AR Applications: Wayfinding at Health Centres for Disabled Users

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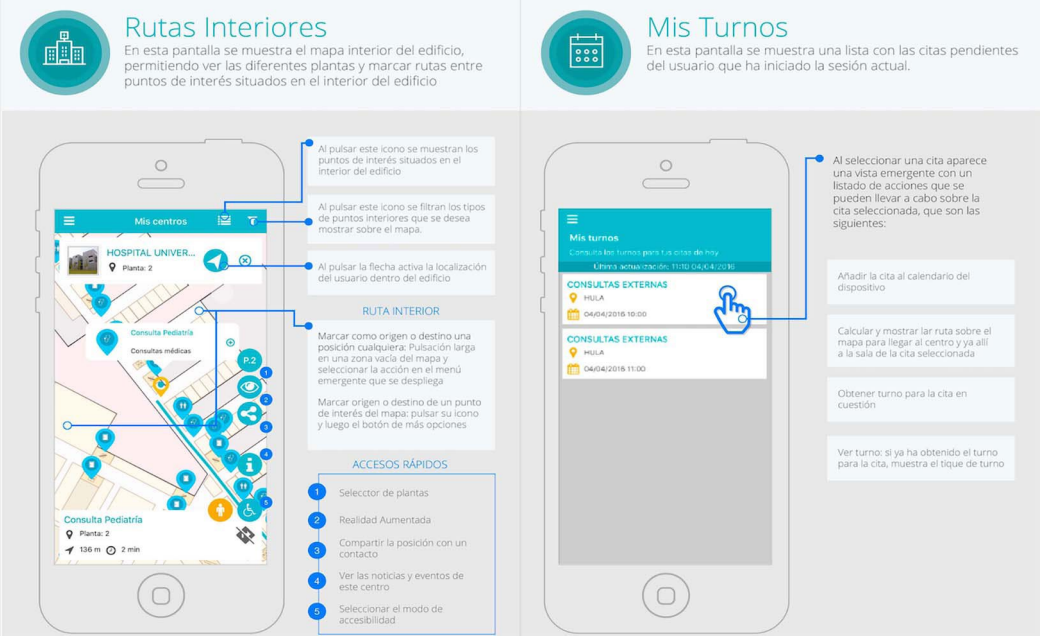
Abstract

The term *wayfinding* describes the processes people go through to find their way round an environment. People's perception of the environment, their ability to orientate themselves spatially, the cognitive and decision-making processes, and the information available, all affect how successfully they find their way. At hospitals and healthcare centres a specific wayfinding strategy is needed. Emerging technologies as computer-based and stand-alone navigation systems tailored to the needs of various types of disabled users. Accordingly, they meet requirements of psychology and human behaviour, and communication technologies. GPS technology, 3D modelling and Augmented Reality (AR) among other, are revolutionising the way people navigate. Such solutions applied to motor and sensorially disabled people, and mentally impaired users become an increasing societal demand in the face of EU integration challenges. The University Hospital Príncipe de Asturias in Alcalá de Henares (Madrid, Spain) is used as a case study.

Keywords
wayfinding, navigation tools, people with disabilities, customised apps.



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Introduction

"Wayfinding is the process of finding routes between pairs of locations and is often used for pre-trip planning. Navigation is the process of finding the current location of a person or object in real time and providing step-by-step directions to reach a destination" [Karimi 2017, p. 2455].
In any publicly-accessed site, people can have problems finding their way. Getting lost at a hospital or healthcare centre is so much a part of daily life, that solving wayfinding problems is a severe problem that creates anxiety and rises stress levels in users.
To develop an inclusive indoor and outdoor navigation system, a wayfinding strategy that covers all possible disabilities is needed. Though signs do play a key role in any wayfinding system, signs alone cannot overcome the wayfinding problems caused by complex site layouts as in hospitals. Moreover, signs are only useful if they are linked to other navigation strategies as pre-visit information and environmental and design factors, such as clearly defined safe pathways, prominent entrances, natural lighting, changes in texture and colour, etc.
This chapter shows some results of the Spanish National Research Project PID2020-118796RB-I00_2020, that is still ongoing. University Hospital Príncipe de Asturias in Alcalá de Henares (HUPA, Madrid, Spain) is used as a case study.
Firstly, we provide a study on the specific needs and requirements of users focusing on the various motor and sensorial disabilities. Secondly, we show some interesting best practice guidelines to produce a more effective wayfinding system, they need to be adapted to each case study and site users after careful evaluation of the current navigation system. Thirdly, 3D modelling and ICT Technologies application to health centre knowledge and management are reviewed and analysed, as well as the pros and cons of current navigation solutions based on GPS technology, and Augmented Reality (AR). Conclusions show how architectural design and communication technologies can affect the user's wellness and recovery if they consider psychology and human behaviour.

