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Assistive Technologies in Smart Cities

Edited by Alejandro Rafael Garcia Ramirez and Marcelo Gitirana Gomes Ferreira

ASSISTIVE TECHNOLOGIES IN SMART CITIES

Edited by **Alejandro Rafael Garcia Ramirez**
and **Marcelo Gitirana Gomes Ferreira**

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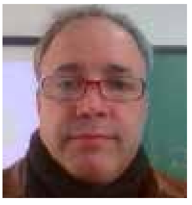
Meet the editors



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Contents

Preface

This book discusses how assistive technologies can be adapted to today's world. Several challenges arise, stimulating the evolution of current solutions. The topics discussed in this book present research under development showing the relevance of assistive technologies and their applications in smart city scenarios. The book is divided into five sections.

The first section presents Raspcare, which consists of a domestic gateway to allow interaction with household devices to execute the user's health plan, involving periodic measurements, medications, and dietary care. In the second section, the requirements for general Internet-of-Things (IoT) applications in a smart city context are analyzed, discussing the state of the art for the use of IoT for accessible tourism applications. Architecture together with a practical implementation tailored for the use case of accessible tourism to persons with physical impairments in the urban environment of Cagliari is proposed. The third section presents key characteristics that intuitive tactile interfaces should capture for elderly end-users. Sample projects showcase unique applications and designs that identify the limitations of universal interfaces and end-user needs. The fourth section highlights past and future roles of communication and pattern formation in the local cluster of the developing smart city. The goal is to transform a city via better cluster management, urban planning, coordination, citizen enablement, integration, and citizen feedback into a better functioning, convenient, and intelligent place for all of us, including disabled, ill, young, or aged persons. In the last section, an overview of theories and models helps us understand why assistive technology is considered to be a promising opportunity to address the challenges of an aging population. Specific attention is devoted to the implementation of technology within healthcare organizations. The importance of human-centered design in the development of new assistive devices is also discussed. Several examples illustrate the daily practice of the different perspectives of involved stakeholders.

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Chapter 1

Introductory Chapter: The Role of Assistive Technologies in Smart Cities

Marion Hersh, Marcelo Gitirana Gomes Ferreira and
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Additional information is available at the end of the chapter

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1. Introduction

1.1. What is a smart city?

There is not (yet) a generally accepted definition of the term 'smart city'. However, 'smart' systems are often considered to have the following three characteristics [1]: (i) the provision of technological assistance, including through the use of a combination of a physical infrastructure and information and communication technologies (ICT); for carrying out activities; (ii) information sharing and networking between different applications, systems, services and/or appliances and (iii) the application of the combination of ICT and other technologies, information sharing and networking with the aim of improving the quantity or quality of systems, services or applications provided.

These three characteristics can also be used to define smart cities. Smart cities have the potential to provide higher quality, more accessible services at a lower cost [2]. In addition, they have the potential to improve the city environment, the quantity and diversity of services and quality of life. They may have particular benefits for disabled and older people and may reduce or eliminate some of the barriers they might otherwise experience to participating in all aspects of life and enjoying the same opportunities and quality of life as non-disabled and younger people.

As will be discussed further below, smart cities have considerable potential to improve quality of life for both disabled and older people and the population as a whole. Technological and other systems also have disadvantages, but the focus has been on positive applications, with minimal attention to any potential disadvantages or problems. One potential problem is avoiding unauthorised access to personal and confidential organisational data and ensuring that citizens are able to manage their privacy in a way that enables them to make the maximum use of applications. This is important because privacy is valuable both in itself and to avoid risks to disabled and older people and other groups who may be seen as soft targets by unscrupulous people. Attention to privacy management could improve the design of smart cities. In addition, though beyond the scope of this chapter, the very aspects of smart cities that give them their positive potential also give rise to the potential for abuse, whether by totalitarian regimes to remove civil liberties or by more ordinarily corrupt city administrations to hide their excessive expenses. Awareness of such possibilities could be used to design in safeguards to reduce the likelihood of abuse.

1.2. Smart homes

Interest in smart cities is relatively recent, though a body of literature has developed. Smart home technologies date back to the 1970s home automation technologies. A smart home involves the use of sensors, actuators and computational units to interconnect appliances and other features and anticipating and responding to the occupant's needs by means of ICT [3, 4]. Alternatively, a smart home involves systems equipped with sensors and actuators to enable them to communicate with each other, monitor the occupants and support them in their daily activities [5]. This integration of home systems, including with the assistance of multi-agent systems, allows communication between them through the home computer and the simultaneous control of different systems in operating or pre-programmed modes using speech and single buttons [6]. Data mining and machine learning techniques can be applied to this data to discover frequent activity patterns and predict events to support automation of interactions with the environment and enable context-aware responses. Adaptation to changing requirements can also be facilitated by context awareness [7].

Active or passive radio frequency identification device (RFID) tags which are able to identify people, animals and objects and which are now inexpensive can be used to support the smart and context-aware functions [7]. Mobile robots with RFID readers can be used to navigate tagged environments and locate and move objects. Technological advances have enabled sensors to be located in the environment rather than on the robot, reducing its size and weight [7]. However, despite various proposed solutions, RFID tags are an insecure technology and could be used to track people and their activities [8, 9].

Initially, smart home design was based on a centralised architecture with all appliances connected to the home network and controlled by the home gateway. However, the availability of ubiquitous computing devices has enabled the use of distributed architectures with incompatibility between different products avoided by the use of open standards. Options include the Open Services Gateway Initiative (OSGi); a peer-to-peer architecture with multiple platforms [10]; and a generic five-layer context stack with each layer having a different function [11]. The OSGi is generally based on the client-server model, and is unfortunately at risk of single point of failure in the home gateway [10]. The use of multiple platforms can avoid this by distributing the working load over the system with service-oriented components augmented by mobile agent technology for system interaction [10].

There has been some involvement of disabled people in smart home design. Consultations with them have obtained the following preferences [12]: (i) lights turning on automatically when they return home, go into a room and at night; (ii) access to a garden and items of equipment; (iii) security, including an option for viewing visitors at the front door before opening it; (iv) automatically closing curtains and insulating shutters at night; (v) an 'ordinary' external appearance; (vi) a non-open-plan layout, with sufficient space for manoeuvring and activities and (vii) a self-contained home in a central, secure, quiet, private location on the ground floor and on level ground. An investigation of different projects has found a greater focus on physical and functional health rather than social interaction, possibly because it is more difficult to integrate social interaction technologies [13, 14]. Examples include the Portsmouth Smart Home [12] and The Intelligent Sweet Home [15, 16] developed at KAIST, Korea and aimed specifically at wheelchair users. There are also home healthcare (telemedicine) applications, for example, [17].

1.3. Smart city technologies and applications

While an initial smart cities approach could draw on smart home technologies and link some or all buildings in the city, smart cities have considerably greater potential. They may involve various stakeholders, including citizens, city administrations, local projects (non-governmental organisations), private firms, researchers and educational institutions. They can support city administrations in providing services of different kinds and promoting culture and education [18]. Citizen-centred approaches to smart cities with a focus on people rather than technology, administration or business are likely to be particularly valuable. One model involves an ecosystem of participative innovation [19] leading to innovative user-centred services and needs to be supported by new models of city government [17].

Smart city applications generally rely on perceivable or ubiquitous sensing, and anytime/anywhere access and control [19]. The available infrastructure (including sensors, personal technologies, smartphones and use of the Internet) allows the exploration of different options for development, quality of life, welfare and the economy [20]. However, they are not some sort of universal panacea. As well as opportunities, bringing a large number of people together in a relatively compact geographic area can also lead to problems which smart city approaches are not able to resolve.

There has been particular interest in the use of the Internet of things (IoT) as an enabling technology for smart cities [21]. The IoT involves a proliferation of different types of devices which are wirelessly interconnected and interacting [22]. Sensors and actuators are integrated into the environment and information sharing takes place across various platforms. In principle, the IoT can be used to measure, analyse and understand environmental indicators of different types and of different sizes and complexities [21]. Smart city services are generally based on a centralised architecture with a dense and diverse set of peripheral devices [22]. In addition to the IoT supporting smart cities, the very dense techno-social city ecosystems can serve as a useful test bed for IoT research [21]. A number of very different approaches have been used to the design of smart city architectures, but there are some common features. In particular, smart cities are generally data-centric and multidisciplinary [20].

Examples of smart cities include the Barcelona smart city initiative [23], the Padova smart city [22] and SmartSantander [18]. The main aim of the Padova smart city is encouraging early adoption of open data and ICT solutions by the city administration. It is being used to collect environmental data and monitor street lighting via different types of sensors mounted on the lamp poles and connected to the Internet [22]. The Barcelona smart city initiative is part of its strategy for transformation from deep economic crisis and infrastructure deficit to becoming a leading metropolis [23]. Its main components are smart districts, living labs, initiatives, e-services, infrastructures and open data. In particular, smart services have been used to encourage cooperation, innovation and development.

Smart cities have a wide range of different (potential) applications. A hierarchical classification includes the domains of transport, mobility and logistics, education and culture and public administration and (e-)government [24]. At least some and frequently many or most disabled and older people experience barriers to participation in all these areas. Smart cities offer potential solutions, as long as they are appropriately designed to take account of the accessibility and other requirements of older and disabled people. In some cases, it may be necessary to target solutions at particular groups of disabled or older people.

However, there are advantages in design for all/universal design to make all (smart) facilities and features accessible and usable by as wide a range of the population as possible, regardless of factors such as age, gender, disability, size, culture and class [25]. Design for all should be considered part of standard good design practice [26]. A set of seven design for all principles have been drawn up [27, 28] including the following: the same or equivalent means of use for all users; accommodating a wide range of user preferences and characteristics; minimising negative consequences of user errors or unintended action; and efficient and comfortable use with a minimum of fatigue. Smart Cities for All [29] is an important initiative for the dissemination of universal design in the ICT business environment. It aims to close the digital divide between disabled and older people and the rest of the population. It is trying to develop the strategies necessary to build more inclusive smart cities in partnership with ICT companies.

Smart city approaches to overcoming the barriers experienced by disabled and older people will only have their full potential if restrictive assumptions about what facilities are appropriate or of interest to them are avoided. For instance, it has been suggested that smart cities should address the needs of older people across the areas of housing, transport, social participation, social inclusion, health care, communication, community support services, leisure and culture [30]. Unfortunately, employment and learning (education, training and informal learning) are not mentioned, though they are equally important for many disabled and older people. The authors also provide a very brief overview of various systems for older people developed and, in some cases, implemented in the Finnish city of Oulu. They include basic IT skills training at home, online grocery order and home delivery and a pilot for nurses to open locks with mobile handsets. However, considering some of the other applications mentioned smart city applications is probably stretching the concept.

This chapter is part of a small body of work on the applications of smart cities to disabled and older people. The focus seems to be health-related applications, rather than using smart approaches to overcome the barriers to full participation, including in employment, education, travel, leisure and other activities. However, other potentially interesting applications include connecting public buildings and public transport. This could be used, for instance, to determine when a disabled person needs to leave their house to reach a public building in time for an appointment [25]. This type of connection could be extended to, for instance, enable autistic people to choose times when buildings and public transport are relatively quiet. A networked system could be used to provide tactile and audio information and alerts to support unaccompanied travel by visually impaired people [31].

2. Conclusions

Research on smart homes dates back to the 1970s, whereas that on smart cities is considerably more recent. They have the potential to overcome many of the barriers to full participation experienced by disabled and older people. However, this requires consideration of their accessibility and usability requirements, preferably as part of design for all approaches and recognition of the wide range of applications that they might be interested in. To date, there has been very little work on smart cities for disabled and older people or design for all approaches to smart cities.

This book aims to start filling this gap. The five chapters present a number of different approaches to smart city design for older and disabled people. They consider interfaces, design approaches, specific technologies and applications. Haptic interfaces are proposed as a means of overcoming information overload and improved city design based on communication and local clusters is discussed. IoT is presented as the basis of smart city architectures. The applications presented are accessible tourism and health care.

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Chapter 2

Raspcare: A Telemedicine Platform for the Treatment and Monitoring of Patients with Chronic Diseases

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Abstract

Metabolic and electrophysiological measures must remain within normal values to maintain the quality of life of chronic patients. Furthermore, depending on the age and disease stage of the individual, automatic identification of risk situations is critical for emergency support. To achieve these goals, this study proposes a technological solution termed Raspcare to help both the patients in their self-care and the medical teams monitoring the patients. The solution consists of a domestic gateway equipped with a microcontroller and various interfaces to allow interaction between the platform and household devices, such as televisions, biometric sensors, blood glucose metres, non-invasive pressure gauges, smartphones and smartwatches, among others. The gateway implements a Linux OS application responsible for executing the user's health plan, which involves periodic measurements, medications and dietary care. Moreover, the application has data processing algorithms to establish alerts for the automatic detection of abnormal measurements and falls.

Keywords: mobile health, chronic disease, gateway, blood pressure, glycaemia

1. Introduction

Chronic diseases affect a significant portion of the population, especially when we select the group of individuals older than 60 years. As the population ages, the percentage of chronic patients tends to increase. Chronic diseases associated with hypertension are the leading risk factors causing mortality, accounting for 9.4 million deaths worldwide in 2010 [1]. Nevertheless, hypertension is not an inevitable consequence of ageing, but a lack of monitoring and adequate treatment increase the risk of consequences of the disease. Another chronic disease with serious consequences for quality of life is diabetes. The global prevalence of this disease in 2014 was 7% of the population, accounting for 1.5 million deaths in 2012 [1], which leads to a pessimistic long-term view. In general, chronic patients financially burden the healthcare system. Furthermore, chronic patients at an advanced stage of disease are no longer able to perform their daily activities, directly affecting their quality of life and therefore aggravating their state of health.

The best method to address this issue is to implement preventive measures. Prevention consists of monitoring the health status of chronic patients over time by conducting regular clinical examinations. Therefore, the issue is addressed at its initial stage, enabling chronic patients to treat their disease and preventing its rapid and devastating progression. Long-term prevention enables patients to maintain their quality of life and directly affects the percentage of health spending. Finally, for health managers, prevention improves the distribution of health resources, thus avoiding their collapse.

For the task of prevention, the use of telemedicine strategies is a low-cost alternative that has demonstrated effectiveness in treating chronic patients [2, 3]. The strategies presented in the specialised literature [2–13] involve monitoring the health status of the patient by periodic telephone and house calls, completing an electronic patient diary with information on routine daily activities and health status and transmitting biomedical data using medical devices. Among these strategies, the best results have been achieved when strategies are combined, particularly when medical devices with data transmission capability are used.

The literature indicates that maintaining the relationship between patient and healthcare professional is a prerequisite for the success of telemedicine in the case of diabetic patients [3]. This relationship may be enhanced by telephone or web conferencing. Conversely, some of the requirements of the technology used by the patient directly affect patient adherence to the technology [3]: (i) Regarding ease of use and small size, desktop computer-based solutions have not generated good results. (ii) Transmission of patient health status data (e.g. blood glucose, blood pressure and heart rate, among others) to the specialist cannot be lengthy given its direct impact on treatment and insulin administration. In this case, algorithms that perform embedded data processing are more effective; (iii) The Internet facilitates the interaction between the patient and healthcare professionals. Internet communication is one of the secrets to the success of teleconsultation projects.

Some studies have proposed prototypes to meet the above requisites. In addition to using a smart TV as platform, which is still difficult to use due to remote control limitations, Laura et al. [9] used near-field communication (NFC) with the pressure gauge, making it difficult to purchase devices with this function. Mageroski et al. [10] used wireless sensors in clothing, on the body and in the environment. Although the solution is simple because it is wireless, its use is extremely limited by its dependency on the Internet. Furthermore, a reliable wireless broadband network is necessary, which is also an important limiting factor. Yu-Fang Chung [11] proposed a monitoring solution through a network of ZigBee wireless sensors, which provide an interface for real-time temperature and heart rate monitoring and video streaming.

According to Henriksen et al. [12], the use of patient monitoring platforms involves several risks because their data are stored and therefore may be leaked. Alternatively, another type of failure may occur. Unauthorised data access was considered a high risk due to weak or predictable passwords; however, a biometric sensor can be used to minimise this problem.

The study conducted by Santos et al. [13] should be noted. The authors designed the CareBox, a hardware based on an NVIDIA ION mini-PC with an Atom 1.6 GHz processor and 2 GB RAM, an operating system based on OpenELEC distribution and the Firefox browser. The programming was based on the Python programming language. The study focused on developing an interoperability, configuration and remote update solution. The interfaces available in the solution involve Ethernet network, Wi-Fi network and infrared, High-Definition Multimedia Interface (HDMI) and Universal Serial Bus (USB) ports. Furthermore, the solution implements fingerprint biometrics for user authentication. Regarding patient treatment, the solution implements an electronic calendar in the daily routine of the individual, including medication schedules. The solution only measures the blood pressure via Bluetooth. Finally, the television is controlled via an external device termed the Universal Serial Bus-Consumer Electronics Control (USB-CEC), which receives commands via USB and controls the television via the HDMI port. The study identified some limitations that became perspectives for future research: the remote control is not sufficiently practical for the user to perform the intended functions; no integration with smartphones is available; and more sensors must be integrated. Furthermore, the solution depends on local connectivity to load the patient care plan with the information from the schedule of activities related to the treatment of the patient.

This study proposes a new home support technological solution to monitor diabetic and hypertensive patients. In addition to helping a significant portion of chronic patients, the proposed solution is original for the following reasons: (i) it combines commercial devices certified for medical measuring; (ii) it implements a fall detection algorithm for patients using a smartwatch device [14]; (iii) it provides local operation in the absence of connectivity; and (iv) it integrates the care plan with the Google Calendar feature that is compatible with mobile devices with Android operating system. Finally, despite the exponential increase in the number of studies focused on the use of smartphones in the field of mobile health, this study proposes a platform that also meets the technological requirements of a large portion of the Brazilian population (46%) [15] with chronic diseases who have conventional television sets but no Internet access at home.

2. Materials and methods

2.1. Requirements of the diabetic and hypertensive patient home monitoring platform

To monitor chronic patients at home, an indispensable device is the gateway, which is the base of the telemedicine platform. This device should act as a concentrator of the data generated by the e-health sensors, storing the data locally and synchronising them with a remote database for subsequent access by the medical team. Sensor data may or may not undergo local post-processing to generate alarms. For improved chronic patient adherence to the treatment, a patient care plan prepared by the health team should be synchronised with the patient electronic calendar to guide the daily treatment routine from medication and data acquisition times to dietary and physical activity suggestions. The architecture of the telemedicine platform with the above characteristics is presented in **Figure 1**.

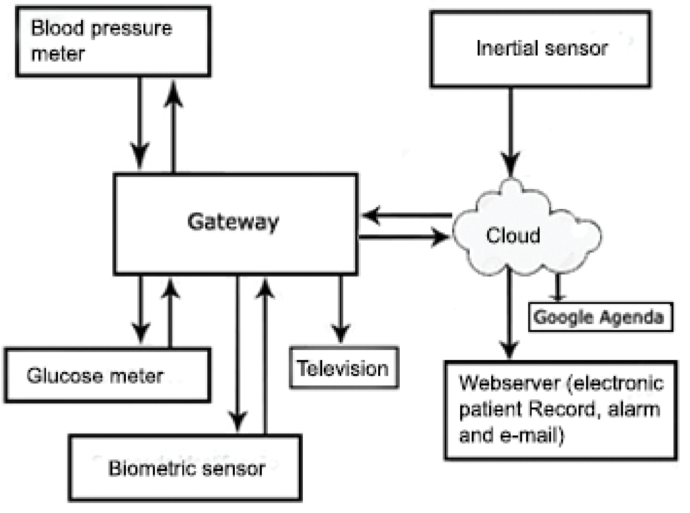

Figure 1. Schematic representation describing the architecture of the Raspcare platform.

Based on the architecture presented in **Figure 1**, the Raspcare platform proposed in this study implements a set of requisites for its operation in a home environment, namely:

- Independent home base working as a sensor data concentrator of devices integrated with the base
- Interaction with television interfaces via HDMI-CEC technology and with Android mobile devices (smartwatches and smartphones) via wireless communication
- Support to wired and wireless e-health devices (medical measuring devices)
- Possibility to load the care plan locally or remotely (via the Internet)
- Interoperability with Google Calendar
- Compatibility with Android mobile devices
- Secure user authentication via a biometric interface
- Fall detection algorithm
- Web application allowing monitoring of vital signs
- Generation of alerts through automatic processing of vital signs and movement enabling the prevention and detection of risk situations (blood glucose and pressure values and falls)

2.2. Raspcare platform architecture

To implement the above requisites, the architecture presented in **Figure 1** is proposed. Each block is described below.

