs, and preferences. Compared to the Patient app, this application is still in the early stages of study and needs more investigation.

After completing the DTALS prototype, the testing phase begins to assess the positive aspects and critical issues for improvement by directly involving patients. In this regard, two form were developed to involve both patients in direct use and medical practitioners to define the content of the telemedicine application. The latter were also asked questions related to the *Patient App* to improve the usability of the application. Through both the surveys and the testing phase of the *Patient App*, the key aspect was to involve users by making them become active participants in the project.

The use of serious gaming and gamification, enhanced telepresence, and increased use of persuasive technology are promising in this regard. Moreover, the routine assessment of engagement may help to further develop the field and monitor progress toward this goal.

Figure 5. Examples of Medical App dashboard

Survey of User Needs – Questionnaire

A specific questionnaire was drawn up for ALS patients in order to get to know the user and his/her needs better so that the *Patient App* could be calibrated according to the feedback obtained.

The user was asked the following questions: (i) Age; (ii) Gender; (iii) City; (iv) Do you know what Virtual Reality (VR) is? (Yes, no); (v) Have you ever used Virtual Reality (VR)? (Yes, Yes – immersive VR, Yes – non-immersive VR, No); (vi) Do you think that VR could be an added-value? If Yes, explain how (Yes, No, I don't know); (vii) Do you know what an eye-tracker is? (Yes, No); (viii) Have you ever used an eye-tracker? (Yes, No); (ix) Would you like to be able to perform certain actions of daily living by yourself (e.g., turn on/off the light or the TV)? (Yes, No); (x) If you were alone in your room, which of these daily actions would you like to be able to perform? (Turn on/off the light, Turn on/off the television, Check if there is anyone in the room around you, Call the nurse, Open/close the shutter, Manage room temperature); (xi) Here you can list other actions you would like to be able to do: (free short answer).

The first three more general questions were asked to identify the type of user. Questions (iv) to (viii) were introduced to investigate his/her knowledge and experience (if any) with Virtual Reality and Eye-tracker, so as to begin to understand how well trained the average ALS patient is and consequently whether training is necessary. Questions (ix) to (xi) were introduced to investigate the user's needs and wishes.

Further questions were asked to those users who already had a communicator: (i) Your communicator is composed by: (All-in-one, Computer and eye-tracker, Tablet and eye-tracker); (ii) If you have an eye-tracker, indicate its brand (free short answer); (iii) How long do you use the communicator per day? (5 min, 15 min, 30 min, 45 min, 1 hour, more than 1 hour); (iv) How do you get on with the communicator you have? (1, 2, 3, 4, 5); (v) If you have a communication system, does it let you to perform everyday actions independently? (Yes, no); (vi) Do you feel that the interface (i.e., the way you can navigate) of your communicator slows down the execution of certain actions? (Yes, No, I don't know).

Furthermore, DTALS prototype was tested with a patient of 36 years old, affected by ALS. This candidate was selected with the help of a remarkable Italian hospital. She was allowed to fully use the *Patient App* and to navigate the virtual world. At the end of the experience, she was given a post-experience questionnaire to evaluate her degree of engagement. She was asked: (i) How much did you enjoy navigating virtual environments using your eyes? (Rate from 1-very little to 5-very much); (ii) How useful did you find using the application to perform actions such as switching on the light? (Rate from 1-very little to 5-very much); (iii) How important to you is the ability to play a video game with your eyes? (Rate from 1-very little to 5-very much); (iv) How intuitive did you find using the application? (Rate from 1-very little to 5-very much); (v) How do you rate the application in general as an aid in performing simple actions? (e.g., switching on lights)? (Rate from 1-very little to 5-very much); (vi) How do you rate the application in general as a game and pastime? (Rate from 1-very little to 5-very much); (vii) Which aspects of the application do you think could be improved? (Movement commands, Main menu, Real world interactions, Virtual world interactions, Navigable models, Graphic, Other...); (viii) Did the application make you tired? (Yes - more than programs I use, Yes - as other programs I use, Not so much, No); (ix) How realistic did you find navigation in the virtual environment? (Rate Apartment, Colosseo, Neighborhood and Cloister from 1-very little to 5-very much).