State of the Art

We are witnessing a rise of concerns about indoor and outdoor navigation related to public facilities, and particularly to health centres. But literature on related topics is far from being homogeneous. While signage – as a part of the visual identity of public administrations and companies – and motor disabilities are widely discussed, mentally impaired patients' needs are still insufficiently studied despite their increasing prevalence in population [1].
For years, sensorial disabled people other than visual have been neglected for the study of hospital navigation, together with mentally disabled people. Due to this lack of awareness and knowledge, architectural design has been far from promoting self-sufficiency and self-esteem to health centres users.
Precedents for wayfinding and navigation services with reference to architectural design are the human-centered studies by Topo and Kotilainen [Topo, Kotilainen 2009], Marquardt [Marquardt 2011], Brusilovsky [Brusilovsky 2015], Karimi and Hashemi [Karimi, Hasehmi 2015], and Karimi [Karimi 2017] must be stressed, together with the guidelines produced by agencies such as the American Psychiatric Association [APA 2007], the Americans with Disabilities Act [ADA 2010] standards, and the *Health Building Notes* (HBN) and *Health Technical Memoranda* by Department of Health, UK. For the purposes of research project, the following are of particular interest: HBN 03 'Mental health', HBN 05 'Older people', and HBN 08-02 'Dementia-friendly Health and Social Care Environments'. The Spanish Organización Nacional de Ciegos (ONCE), the Spanish Ministerio de Sanidad, Servicios Sociales e Igualdad, and the Real Patronato sobre Discapacidad are promoting numerous initiatives related to universal accessibility and inclusive architecture.
Literature is abundant on 3D modelling and visualisation problems, too. After the pioneering studies in the 1990's, an interesting review can be found in Remondino [Remondino 2003]. Advanced technologies for historical cities visualisation have been summarised and applied by Giordano and Love [Giordano, Love 2018].

From the perspective of Augmented Reality and TIC, some recent applications to the built Heritage must be stressed as those by Giordano and Repola [Giordano, Repola 2016], by Spallone and Palma [Spallone, Palma 2021], among other.
Applications to interactive museums by Fatta, Basetta and Manti [Fatta, Basetta, Manti 2016] can be directly related to hospitals' navigation and 'edutaiment' [2] (Fig. 1).

Mentally and Physically Impaired Users of Health Centres: From Needs to Preferences

To be aware of how accessible the traveling indoor and outdoor environment is, and how people with mental or physical disabilities find their way and navigate is of great importance. Considering the existing standards, the challenge is how to particularise the general guidelines for healthcare environments.
Ontologies focused on wayfinding and navigation activities of disabled people can help, as they reveal their needs and preferences. Consequently, an ontology should be defined for each disability and particular site (Fig. 2).
Moreover, for people with disabilities it is crucial to know in advance whether the health centre to which they need to travel have accessible entrances. Consequently, indoor and outdoor points of interest must be checked to know if they comply with the set of standards. Afterwards models that reflect the wayfinding needs of people with disabilities must be developed.