The schematic representation presented in **Figure 1** represents the architecture of the platform proposed in this study, termed Raspcare. The Raspcare platform has a main module that plays the role of gateway, interfacing with the various in-home patient monitoring devices, namely:

- Blood glucose and pressure metres
- Biometric sensor
- Television
- Fall detection sensor

The data collected by the blood glucose and pressure metres and the fall detection sensor are stored both locally on the gateway through the local monitoring software and remotely in the web application. The gateway connection with the television enables the patient to view the alarms and the history of measurements over time. The platform also implements two types of alarms:

- Alarm from the Care Plan Calendar: the care plan is the treatment proposed by the physician for the patient. The plan includes dietary recommendations and the medication and measurements the patient should take throughout the day.
- Alarm indicating an abnormal situation: two abnormal situations are detected by the monitoring software. The first situation refers to blood glucose and pressure values that are compared with the abnormal values set in the monitoring software. Every time the blood glucose and pressure values are abnormal, an alarm is triggered. The second situation is related to the fall detection sensor. Every time a fall is detected, the alarm is activated.

The alarms are turned off by the patients themselves. To do this, the patient must place his or her finger on the biometric sensor that will identify the patient and inform the monitoring software to turn off the alarm.

Details on each component of the Raspcare platform are presented below.

2.3. Sensors

The sensors used in the proposed system enable telemonitoring the patient health status (blood glucose and pressure values) and activity (falls). A biometric sensor is used to scan the patient's fingerprint to ensure secure user authentication when collecting the data.

To monitor the health status, patients use portable blood glucose and pressure metres certified for medical use. These devices have a communication interface to share data. The blood glucose metre used was the OneTouch UltraMini [16], which has memory for 500 blood glucose test results, operating range of 20–600 mg/dl, and analysis method based on a glucose oxidase biosensor. The data from the blood glucose metre are transferred using an RS232-USB converter because the gateway has a USB port. The converter implements the manufacturer's protocol for accessing data stored in the device's memory. The blood pressure metre used was the G-Tech RW-450, which measures the wrist blood pressure of the individual. This is the first blood pressure monitor available in the Brazilian market with the capacity to transmit measurements stored in the memory to a computer. To collect data, serial communication with the blood pressure metre was used according to the manufacturer's communication protocols [17], as the blood pressure metre has a USB interface cable for connection with the gateway.

For activity monitoring and fall detection, accelerometre and gyroscope inertial sensors are used, which are available in most smartwatches in the market. In this study, the LG Urbane smartwatch was used.

To increase data security and facilitate user authentication, a biometric sensor was used. The authentication procedure makes it possible to disable alarms and interact with the platform. The biometric sensor used was the GT-511C1R. The biometric sensor used has a CPU ARM Cortex M3 Core, optical sensor with 14 × 12.5 mm effective area, universal asynchronous receiver/transmitter (UART) communication interface operating at 3.3 V and storage capacity for 20 fingerprints. The communication between this sensor and the gateway uses the sensor transistor-transistor logic (TTL) serial communication in addition to some resistors to change the sensor voltage (5 V) to the gateway voltage (3.3 V), and the manufacture's communication protocols [18] were used to identify the user for data input.

2.4. Gateway

The data concentrator or gateway is a device able to collect, process and communicate data on patient health and activities. The data collected by the sensors are processed and analysed in real-time through embedded algorithms (signal processing and machine learning) to identify risk situations and generate alerts sent to the cloud through the Internet. The cloud remotely stores and processes the data. The data may be accessed and monitored remotely through the user's personal devices, including televisions, smartphones, smartwatches, tablets and laptops.

The Raspcare platform includes another gateway function. This is the patient care plan, which establishes the treatment routine, measurements, medications and dietary recommendations. To ensure that the patient adequately follows the care plan and that treatment is effective, the proposed alarm generation module generates alarms according to the Care Plan Calendar, which is implemented in the gateway and is synchronised with Google Calendar. Therefore, both the gateway connected to the television and the smartphone or smartwatch receive the alarm notification in the form of a task scheduled in Google Calendar. The loading of the Care Plan Calendar is addressed in the next section.

The hardware used to develop the platform was the Raspberry Pi 2 [19], a microcomputer with an embedded Linux operating system and Raspbian distribution, an adaptation from the Debian distribution developed by the manufacturer. This microcomputer has a 900 MHz ARM Cortex-A7 processor and 1 GB of RAM memory. **Figure 2** presents the communication technologies used in each Raspcare platform device.

A base was designed and developed through 3D printing to accommodate the gateway and its peripherals, as shown in **Figure 3**. A frontal view depicts the position of the Raspberry board, and a top-down view shows the space for the cables and connections of the sensors.

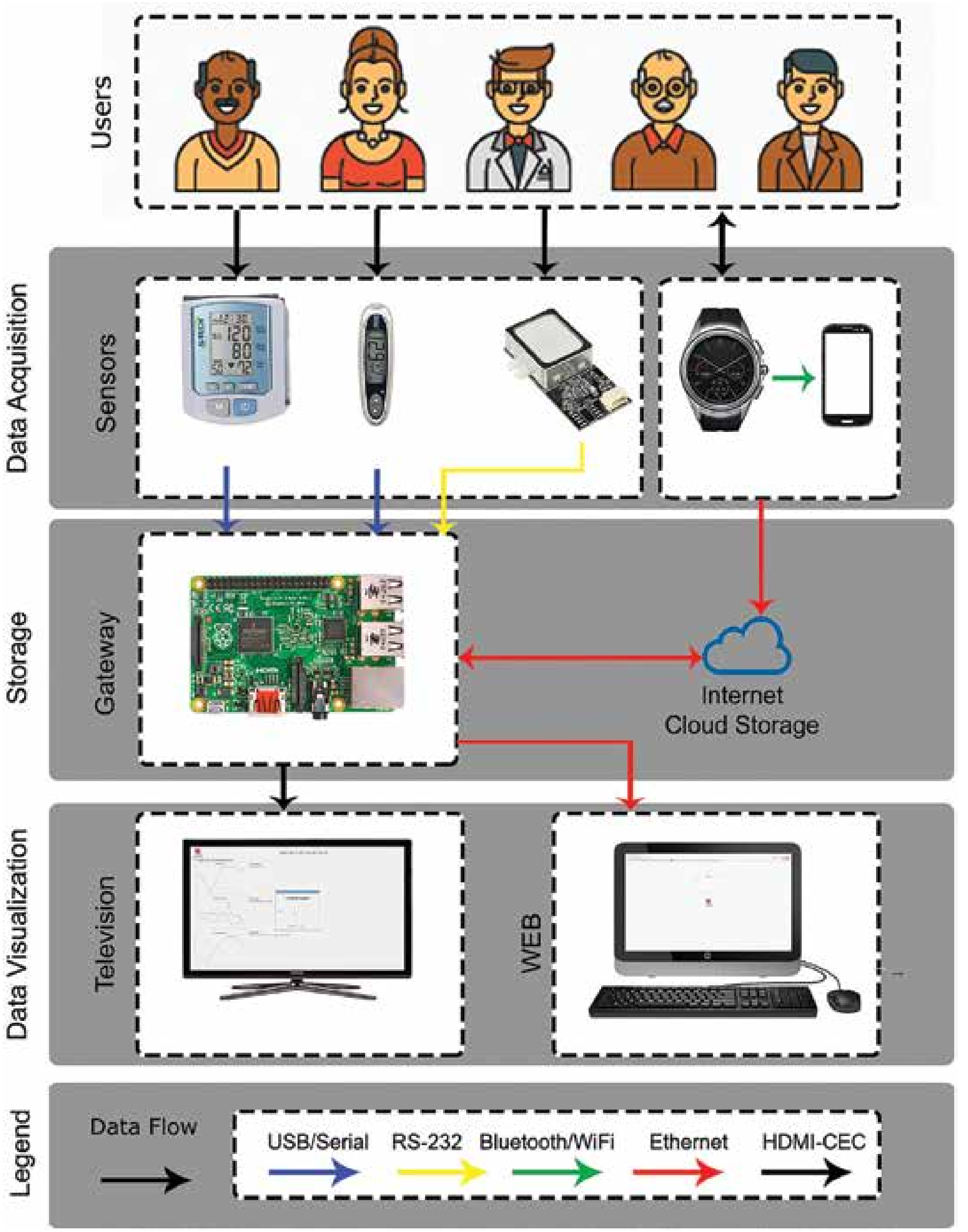

Figure 2. Technologies used for communication between devices.

2.5. Application modules

The Raspcare platform has three main application modules: client application, web application and fall detection application for smartwatch. As shown in **Figure 4**, the applications

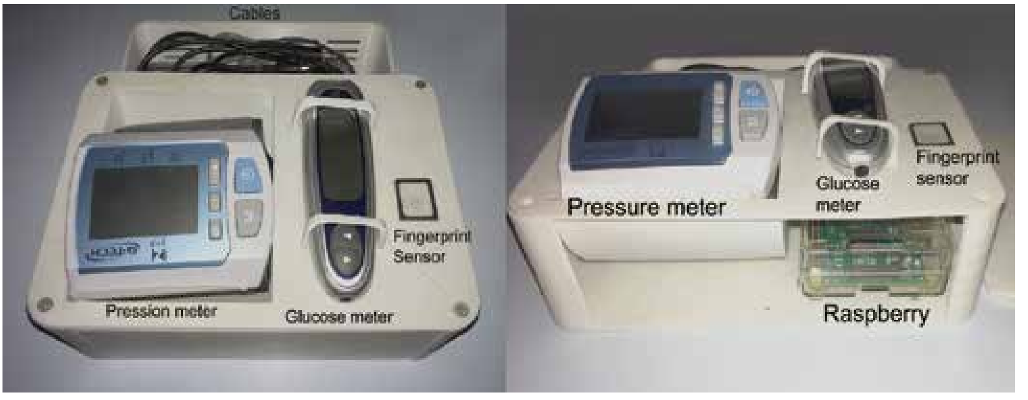

Figure 3. Base developed to accommodate the gateway and the Raspcare platform devices.

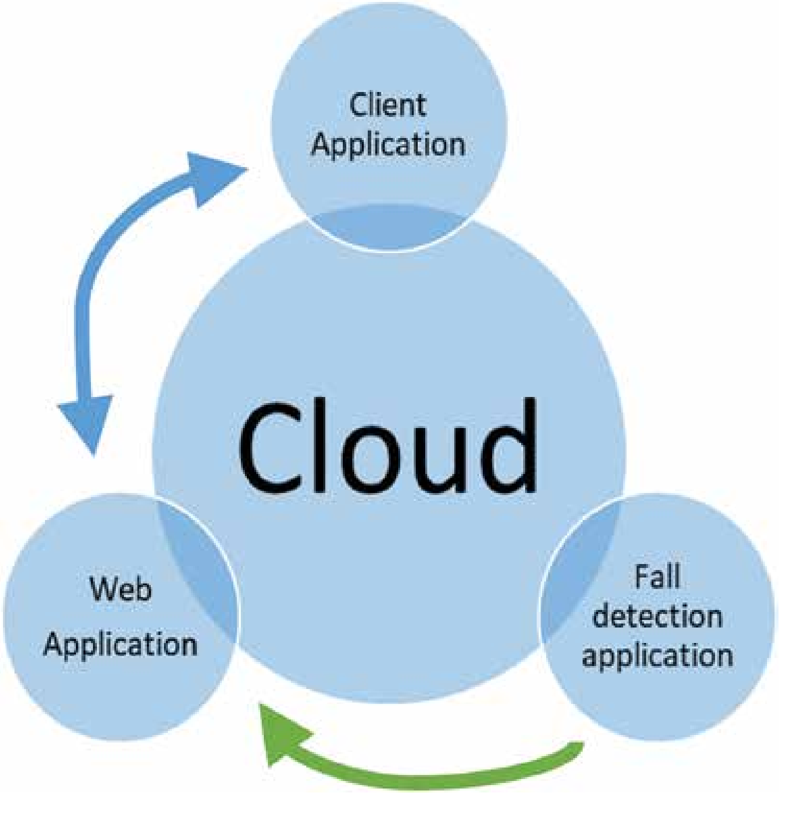

Figure 4. Main applications of the Raspcare platform.

communicate through the cloud. The fall detection application installed in the smartwatch sends the fall alert to the web application only through an HTTP request, which subsequently inserts the alert into the database. Similarly, the client application installed on the gateway connected to the Internet synchronises the blood glucose and pressure measurement data stored locally with the web application, which inserts them into the remote database. Each patient is identified through their unique ID in all operations between applications.

The client application was developed in Python language [20] due to its large number of libraries, vast documentation and efficiency. The interface was designed using the pyQt4 framework [21], and a MySQL database was used to store the data.

The database modelled consists of seven tables, namely, three tables for the data generated by the blood glucose and pressure metres with the identification (Integer), collection date (Datetime) and value inserted (String) fields; one table for medication data storage, containing a medication identification (Integer), time (Time) and description (String) field; one table to store data on doctor visits with the identification (Integer), collection date (Datetime) and visit description (String) fields; one table for dietary data storage containing the meal identification (Integer), time (Time), type (String) and suggestion (String) fields; and, finally, one table for storage of collection times containing the identification (Integer), collection time (Time) and type (String) fields.

Regarding the identification and data manipulation criteria, ID columns with an auto-increment setting were used in all tables, and all types of data are recorded in MySQL Standard Edition.

Libraries were also used to insert data into Google Calendar (Calendar API) such that by establishing a connection with the Internet, the client application will synchronise reminders in the Google Calendar of the user's personal account with prior user permission. Synchronisation with Google Calendar occurs when the Internet is available. If the user account is not registered, the browser window opens, requesting the Gmail user login and password data, which are recorded in the database for future synchronisations. Thus, the user will receive notifications on their personal tablet, smartphone or smartwatch devices.

For remote access to the data generated by the client application and by the fall detection application, the web application has a database that synchronises the data from the blood glucose and pressure measurements and the fall events detected, enabling the health team to monitor the patient remotely through a conventional webpage. The web application stores some configuration data in the database, including the login and password of the consultant physician, name and e-mail of the consultant physician and ID and name of each patient.

Figure 5 presents the flowchart of the client application functions. First, the application checks if the Internet is available to add events recorded locally on the Google Calendar account of the users to notify them through their personal devices. Then, the client application queries the remote database for detected fall events. Subsequently, the application queries the activities in the Care Plan Calendar of the patient and assesses whether it is time for some activity, i.e. medication, measurement or meal. If it is time for some recorded activity, the television turns on or is switched to the HDMI channel through the HDMI-CEC protocol, and an Alarm window with the corresponding activity is displayed on the television screen. In addition, Google Calendar, via Android OS, generates a message on

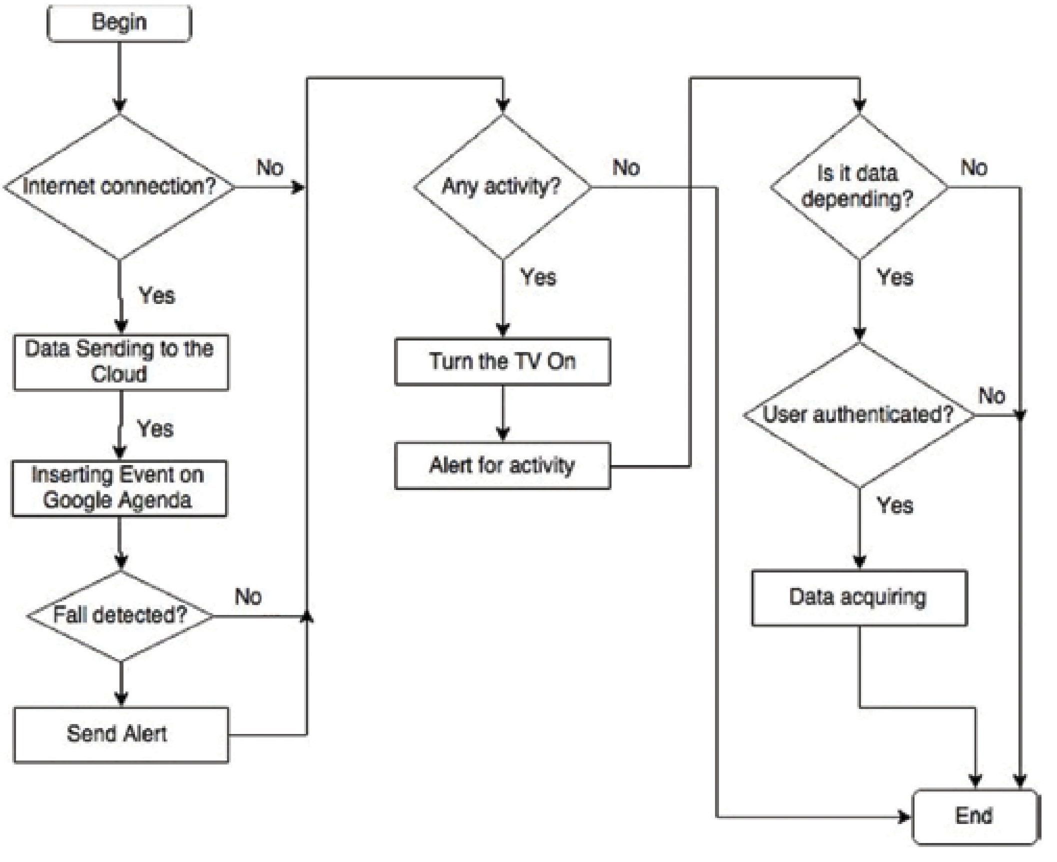

Figure 5. Flowchart of the client application.

the devices registered in the patient's personal account, namely, smartphone, tablet and smartwatch. If the activity is a blood glucose or pressure measurement, prior patient biometric identification is required to allow the client application to collect the data. If the patient has an Internet connection, the client application sends the data to a remote server located in the cloud to allow the healthcare professional to process and analyse the data.

The fall detection application WatchAlert [14] was integrated into the Raspcare platform. WatchAlert is executed in two devices, a smartwatch and a smartphone. Sensor data are collected in the smartwatch. Then, data are sent to the smartphone for processing. If a fall occurs, it is identified. Data on falls were integrated into the database of the web application for combined analysis with the health monitoring data. For WatchAlert configuration, the users must enter their personal data, such as address, e-mail and telephone number, as shown in **Figure 6**. WatchAlert is turned on or off through the smartphone application.

Data on user activities and health stored in the database may be analysed and processed using an analysis and procession module of the application. This module aims to extract risk information for the user and to interpret it as an alarm that is sent to the actors (healthcare

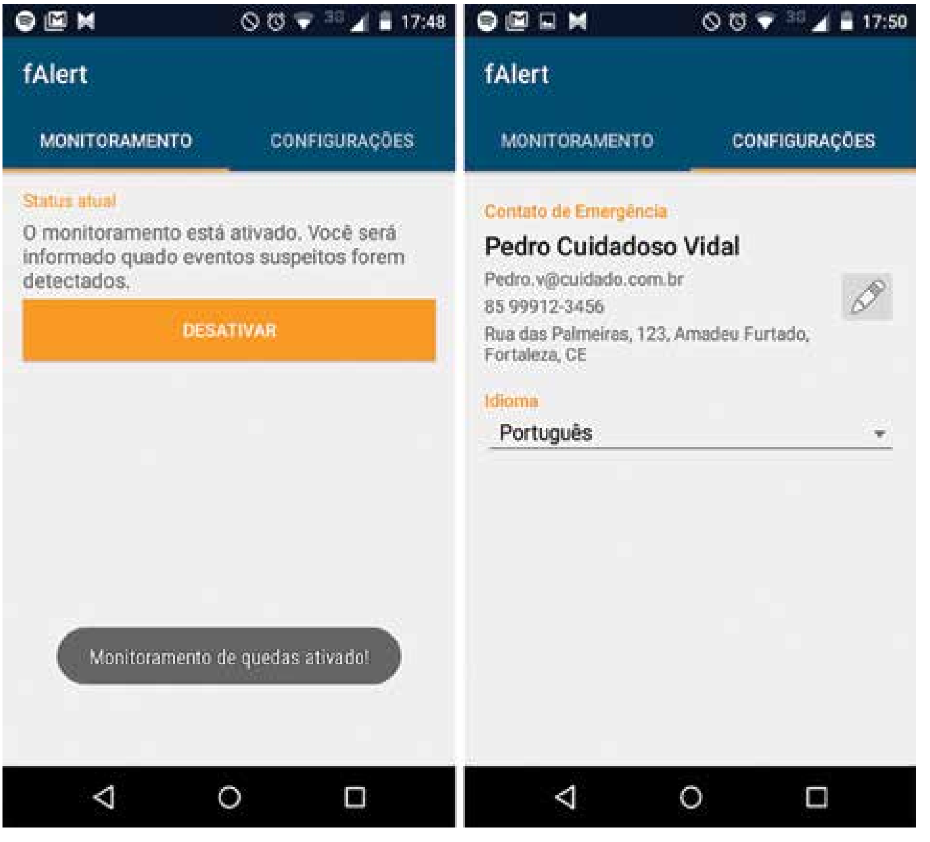

Figure 6. Screens of the fall detection application WatchAlert.

professionals and family members) involved in the care of the user. In the present version of the Raspcare platform, only the use of thresholds was implemented. The thresholds are preset according to abnormal blood glucose and pressure values.