Specifically, some questions were asked in order to understand the strengths and weaknesses of DTALS to work on: (i) Do you find the possibility of being able to choose the speed of movement useful in using the application? (Yes - I change velocity due to the model, Yes but I would like to go faster, No - I used 0.5, No – I used 1, No – I used 1.5); (ii) How do you rate the speed of rotation (rate from 1-very little to 5-very much); (iii) Are you satisfied with the method of switching on the lights? (Yes, I would like to turn them on with the virtual switch, I would like to turn them on trough a dedicated screen, no); (iv) How do you rate the navigation of the neighborhood with the car? (Difficult, Easy, Funny, I would like to do more things); (v) Do you have recommendations on how to improve the application interface? (Free short answer).

Survey of Physician's Needs – Questionnaire

As mentioned before, a key role for patients is played by the healthcare personnel who treat and monitor them, especially since many of these patients are followed thanks to Telemedicine. These questions were submitted to the medical staff to define the contents of the *Medical App*.

Again, the role played by the specialists who participated in the survey was put into context. Here there are the general questions that were asked: (i) What is your job? (Doctor, Nurse, Psychologist, Physiotherapist, Speech Therapist, Other...); (ii) In what type of structure do you work? (Hospital, RSA, Clinic, Other...); (iii) Do you work: (Alone, In a multidisciplinary team); (iv) In which city do you work? (Short open answer).

Regarding VR, the authors would like to understand how trained the medical field is, so they ware asked: (i) Do you know what Virtual Reality (VR) is? (Yes, no); (ii) Have you ever used VR? (Yes, Yes - immersive, Yes - non-immersive, No); (iii) Do you think that the integration of Virtual Reality in the medical field could be an added value? (Yes, if Yes how would you use it?, No).

In a second module the technology was presented, after that they were asked: (i) Do you think our technology could be useful to you? (Yes, No); (ii) Could your facility accommodate our technology (BIM-VR-IoT algorithm)? (Yes, No, don't know); (iii) Does your facility have a domotic control system? (Yes, No, don't know); (iv) Does your facility already adopt digital building models? (Yes, No, I don't know); (v) Is it possible to install additional devices (e.g., IoT devices) in your facility? (Yes, No, I don't know).

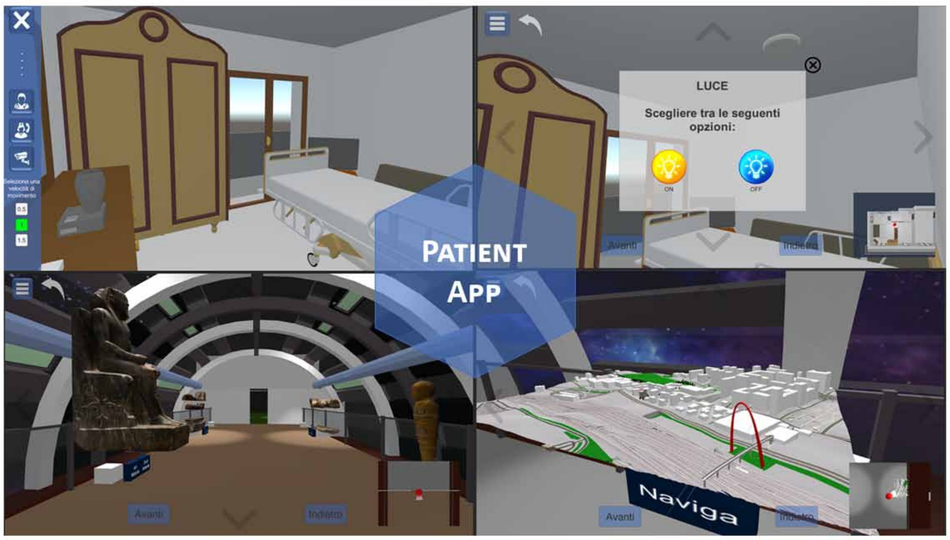
Then the focus was on ALS patients: (i) How many years have you been working with ALS patients?; (ii) How many ALS patients do you follow?; (iii) How many patients (with ALS or similar diseases) are at home?; (iv) How many patients (with ALS or similar diseases) are in health care facilities?; (v) How many of your patients use an optical communicator?; (vi) How much time do you (on average) dedicate to an ALS patient? (5 min, 15 min, 30 min, 45 min, 1 hr, More than 1 hr); (vii) How much time do you spend on an ALS patient does NOT relate to medication or medical treatment? (5 min, 15 min, 30 min, 45 min, 1 hour, More than 1 hour); (viii) Do you think it would be useful to collect data in one platform? (Yes, No, if Yes which data do you think could be prioritised?); (ix) Which data do you think could be collected automatically and could be useful to you for ALS patient care? (Short open answer); (x) Which parameters do you wish could be controlled in the ALS patient's environment? (Short open answer); (xi) Do you think it would be useful for you if the patient could perform daily actions with much more autonomy? (Yes, No); (xii) Based on your experience, in which (simple) actions could the ALS patient be more autonomous? (Short open answer); (xiii) Would it be pleasant for the ALS patient to regain more autonomy in actions of daily living? (Yes, No).