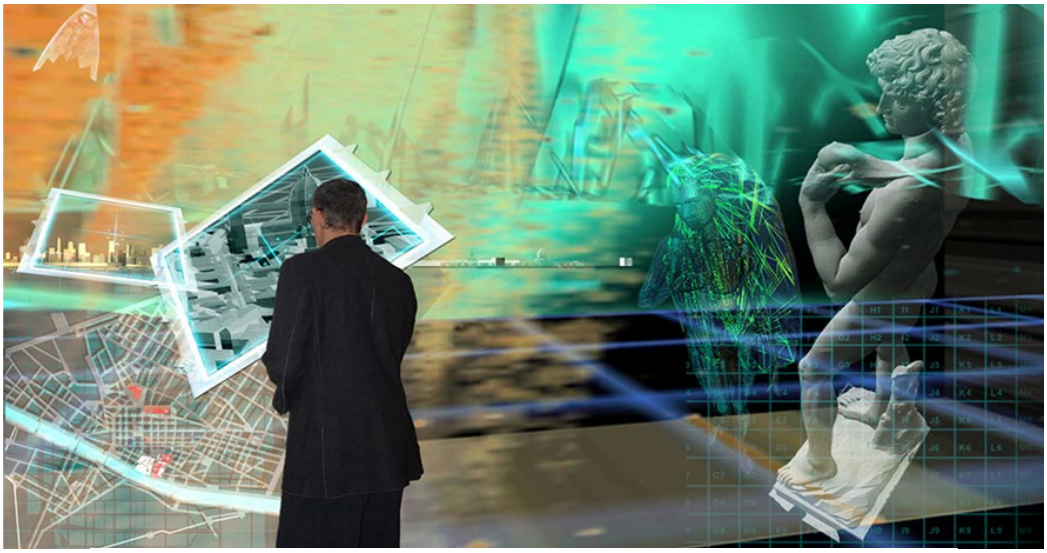

Fig. 1. Franz Fischnaller: City Cluster - From the Renaissance to the Megabite Networking Age [Fatta, Basetta, Manti 2016].

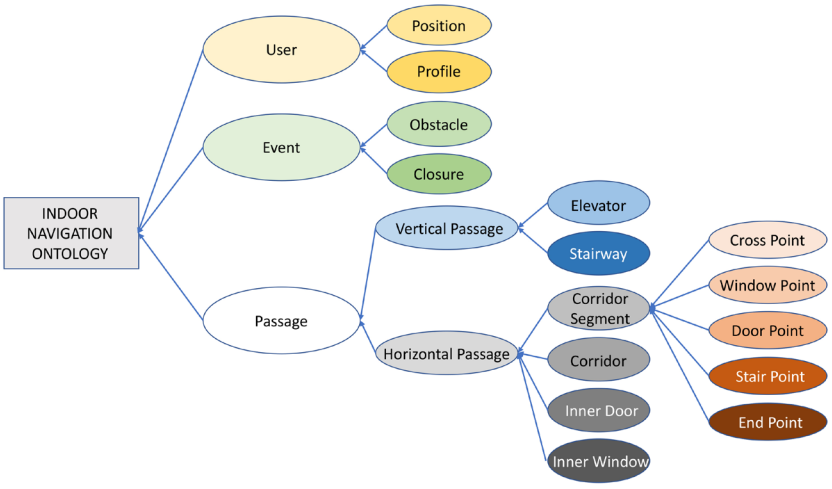

Fig. 2. An ontology for wayfinding and navigation of people with motor and visual disabilities inside the University Hospital Príncipe de Asturias. Ground floor [Chias, Abad 2017].

At the community level, models must address the specific needs of each disability community, while at the individual level the specific preferences of each one.
For example, the challenge is to make dementia-friendly design as a step forward regarding adult mental health unit design.

Best Practice Guidelines for Hospitals' Architectural Design

Health facilities professionals learnt how to embed wayfinding principles into the architecture itself. The solution was no longer hanging more signs that too often confounded the visitors but creating a graphic culture in which handicapped visitors and patients could intuitively navigate while experiencing landmarks and places along the path of journey. As this challenge shifted, the multidisciplinary teams of designers were expected to embrace evidential design, including the new science of wayfinding, and working in collaborative environments.
As a result of this collaborative work, effective wayfinding must be more than just functionality: must be patient-centered and customised. From this perspective the key fundamentals can be summarised in the following points:
1. Wayfinding strategies must show a strong brand identity, providing an ideal platform to communicate the organisation's values and mission to connect with patients on a deeper level.
2. Re-think tradition and tell a story. A meaningful relationship between zones should be created based on the hospital history or prospective (Fig. 3).
3. Truly enhance patients' experience. It supposes more than just direct patients from point A to B: it's a pillar of a great patient experience, turning what can be a frustrating ordeal into a smooth, engaging journey. A more unified experience between all the moving parts – tech, the built environment, staff – is critical to alleviating stress and maximising efficiency.
4. Timeless design for flexibility and consistency.
5. Solicit lots of feedback coming from all sides. Wayfinding in healthcare is supposed to be intuitive – but how can you design it when everyone's intuition and sensitivity are different? Work with the various users and testing were influential on many factors. Prior to a pilot, you need to put yourself in the patient's shoes – literally. Pilot approaches are of great value before rolling out an idea, and must include testing, working with various disabled patients and family focus groups, and then incorporating their feedback to validate processes.
6. Cultural sensitivity becomes essential to reach an inclusive design, universally understandable and culturally acceptable. To make certain a scheme will appeal to diverse populations, it

Fig. 3. Alder Hey Children's Hospital navigation, play and edutainment experience. [Alder Play, Ustwo Games].