2.6. Interaction with the television

Communication via television is a differentiating characteristic of the proposed technology because it benefits from the availability of a television set in virtually all Brazilian homes and is a form of entertainment for the elderly. A solution independent of the brand and the technology used in the television was sought, requiring only an HDMI communication port with HDMI-CEC protocol.

The HDMI-CEC communication protocol enables communication and control between devices through an HDMI cable. Some hexadecimal commands can be sent to turn the television on or off or change the channel.

To use the technology, the library libCEC available for the Linux operating system and an HDMI cable with CEC protocol support were used.

Some commands used to control the television are outlined in **Table 1**.

Command	Result
echo “on 0” | cec-client –s	Television turns on
echo “standby 0” | cec-client –s	Television turns off
echo “as” | cec-client –s	Video input changes

Table 1. Commands sent to control the television.

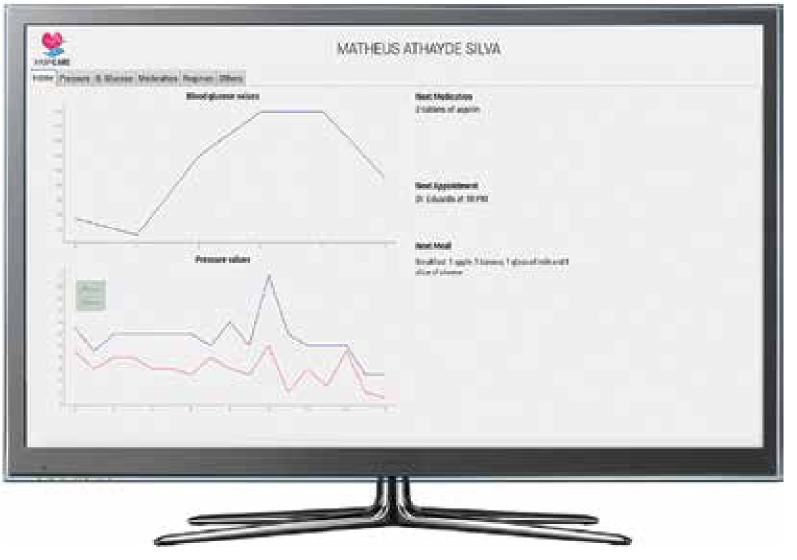

Figure 7. Home screen of the client application.

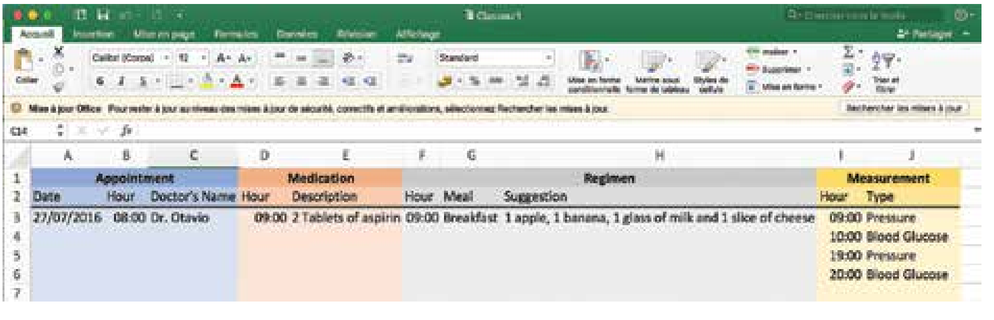

Figure 8. Spreadsheet with data on the patient care plan.

2.7. Patient care plan

The client application has a home screen (**Figure 7**) that displays the parameters monitored, such as blood glucose (top graph) and systolic and diastolic pressure (bottom graph) values. This screen also displays information on the next appointment, medication and meal to enable individuals to monitor their health status in their own television sets.

The home screen of the client application reflects the patient care plan, which consists of a set of patient routine data, such as medication names and times, and diet of the monitored patient. This information should be completed by the consultant physician in a spreadsheet, as shown in **Figure 8**, and the patient should import this information to the gateway through the client application using a pen drive or memory card.

3. Raspcare platform functions

The proposed platform was tested in the laboratory to validate each planned function, namely, task scheduler (interaction with the television, smartphone and smartwatch); generation of alerts/alarms; blood glucose and pressure measurements and history view.

3.1. Task scheduler

The patient care plan proposed by the health team is loaded locally in the gateway from a storage device, such as pen drive or memory card. Based on the patient care plan, the platform updates the task scheduler on the previously registered Google Calendar account of the patient, logging the medical appointments, medication and measurement times and dietary suggestions and meal hours. Of note, if the patient has no Google account or wished not to use this service, the patient will have at least one active calendar in the gateway that will be used for the television as user interface.

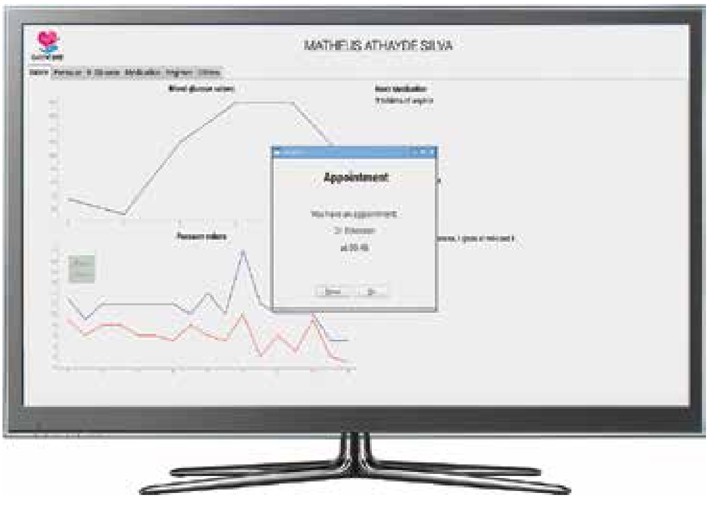

Figure 9. Message with the appointment scheduled on the patient's calendar.

Every time the appointment time is reached, the gateway turns the television on, notifying the patient about the task that must be completed, as shown in **Figure 9**.

Simultaneously, the smartphone and the smartwatch also flag the appointment from the Google Calendar service, as shown in **Figure 10**.

Figure 10. Medical appointment notification on the smartphone and smartwatch.

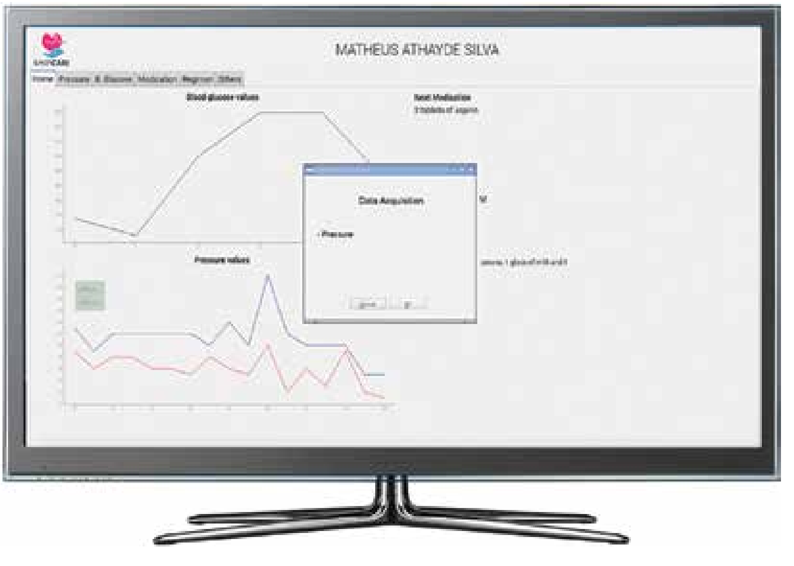

Figure 11. Blood pressure measurement notification.

Warnings generated from the appointment calendar must be acknowledged by the user, both on the portable device, such as the smartphone, smartwatch or tablet and the gateway. From the gateway, the user should simply close the warnings by selecting the button Ok or the close window symbol in the upper right corner.

Another type of task included in the patient care plan is the periodic measurement of blood glucose or pressure values, whose warning has the same characteristics as the medical appointment notification, as shown in **Figure 11**.

The notification of the medication task turns the television on through the HDMI port connected to the gateway, and a notification window opens. The user can cancel the manual entry

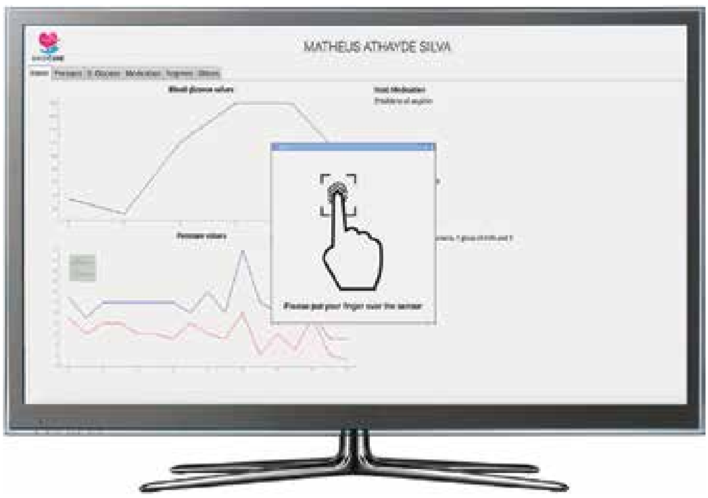

Figure 12. Authentication request.

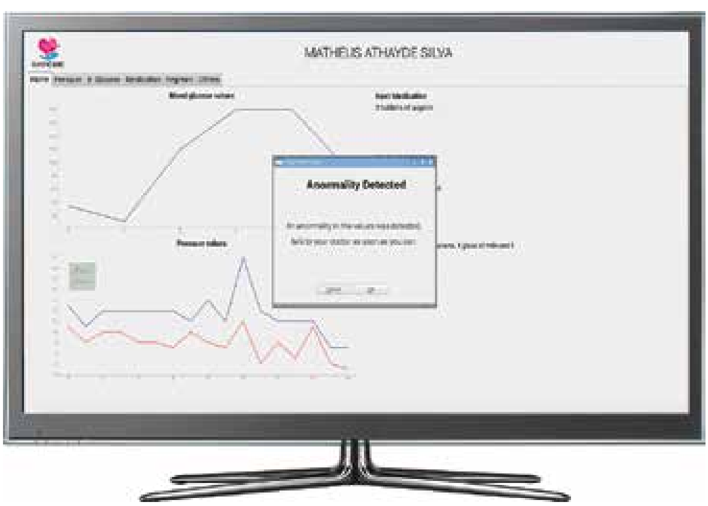

Figure 13. Abnormality notification generated by the gateway and shown on the television.

Figure 14. E-mail with the message on the abnormal value measured received by the consultant physician.

Figure 15. Fall detection alarm generated by the WatchAlert application.

Figure 16. Web environment notifying falls.

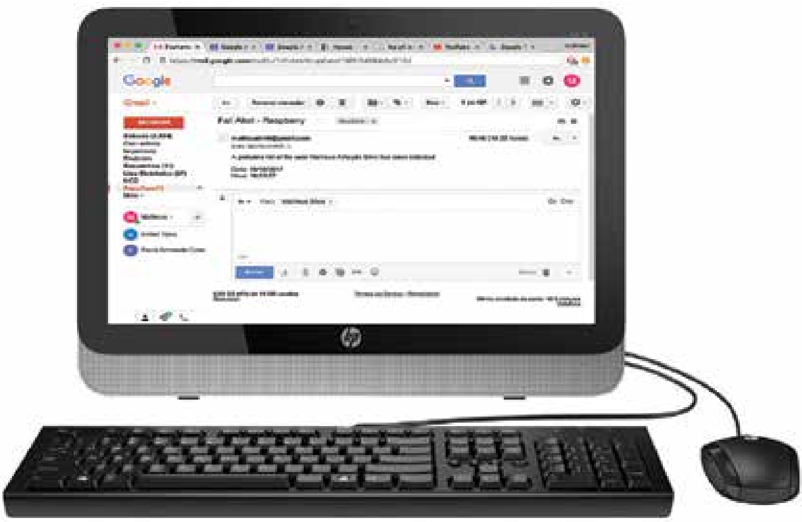

Figure 17. E-mail received by the consultant physician notifying a fall event.

of the values measured or accept the automatic transfer of data from the device to the gateway. In both options above, a new notification window opens that requests user confirmation by biometric authentication, as shown in **Figure 12**.

3.2. Generation of alarms

The Raspcare platform consists of modules that automatically analyse the signals generated by the devices. The result of this analysis may produce two types of alarms:

- Abnormal blood glucose and pressure measurements: every time the gateway client application detects an abnormality after measuring blood glucose and pressure values (comparing the measured value with a preset value in the application), an alarm is triggered, and three messages are generated. One of them is sent to the television, and a window opens that indicates the reason for the alarm (see **Figure 13**). Another message is sent to the web application, indicating the type of alarm and the monitored patient. Finally, a third message is generated by the web application that sends an e-mail to the consultant physician (see **Figure 14**).

- Fall detection: every time the fall detection module installed in the smartwatch detects a fall event, an alarm is triggered, and three messages are generated. One of them appears on the smartwatch screen (see **Figure 15**). Another message is sent to the web application, informing about the type of alarm and the monitored patient (see **Figure 16**). Finally, the third message is sent by e-mail to the consultant physician (see **Figure 17**).

4. Conclusion

The success of the treatment of the chronic patient is directly related to the execution of the care plan prepared by the health team for the patient. Scientific evidence indicates technology as a powerful tool for patient self-care.

The boost in health technology in the context of the Internet of Things (IoT) in recent years has triggered the emergence of various devices and services aimed at the chronic patient.

However, their dissemination among the population remains a great challenge. Most existing solutions are proprietary and difficult to integrate. While the Internet of Things (IoT) occupies an increasingly larger space, the lack of Internet in Brazilian homes prevails. Although wearable devices are becoming fashionable, devices certified for monitoring patient health conditions and for data transfer are rare. In Brazil, during this study, only one blood pressure metre met these requirements, whereas the main brands of blood glucose metres have versions available in the market with ease of communication and proprietary applications to help in controlling blood glucose levels. Despite the demand for health solutions and services using the IoT, much work lies ahead regarding the establishment of standards and requirements for IoT platforms.

In this study, we sought an original solution for the problem of chronic patient monitoring combined with the need for compatibility with televisions and with the possibility of interaction with smartphones and other wearable devices. Typically, studies based on IoT are limited to the development of a new smartphone application that implements the patient care plan and devices that measure either the blood glucose or blood pressure levels.

The study suggests that the starting point for using this technology is the consultant physician, who prepares and loads the patient care plan to the gateway that will be installed in the patient's home. The availability of wireless networks does not prevent the gateway from alerting the patient about tasks and collecting the data from the blood glucose and pressure metres.

User authentication is crucial for data security, which was achieved by a practical and secure solution based on a fingerprint sensor.

Conversely, integration with smartphones and wearable devices, such as smartwatches, was also implemented because these options enable the user to move while maintaining the support provided by the gateway in terms of task alerts and adding fall detection and logging functions. The selection of devices is used to monitor chronic patients with hypertension and diabetes. Other chronic diseases are also indicated for monitoring but are outside the scope of this study.

The present study was limited to discussing the technology that helps with chronic patient self-care and the problem of one user per consultant physician. The issues inherent to the monitoring of several concurrent users by the same team are outside the scope of this study and will be addressed in future studies.

A pilot project aiming at testing the proposed technology is expected in the near future. At least 10 chronic patients with diabetes and hypertension above 70 years old and with a high risk of fall will be selected to test such technology. Internet access at home will be required. After obtained ethical approval and the signed informed consent of the patient, patient will be monitored for at least 6 months, and sensor data will be recorded. Patients will be interviewed in order to evaluate their acceptability. Additionally, recorder data will be used to evaluate usability and impact in patient care.

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Conflict of interest

None.

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Chapter 3

Using IoT for Accessible Tourism in Smart Cities

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Additional information is available at the end of the chapter

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Abstract

In the past few years, the Smart City concept became one of the main driving forces for the transition towards sustainable economy and improved mobility. Tourism, as one of the fastest growing economies worldwide, is an integrated part of the Smart City paradigm. Taking into consideration recent studies performed by the United Nations, stating that almost one third of the population is directly affected by disability, the concept of Accessible Tourism needs also to be integrated in the future vision for tourism, especially in the context of Smart Cities, environments fully benefiting from the recent technological advances. Within the combined framework of Smart Cities and Accessible Tourism, the Internet-of-Things (IoT) concept is the key technological point for the development of smart urban environments. IoT and big data are both technology-driven developments, leading to scenarios such as the Smart Cities one that has the potential to make citizen live smarter, more sustainable and more accessible. This chapter analyses the key requirements for IoT applications in a Smart City context, the state-of-the-art for the use of IoT for Accessible Tourism applications and proposes an architecture together with its practical implementation, tailored for the use-case of accessible tourism for physically impaired persons.

Keywords: Smart Cities, accessible tourism, IoT, route planning

1. Introduction

In the last few years, the IoT concept emerged as the forerunner of a sweeping technical and cultural change with a fast growing number of devices, sensors, actuators and various other objects becoming linked to each other and to upper-level systems [1]. Considering the potential very large amount of connectable devices and generated data, completely new features and services can arise that can constitute the basis for various innovative concepts, as for example, Big Data and Smart Cities. The latter concept has the potential to make citizen lives smarter and more sustainable and, at the same time, to create extended market opportunities.

The Smart Cities architectures implemented or designed up to date are tackling with use cases from the following use cases: transportation, energy, environmental management and waste disposal. The specific architectures for these use cases rely mainly on IoT platforms connecting heterogeneous devices and systems with the upper layers where services and applications are implemented [2]. Among the aforementioned use cases, transportation is of particular interest, taking into consideration that tourism is currently the largest growing economy branch worldwide. Without transportation -local one included- there is little or no tourism, so the development of tourism is tightly linked to the concept of mobility which, for the specific case of an urban environment, can be included in the frame of the Smart Cities paradigm.

Recent estimations state that there are more than 1 billion persons with disabilities worldwide, to be summed to other more than 2 billion representing the spouses, children or caregivers of the persons with disabilities, for a total of almost a third of the population directly affected by disability [3]. While this signifies a huge potential market for the aforementioned economic branches of travel and tourism, it still remains vastly under-served due to inaccessible travel and tourism facilities and services. The concept of accessible tourism [4] is an enabler for all categories of people to be part of and to enjoy tourism. Each person can have a specific access need, related or not to a physical condition. A typical example is the one of older and less mobile persons, that come with specific needs for traveling or touring activities. The concept of accessible tourism is starting to gain importance in order to enable destinations, products and services to all people, independently from their physical limitations, disabilities or age [5]. The changes induced by this new concept can affect public and private tourist locations, facilities and services. From idea to the practical implementation of a trip, a single destination visit normally involves many factors, including accessing information, local transportation, accommodation, shopping, and dining [5]. For these reasons, it can be stated that the impact of the implementation of the accessible tourism concept can reach far beyond the specific case of tourism, adding accessibility to the social and economic values of society [3, 6].

Putting together the previously mentioned elements, this chapter aims, to offer an overview on IoT requirements and technologies for Accessible Tourism applications in a Smart City environment, and to propose a specific architecture together with a practical implementation tailored for the use case of accessible tourism. The proposed implementation is targeted for persons with physical impairments or special access needs.

The content of the chapter is structured as following: the next section analyses briefly the key requirements for an IoT architecture operating in a Smart City environment for the specific implementation; Section 3 presents an overview on the use of IoT technologies for accessible tourism, while Section 4 is dedicated to the proposed general IoT architecture. Section 5 describes the accessible tourism solution based on the optimization algorithm presented in Section 6, while Section 7 presents a series of simulations. Section 8 presents the conclusions and the future work.

2. Key requirements for IoT-based Smart City environments

The Smart City concept has many definitions and implementation approaches. However, from an infrastructural point of view, all Smart Cities have at their core a highly capable ICT system, in the form of an IoT platform, connected to wired and wireless sensor networks. The hardware and communication part, together with advanced data analytics that settle the basis for developing intelligent applications and services for citizens [7]. Still now, even after some years of functionality, the key requirements for the requirements for IoT platforms operating in a Smart City scenario are difficult to define.