RESULTS

Patient App

To meet patients' needs, a dedicated Graphic User Interface (GUI) was therefore built: the *Patient App*. The author solution allows the creation of a scalable system that controls indoor automation through IoT devices by storing information in a BIM model. The physical reality surrounding patients suffering from motor neuron degradation is represented in the BIM 3D model and it can be explored by using an Eye-Tracker. The interaction with the environment is permitted through IoT devices that convert actions into the real-world. In this way, the DTALS is born. By providing the ability to more autonomously control the space around them, patients can regain more control over even simple actions that they were unfortunately no longer able to perform. In addition, they break routines to which they had been adapted to.

Figure 6. Overview of some Patient App's GUI



Data were collected from a sample of 20 ALS patients. Questionnaires showed that 35% of patients were male, the 15% of them were aged between 30 – 40 years old and 40 – 50 years old, 20% were older than 70 years old and the most affected age groups were between 50 – 60 years and 60 – 70 years old with 25% respectively. The most frequent region of origin was Piedmont.

The 80% of patients had never used Virtual Reality, only 20% had interfaced with it: one person used immersive VR, and another didn't know the type of VR used, while two people indicated non-immersive VR. Despite this low number, 60% of interviewed said they knew what an eye-tracker was but 70% had never used one.

Only 25% surveyed own an eye-tracker, 80% of which were all-in-one devices. The most popular brands of eye-trackers.

Unanimously, ALS patient reported using the communicator for more than 1 hour per day, expressing the fact that a communication system in 80% of cases enables them to carry out daily life actions and it is the only way they can have to communicate with others. Despite talking about more than most, 100% of patients still express a desire for more independence in daily actions. With this in mind, examples of activities were given, and candidates expressed their interest as shown in Figure 7.

Figure 8 reports which kind of actions patients would like to do, excluding the one previously suggested by the authors.

Since people with ALS can't interact with others, excluding doctors and caregivers, with the technology here presented, the goal was to investigate the emotional state of their experience. Whether interaction with the outside world and with other people could be a source of relief for them. The 100% believe that having the opportunity to interact with the world outside the room could provide them with a sense of well-being and the 89.5% is interested in visiting places with VR. A special interest emerged for natural environments (sea, mountains) but also places of cultural interaction such as cinemas, museums, cities and monumental landmarks.