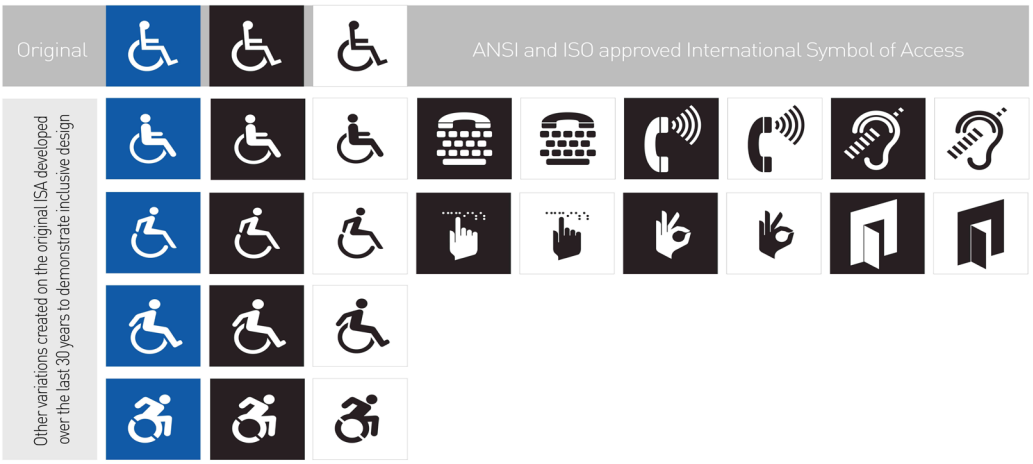

Fig. 4. Accessibility symbols that seek to create experiences that are inclusive, legible, and accessible to all [Hablamos Juntos, SEGD 2010].

is essential to put it through many different filters. Multilingual signage is becoming the standard, but inclusivity extends to those with different types of colour blindness. In the United States, initiatives developed by the partnership between 'Hablamos Juntos' and the Society of Experiential Graphic Design SEGD provide universal symbols and practical solutions to language barriers in health care [Hablamos Juntos, SEGD 2010] (Fig. 4).

7. Make maintenance and updating a priority.

Wayfinding should be addressed in the programmatic phase, when handicapped users can be surveyed. Wayfinding nomenclature can be developed based on a hierarchy of information. For instance, information should be developed that leads from point-to-point rather than confusing visitors with too much information, typical of directional flagpoles and directory floor plans – that cannot be used as unique points of orientation by visually or mentally impaired people, as well as by many elders. Most people can recall a landmark before they can recall a floor plan with a You are here' spot. According to this, walls, furniture, and art can be embedded to be points of orientation.

As it becomes extremely important to design space that could be recalled in a cognitive map, often a mock 'patient journey' has been undertaken. It can be available from a patient's home to the health care facility parking lot and, once there, hospitals should be equipped with interactive kiosks and app utilities that give directions in multiple languages and user-friendly interfaces.

Mapping software can help at every turn, giving designers opportunities to be language-friendly and accessible to the disabled.

3D Modelling and GIS for Health Centre Knowledge and Management

Health centres knowledge and management need the integration of computer vision technologies with wide multiformat databases that include objective and subjective datasets, and must be constantly updated [Chias, Abad 2021, pp. 44-45]. An ontology model defining the interaction between digital databases and Interfaces was previously defined [Palma, Spallone, Vitali 2019].

Consequently, data sources are varied depending on the kind of data. Objective datasets as health care building geometry, dimensions, visible architectural elements and finishings are recorded by means of laser scanning technologies and integrated into a 3D model (Fig. 5). High precision differential GPS sensors were used as location sensors, mainly in outdoor areas at the Hospital.

From scans and GPS datasets we produced the digital base maps of the Hospital for GIS implementation.

Accessible sidewalk networks composed by segments were defined with accessibility attributes and according to topologic relationships. For indoor wayfinding and navigation, the base map contains hallway network on each storey, and connection between stories with accessibility attributes of each hallway segment – as door width, or surface condition. Queries on accessible points of interest – such as entrances – and optimal routes can be answered through GIS.