A forerunner of architectural designs is the PROBE IT EU-financed project having as main aim to benchmark IoT deployments and to set the guidelines for IoT roll-outs for Smart Cities [8]. Using some of these guidelines, considering various other surveys [9–12] and consulting the requirements fulfilled by some of the existing commercial IoT architectures and platforms [13, 14], we extracted a set of key requirements tailored specifically for accessible tourism applications in the Smart City context.

2.1. Security requirements

By the year 2020, worldwide there will be 50 billion connected devices [13], accounting for a mean value of 6 devices pro capita. IoT platforms aggregating data imply that these devices can be accessible over the Internet. Data networks, especially poorly configure ones, are vulnerable to all kind of attacks. IoT environments, always connected to the Internet, are not at all different, therefore there is the need for solid security mechanisms, which, specifically for a Smart City environment can be summarized in the following form:

1. *Data encryption and security mechanisms:* In most of the cases, data is more vulnerable when it's in transit using cabled or wireless transmission methods because most of the services encrypt data only when it gets to the data center. The challenge here is to enable end-to-end security by making the entire authentication happen without the user's intervention, so the data encrypts automatically at the source.

2. *Hardened cloud infrastructure:* Hosting data in the cloud can be far more secure than keeping in a data center but the cloud infrastructure may be also subject to attacks. ISO 27001 is a security certification standard that specifies security management best-practices and controls for data centers and cloud environments.

3. *Activity logging:* For both developers and users, activity logging is an important part of the intrinsic security of an IoT platform. Especially in a Smart City environment, and specifically for the present use case with large amounts of sensor data triggering certain actions, logging is critical for monitoring the functionality of the platform and to contrast possible malfunctions and security breaches.

2.2. Flexibility

The IoT market is still in its early stages of adoption, as it is also the case for the Smart City concept. The next generation of connected devices and products needs to rely on a certain software flexibility and for these reasons, an IoT platform in a Smart City environment should comply with following flexibility rules [15]:

1. *Device agnosticism:* The changes in the configuration of a device should be limited to updating the driver and at maximum the data format when adding or updating a devices, allowing hardware developers to develop their new generations of products without being limited by legacy or compatibility issues.
2. *Device manageability:* An inherent characteristic of a Smart Cities deployment is that the devices and sensors are placed at large distances in a Smart City environment, the IoT platform has to include methods for the remote management of devices.
3. *Usage of open APIs:* The devices and sensors present in a Smart City context inherently generate large amounts of data. It can happen that a conspicuous amount of this data remains not analyzed due to its unavailability to other users than the ones originally intended. The IoT platforms should therefore allow the access to shareable data, becoming like this a true motor for future innovative applications.

2.3. Data requirements

The data in the IoT world comes mainly from things but can also arrive in the form of metadata from users. IoT and Smart Cities are more than a sink for incoming data, data intelligence being the key concept. This implies relatively strict requirements in terms of data [13, 14]:

1. *Data processing and analytics services:* An IoT platform's usefulness is given by its ability to process the collected data and turn it to usable information.
2. *Data scalability:* Especially in a Smart City environment the amount of IoT data has the tendency to grow fast, for example when monitoring environmental data. The IoT platform should therefore have the necessary features in order to manage the data using archiviation and culling methods, preferably fully automated.

3. Overview on the use of IoT technologies for accessible tourism

In the last decade, Travel Recommendation Systems (TRSs) have benefited from the Information Communication Technology (ICT), which has become the main source of information for the tourists, assisting them in choosing services around them [16]. As the technology makes its way into the fabric of everyday life, it become easier even for people with disabilities to take advantage of TRSs.

In particular, the IoT, as an enabler technology, can offer people with disabilities the assistance and support they need to achieve a good quality of life and allows them to participate in the social and economic life. In [17], the authors propose an IoT architecture to assist people with disabilities and envision some application scenarios where such users can benefit from the IoT, such as during shopping, at school or in a domestic environment. They claim how the IoT can make easier for people with some kind of impairments to carry out their daily activities and then increase their autonomy and self-confidence.

However, despite the rapidly increasing number of tourists with disabilities, both the tourism industry and the scientific community has paid little to no attention to find solutions to facilitate and make their tourist experience more enjoyable, due to the assumption that this group of people is usually not interested in traveling [18].

The few works analyzing the needs of people with disabilities aim to understand which can be their stimuli to travel; in [5], for example, the authors research the criteria consumers with disabilities regards as being important to their choice of accessible accommodation; similarly, the work proposed in [19] deals with understanding how tourists with mobility disabilities make decisions to choose accessible travel products.

Nevertheless, even if there are several solutions which apply the IoT paradigm to sustain and manage tourism (smart tourism scenarios), little work has been done to offer assistance and support to people with disabilities. In [20], the authors underline the strict correlation between smart city and smart tourism conceptualizations and the focus on public service models at the expense of comprehensive and systematic exploration of its business opportunities and implications. In [21], several possible smart tourism scenarios are presented: from services to help select destinations and search suitable travel arrangement to services that provide on-site support to the tourist during the trip helping her/him to discover nearest places of interest. Another example is proposed in [22], where the authors propose an agent-based system; such a system enables to model different kinds of activities in a flexible way, and allows the implementation of location-aware applications.

Finally, in [23], an IoT solution for sustainable tourism has been proposed and applied to a specific Smart City scenario. The authors take into account two main elements in order to propose the best set of Point of Interests (PoIs) for the tourist, namely the choice of the transportation mode and the information regarding the queue time expected at each PoI. Even if no implementation has been provided, simulated results show how such an approach based on the IoT paradigm can increase the tourists' satisfaction.

To the best of our knowledge, in this chapter we go for the first time beyond the state of the art, by proposing a solution to apply the IoT paradigm to accessible tourism for people with disabilities, in which cruise ship tourists, with limited available time, wants to maximize their tourist experience.

4. Proposed architecture

As mentioned in Section 1, in this work we introduce an IoT platform suitable for a Smart City environment and applied to the sustainable management of the tourist flow in the city of Cagliari, Sardinia's capital, which is one of the two biggest island in Italy and one of the most attractive point for tourism, especially in summer. In such a scenario, we envision that, through the use of virtualization technologies, each object in the real world is associated to its virtual counterpart in the cloud. This is a common practice in the latest IoT research efforts [24], since the virtualization of the physical devices enhances their capabilities, making the objects capable to: (i) describe their characteristics with semantic technologies in order to be able to interact with other virtual objects; (ii) identify, analyze and manage the context of the object's surroundings, taking the decision accordingly; (iii) facilitate the search and discovery of devices and services, continuously joining, moving across and leaving the network.

4.1. Proposed architecture

The proposed platform relies on the Cloud IoT architecture [25], named Lysis, organized on four distinct levels (**Figure 1**). Service discovery and information exchange do not need objects to be in vicinity of each other, since they take place in the virtual world through the exploit of social relations.

In the following the four levels as described in details: the highest level is the *Application Layer* in which user-oriented applications are deployed; the *Service Layer* is responsible to receive the application requests and map them to the atomic services available in the lower layer; this layer is the *Virtualization Layer*, which interfaces directly with the real world and enhances objects' functionalities; the last level is the *Real World Layer*, containing the real physical devices of the Smart City. Two additional cross-layers are needed to manage the quality requirements of the applications and to ensure that every communication takes place in a trustworthy and secure way, according to the previously listed requirements.

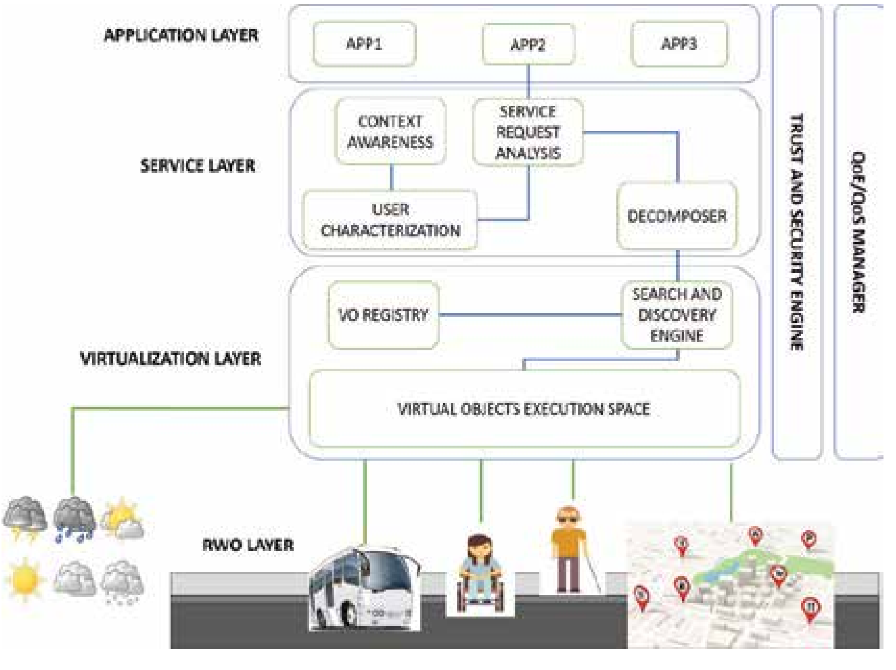

Figure 1. Cloud-based IoT architectural solution.

This approach has manifold motivations: (i) it enables objects to speak the same language at the virtual level; (ii) it enhances the service search and discovery; (iii) it decouples the service requests and the actual IoT objects which satisfy the request and (iv) it offers personalized experience to users based on their own needs and traits.

In the following paragraphs, we describe in detail the layers proposed for the architecture.

(1) *Application layer:* This is where user applications are deployed. Each application is composed of two interfaces: a front-end interface, which represent the access point for users or objects to interact with the system, and a back-end interface, which connects this layer to the rest of the platform and enables the application to be fulfilled by the lower layer.

(2) *Service layer:* At this level, service requests are analyzed and augmented with a range of facts concerning the human user, including user context, the type of disability, his/her profile, the preferences in terms of PoI categories and security policies.

The *Service Request Analysis* (SRA) receives the query from the Application layer and interact with the User Characterization block to obtain information regarding the user and the context in which the query has been made.

In particular, the *User Characterization* (UC) includes all the knowledge the system has accumulated regarding each user interacting with the system and his/her preferences. This block has then the ability to complement the query with additional information so that each application is truly personalized based on the user. This is an important component in our platform because many applications in a Smart City scenario, such as the one for sustainable tourism, are characterized by personal choices: requests coming from different users can have different solutions. This is particularly true for the use case of disabled persons, posing new constraints in the SRA that have to be taken into account when solving the query.

To have a broader view of the user, the UC block alone is not enough. This is due to the fact that the UC only accumulate static information, and does not take into account the specific situation the user is involved in. This is the role of the *Context Awareness* block, which considers the context in which the query has been made. For example, a tourist with a certain disability looking for a museum to visit, can receive different recommendations based on the accessibility of the structure, the time of day, the possible routes to reach it, the presence of uphills and downhills, the distance from other museums or the number of people in the queue waiting to visit it.

Finally, since an application is composed of one or more services, there is the need of a *Decomposer*, which collect the information obtained by the other blocks in this layer and decide which atomic tasks (sensing, actuation, computational) are needed to fulfill the query. Then, it forward a group of subqueries for the Virtualization Layer.

(3) *Virtualization Layer:* This layer is responsible for virtualizing the sensor (& actuation) data *for* any service needs, which is stored in a related database. Objects and devices of the real world are represented digitally in this level in the form of *Virtual Objects* (VOs) and their offered services are described in terms of semantics.

To overcome the limited capabilities of the IoT objects, in the virtual world the VOs enhance their capabilities and enable them to perform additional operations. White canes, i.e. canes for blind or visually impaired people, wheelchair but also museums, parks or busses can communicate among them without any problem at this level even if they all use different communication technologies: simple technologies, such as RFID tags and NFC, can be attached to Points of Interest (PoIs) to enhance the visiting experience of tourists by interpreting information about the environment and making choices accordingly, for example by pushing additional information regarding the PoI to users [26].

To activate a new VO, the system has to find a match between the possible VO templates and the information (metadata) provided by the physical device; such information comprehends: objects' characteristics; objects' location; resources, services, and quality parameters provided by objects. When a match is found, a new instance of the object is created (i.e. the web server representing the VO itself), which run in the *Virtual Object Execution Space* (VOES), where all the instances of VOs run.

Each VO has two interfaces: the first one enables the VO to create a standardized communication procedure with the physical object; this way, the VO can communicate with the object using a set of different protocols based on the situation at hand. The other interface allows the VO to "speak" with all the other VOs in the VOES; thank to this, it is possible even for physical objects with have different communication technologies to communicate among them and become interoperable at the virtual level.

The VO registry stores a semantic description for each active VOs in the VOES, in the form of metadata, which is then used every time there is the need to search for a particular VO.

This metadata is particularly useful in the case of accessible tourism, where the information regarding the different objects available for people with disability needs to be described with the correct metadata in order to be easily discoverable; this is the case for example of busses with a platform for tourists in a wheelchair or of museums which provide audio guides for visually impaired tourists.

When the *Search and Discovery Engine* is activated by the upper layers, it search in the VO registry to find any potential available VO that can match the query, i.e. any VO whose metadata can match the services required.

(4) *Real-World Object Layer:* Implemented out of the cloud, this level includes every device that is capable of *accessing* the Internet. These devices are called Real World Objects (RWOs) due to their direct connection with the physical environment where they sense and act.

(5) *Trust and Security Engine:* This layer focuses on the implementation of appropriate security procedures to guarantee that attacks and malfunctions in the platform will not outweigh any of its benefits. At the Virtualization level, for example, this plane needs to understand how the information provided by the VOs have to be processed so as to build a reliable system on the basis of their behavior. In the Application level, the Security Engine could determine the accessibility of the different applications to grant access only to authorized users.

(6) *QoE/QoS Manager:* The management of quality is an important issue in classical IoT implementation mainly due to the heterogeneity of the objects and to their mobility. In the proposed platform, we address these problems making use of VOs; however, even with

the adoption of virtual counterparts, in order to monitor the overall level of the applications, both from a communication point of view (Quality of Service) and from a user point of view (Quality of Experience), a quality manager is still needed.

5. Proposed accessible tourism solution

This section presents an accessible solution designed on top of the IoT platform presented in the previous section, aiming to provide useful information to tourists in general, with particular attention to the ones with special needs. The application has been developed for the cruise ship tourists who land in the city of Cagliari, but it could be applied to many Western European tourist destinations, regardless of the means of arrival (i.e. plane, train, or ship).

5.1. Cruise tourism

When arriving in Cagliari, many cruise ship tourists, often prefer to take a walking tour rather than taking an organized tour. After getting off the cruise ship, these people have to spend too much time to get the needed information about programming their visit. And time is a very critical aspect for cruise ship tourists, due to the limited number of hours the cruise ship usually stays at the call port. This aspect gets worse for disabled people, depending on the type and degree of disability. In the case of mobility disability, for instance, a destination like Cagliari, where reaching the most important attractions require a lot of walking uphill, due to the natural and geographical features of the city, many tourists are constrained to limit their visit to the areas around the port. Instead, with some detailed information about accessible routes in the city, more tourists could reach all the attractions of interest within walking distance of the port getting a better experience from their visit. This is why we designed and developed a mobile application dedicated to generic tourists and specifically adapted to accessible tourism. In case of physical impairments, this mobile application is capable to optimize visits to specific mobility user needs. In this work we adopt the paradigm of people inclusion and universal access to information and tourism assets.

In the recent years, tourism experiences of people with disabilities have largely been a research key topic [27]. Research results have been focused on accessible tourism and accommodation preferences [5]. Most of the available tools are based on web sites for travel planning with focus on inclusive tourism such as Tur4All (https://www.tur4all.com/) and Jaccede.com (https://www.jaccede.com/). Specific tools face just single aspects of the problem. LinkedQR [28] is a tool to improve the collaboration between QR codes and Linked Data, through mobile and Web technologies. Nevertheless, the role of IoT in tourism is expected to create innovative experiences for consumers [29].

There is a lack of tools specifically designed for everyone and able to perform specific outcomes for disabled. Our application addresses this challenge, following the paradigm of whole-of-life to tourism, considering that 30% of a population will have access requirements at some stage during their life [4].

5.2. The tour planner application

The Tour Planner is a mobile application, useful to build a dynamic itinerary through a city, based on a repository of Points of Interest (PoIs), each one of them is represented as a VO on the platform (**Figure 2**).

The Tour Planner application is developed on top of the proposed platform, and it takes in input not only the Points of Interest related to monuments, museums, archeological sites, parks, botanical gardens, shopping areas, restaurants, but also commercial offers and events as well as every information that can be important for the user, such as his/her particular needs, the length of the queue in real time from the PoIs or the weather.

Moreover, the Tour Planner allows to save the itineraries built by the end users (the tourists) in a format suitable to be saved in the platform, then making it available for other users. The information available on the platform are regularly taken and stored (updated) in the back end of the mobile application. The mobile application has been developed with the Ionic Framework in order to be suitable for any mobile platform.

The platform takes all the information about the Points of Interest (PoI) in a certain geographical area. The PoIs are stored in the platform according to a classification related to the type (the already mentioned, monument, museum, archeological site, etc.).

5.3. How the tour planner works?

The Tour Planner aims to improve accessible tourism because it provides the possibility to build itineraries suitable for people with disability, adding detailed information about the accessibility of each Point of Interest, whenever available. Unfortunately, a well-known problem is related to the fact that most of the web sites based on the Points of Interest paradigm do not follow standards like the “ISO 7001:2007 Graphical Symbols” (https://www.iso.org/obp/ui/#search/grs/7001). Although not comprehensive, these standards are suitable to notify tourists

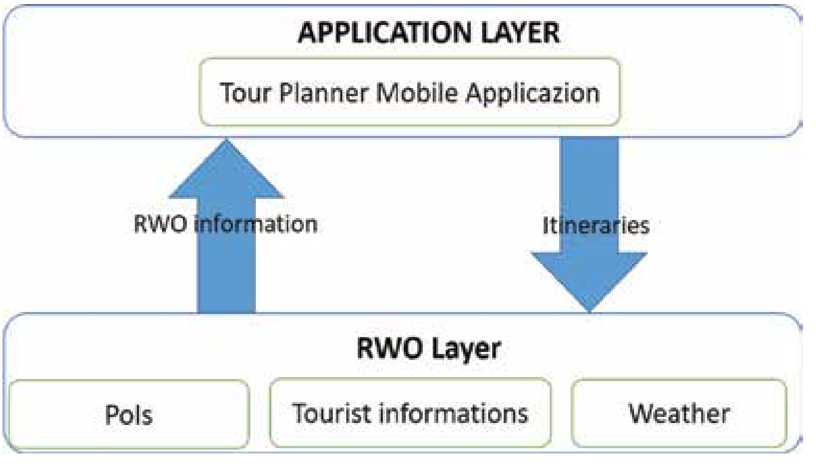

Figure 2. The RWO and the tour planner exchange information each other.

about the existence of facilities for disabled people. The information would be complete if also the "not existence" of the facilities would be reported (in a standard way, as well). Another issue in relation to this aspect is that quite often the presence of these facilities is not compliant to standard like the ISO 21542:2011 for building construction - Accessibility and usability of the built environment (https://www.iso.org/obp/ui/#iso:std:50498:en).

Some disability rights organizations periodically (for instance, yearly) verify if declared accessibilities are compliant to the standard. As a good example of this, in UK, there are important providers of access information like DisabledGo (https://www.disabledgo.com/). If this kind of verified information could be automatically collected and stored in the platform, the Tour Planner application would be able to acquire them and to build proper itineraries accordingly. In our case, a further improvement should come from the municipality of Cagliari by providing access infrastructures through the streets of the historical city, and making the related information available.

In this accessible destination scenario, a disabled person, for example with a limited degree of mobility, could use the Tour Planner application to properly construct his or her tour, including the PoIs and the routes that connect them, depending on the needed level of accessibility.

Obviously, the presented Tour Planner application represents only a technology which allows this scenario of accessible destination to become reality; in fact, the solution requires some effort by the decision makers in order to make all the actors of the scenario to co-operate for realizing it (**Figures 3** and **4**).