Figure 7. Daily life actions suggested in the questionnaire

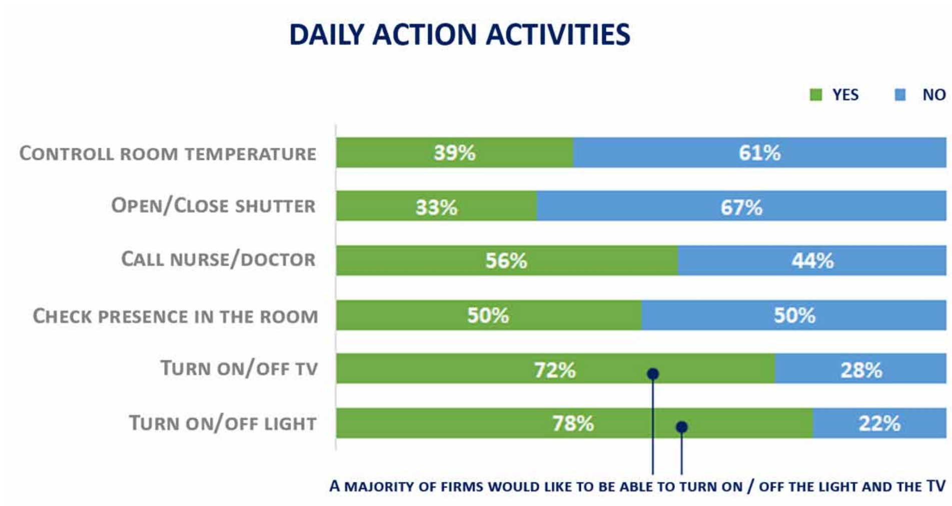


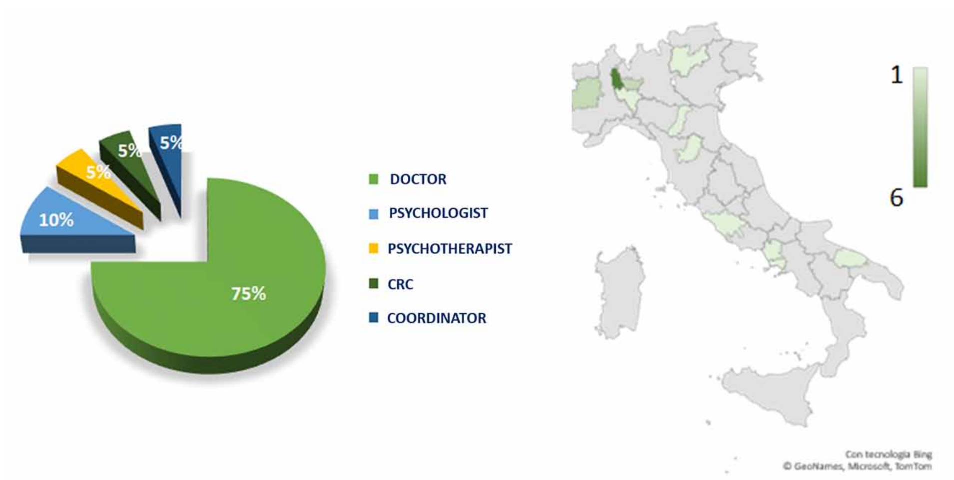
Figure 8. Summary of actions that ALS patients would like to perform

Medical App

The Medical App has been investigated in a form of mock-up to envision the Hospital Information System (HIS). The author solution allows to improve patients and environments monitoring, becoming more independent, to control home automation devices and improving patients' quality of life. Doctors can monitor patients by checking their health parameter over the time, administrating pharmaceutical therapies, managing diagnoses and updating follow-ups.

The healthcare personnel involved in the survey carry out their duties in hospital, only 5% work in a rehabilitation centre and on average they are part of a multidisciplinary team. Given that many people interact with ALS patients, it is clear that research to improve communication and autonomy of patients implies an improvement in the quality of life of all people involved, which also benefits the facilities that accommodate them. Figure 9 shows a pie chart defining the role of healthcare professionals, together with the map in which their working-area can be seen. Most of them are concentrated in Northern of Italy and are mostly doctors.

Figure 9. Pie chart depicting the main health professionals involved in the survey and their areas of work



The 90% of interviewed knew what Virtual Reality was, however, 60% have used it and in 25% cases it was non-immersive VR. All doctors and medical personnel believe that the DTALS could be useful to their work, even if their facilities don't have a domotic control system and digital building models aren't adopted yet in 45% of case – 30% of people didn't know the information about their facilities.

On patient side, the 20 professionals involved follow more than 2500 patients, most of whom are homebound, as it can be seen from Figure 10. Among all professionals, the psychologist was the one who followed the largest number of patients. The orange line indicates the average number of patients, hospitalised and non-hospitalised, that each professional manages.

It was found that doctors spend about 45 minutes per ALS patient in 40% of cases, only 20% require care that may last for more than 1 hour. Not all the time that is devoted to each patient is for the drugs administration or medical treatments, in fact 45% of professionals dedicate 30 minutes to other treatments and patient care. The 65% of them were interested in centralizing the information of each patient, with a view to simplifying their treatment and optimizing time. Asking what type of data, they would like to control and/or collect automatically on a single platform, the main themes were identified and summarized in Figure 11.