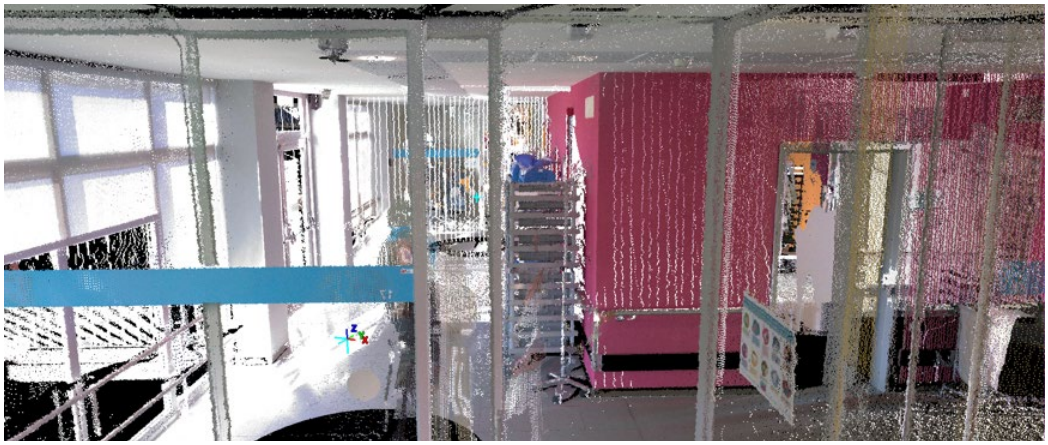

Fig. 5. 3D model for Augmented Reality of the Paediatric ward, University Hospital Príncipe de Asturias, Alcalá de Henares, Madrid [Chias, Abad 2021].

Other objective data collected refer to technical equipment and facilities, indoor traffic flows, scheduling, patients' medical record, pharmacy, etc.
In contrast, subjective data are gathered about handicapped users and accompanying people personal experience during and after a hospital stay, by means of interviews and questionnaires. In this case, materials collected are highly sensitive and privacy protocols must be previously established to safeguard health information. Data sets are structured in multiple layers to progressively extract higher-level features from the raw input by means of machine learning algorithms.
Next step required to customise an app for a mobile platform to develop 3D object recognition and tracking functions, on which AR tools are based. Simultaneous locating and mapping systems (SLAM) [3] based on tailored algorithms are used. Sensors as laser scans and visual features provide details of many points within the study area at the University Hospital Príncipe de Asturias (HUPA), working at the architectural scale. Point clouds were then recognised and compared with the environment surveyed at runtime (Fig. 6).
Consistency and accuracy of positioning data gathered with the GPS sensor proved to be adequate to the research aims.

ITC Technologies and AR-based Solutions for Indoor and Outdoor Navigation

Next stage is to integrate subjective and objective datasets from the various data sources using image recognition functions enabled by Deep Learning (DL). Through image processing, lower layers may identify edges, while higher layers may identify the concepts relevant to navigation purposes.
Wayfinding and navigation systems are customised computer systems – stand-alone systems – that perform all operations without needing remote servers. Two main technologies are being applied to health centres.
On the one hand, the use of beacons or similar technologies to provide indoor GPS' directions exists but is rarely implemented – primarily due to cost, that is a serious disadvantage.
But the most mature and widely deployed wayfinding technology is web-based tools, that allow out-patients to plan their visits ahead of time. Mobile solutions and personalised apps have moved electronic signage to a next level, as smartphones can be used to access the wayfinding website to get visual and aural guidance along their journey. 3D wayfinding tools use mobile-friendly 3D maps to provide point-to-point directions and seamless transitions between multiple floors and across facilities and medical campuses, including audio to engage another sense (Fig. 7).
Alternatively, users of health centres can chart their course from an interactive kiosk in the lobby and download the map to their phone using a QR code. As a step towards highly personalised health care, some stand-alone kiosks have talking avatars or video greeters that facilitate comprehension and give additional information such as walk times. They can also include magnetic stripe readers and bar-code scanners that provide an additional point