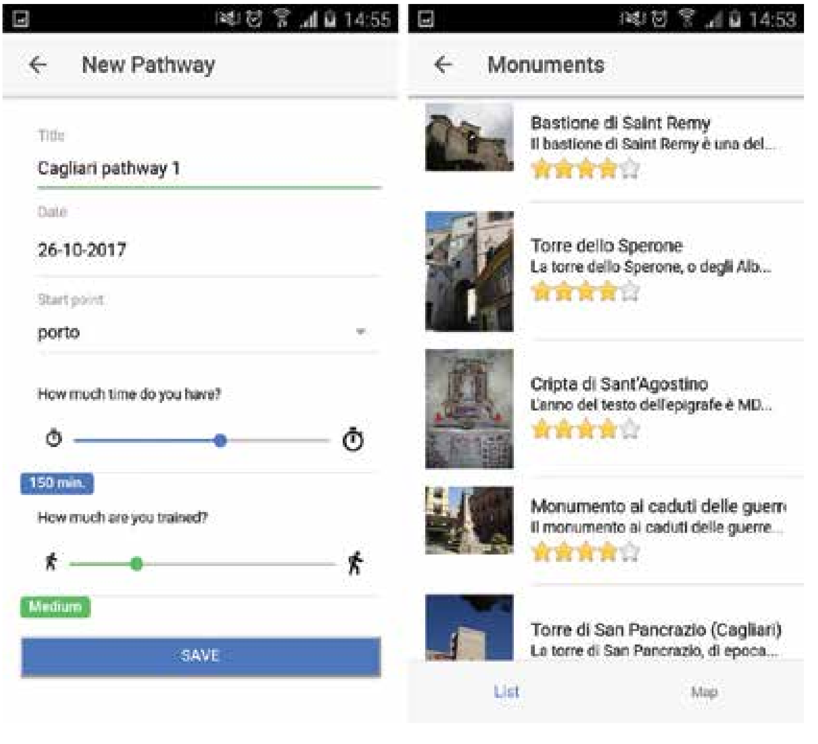

Figure 3. The tour planner set up and the list of PoIs.

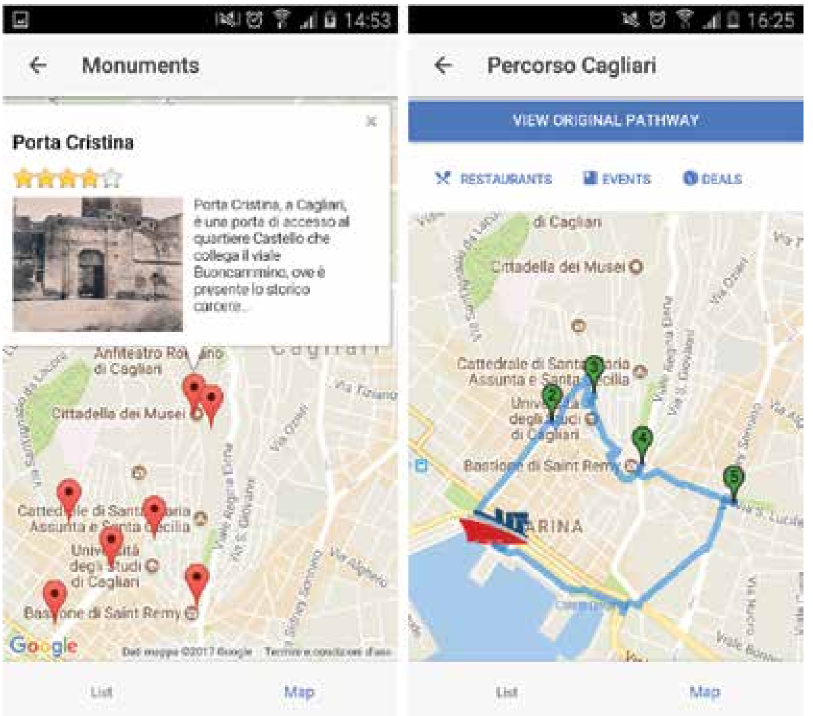

Figure 4. The map showing the PoIs chosen by the tourist (on the left), and the optimized itinerary (on the right).

The aim of the Tour Planner application is to make the visit of a destination accessible for everyone, addressing the described critical aspects through the following features:

1. The tourist defines the total amount of time he has to visit, his physical training level with respect to available paths, and the type of preferred attractions.
2. The application shows a list of most important Points of Interest, sorted according to the information described in 1.
3. The tourist can select each Point of Interest to get more information, including those related to accessibility, and then has the possibility to choose what to see during the visit.
4. The application connects the Points of Interest selected and optimizes the resulting path producing a tour suitable to the tourist.

6. Optimization modeling

Two optimization models are implemented to plan the tour of tourists. In the first model, a subset of PoIs is selected in order to maximize their attractiveness. In the second model, an optimal tour among this subset of PoIs is determined by solving a Traveling Salesman

Problem: the tourist is given an optimal route where he/she visits each POI only once, minimizing the cost of moving between the selected PoIs.

6.1. First model

We consider the current location 0 of the tourist and a set I of POIs. A time interval d can be spent at most to visit a number POIs from the current location. Each POI is associated with a ranking p_i representing its attractiveness for tourists and a visiting time v_i.

The problem can be described as the following graph theoretic problem. Let $G(N, A)$ be a direct and complete graph, where N is the node set and A the set of arcs connecting nodes of set N. Nodes correspond to the points of interest and the current position of the tourist, i.e., $N = I \cup 0$. Arcs represent possible connections between two distinct nodes. Let $t_{i,j}$ be the time to move along arc $(i, j) \in A$ and M a large positive constant.

The following decision variables are defined:

- $X_{i,j} \in \{0, 1\}$ is equal to 1 if the tourist moves along arc $(i, j) \in A$, 0 otherwise;
- $Y_i \in \{0, 1\}$ is equal to 1 if POI $i \in I$ is selected for the visit, 0 otherwise;
- $U_i \in \{0, \ldots, |N|\}$ is the position of POI $i \in N$ in the current trip.

The problem can be formulated as follows:

$$Max \sum_{i \in \mathcal{J}} Y_i \cdot p_i \tag{1}$$

$$\sum_{j \in \mathcal{J}} X_{0,j} = 1 \tag{2}$$

$$\sum_{j \in \mathcal{J}} X_{j,0} = 1 \tag{3}$$

$$\sum_{j \in \mathcal{N}, j \neq i} X_{j,i} = \sum_{j \in \mathcal{N}, j \neq i} X_{i,j} \quad \forall i \in I \tag{4}$$

$$\sum_{j \in N, i \neq j} X_{i,j} = Y_i \quad \forall i \in I \tag{5}$$

$$U_j - U_i - 1 + M \cdot \left(1 - X_{i,j}\right) >= 0 \quad \forall (i,j) \in A \tag{6}$$

$$\sum_{i \in \mathcal{J}} Y_i \cdot v_i + \sum_{(i,j) \in A} X_{i,j} \cdot t_{i,j} \leq d \tag{7}$$

$$X_{i,j} \in \{0, 1\} \quad \forall (i,j) \in A \tag{8}$$

$$Y_i \in \{0, 1\} \quad \forall i \in I \tag{9}$$

$$U_i \in \{0, \ldots, |N|\} \quad \forall i \in N \tag{10}$$

In (Eq. (1)) one maximizes the ranking generated by the selected POIs. According to (Eq. (2)), a PoI must be visited after the current location. Constraints (Eq. (3)) enforce for the tourist to come back to the current location after the visit of the last PoI. Constraints (Eq. (4)) guarantee that a tourists arriving at any PoI must also leave from that PoI. Constrains (Eq. (5)) link decisions variables on POIs selections and movement between nodes. Constraints (Eq. (6)) are the subtour elimination constraints of Miller, Tucker, and Zemlin. Constraints (Eq. (7)) enforce that the overall time spent to move between nodes and visit POIs is lower that the planned time interval. Finally, (Eq. (8)), (Eq. (9)), and (Eq. (10)) are the domain of decision variables.

It is worth noting that one does not have to visit all nodes of the N, unless a large value of d is considered. Moreover, the direct graph makes very easy to model the case in which starting and arrival points are different.

6.2. Second model

Consider the subset $\overline{N}$ of nodes selected in the previous model. These nodes may not be visited in an effective order, as this model does not aim to minimize the costs of movement between nodes. To correct this drawback, we consider a second model, in which a formulation of the Traveling Salesman Problem (TSP) is presented. The solution of the TSP determined the so-called *optimized itineraries* mentioned throughout this paper.

The TSP can be described as the following graph theoretic problem. Let $G(\overline{N},\overline{A})$ be a direct and complete graph, where $\overline{A}$ the set of arcs connecting nodes of set $\overline{N}$. The following decision variables are defined:

- $X_{i,j} \in \{0,1\}$ is equal to 1 if the tourist moves along arc $(i,j) \in \overline{A}$, 0 otherwise;
- $U_i \in \{0,\ldots,|\overline{N}|\}$ is the position of POI $i \in \overline{N}$ in the current trip.

The problem can be formulated as follows:

$$Min \sum_{i\in\overline{N}} \sum_{j\in\overline{N}} t_{i,j} \cdot X_{i,j} \tag{11}$$

$$\sum_{j\in\overline{N},\, j\neq i} X_{i,j} = 1 \quad \forall i \in \overline{N} \tag{12}$$

$$\sum_{j\in\overline{N},\, j\neq i} X_{j,i} = 1 \quad \forall i \in \overline{N} \tag{13}$$

$$U_j - U_i - 1 + M \cdot (1 - X_{i,j}) >= 0 \quad \forall (i,j) \in \overline{A} \tag{14}$$

$$X_{i,j} \in \{0,1\} \quad \forall (i,j) \in \overline{A} \tag{15}$$

$$U_i \in \{0\ldots N\} \quad \forall i \in \overline{N} \tag{16}$$

In (Eq. (11)) one maximizes the ranking generated by the selected POIs. According to (Eq. (12)) and (Eq. (13)), a node must be visited before and after the current one, respectively. Constraints in (Eq. (14)) are the subtour elimination constraints of Miller, Tucker, and Zemlin. Finally, (Eq. (15)) and (Eq. (16)) are the domain of decision variables.

7. Results

In this section we show the viability of the proposed tools to support the mobility of physically disabled tourists or elder persons. We also analyze the case of able-bodied tourists for the sake of comparison. The difference between the two cases is shown by increasing travel times along uphill and downhill routes for disabled tourists as opposed to able-bodied ones. The experimentation is carried out in the city of Cagliari, where many tourists disembark from cruise ships at the harbor. They typically aim to visit the oldest part of Cagliari, which is known as the Castello. It clings to the slopes of a hill that rises steeply from the harbor. Therefore, in this case study it is of particular relevance to distinguish between the waking times of disabled and able-bodies tourists, in order to properly plan which subset of PoI should be visited, as well as the order of the visit.

Four classes of PoIs are considered, which correspond to different profiles of tourists interested in museums, monuments, gardens or shops. We took their location and their altitude from the open data platform and we derived the average slope of the streets connecting PoIs. The average travel time per unitary distance was calibrated by a sample of tourists with similar disabilities over a set of streets with different slopes. Since the distance between all PoIs is known, we easily derived the travel times among them.

All the PoIs are ranked with a value ranging from 1, less attractive, to 5, most attractive. A subset of PoIs is considered for each class by a score threshold, which specifies the PoIs the tourist wants to visit. For example, if it taken on value 2, we consider all PoIs with a score bigger than or equal to 2. We initially set the score threshold to 3 and relax the constrain on (7) and compute the itineraries for each class of PoIs. In **Figure 5** the time to visit all PoIs is reported for all class of PoIs in four cases:

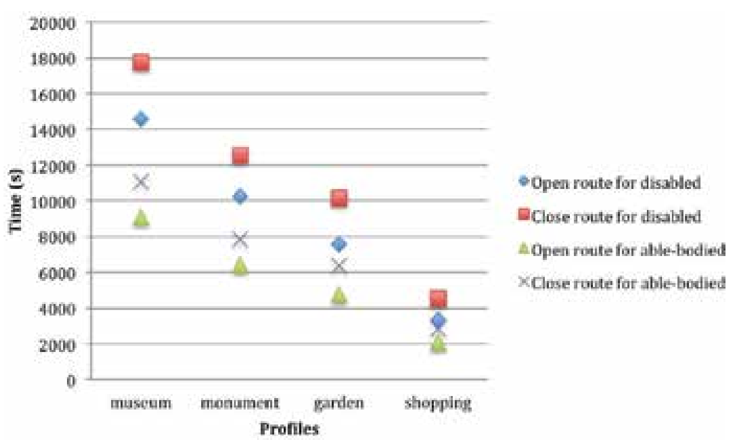

Figure 5. Minimum time for optimized itineraries with threshold = 3.

- Open itineraries of disabled tourists from a given GPS location to the port (blue rhombus);
- Closed itineraries of disabled tourists leaving and returning back to the port (red square);
- Open itineraries of able-bodied tourists from a given GPS location to the port (green triangle);
- Closed itineraries of able-bodied tourists leaving and returning back to the port (gray cross).

As expected, it takes longer to make closed itineraries than open ones and the overall visiting time for disabled tourists is larger than that of able-bodied ones. Next, we reintroduce constrain (Eq. (7)) and plan itineraries according to settings of the time limit *d* and score threshold. More precisely:

- In the results of **Figure 6**, *d* is set to 120 min and the score threshold to 3;
- In the results of **Figure 7**, *d* is set to 240 min and the score threshold to 3;

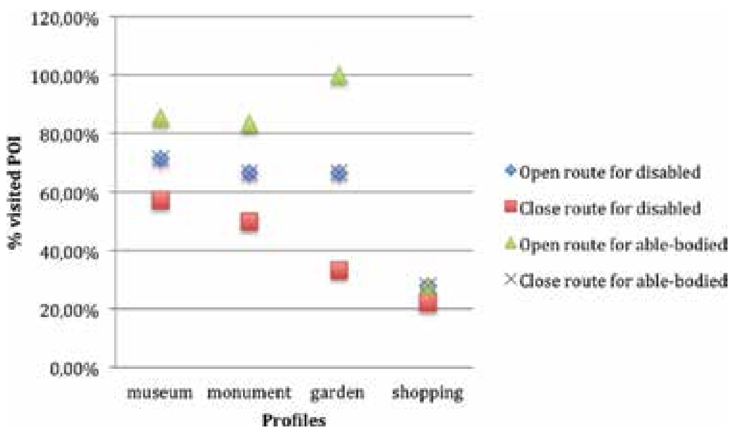

Figure 6. Optimized itineraries with maximum time 120 min and threshold = 3.

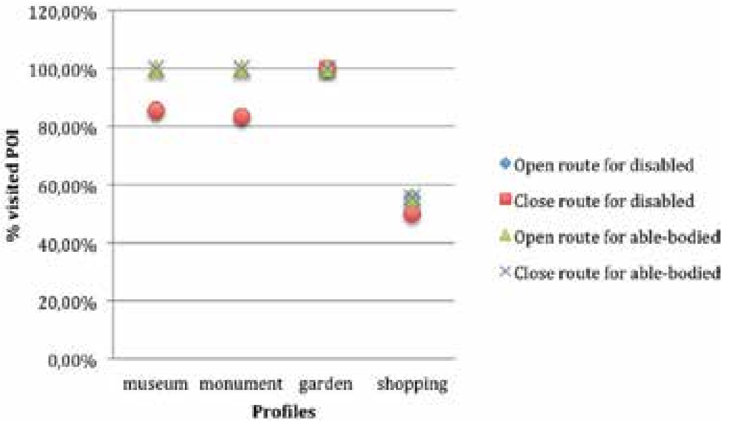

Figure 7. Optimized itineraries with maximum time 240 min and threshold = 3.

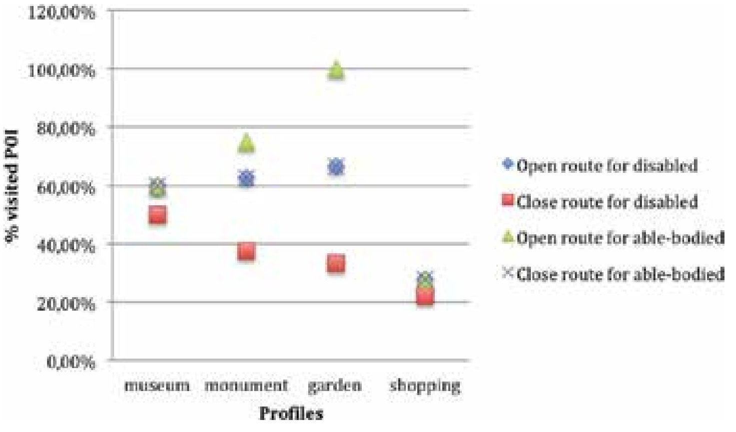

Figure 8. Optimized itineraries with maximum time 120 min and threshold = 2.

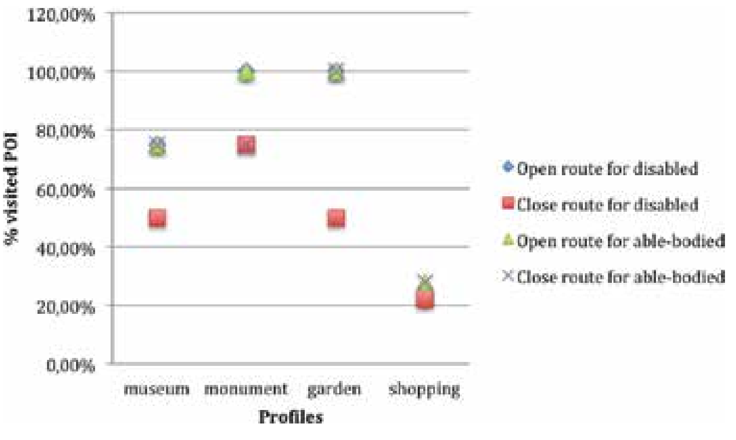

Figure 9. Optimized itineraries with maximum time 120 min and threshold = 4.

- In the results of **Figure 8**, d is set to 120 min and the score threshold to 2;
- In the results of **Figure 9**, d is set to 120 min and the score threshold to 4;

The obtained results show that the proposed tools can be customized to return a subset of PoIs for physically disabled tourists as opposed to the set of routes determined for able-bodied persons.

8. Conclusions and future work

Within the framework of Smart Cities, Accessible Tourism and Internet-of-Things (IoT), this paper analyses the key requirements for IoT applications in a Smart City context, the state-of-the-art for the use of IoT for Accessible Tourism and presents an IoT architecture for the specific Smart City scenario dedicated to the sustainable management of the tourist flow in the urban environment of Cagliari. Based on the presented IoT architecture, a Tour Planner Application with features for accessible tourism is presented, together with the mathematical optimization model used for generating a specific tour including a subset of PoIs. The proposed application is tailored for persons with physical impairments. The results of the initial tests are presented and first conclusions are drawn. The obtained results showed that the proposed algorithm can be customized to return a subset of PoIs for disabled tourists as opposed to the set of routes determined for able-bodied tourists. The future work will be focused on refining the used algorithm by taking into considerations new accessibility constraints and also other types of input, such as for example live accessibility data from public transportation.

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Chapter 4

Creative Haptic Interface Design for the Aging Population

Eric Heng Gu

Additional information is available at the end of the chapter

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Abstract

Audiovisual human-computer-interfaces still make up the majority of content to the public; however, haptic interfaces offer unique advantage over the dominant information infrastructure, particularly for users with a disability or diminishing cognitive and physical skills like the elderly. The tactile sense allows users to integrate new, unobstructive channels for digital information into their sensorium, one that is less likely to be overwhelmed compared to vision and audition. Haptics research focus on the development of hardware, improving resolution, modality, and fidelity of the actuators. Despite the technological limitations, haptic interfaces are shown to reinforce physical skill acquisition, therapy, and communication. This chapter will present key characteristics intuitive tactile interfaces should capture for elderly end-users; sample projects will showcase unique applications and designs that identify the limitations of the UI.

Keywords: haptic interface, tactile user interface, HCI, UI/UX, aging population, assistive technology

1. Introduction

Our society has been designed to be sight dominated. Information is typically presented graphically; human-computer interaction (HCI) research under-represents the needs of users with disabilities. Particularly for the elderly with diminished cognitive and motor skills, graphical user interfaces further hamper their ability to adapt to new technology. Interfaces specifically designed to engage the other sensory organs are promising alternatives. The haptic and auditory senses for example are more suitable for intuitively extracting meaningful patterns from big data. Sonification as a data processing method has had success in a number of industries, most notably NASA's application on solar flare data [1]. Even a layman can listen to the transmuted data and pick out the rhythms of solar activity. These modalities also suffer less from fatigue than visual displays and benefit from tolerance, which filters out unimportant steady-state data and highlights anomalies. This chapter will discuss specifically the design of haptic interfaces for the aging population, while drawing examples and inspiration from other fields.

By 2050, an estimated 2 billion people will be over the age of 60, with 20% suffering from a mental or neurological disorder [2]. In Japan, a projected 25% of the population will be above 65 by 2020 [3]. In the United States, a projected $17 trillion in Medicare expense will be necessary to cope with the rapidly growing segment of the population over 65. High costs associated to therapy for dementia, Alzheimer's, and other neurological conditions [2]. Digital technological illiteracy coupled with growing societal isolationism and sedentarism severely hamper their ability to engage socially, leading to negative impacts on mental wellbeing. Loss of income, partners and friends, mobility, and sense of purpose are risk factors to health, resulting in lowered quality of life. We hope to investigate the design of technology that enhances the lives of the elderly, specifically projects that capture the following characteristics of HCI in haptic interfaces:

1.1. Immersion

Effective simulation of a realistic environment, given technological limitations, to capture essential elements or within unique contexts.