Figure 10. Combined graph of domiciled and hospitalized patients that each healthcare figure cares for

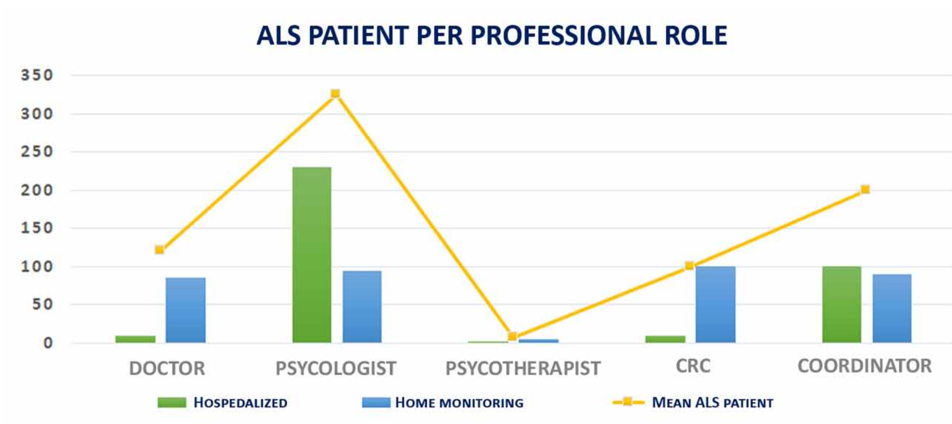
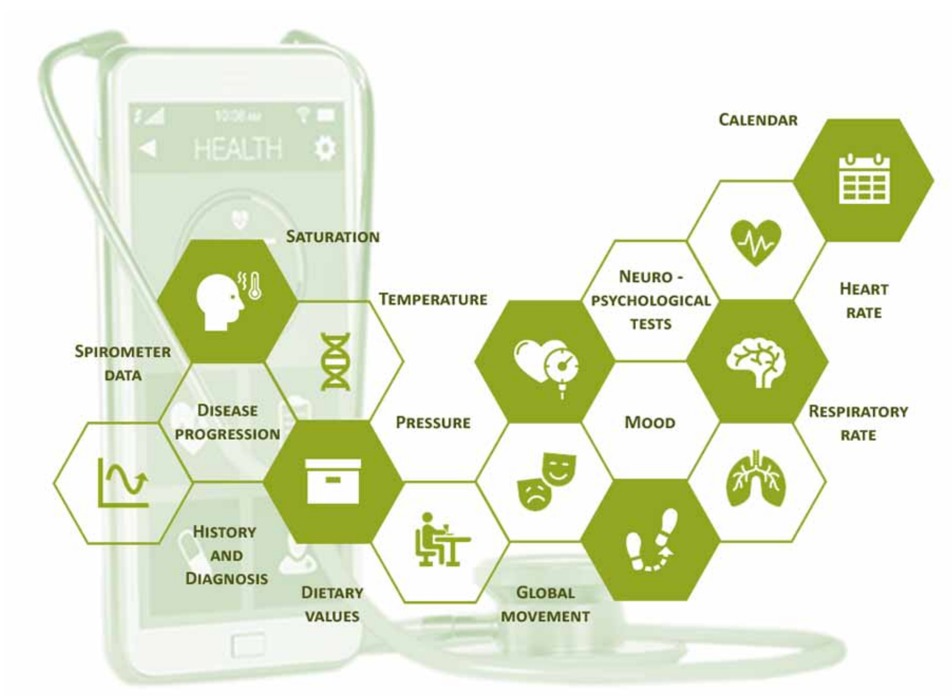


Figure 11. Summary of data health professionals consider useful for ALS patient care



Patient Post-Experience – Questionnaire

The DTALS technology test candidate enjoyed navigating through virtual environments using her eyes, in fact she gave 5 points to the intuitiveness of the *Patient App*. In addition, she liked being able to do certain actions (such as switching on/off the light), affecting the physical reality around her. It was not relevant for her to use a visual communicator to play a video game, but overall, she rated the use of the App with 5 points.

One of the most important aspects of this experience was to ensure that user's eyes wouldn't be excessively tired. She didn't experience a sense of fatigue after using it, but she recommended to introduce the stand-by mode to rest eyes.