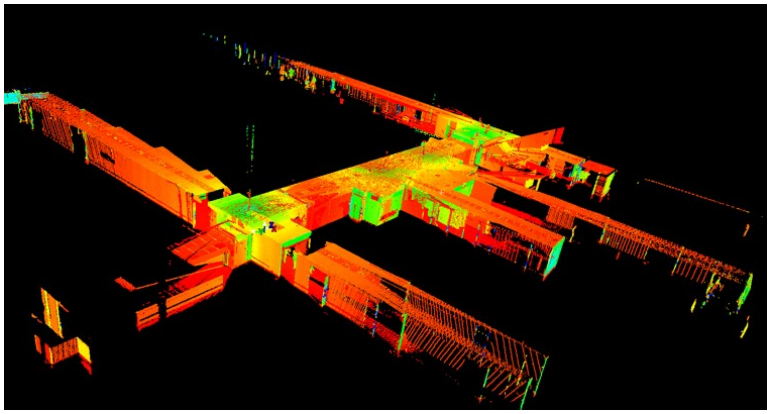

Fig. 6. Accumulated registered point cloud from scanner laser. Emergency department, Paediatric ward, University Hospital Príncipe de Asturias, Alcalá de Henares, Madrid [Chias, Abad 2021].

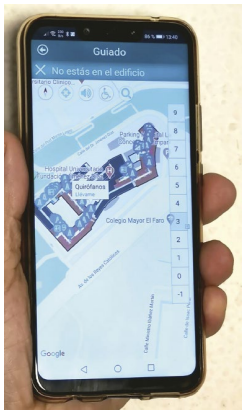

Fig. 7. Patient portal of the University Hospital Fundación Jiménez Díaz, Madrid [Chias, Abad 2021].

of integration. Moreover, they can deliver personalised content and applications such as appointment scheduling, pharmacy check-ins and patient-to-doctor communication.
Among other advantages of mixed navigation systems are the possibility of quick updates and the integration of Media Nav maps including BLE beacons, WIFI, located-based messaging, voice-activated search, and geomagnetic positioning to accurately track a user's location indoors via a 'blue dot'. By using a built-in magnetometer and other smartphone sensors, the magnetic field inside buildings can be used to pinpoint and track users within 90 cm and 1,5 m. These systems improve venue safety, accessibility, and the overall user experience. Moreover, as powerful integrative tools they should address language barriers and solutions that are landmark-based.
In addition, most of the systems can be managed remotely from an internet-enabled device.

Conclusions

Digital wayfinding is making inroads in health care centres but still has a way to go. However, no matter the size of the digital display, the impact also is significantly determined by the quality of the content.
One of the key features associated with digital signage solutions is data collection and management.
Location-based tracking, reporting and analytics give hospitals real-time visibility into the location and status of patients, visitors, vendors, and staff, coupled with visual analytics on historic patient, on visitor and staff workflows.
In particular, the following information on experience of handicapped users has high value: waiting times at different surgeries, transit times for different patient journeys to book appointments, etc.
Obviously, among key best practices the possibility of changing the wayfinding program as often as the health care centre changes, becomes mandatory. However, technology is a friend to younger patients and family members, but it can be also a perceived enemy to older populations, particularly to those who are sight-impaired or mentally handicapped people. This has consequences for elderly populations and major implications for the larger boomer generation that will become the primary user of health care facilities.
But can navigation technologies replace face-to-face contact? Challenges include the potential loss of the personal touch. A front door valet and concierge greeter make visitor feel special and safe, having the opportunity of being emphatic. They can answer questions directly and even walk patients to their destinations within the hospital. Thinking of the consequences of a technology failure, visitors may be confused, frustrated, and perhaps lost, but when wayfinding programs incorporate the human connection, they feel relieved.
Patients and hospital users need navigation support, not natural navigational replacement
As a conclusion, the challenge is to make dementia-friendly design as a step forward with regard to adult mental health unit design.

Notes

[1] The prevalence increases dramatically with age: approximately 5% to 8% of individuals over the age of 65, 15% to 20% of individuals over the age of 75, and 25% to 50% of individuals over the age of 85 years are affected. Source: Eurostat.

[2] Edutainment platforms are working with hospitals to optimize their education strategy and extending it beyond the four walls of the facility, both pre- and post-stay. They are finding new ways to serve as patient's digital personal assistants and engagement tools, playing a complementary role in the interactive patient experience and in data collection.

[3] SLAM is the computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of an agent's location within it. The system requires a previous acquisition of point clouds of the chosen areas at the HUPA.

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