1.2. Animacy

Conveyance the qualities an animate being (abstract feelings, i.e., presence, intimacy, and pleasantness), on top of basic sensory information and mechanical characteristics.

1.3. Affordance

Inclusive, intuitive UI design for and consistent communication of possible usage.

As technology improves, higher fidelity simulations will be available, but conscious design for extreme users is still necessary. To put it simply, if individuals are struggling to perform in the real world due to their physical and cognitive limitations, then they would be equally disadvantaged in a precise simulation of the real world. Artificial generation and selective curation of sensory information based on the needs and preferences of the user is the goal. Haptic technology is far from creating precise representation of reality. At best, it can be intuitive in its conveyance or takes advantage of pre-existing quirks of our brain. This chapter will showcase examples of haptic interfaces with novel, creative designs and/or implementations that bypass the technological limitations of the devices, with a particular focus on their potential for elderly users. The word creativity in this context implies some novelty in its design and/or application, particularly highlighting designs that exploit existing quirks in our haptic perception.

2. Background on haptic processing

Haptic interfaces as assistive technology gained prominence in the 1960s with the discovery of neuroplasticity and became a promising modality for treating patients with disabilities. The term "Sensory Substitution" coined by Paul Bach-y-Rita to describe the method of replaces a missing or ineffective sensory input with one that is functional [4]. This requires the translation of one form of information into another; Bach-y-Rita et al. created BrainPort to investigate the translation of visual information for the blind into electro-tactile stimuli supplied to the tongue [4]. Other examples of sensory substitution as a non-invasive technique is used in projects like haptic-vest for the deaf (sound-to-touch) [13], and sonic-glasses for the blind (sight-to-sound) [5]. Progress in sensory substitution for the disabled overlap with the elderly with diminishing sensory capabilities.

We already use substitution as a treatment for age-related diseases. Age-related macular degeneration is a condition that plague predominately individuals over 60; one of its remedies is an Implantable Miniature Telescope that refocuses the light from the damaged portion of the retina to less-damaged portions originally used for peripheral vision [6]. This is substitution within the same sensory organ, swapping damaged center of vision for the better functioning peripheral vision.

Haptic interfaces facilitate the development of motor skills, [paper on training motor skills using haptic interfaces]. We investigated physical skill acquisition in sports like archery, and explored the use of haptic interfaces to establish a closed-loop system for training muscle memory [7]. Instead of requiring the visual confirmation of proper posture, the haptic feedback informs the user through vibration patterns. Our brain integrates redundant information from multiple sensory organs to accelerate learning; thus, haptic feedback is frequently supplemented onto existing modalities. Telepresence physiotherapy with mediated touch is found to be more engaging and effective than visual instructions alone [8].

Cross-modal applications are also more compelling to our sensorium; haptic perception is heightened when coupled with other sensory inputs (proprioception, vision, audition). The haptic illusion of a texture is more powerful when the vibrotactile sensations are provided and synchronized with the movement of the participant's finger [9]. The ventriloquism effect [10] is an example of cross-modal stimuli forming a compelling unified perception of disparate visual and auditory information.

Researchers have been steadily improving the qualities of haptic actuators, which fall into several major categories, from most commonly used to least: (1) vibrotactile actuators, (2) electro-tactile actuators, (3) compressive/deformation (air-sacs, solenoids, etc.), (4) fluid mediums. Despite a steeper familiarity curve than other senses, haptic interfaces have several advantages. Specifically in application for the elderly with diminishing cognitive functions, the clutter of visual and auditory information become overwhelming and cause fatigue over time. Evaluation of visual, auditory, and multi-modal displays for elderly drivers (mean age 68) show that additional visual information led to less safe driving due apparently to higher demand on attention, with multi-modal being reportedly the most comfortable and useful [11].

We believe that the only limitation to immersive simulations are the quality of actuators. Mimicking reality is therefore not the focus of this chapter. Instead, we will discuss creative applications of haptic interfaces in terms of the types of experiences they allow for, given the technological constraints. Most of these fall under "haptic illusions" that our sensorium constructs. As a researcher, creating these powerful haptic experiences is most often a process of discovering an existing neurological phenomenon.

Our experience of haptic information in the real world is almost always coupled with other senses, predominantly vision and proprioception. Haptic sensation itself is also vibration [12], same as audition. By connecting spatial information and haptic sensation, the tactile nature of the target is generated internally. The discovery of frequency nature of haptic stimuli, we are able to create better simulations drawn from reality. Recording and playing back textures for example has a wide range of applications from more immersive telepresence and VR experiences to very specialized utility tools for designers [9]. However, in designing tactile displays, the goal need not be to reproduce known phenomenon; the brain can learn and adapt to new interfaces with new intentions. Simplest forms of haptic interfaces of binary activation (ON or OFF) is easiest to learn. By augmenting this information temporally and/or spatially, much more complicated information can be sent to the brain. In the case of sensory substitution, Eagleman Lab showed that the deaf can make use of temporal–spatial, vibrotactile stimuli to decipher auditory input of spoken words [13]. Similar methodology applied on abstract datasets, such as stock market [14], further supports the power of neuroplasticity to adapt.

3. Haptic interface design

The main focus of haptic technology development is to produce higher resolution and higher fidelity of actuators that improve simulation quality. Applications of this technology give designers versatility to conjure immersive realities or surrealities. The electrotactile feedback to simulate virtual walls [15] is a literal representation of reality; projects like the electromagnetic shoes simulating dynamic gravity [16] offer other worldly realities. There are also unique haptic interfaces allow for very specialized applications, such as Microsoft's HapticLink, a bimanual controllers [17] that are connected and can simulate stiffness of operating two-handed objects (i.e., operating keys of an instrument, shooting a bow, etc.). Wearable haptic device like the Microsoft's Claw [18] and EXIII's Exos wrist DK [19] both use servos to provide resistance to your palm and fingers to "touch" digital shapes.

Specialized embodiments of the design, like dynamically deformable surfaces (i.e., ForceForm) can vary in stiffness (simulate lumps, indents) to facilitate telepresence diagnosis [20].

Rather than simulating reality, "haptic special effect" are similar to sound effects in movies. The Star Wars lightsaber sounds, which have no real world counterpart, are recorded with metal wires slapping against a hard surface. When paired with appropriate visual and/or auditory stimuli, haptic illusions can be very compelling. The iconic cutaneous bunny-hop illusion involves several point source of tactile actuators on a subject's arm; when triggered in sequence, the brain's change bias combines the separate sources into one moving source

[21]. An evolution of the illusion, the "/ed" (slashed) project by Watanabe et al. creates the illusion of being sliced in half with haptic feedback coupled with seeing a fake sword slash [22]. Speakers in front of the subject triggers, followed by those on the back, giving the subject a sensation of object passing through the body.

The gaming industry makes use of haptic illusions to supplement their gameplay. REZ's Synesthesia suit uses vibrotactile feedback to enhance the psychedelic visual and auditory gaming experience [23]. The overload of multi-modal stimulation is suitable in the context of the game. The KOR-FX haptic vest recreates a reduced version of bullet impact [24]. Disney Research's haptic chair does not reproduce the sensation of driving, but its vibrotactile actuators can influence and possibly supplement the spatial awareness of the player [25].

The elderly are found to be more receptive toward haptic than visual interfaces [26]. Since the first graphic user interface appeared, the windows, icons, menus, and pointing device (WIMP) design has not changed. All current GUIs are derivatives of the original concept and build off of users' prior experience with them. It is possible that as the part of the population that grew up with technology and are familiar computing esthetics age, this will change. For the currently and imminently senior population, metaphorical UI and association with tangible objects from real life are much more approachable [27]. Immersive simulations can offer a new life for those with reduced mobility. "Second-life" platforms are making a comeback as a result of VR technology [28]. Through design and improvements in technology, immersion can be powerful enough to trigger our body image plasticity that allows for remapping of motor controls and development of new habits. From remapping of existing nerves to operate a prosthetic arm [29], to EEG-enabled direct brain-computer interaction by a monkey [30], the brain demonstrates profound adaptivity in reaction to the new interfaces.

Neuroplasticity and increase in brain matter have been observed in elderly subjects tasked with learning a new motor skill for 90 days (juggling & navigation games) [31], with apparent delay of Alzheimer's [32]. These improvements, however, were seen to disappear after 90 days of inactivity, implying the need for continued intervention [31]. Therefore, the design of interfaces that accompany the elderly need to be engaging enough for continued usage, or risk atrophy and difficulties in relearning. In the following sections, we will present some key characteristics to designing haptic interfaces for the elderly with diminishing cognitive and motor functions.

3.1. Animacy

Animacy is a subcategory of Immersion that deserves highlighting. If Immersion can be seen as providing enough information to make a simulation compelling, then Animacy is conveying enough information to make sentient elements believable or imbue traits of sentience. Tactile information is crucial to the expression of emotion in humans and animals [34], and to the formation of social bonds [35]. We can even form these intimate bonds with inanimate objects when the right stimuli are present; symphonic musicians respond emotionally to the haptic feedback from their instruments [36].

Social isolation and sedentarism are becoming more rampant. As the population ages alongside this shift, the elderly are more likely to be living independently and in isolated situations. Reduced mobility lead to reduced social interactions, so telepresence communication is becoming the dominant way for comprehensive communication. While our information infrastructure make this possible already, a larger amount of data can be designed into the interaction to enhance the Animacy of the communication partner. One study shows that haptic stimuli provided in conjunction with audio clips of conversations enhanced our perception of the conversations' qualities (more animate, pleasant, warm, etc.) [37]. However, the influence of the stimuli is not reported by the participants, despite observed differences when compared to a control group [37]. Similarly, the inclusion of haptic qualities of a conversation in telecommunication is often overlooked when designing immersive experiences, despite their powerfully persuasive effects. Essential to the conveying sense of emotional intensity and Animacy, haptic telepresence, or mediated touch, is a crucial piece of telepresence technology [38].

CASPER by Tokyo University effectively uses haptic telepresence (air-cannon) to transmit instructor's touches to parts of the participant's body; some of the participants of the experiments noted that they could feel the presence of the instructor there with them [8]. Some elderly participants even shared their desire to have remote interactions with family and friends through the device [8]. By successfully capturing Animacy through mediated touch, we can mitigate the problems caused by social isolationism and sedentarism. These solutions can also be easily augmented onto existing platforms and other modalities.

Daily interpersonal communication make use of physical contact to convey and receive haptic sensations that inform on the emotional state and animacy of others. Rigid correlation between stimuli and resulting abstract feelings has not been drawn, but the presence, not the content, of haptic stimuli reveal a non-trivial impact on the quality of communication [37]. Nevertheless, we have found that temperature, pressure and frequency of haptic outputs are important characteristics to triggering emotional responses in the user. Changes to initial body temperature affect subjects' emotional response measured with skin conductance response (SCR); higher ratings of arousal and dominance are reported with contact to a pre-adjusted temperature source than through dynamically adjusting the contact to a target temperature [37]. The same study suggests that warmer or colder stimuli do not matter, while other literature suggests warmer stimuli are associated with pleasantness [39, 40]. A larger range of temperature thresholds is necessary to trigger avoidance and approach behaviors. Pressure is a common modality for conveying emotion, such as its use to comfort children with autism [33]. Temporally supplied stimulation is another powerful indicator: with low frequency of feedback are linked to stronger feelings of intimacy, and higher frequencies correlate to anxiety. Commercial devices such as Doppel have been built under the premise that our body's rhythms can be influenced by an external stimulus. Doppel operates by vibrating at particular frequencies that appear to influence wearer's heart rate [41].

Haptic feedback in telepresence situations offer unique interactions to capture non-verbal communications. Haptic pajamas that allow parents to remotely hug their children [42]. The Pebble smartwatch transmits intensity of activity (body motion) between two people through vibration [43]. User feedback for Pebble confirmed a sense of animacy and presence of their partners. Interestingly, the users combined their knowledge of the partners with the device. For instance, when the Pebble is outside the range of internet and stops transmitting, the receiver could tell their partner had entered the subway and felt reassurance when the signal re-appeared [43]. Reassurance does not have to come from a human source; Keio University's Nene projects uses a soft robot avatar of the participants' pets to study effect of haptic telepresence on loneliness [44]. The pet cats' or dogs' body temperature is reproduced in the doll, as are the sounds they make; purring is translated to vibration sensations. Compared to the control group, subjects report a decrease in loneliness over the 2 weeks of usage. The thermal, auditory, and vibrotactile stimuli produced a sense of Animacy and presence of the pet, which had a calming effect on the subjects [44]. It would be interesting to investigate whether the existence of a real-world source of the stimuli is crucial to the calming effect, or that an algorithm generated simulation of the pet is enough. The following section will discuss telepresence therapy and design for elderly in more detail.

3.2. Affordance

Physical and cognitive impairments are rising alongside the growing life expectancies of an aging population. Visual and auditory deficiencies affect the sufferer's ability to engage with much of the predominated infrastructures. Deterioration of cognitive and motor skills mean that the elderly have lowered independence and mobility, leading to decreased quality of life. Technology driven solutions in virtual reality (i.e., Rendever) and artificial intelligence [45] can mitigate some of these problems, but their designs likewise underrepresented this demographic. Virtual reality in particular offer advantages for the elderly: (1) simplified, safe, simulated space for learning, therapy, and exploration, (2) adaptive, responsive modalities based on user's requirements and preferences. Comparable to solutions for people with disabilities or autism, these technological interventions for the elderly face the challenge of dealing with minority population of extreme or unique users. Thus, one solution is not enough for the variety of contexts, but bespoke solutions are costly. Affordances in the design of UI for these technologies can have life changing impacts.

Just as visual and auditory VR have shown to help with people with physical [46], sensorial [47], and cognitive [48] disabilities, haptic feedback enhances activities like rehabilitation, learning, and behavioral change. Stroke victims regaining motion benefit from visual and haptic feedback in their training process [46]. Memory retention and information acquisition is enhanced by haptic layer of redundancy, as we found in our work on multi-modal reading [49].

Redundancy is a powerful tool in designing UI for extreme users. Especially for novel UI elements, redundant conveyance through multiple modalities can make learning easier. In the conditions that they work, jet pilots require haptic feedback in order to effectively operate their vehicles [50]. Haptic helmets and chairs are used to offer a level of redundant information on the state of their aircraft when the other senses (proprioception, vision, audition) are unreliable or unavailable. Elderly users can benefit from a similar technique of redundancy to supplement their diminishing senses: navigation for the blind through a haptic belt [51], and for the elderly through augmented reality [11] are some examples. Movement rehabilitation

[8] and motor skill learning especially benefit from the haptic feedback. However, the designer needs to be conscious of the different needs and offer affordances in their product for the extreme users.

The term "Affordance" arose from psychology and later adopted by HCI as the consistency between possible actions and the user's perception of the possibilities. Dan Norman expanded on the definition in his book "*The Design of Everyday Things*" [52] to perceived versus real affordances. Unlike the perceived affordances of GUI design for visual displays, real affordances do not require the user to have a preconceived notion about an element's function. Visual interfaces in our products often build off of user's prior digital literacy and familiarity. A graphical representation of a button requires you to understand the nature of its real world counterpart; a dropdown menu is a mutation of the button that do not have a physical analog to draw prior knowledge from. For the elderly and extreme users, we should not design with reliance on domain-specific conventions and consistencies, which they may have neither the familiarity with nor the capability of using. Our interview with elderly PACE participants in the United States reveal their preference of Kindle over smart-tablet devices because of the former's affordances for viewing content, yet apps for the elderly are still predominantly on the latter. We highlight three main challenges for the elderly subjects to using haptic interfaces, which can be overcome with Affordances designed into the device.

3.2.1. Learning/familiarity curve

The most challenging aspect of learning a new haptic interfaces is need to experience the interface first-hand; an intellectual demo is often not enough. Instead, the user must try it out, which also adds difficulty for the iterative design process. The learning curve can be lowered through design. By taking advantage of our instincts and other senses, we can encode haptic information in intuitable ways. For instance, animals and insects make use of the haptic sense to construct their mental model of the world around them [53]. Biomimetic design for sensory augmentation such as Tokyo University's Haptic Radar demonstrates the effectiveness of intuitive haptic stimuli to trigger responses with no training [54]. The radar is a good example of affordance due to its simplicity: haptic feedback equates to the presence of an obstacle which triggers user reaction. There is alternative interpretation possible. A notable product for the elderly that achieves this are the emergency alert devices (i.e., MobileHelp, Lifeline). It is a simple button that transmits a signal to the emergency response facilities; particularly useful for the elderly in independent-living situations, the device allows for only singular purpose that is intuitable even when the user is confused or in duress.

Inspired by the mnemonic device of "memory palaces" in cognitive psychology [55], we created a virtual reality memory box, Keepsake, to explore the retrieval of memory using spatial coordinates around the user [56]. The association of a life event with a general direction relative to the body was a preferable alternative to the linear timeline of most graphic displays. Likewise, physical objects enhance recall: asking an elderly subject to recount memories regarding a souvenir have much more detailed responses than without the physical aide [57]. Metaphorical UIs are powerful tools for guiding intuition, as long as the users are already familiar the metaphor. In the context of design for extreme users and technologically illiterate, analogies from culture and psychology are more reliable starting points than established UI design practices.

Social learning is the theory that we observe and learn from others' behavior. Our mental model of another's mind and action help us inform our own. Therefore, collective, group learning is another useful technique for reducing the familiarity curve. Keio University Fujisawa et al. experimented with a group of participants learning to operate artificial tails [58]. Some group of participants were allowed to communicate with each other and share their discoveries. In those groups, the experiment identified a cascade effect in which proficiency rapidly spread through all participants when a single individual discovers a breakthrough.

3.2.2. Malfunctions and failures

All technology can malfunction. The results of malfunction or failures in systems we heavily rely upon can cause detrimental results for the user. In the case of telepresence devices that are linked to the user's partner (Pebble) or pets (Nene), a severed connection can cause unnecessary stress over their perceived condition. Reviews for the commercial devices like the BOND bracelet that allow users to send "touches" to a partner is a good example of technical failure causing severe emotional responses [59]. Designers need to clearly indicate to the user of system failure rather than something catastrophic on the other end of the telepresence. If the BOND bracelet could have informed the user the difference between a problem with the app or device and a problem with the partner, customers may be more forgiving with technical difficulties. More serious cases of technology that enable certain actions or aide motion require special attention: unexpected failures in haptic feedback in devices helping the elderly with activities like maintaining balance or navigation can have dangerous consequences. Fail-safes must be implemented prior to unsupervised usage.

3.2.3. Personalization and diversity of needs

One of the greatest barriers to the proliferation of this technology is the diversity of extreme user needs. Variations in body types and deficiencies require bespoke and often singular solutions, thus significantly increase the costs for development. The field of prosthetics design for the physically disabled face a similar problem. Body type difference and varying needs means one design cannot have full coverage. Techniques like crowdsourcing and rapid-prototyping have been a boon for prosthetics design and can likewise be useful for haptic interfaces. Developers of products should look upstream, prior to the actual usage, to implement ways to grant wider access for extreme users.

In the case of prosthetics, makers are creating bespoke solutions from off the shelf components [60]. Open-sourced platforms (i.e., OpenBionics, Open Hand Project) provide editable templates for 3D printing. Prototypes for haptic research often use the same fabrication methods, powered by the same open-source electronics platforms, like Arduino and Raspberry Pi. Modular, DIY electronics components and kits for wearable technology have promising overlaps with creating personalized haptic interfaces, allowing users to tailor the solution to their unique needs. Manufacturers have created custom boards and components for haptic applications [61]. However, this development technique still has a technical barrier to entry.

Crowdsourcing design is a promising method to overcome this barrier. Adjustable templates and modular components can enable the democratization of design, so individual solutions can be generated as iterations off of the original. These design features need to be intentional and customization perceivable by the users as intended by its creator.

4. Tactile user interfaces

Tactile user interfaces incorporate all of the above discussed qualities in haptic interface design. Tangible objects in which the physical configuration of the components intuitively map to the function of the object. They have high Affordance in their design simply because the physical and mechanistic nature of the object allow for limited options and limited interpretations of those options. We encounter tangible, tactile user interfaces everywhere (i.e., flipping a wall button to turn on the lights). The physical sensation of flipping a switch gives a first level of confirmation.