The virtual environments she visited were all rated with 4 pts, while the representation of her flat reached 5 pts outlining excellent feedback on the 3D representation realism. As far as the use of the controls was concerned, the adjustable speed was the best solution in her opinion to navigate different models; the rotation speed of the controls was more than sufficient, and she found the machine introduction for navigating the neighbourhood pleasant.

CONCLUSIONS

The development of the DTALS prototype was an opportunity to define the interactions between the construction sector, healthcare, and defining new frontiers for companies producing medical support tools for patients with disabilities. Thanks to several technologies on the market, the innovation proposed by the ongoing research activity highlighted how transversal and multidisciplinary skills can be an added value for technological innovation that must have a practical application in order to reduce the deficits that this type of illness causes to patients.

Above all respondents, ALS affects mainly males of about 50 – 70 years old, coming from the North of Italy. The patient questionnaire therefore concluded that in the majority of cases (80%) Virtual Reality is a known technology, however, only a minority have actually dealt with it and own a communicator. Of all the brands suggested, Tobii and Eyetech eye-tracker were found to be the most popular. The preference of those interviewed was for actions such as independently managing the switching on and off of objects such as the light or television, as well as being able to call the doctor or caregiver. In general, all feedback addressed the possibility of acquiring more independence, especially motor independence - as one might expect. Presenting the *Patient App* to the users, they all showed great interest in using it, providing an added impetus to progress with the research. In particular, the field test carried out with the patient scored 4.25/5 overall and also highlighted some aspects that need to be further explored with a view to perfecting the technology.

Of the doctors interviewed, 75% held the occupation of doctor, mainly in Piedmont and Lombardy regions. From their point of view, the proposed technology could both help ALS patients as they agree with the authors that by introducing the possibility to carry out actions of daily living independently, the time caregivers spend caring for these patients would also be reduced. Furthermore, the psychological aspect should not be underestimated either: patients often find themselves lonely and committing time to manage themselves more consciously and independently would help them regain a sense of well-being.

Technological innovation is reducing the distance between patients and doctors, improving the quality of life of the former and improving the efficiency of the latter. With the introduction of methods and tools related to Digital Health, new roles are being created involving the younger generations in the medical field. Interdisciplinary knowledge must be increasingly sought after to offer solutions in which the synergy between different skills is the real added value for the achievement of a Smart Society. Heterogeneous, static, and dynamic data domains may contribute to define a new concept of Digital Reality in which built environment and person constitute are two complementary systems that are continuously improved through new frontiers for data management such as Artificial Intelligence (AI) and Machine Learning (ML). Certainly, the use of DTs in medical care is still in its infancy. It is desirable that the development of these first DTALS applications will improve patients' lifestyles, defining new paradigms linked to the concept of remote living (e.g. metaverse) to improve not only the healthcare aspect but also the social and personal life aspect. Improving people's quality of life through the adoption of ICTs is one of the principles of Society 5.0. Through multidisciplinary, in the near future it will be possible to achieve results that will increasingly place man in the foreground, who will acquire greater autonomy, without being bound by his physical being, having free access to cyberspace.

FUTURE RESEARCH DIRECTIONS

In the future, a digital assistant, GIO, will be introduced to assist the user in interacting with the interface. Secondly, further tests will be carried out by involving other patients in the testing of the interface, integrating post-experience feedback to improve the user interface (doctor and patient). With a view to the future, the possibility of creating a community, within which all owners of the Patient App will be able to interact with each other, will also be set up.

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KEY TERMS AND DEFINITIONS

Building Information Model: It is a data-rich, object oriented, intelligent, and parametric digital representation of the facility, from which views and appropriate data for various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility.

Building Information Modelling: It is a method based on a building model containing any information about the construction. In addition to 3D object-based models, it contains information about specifications, building elements specifications, economy, and programs.

Digital Twin: It is a virtual replica of reality and contains three main parts: physical products in real space, virtual products in virtual space, and the connections of data and information that ties the virtual and real products together.

E-Health: Is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology.

Interoperability: Is defined as the ability of two or more systems or components to exchange information and to use the information that has been exchanged.

User Engagement: The quality of user experience characterised by the depth of an actor 's investment when interacting with a digital system.