We commonly associate these tactile UIs with physical objects, with physical consequences and haptic feedback associated with their purpose. Even input devices with digital outputs like keyboards and mouse utilize haptic actuation to provide immediate feedback on the user's action. UI/UX design guidelines encourage GUI counterparts to reproduce haptic feedback. For example the vibrotactile feedback on the smartphone reproduces the sensation of a button press to provide confirmation that the input is received. However, as touch displays are now dominant due to their versatility, they also inherited the windows, icons, menus, and pointing device model. This approach leaves few options for haptic feedback to supplement the interaction, evident by the "Accessibility Modes" touch displays offer the blind. Voice-overs associated with point inputs force users with disabilities to adapt to the UI schema of our graphic conventions.

We are excited to see the dominance of the WIMP interaction model being challenged by novel UI devices. Designs of input systems specifically tailored to the context of the activity, in which the haptic feedback is an inherent quality of the interface rather than an accessory added after the fact. Colleague Viraj Joshi's collection of tactile user interface (TUI) designs showcase novel and intuitive input devices. Joshi's Beethoven TUI incorporates telescopic, rotational, and push-select motion into one device for navigating through tiers of data (**Figure 1**). Each degree of freedom maps intuitively to an axis of navigation through the breadth of dataset, whereas the conventional UI forces the user to interpret graphic layout to access tiered information.

We hope that the inclusion of TUI design exemplifies the intuitive benefits of haptic design, as well as the misconception that haptic feedback must be a transmutation of digital data. The haptic output can literally be a physical characteristic of the device itself.

Figure 1. Joshi's Beethoven TUI design, virajvjoshi.com.

5. Discussion

We argue that haptic interfaces when designed right have a significant advantage for the elderly, for whom visual and auditory processing can be overwhelming. Haptic interfaces have been applied in a wide range of contexts. Everyone with a smartphone has familiarity with it. As a result, the general understanding of its potential is shaped by the vibrotactile actuator in our smart devices. The development in other industries, notably the video-game industry, of multi-modal devices will steadily introduce the general public to novel haptic experiences. Complementary to the proliferation of virtual reality, haptic technology will enhance the activities VR already allow. However, the trend in Internet-of-Things and smart devices on the market show a lowered consideration for fail-safes in recent years. Cybersecurity breaches are rampant in smart devices. For products that help the disabled and elderly perform and survive, malfunctions or failures, intended or otherwise, can put the user in physical danger.

Assistive technology for the elderly conjures up expectations of advanced robotic automation solutions to help perform functions of a human. In reality, our interviews show that this is not necessary. Technological interventions for the elderly do not actually need to tackle complicated tasks. We spoke with elderly PACE patients and their caretakers, revealing that the most commonly requested help is interpreting information. Bills, medicine descriptions, product setups instructions, and the like, all of which are performed through video/audio calls. House-calls are scheduled and emergencies rare. One caretaker we spoke to notes that calls from patients stems partly from loneliness. Another caretaker remarks that most of the instructional interactions with patients are reminders and repeats of previously given instructions. Due to diminished cognitive function, patients routinely forget portions of how to perform a task and seek repeated guidance. In other cases, pride and desire to be independent often keeps patients from seeking help when necessary. In one instance, a female patient fell in her home but refused to activate her emergency alert device until hours later, when her own efforts were proven to be ineffective. These varying degrees of needs and different preferences make designing for the elderly difficult. But we need not complicated solutions. Instead, we need customizable tools and interfaces for each unique situation.

6. Conclusion and future work

Advancements in virtual reality technology catalyzes the development of haptic technology but do not exactly overlap with the needs of extreme and elderly users. Most of them deal with sensory and cognitive disabilities and deficiencies. Despite numerous advantages that the technology offer these people, they cannot make good use of the interfaces to access them. The most common outcome is sensory overload. This chapter outlined three desired characteristics to strive for when designing novel haptic interfaces: Immersion, Animacy, and Affordance. The goal of Immersion in this case is not more detailed simulations but more thoughtful ones, often simpler ones. Particularly for immersive experiences involving telepresence, the mediated touch need not be able to convey complex information. As previously stated, Animacy is produced simply from the presence of haptic stimulus rather than its actual content. We argue that long-term usage, rather than isolated instances of use, is the key to fostering connection. Stimuli provided organically over time informs the feeling of Animacy in the interaction.

Affordances in design of the interfaces for the elderly should seek to capture and communicate the crucial elements of the interaction while filtering out the rest, resulting in an artificial model within the informational processing capacity of the user. While neuroplasticity allows the brain to adapt to new interfaces, old age does come with a reduction in its ability to remap new information and action. Therefore, taking advantage of existing neurological phenomenon (haptic illusions), using metaphorical UI's, and/or combining with other modalities are promising ways to engage new users without training. If training is necessary, incorporating social learning opportunities is encouraged.

In information design, there is already pushback from the general public on the abundance of data we are exposed to in our day-to-day. Designed visual stimuli bombard us everywhere we are, primarily through displays that we own. Trends indicate a desire for more simplified and curated representations, less clutter in our visual field. In the future, we can expect haptic interfaces to be more prevalent in our activities, where more design leads to less information but refined presentation. This shift will be a boon to the rapidly aging population. We believe that this prediction holds in the long run, even as the generation with proficiency in computing esthetics and practices become elderly. Simply because by 2050, half of the population is expected to be nearsighted due to our computer obsessed lifestyle [62].

We hope to take this work further by creating a set of heuristics for the design of haptic interfaces, expand upon the three key qualities of Immersion, Animacy, and Affordance we distilled from a broad analysis of existing products and research prototypes. We will continue monitoring this design space and categorizing the emergent features to ideally create a taxonomy and design toolkit for haptic interfaces.

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Chapter 5

Intelligent Communication and Patterning in Smart Cities

Roman Anton

Additional information is available at the end of the chapter

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Abstract

What makes a city great and smart has puzzled many, and millions are fascinated by metropolises and interested in the effects and phenotypes of urbanization. More than ever before, citizens are demanding smart cities, which are in progress and have co-evolved and shaped us, the citizens, the country, the economy, and the world, reciprocally over many centuries. This chapter highlights the past and future roles of communication and pattern formation in the local cluster of the developing smart city and "assistive technologies" and catalyzes that were and will be needed to transform a city via better cluster management, urban planning, coordination, citizen enablement, integration, and citizen feedback into a better functioning, convenient, and intelligent place for all of us including disabled, ill, young, or aged persons. With some explicatory analogy, the "metacity" is becoming a new living entity that is either more or less disable and needs "smart enablement," new solutions that solve old bottlenecks, as the city is as enabled as its citizens that need some aids. Hence, smart cities are on the agenda in most countries, and fair opportunity, city functioning, smart communication, and smart pattern formation play pivotal roles in the unmatched urban enablement of all citizens and, concomitantly, the enablement of the "metacity" entity. Smart cities thus hold the key to stimulate the economy, to create the pattern of great places for all, to meet our Maslow's pyramid of needs also on the city level, and without leaving anyone of us behind.

Keywords: communication, assistive, technology, patter formation, smart, cities, city, disabled, enablement, form-follows-function, patterning, cluster, management, urban

1. Introduction

Cities can be defined and understood as developing clusters with spatial localization and a heterogeneous but cohesive density function of human sojourn probability, demand and supply, culture, and the respective architecture and infrastructure, and city systems. Our cities have developed over a long time and they still evolve into modern-day "smart cities," as onset and the ongoing trend since centuries, which can be best understood if one reveals their historical development and evolution over time worldwide. An understanding of past developments, the demand and wish to improve our cities, creativity, and economic interests are among the major driving forces that will frequently propose and demand smarter cities including "new assistive technologies" for all smart citizens including disabled persons. Improvements can be best achieved by learning from unbiased evaluations of previous developments, empirical and apodictic facts, performances within contexts, and circumstances. We do not only need to know and understand what really matters to create intelligent cities, we also must ask the question what "smart cities" really are or should be—a common goal of human endeavor. Eventually, we all live in city that will have some goals.

On the roadmap toward smart cities, there are many streets and crossroads where form follows function but everything is a function including esthetics and aid. We want a city to function, we want a city to be a nice, good, clean, great, comfortable, and a compatible place to live with all basic amenities and even more, if possible, in a step-by-step approach undertaken in the right order and priority for a citizen with general or specific Maslow's pyramid-like demands and requirements and for everyone in the city as a whole. We want to integrate into the one-species biocenosis of a city that takes care of the multispecies biocenosis in a biomedical way via health care system supply.

Whenever a smart city integrates us we become smart, rise, and grow beyond ourselves. Without enablement and integration into the smart city, we are all disabled—all of us. The smart city is designed to extend us by providing us with everything we need to work and live and for our pursuit of happiness and at least our basic human rights. In the developed and developing world, urgent city demands can vary at very different stages and many segments. What makes a city great, what makes it smart, and what attracts and enables their citizens the most? What is needed to unleash the entire potential of a city and its citizens and to diversify and upgrade its functions? The best strategy is to help the weakest link in the chain, the weakest infrastructure, the weakest citizens, the most urgent requirements [1].

To say it with Aristoteles, the whole of a smart city is more than its smart city components.

This synergistic effect is known to be the key driver of the urban economic and cultural engine, only if all economic dimensions are met, only if all drivers of growth are supplied, and improving the bottlenecks first, than gross domestic product (GDP) and wealth and functional key performance indicator (KPIs) will soar [1]. The whole is more than its sum as the important elements network together and make a city great and smart and an economic cluster of co-dependencies, and as a result, all bottlenecks must be improved and advanced as the major take-home message of the math behind it [1]. By enabling all citizens, disabled and unemployed ones, they will be a part of new growth. If one of the key component is missing, it would cause a bottleneck to be understood as the weakest link in a chain [1]. Solving this bottleneck for all citizens [1] means to pull the city and its citizens upward into a more productive, intelligent, wealthy, healthy, qualitative, cultural living without forgetting about anyone of its citizens by integrating all [1]. A further advancement of city entrepreneurship takes dimensions of intra-preneuring into account [1].

As important as it is for a country to unleash the power of intrapreneurs [1] and to close all bottlenecks, to be attractive for investors and to stimulate qualitative and quantitative economic growth [1], as important it becomes for a city to be an economic, functioning, great, and sustainable place. All individual and all common goals must be better aligned, channeled, and met. Every urban planning can be thought top-down and bottom-up, centralized or decentralized, and private or public, and "the big things" are only standing strong in a well-founded detail solution and highly interact with "the small things." Small mirrors big, and big mirrors small, in a city like in a country, and this reciprocal patterning could distantly remind on a fractal-like pattern (**Figure 1**) – to better remember this urbanistic effect. It seems to be a fundamental principle in all cities, countries, and governing in general due to the reason that everything is interconnected, and also cities shape us, and we shape the cities.

If we are enabled in the cities, then the cities become enabled too. As form follows function, all forms will strive toward a functional form, but as function also follows form, for example in art, design, and esthetics, all functions will also strive for a form function, and now both can happen at the same time to a different extent smart cities should be aware of. These patterns often have an anthropocentric reason and are centered on human demands, communication, intelligence, cycles of evaluation, planning, and implementation, steadily forming demand and supply functions, and the requirement to meet the challenges of an ongoing urbanization.

Figure 1. City evolution in fractal-like patterns or rethinking the reoccurring themes. For example, in megacities, there are often patterns of subcities and towns with one metropolis; art, design, architecture, culture, and how things are done influence each other on all layers. The small things that are relevant for all citizens make the city's big things, and vice versa.

Communication and patterning, aiming at smart city goals and the enablement of all citizens, comprising responsiveness, planning, and implementing, are some major pillars that might summarize and can help direct the cities into human-friendly places of good living and working. Cities are not only places of mass enablement that bear economies of scale and scope but also difficulties and new challenges of size and magnitude. To solve social problems or the needs of disabled persons in a developing megacity, it can bear much intricacy and requires a city masterplan that is more powerful if done for everyone.

To resolve all citizens' issues, one must always start at the individual urbanite and integrate and coordinate the required actions and smart city planology for all townsmen and even more than that, for all potential visitors and even for people that will only get an opinion about the city – smart cities are big in our mind. Money, wealth, and luxury are not everything that makes a city smart and big, there are also affordable ways to do so and it is worthwhile to try a real mastery to find top alternatives.

Communication is the beginning of solution finding, planology, and patterning a smart city. The economy and society turns into an uncontrolled network of co-dependencies and leave the free market and normal government [2] and the city become a part of the rising network economy, and competitive advantage becomes more and more defined by smartness, information, and technology [2]. But smartness can be good or bad for people if there is no common goal. For example, smart consultancies have destroyed the global job markets via billion dollar HR consulting that hinders the smart workforce to find an entry position. Good smartness would be to allow intelligent workforce to get an entry position vice versa. Thus, we need smart cities with good goals: it would be surely good to integrate everyone.

The information age [2] has quantitatively ended patriarchalism in the western world [2] and has led to advancement of females over males via betterment of females in job sectors. This has fully destroyed the lives and careers of many male citizens, and concomitantly science and the common sense in the society is not functioning any longer. The city is the arena of this interplay between female femo-fascistic and male job stealing organized crime networks. Hence, there would be no good development without smart city goals that would happen naturally in such unopposed information and organized crime network societies [2]. Consequentially, smart city movement is the only good integrative idea to move forward as they intend to help everyone living in the city irrespective of the gender or employment. A key idea is enablement of all citizens via integration and assistive technologies that are a help. New cutting-edge technologies can help to assure mobility, interactivity, information, jobs, a more convenient supply and a better understanding of demand via assistive technologies. Such citizen-centered solutions can empower and enable disabled and nondisabled persons.

Assistive technologies can be defined in the widest sense to enable citizens that deal with a lack of mobility in the city, lack of instructions and information, lack of any specific need that the city should, and can take care of using technology to thrive humane city evolution, and assistive technologies can be defined in a narrow sense to help disabled persons. Both definitions are used here because enablement is important for basically all citizens and it will never be helpful if we are divided and conquered on every topic—all citizens are one.

This book chapter deals with catalysts, enablement, and principles of evolving smart cities and assistive technologies and that we can learn from developments over time. It will also discuss some major drivers, general goals, and key game-changers of "smart cities." Myriads of dichotomous influences, let it be historic or present, materialistic or intangible, accumulative or ephemeral, arbitrary and planned, rational and creative, considerate or impulsive, conservative or progressive, liberal or conventional, with capitalistic or social focus, have altogether, and many more, parametrically and incidentally shaped the cluster of the city in many patterns of central or decentral, private, and public decisions. The right theoretical frameworks are still missing and without them smart city evolution will not work. Hence, this work must give a general understanding of smart city and enablement and makes the assistive technologies case examples of the smart city goal theory and evolution.

We are just about to begin to better understand, reveal, and track all city and cluster patterns scientifically, statistically, spatiotemporarily, logically, and we still need to find the right readouts and KPIs to measure the ongoing smart city success, e.g., from year to year. We are still at the beginning to control smart city evolution, and smart cities have already formed coincidentally due to the obvious requirements of the cities and by trial and error, but sometimes also by good planning and foresight for all citizens. City planning has gone a long way like all of the city technologies, both the inventions and their implementation. The smart city planning must also protect citizens from bad and evil networking and must enable transparent and good networking to direct the evolution of the information age [2].

In ancient Egypt, in the Roman empire, the Greek polis, ancient Chinese cities, or in some big western capital cities, the idea of top-down planning, centralization, purpose function, and order was part of planology and urban management. This has yielded nice overall city structures, city architecture was keeping the big picture and impression in mind, and both aesthetical and functional aspects were sometimes considered more rigorously, especially in capitals or important cities for the emperors or leaders. Today's modern-day cities are more decentralized, market-like, with residential, industrial, scientific, governmental, recreational, and many more designated areas for building. This new bottom-up freedom has yielded great developments, but there are upsides and downsides to both models of urban planning. Dialectically, it might be advisable to search for the best of both worlds and to assure right contexts, frameworks, and conditions of deciders, to assure a free but also well-planned city.

For instance, a recent experiment with people who had never studied town planning before were asked to design like city architects the regular city areas and streets, which resulted in the same pattern we see everywhere in our cities. This might show that cities could lack behind in advancing or planning the city in a more aesthetical and accessible way for all citizens.

Consequentially, we see positive and negative developments of this decentralization and both must be questioning it when needed and celebrate it when needed too. Still many city issues and challenges of today will only be resolved by centralized planning and top-down design. Everything that the market would not achieve must be achieved differently; "assistive technologies" for example, often need governmental, state, and city support—but not always.

We need to research to gain a better understanding how to achieve intelligent smart cities in a cost-effective and most suitable manner. Generally spoken, decentralization can work fine whenever a special and personalized particulate private interest had to be met. But this decentralization has not worked out for common societal goals due to a lack of incentives.

Particulate interests seem not to have been able to sustainably team up in a marketplace to build a smart city for all of its inhabitants and citizens, while the city fathers also believed in "the market" for centuries. Examples are health care, assistive technologies, education, infrastructure, and many more. These prerequisites must be actively enabled in smart cities whenever the market does not meet the needs of all citizens, or if the market cannot be channeled or does not get any smarter or better over time.

Our cities still lack intelligent communication, and communication solutions are still at their very beginning despite the digitalization, the internet, and the "mobile phone area" of the world. Taxes and governmental funding are key drivers and needed to build infrastructure, hospitals, transportation, halls, theaters, parks, bridges and tunnels, airports and seaports, to enable city vitality, to enable city growth, to enable investors, to enable functionalities, and to enable all citizens including disabled citizens with both mobile and nonmobile assistances. Smart city communication is still in its infancy, like mobiles, and more serious helpful apps.

If you want your city to function, you must enable your citizens to do all their functions. Enablement is a common welfare goal that was not reached by an invisible hand or market so far. Although the "invisible hand" is known to channel private economic egotisms into economic activity that manifold supplies the society—it is also a system and machine to manifest social inequality and oppression and also did not serve any higher common coals, like welfare, healthcare, social justice, fairness, equalization, and protection of citizens irrespective of gender, race, disability, or any individualism. Adam Smith did also never intend what neo market radicals have made out of it. All he was saying is that the capital market organization provides incentives to make egotisms indirectly work toward a common goal of overall supply and that there were not only bad things and downsides of capitalism [3]. This misunderstanding has caused suboptional pattern formation around the globe until today. The right decision about public and private in all cases is the solution.

For instance, which markets should solve all the problems of all disabled persons? There are not enough incentives to solve all of the market failures that we see today, and the market lacks centralized solutions for common goals if needed. So the governments, states, and cities have had to step in with laws, regulations, and governmental funding. Until today, cities, towns, states, and countries have not sustainably solved common goal questions, and there is hope that new "assistive technologies"—in the widest sense for all people and questions—might help in these endeavors, like public transportation, ICT, or infrastructure.

Thus, if we start aiming to solve citizen problems, enablement comes into play for both disabled and abled persons. Enablement using technologies is thus a key defining feature of modern smart cities, no matter how we are disabled or hampered to do something we need to do. By making public transportation compatible with wheelchairs, it can save costs that individuals or the public have to bear for alternatives and give back some normality in life. Vehicles and cities can be better designed for wheelchair paths or blind persons. One can thereby learn from the solutions for disabled persons to provide solutions for all citizens.

Since centuries, cities develop into smarter places, but it will still take a long time until they are all there. This development can be best understood as a process in time. Not only new inventions, socioeconomic, cultural, political, and technological developments, but also health care, migration, defense, employment opportunities, industrial diversification, financial and service sector development, arts and architecture, and much more has all impacted smart city urbanization and city cluster aggregation. New assistive technologies are game changers for citizens, both disabled or not, and will help to enable citizens in smarter cities.

2. Smart cities

What is a smart city, what are smart cities? Today, there are still no universally accepted definitions. Many have heard the terminology, but are not familiar with what it really means or have precise definition. Worldwide and also per country, the definitions vary much and it is interesting and worth doing to have a closer look at recent definitions:

The government of India, for example, has created an important “Smart Cities Mission” with a wish list of infrastructure and services and with universal core set of the basic requirements that holds true for all cities: (I) adequate water supply, (II) assured electricity supply, (III) Sanitation, incl. Solid waste management, (IV) efficient urban mobility and public transport, (V) affordable housing, especially for the poor, (VI) robust IT connectivity and digitalization, (VII) good governance, especially e-governance, and citizen participation, (VIII) sustainable development, (IX) safety and security of citizens, and (X) health and education [4]. Smart cities can act like a lighthouse to other aspiring smart cities, and one can learn from one another to speed up developments, and smart cities become part of an international network of cities that could help each other. The conceptualization varies toward more advanced needs in more developed cities and countries that often have solved fundamental issues some time ago, but also advanced and developed cities have not done everything right and must learn from their mistakes. Developing cities can benefit from this city learning and can try to do the specific right things for them immediately. Maslow’s pyramid or hierarchy of needs provides a good general understanding. It is not just a psychological phenomenon or explicatory model of the psyche, individual needs but also a real-world challenge for all people and all cities and their needs. Maslow’s pyramid of needs holds true for the city, the country, all citizens, and also disabled citizens.

As a result, the phases of smart city evolution could be ordered in a fashion related to Maslow’s pyramid of needs and requirements (see **Figure 2**). The UK Government’s BIS (Department of Business Innovation and Skills) “considers smart cities a process rather than a static outcome, in which increased citizen engagement, hard infrastructure, social capital, and digital technologies make cities more livable, resilient, and better able to respond to challenges” [5]. The British Standards Institute (BSI) defines the term as “the effective integration of physical, digital, and human systems in the built environment to deliver sustainable, prosperous, and inclusive future for its citizens” [5, 6]. Recently, the United Nations Economic Commissions for Europe (UNECE) has started a United Smart Cities program that is sharing the same key areas comprising urban mobility, sustainable housing, clean energy, waste management, and information and communication technology (ICT) [7, 8] and fulfills as a mission the SMART criteria of specific, measurable, achievable, results-focused, and time-bound goals [9]. And there are many more missions like these ones, but much nebulosity exists over what a smart city is, globally. When we think about smart city evolution, it has already gone a long way,

Figure 2. Maslow's pyramid in analogy to the evolutionary phases of smart cities.

a very long and complex journey, not fully perceivable in all billions of details, and yet there is still much to come to reach to goal of a smart city, as it seems to be a never-ending process. Would it not be nice to have free public transportation in a free smart city? Would it not be nice to have a compatible site for disabled persons with wheelchairs? Would it not be nice that the city has a solution to all our problems and is responsive to what we want to know or what we want? Utopic, idealistic or even realistic—the future will show, but there is already strong evidence that the attractiveness increases in smart cities also for investors, for tourists, and growth with all benefits the city and the citizens.

Whenever we use the terminology of evolution, a selection from diversity, survival of the fittest, we often end in misunderstandings and wrong comparisons. But cities do evolve but differently, like the economy, the country, the sciences, engineering, or IT [7], but this cultural type of evolution is clearly different, and it follows very different rules, still it is an evolutionary principle at work, with a different type of DNA, entities, selection, incentives, and diversity. If we have to distantly compare city evolution to biological evolution, we might think of the transition from isolated single cells to multicellular organisms that adhere and have started a division of a labor and a specialization in the common cluster and reproducible vehicle with a genotype and phenotype. Multicellular organisms, the metazoan, had an increasingly competitive advantage, this way spread all over the world, found and developed in their also changing niches. We the "*metacitizens*" are the biological component of the city that evolved biologically and culturally, while the city evolves differently and shapes our niches.

When people settled down and towns grew to cities, a division of citizen labor took place: architectonically, functionally, and on many different levels, so that we could think of cities in the same way, as forming multicompartmental, multifunctional *metacitizen* lifeforms that

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cluster and slightly integrate in metacities, which also appear like lifeforms, new collective entities that wire together via infrastructure, streets, internet and ICT, governing, and more. At the same time, smart cities will co-evolve the forefront of the internet [7] as nerve system.

But this development into multicellular organisms created many new requirements and challenges for both biology and urbanization. An organism or city that is growing naturally or due to the influx of immigration, new residents must have new structures, body plans, and procedures. Among the new needs are those listed in the smart city missions and in Maslow's pyramid of requirements (**Figure 2**) mentioned earlier: transportation, energy, health, education, ICT [7, 8], economy, governance, research, social and technology assistance and help and aid for sick, aged, young and disabled persons, and much more. This might correspond to the need of a transporting blood and vessel infrastructure system, heart, brain, internal organs, skeleton, muscles, several senses, digestive system, blueprints, specializations, and mechanisms, which make the big thing work. The immune system helps fighting pathogens like the police and fire departments, and regeneration is also in place. We should not overstress the comparison, but when we are thinking about *smart city* definitions, it might be important to include a distant analogy to evolution. In the light of such comparisons, one could view or define *smart cities* as locally evolving cohabitation clusters with the division of functionalities that develop economies of scale and scope and thereby become intelligent entities with own goals and strategies and relevant engines of the economy, culture, science, and country, social policy, and for human development. All of this depends on communication, integration, coordination, in the first place or phase, while responsiveness, patterning, and implementation are the part of the second phase.

The more city townsmen are integrated and enabled the better. *Metacitizens*, m*etacitizens*, or *metabürger* are members of the evolving city or town and state or country. Such inevitable democratic *metacitizens* for smart cities evolve by sharing common goals of a fair and sustainable civic society with help and integration for all. Smart cities evolve over centuries and "widest sense assistive technologies" are key driver, e.g., sewerages (see **Table 1**).

Time	Smart City Goal	Cultures and Countries
5000 B.C.	Single Sewerages, First Toiletts	Tribes
3000 B.C.	System of Sewerages	Sumerians
2000 B.C.	Sewerages, Aqueducts	Greeks
1000 B.C.	Uphill Water Supply	Persians
600 B.C.	Sewerages, Aqueducts, Indoor Water	City of Rome
500-1500 A.D.	Medieval Period	Slowdown of Smart City Development
1500 1700 A.D., 1700 1800 A.D.	Renaissance, Age of Enlightenment	Revival of Smart Cities; Europe, UK, USA
1700 A.D.	Sewerages, Aqueducts, Water Supply	France, England, etc.
1800 A.D.	Sewerages, Aqueducts, Water Supply	Paris (new standard setting)
1840 - 1890 A.D.	Sewerages, Aqueducts, Water Supply	New York, London (standard setting)
1900 A.D.	Sewerages, Aqueducts, Water Supply	Became Standard in European Cities

Table 1. The invention of sewerage is 8000 years old but reached Euro cities 7900 years later.

How well are city development and technology evolution really doing if an invention like sewerage, in fact, took up to 7900 years to be fully implemented as a working standard? How well is human cultural and smart city evolution really doing? What is it that holds us back? What slows human city development, planning, and implementation, and hampers the human civilization so much? What are we doing for all that research and innovation if it takes another thousands of years before the most logical and needed things find their way? Where does the implementation delay stem from? How to speed up the help the citizens need?

Maybe the answer can be found in the circumstances of the long medieval period in which much of the previous knowledge and know-how of the ancient and antique cultures was lost or not implemented for all, including most of their inventions. Lack of communication, education, and communication systems like universities, schools, a free or functioning press or information collection and distribution system, lack of libraries, books, and knowledge and information dissemination technologies, but also censorship, and a strict obedience to all hierarchies might have repressed a faster evolution toward smart cities. Key inventions were already made but not implemented. The Renaissance and *Age of Enlightenment* have speed-up smart city evolution again by reviving previous ideas including sewerages (see **Table 1**), knowledge, technologies, art, and humanism, which were essential for integration of citizens in this important ascent. This has changed perceptions of the city, it has reduced its feces, odor, all around the clock in many corners of most streets, and has simultaneously improved the health situation of millions of people by reanimating assistive technologies of leverage aqueducts and pressured water supply, that limited the deadly cholera epidemics.

We can assume that assistive technologies—in the widest and in the narrow sense—are still delayed and lacking until today, and we can also learn from the past that effective communication and implementation patterning are needed to improve smart city comfort, inclusiveness, and development and to unleash the help for all of the citizens including disabled persons. After the *enlightenment area,* the city also became more enlightened, more intelligent, and steadily gave rise to more intelligent and educated citizens that frequently shared some common goals, which became an important building block of today's smart cities (that might be at risk again) as the pattern reoccurs from small to big and vice versa, like also happens in a fractal (see **Figure 1**). The more the city grows, from hundreds to thousands, to millions, the more externalities and issues are concentrated in space, which is causing imaginational smart city inhibitors that repress city evolution, which is causing a major *metacity* issue that requires more infrastructure, supply, order, technology, and more.

Without such "assistive technologies," all the citizens become somehow disabled in their functions and one need to enable them again: for example, if commute distance per citizen increases, while parking spots and cars have reached a steady-state or saturation phase, public transportation needs to be extended, advanced, and a full coverage will be important. Another example is unemployed persons in the city that are disabled in their professions by a big lack of good or adequate employment opportunities in most of all countries today. Enablement of citizens, especially of those who need help, disabled or not, is a key solution. Further examples are if modern life impairs family formation and there are more and more lonely persons and singles in cities, or poor and needy people, lack of money impairs them.

Smart city evolution has much been driven by the enablement, empowerment, and by fair enhancement of citizens. Fairness and adequate enablement seem to be a dimension of economics [1] and also of the city: intrapreneur in the firms and economy is comparable to metacitizens in the metacity. City-driven enablement of all citizens in this context always means the enablement of all citizens that need the assistance to perform their functions and meet reasonable expectations, key demands, and wishes. Hereby, city planning can learn a lot from helping disabled citizens: this offers many lessons to be learned for all citizens. The barriers that disabled people become challenges to overcome with ideas, planning, assistive technologies, city strategies, and the same hold true for all citizens that face any sort of issue and barrier to anything in the pyramid of needs.

The city, resembling a living entity, not only becomes apparent by growing wires, tubes, sewerage, water supply, headquarters, streets, public transportation, energy, supply and waste systems, functional specializations, and interfaces for interaction—but also by the group and mass behavior and behavioral patterns of its citizens and via communication. The individual behavior determines the group behavior, and vice versa the group behavior is taken over by the individual; this makes independent thinking important or everything can go wrong, only if communication and pattering allow smart inputs it works.

Once you build a plant or home you become linked to the city systems. Would not it be nice if the city is compatible with all of us and has already thought about the interfaces and aids? Now how the city patterns depend on centralized and decentralized pattern formation and there are many city patterns to study and publicly reported to citizens today (**Figure 2**). Would not it be nice to have such mappings also for a disabled person? For example, imagine you could simply check on a map if there would be a problem to go there by wheelchair. New assistive technologies of today for disabled and all citizens will often need a central and quality controlled mapping and database and public information management systems.

How are we designing the city is a function of many activities that are either interdependent, private or public, centralized or decentralized, normed and standardized or free to the owner and basically managed by the city or not? These entire sets of the accumulated decision, historic and new, regulations and investments, and more variables, define the city patterns together with the recent economic, cultural, domestic and global trends and sentiments. Importantly, these city patterns are becoming recorded and monitored more systematically over time, and some cities make them publicly available like the City of New York's (**Figure 2**) NYC Open data that everyone may study further [10] of its key office of strategic planning. This creates a cycle of communication and patterning but mostly city fathers are the drivers. The pattering of the city happens always, planned or not, and size and historic decision pose some additional challenges but also great things become possible in smart cities, unique in the country and can get important even worldwide. Access to information is an assistive technology for all citizens, enabled or not, and eligibility and transparency are always helpful to smarten your city and to enable citizens. Accessibility is an important thing to have for all citizens and one thus also needs "Enablement of Assistive Technologies." The first example is again the wheelchair path or captions for people with sensory disabilities, but there is much more to do to enable technologies for disabled and all further citizens too.

Figure 3. Concept of the metacity, the metacitizen, and bridges of enablement thinking. Bridges of enablement for disabled citizens and others to enable them to participate. The bridge of enablement is needed for all metacitizens in the metacity to best integrate their potentials.

To illustrate pictures, we need many bridges of enablement to integrate the metacitizen into the metacity (see **Figure 3**). It shall become a city where everyone takes care of citizens and the city and each other, basically a city for citizens, a friendly entity that integrates and that gives us a chance in life and the supply, the information, aid, and comfort that we need. But economic, sociocultural, scientific and urbanization steadily also raise new challenges of eligibility, accessibility, integration, transparency of information, fairness, and assistance.

What can the city and government do to help disabled citizens and what can citizens do to help the city? To channel such endeavors incentives and assistive platforms of participation, integration and coordination are needed. IT platforms will be the basis of the service economy for smart cities that can shape the horizon of city governance [11, 12]. This leads to the question, what can the city do for both disabled and not disabled citizens, in general, to be kept in mind. In both cases, the question arises from the standpoint how can we bridge the gap to citizens to fully enable them and what gaps are to be closed. We need to research the gaps and find innovative ways to close them. Assistive technologies and models can catalyze bridges over these gaps. A new mindset of how to enable citizens would lead to many new breakthrough innovations. So what halts human development and smart city development? It is often also the lack of exactly these bridges of enablement (**Figure 3**) and the lack of communication and patterning that leads to an understanding that implements new important findings. So how can we improve this situation in the future? We need to build elusive bridges of enablement again that take care of all citizens, no matter if disabled or not, as nobody should be left behind in a modern world like this where; we are all dependent on each other and in cities like these. How can we reach such goals? We must generate the economic and political momentum to lever smart city goals and developments. For smart cities, an economic and political momentum can be gained to sustainably lever the smart city goals and developments as an inclusion-of-all-citizens policy. This is very feasible, if all newly generated money may only enter the economy in a monetary transmission that benefits the smart country or smart city goals [13]. Recently, the growth of the monetary aggregates (M1, M2, M3) equals a big part of the money that the government is losing, and could be invested into smart goals [13]. By generating firms that generate value-adding jobs in the city, state, and country to always keep jobs in access in order to "avoid social hostility for citizens" including disabled ones. The internet of things and smart environments, if done in the right platforms [11], could create jobs and supply, e-inclusion, and assistive devices [14].

Catalysis of bridges of enablement between the metacitizen and the metacity is needed all along the pyramid of needs (**Figure 2**)—starting from the bottom to meet all basic needs to the top, while especially taking care of critical bottlenecks generally bottom-up, there are some exceptions. This simple strategy still inquire for very big effort, especially in cities in developing countries that can be accelerated and catalyzed by the lessons and methods learned, and aid in assistance in the planning and implementing from some of the more advanced cities.

Figures 2 and **4** also indicate that smart city management requires smart communication systems and feedback pattering cycle that starts with information gathering to match all demand with suitable supply including infrastructure and assistive technologies. The cities develop into smart cities via positive interactions and values for their citizens. These interactions are mainly physical and technical: ground, electricity, water, waste, and so on. The next big step in smart city development could be based on "intelligent city interfaces" and intelligent platforms that help to make citizens function and unleash their capacities.

Only if there is feedback, signaling, and responsiveness mechanisms between the living metacitizen and the living metacity, it will become a friendly metaentity that we want and it will be possible to better coordinate and integrate the two, which happens reciprocally in

Figure 4. City patterns on city maps of New York City (from NYC.gov).

interactively. One feasible way to do this remains to be the internet that will be shaped by the smart city developments [7], as the world is reaching a high coverage and infrastructure for a service economy, and ICT is given [11] like computers and smartphones and a more comprehensive assistive internet of things [14]. We are already linked to the worldwide web, but smart and trustworthy assistive city apps are still missing as most private internet platforms are not quality assured and there is a big misuse of data and asymmetric information on most private sites. Should all go public? For example, there is not one trustworthy dating site worldwide that is not cheating by fooling and stealing the citizens to rob good-looking candidate for conspiracy network mating and alike. There is not much fairness-checked internet services [11, 7, 11] for all, and the remaining lack of helpful professional assistive technology apps that intend to make the life easier for disabled or other citizens, mainly fake and false information, and a lack of quality of IT and services [11]. Free and fair ICT sites and assistive technology hubs thus must be generated and always quality assured by an independent agency to assure information symmetry and a fair-play open environment for supply and demand for all citizens. Maybe everything important in life must be quality assured by a governmental agency, as there is simply much misuse of information and ICT procedures. Not only dating sites, not only assistive technology databases, basically everything, starting from platforms of offerings, meetings, housing, healthcare, assistance and mappings for disabled, and much more. Maybe, we can learn the following from smart cities and assistive technologies: we need platforms of enablement [11], quality-assured marketplaces where products and services can compete fairly with each other and where you find whatever you need; if the private market does not deliver, then there will be a city or public offering. Moreover, using such internet platforms [11, 14], it will also be possible to advance them via feedback and platform learning while quality is assured independently.

What about if every citizen had an interaction cockpit with the city like in a Borg spaceship? This could assure ideal demand and supply [11, 7, 11] in the IT network economy [2], but fairness must be fully assured—that is not happening so far by today. That might be still too early but a very first interactive interface in the internet would be possible to do all important things with the city and country, like taxes, bureaucracy, and all from your home computer, no need to find your way through the city or to find a good time for that, no need to take holidays to see an administrative office during opening hours, etc. This assistive ICT and platform technology [11] could help all citizens and especially disabled persons. It is catalytic to look for overlapping things that synergize—and provide special help for all. Every metacitizen could obtain a one-for-all login and password for the metacity, metastate, and metacountry. One-for-all would be one of the slogans of the metacitizen, as nobody should be left behind as part of the common smart city goals. Public-ran website of the government would be provided [11] to offer citizens to freely interact, exchange, and trade in a mutually beneficial way. IT care must be taken, or privacy and individual will never ever be protected.

This website can be designed as an assistive technology that could be used for many things by all citizens including disabled persons, as listed in **Table 2**. Using a web-based interface, it would become possible to personalize the smart city help for its citizens. It could be used to gather the demand information from all citizens in order to adjust the supply function of the smart city. Such information can be used or misused. Assuming that this information

Smart City Web Interface	Topic	Detail
Polls	What do citizens think about politics or city questions?	realtime, anonymous, weekly, monthly
Election	Online voting, mor interest in topics	anonymous, yearly (or more often)
Parties	Which party stands in for what? Who verifies?	unbiased political information (neutral)
Interests	What are the preferences of citizens?	what should the city invest in? (Stats)
News, Stats, Facts, Info	The latest city news and city information	official world, country, state, city news
Tax	Automated taxation (no need to file any longer)	no need to file your taxes any longer
Aids or Disabled	Assistive technologies (apps, information, ICT), aids	smart city services, aid, and information
Segmentation	Citizens of known segements can be better served	personalized/Customized Support and Help
Transparency	City, State & Country finance and performance	what did the city do about it?
Jobs, Occupational Topics	Sustainable career paths assured for all citizens	who wants a job should get one.
Health and Assistance	Hospitals, physician, experts, nearest help?	a network of health care system support
Police, Fire, Agencies	Crime, fire, evacuation, scam, any threats?	whatever it is - citizens need to get the help
Feedback	Citizens can give valuable feedback - but how?	feedback for the city is needed to optimize it!
Education	Schools, universities, institutes, publishing Platforms	all schools/universities should be fine and free
Recreation	What recreations would you prefer locally?	parks, sports, groceries, clubs, fitness
Singles or Families, Hobbies	Non-scam infos about events for singles or families?	kindergardens, quality family and dating sites
Music, Events & More	Which events or things would you like in your city?	music, events, talks, congresses
Data safety and anonymity	Who prevents that asymetric information is misused?	independent agencies must assure data safety
Housing, product/services	One site and shop for everything, comparable platforms?	If private market does not deliver then the city does

Table 2. Innovation of smart city interfaces with the citizens (secure web-based platform); assistive technologies can also be ICT and data based and might need public infrastructures like the GPS-system or independent agencies that deliver ICT hubs and assure data quality.

would not be used against the citizens but only for them, it could offer great potential to super-advanced smart city evolution by meeting the demands of integrated *metacitizens* faster.

Taking the case of assistance for disabled citizens again: the smart city web interface would allow collecting all information to integrate and coordinate all efforts to help and assist disabled citizens by interviewing them directly what they really need and by providing them the information and help in a customized fashion. In this customized ways, all metacitizens could be provided with what they need. For instance, everybody needs health care, needs to find a city job, needs to get to work somehow, has hobbies, family, or wants to have further aid and information. Everything could be done on one website with many subsites and hyperlinks. Whatever citizens might urgently need should be available to them to make them feel good at home. Feedback allows officials to research all potential issues. Especially disabled persons, unemployed, aged and poor persons could be helped this way with financial aids, assistive technologies, online education and market-relevant training.

Web interfaces generally offer great opportunities as assistive technologies for all citizens including disabled persons who regularly use a computer. There are many assistive technologies available today for disabled persons that could be one day linked to the internet to get more assistance and help like translations, instructions, or augmented reality and more and more interaction sites and regulations would become possible. All together they help to evolve smart cities with enablement for all people including disabled citizens.

Table 3 given an overview of major assistive technologies for disabled persons. The federal governments worldwide have often recognized the importance of assistive technologies and have founded new regulations for their implementation, especially in the last 10–20 years.

Assisitive Technologies	Modified from NIH/NICHD and other sites
mobility aids	wheelchairs, scooters, walkers, canes, crutches, prostetic devices, orthotic devices
hearing aids	all types of hearing aid technologies, assistive listening, captions, amplifiers
cognitive assistance	computer, electrical assistive divices, computer based instructions, assisted procedures
software and hardware	screen readers, screen enlargement applications, for mobility and sensory impairment
assistive computer interfaces	special keybords, special pronters, special screens for sensory impairment
education assistances	book holder, page turner, adapted pencil grips; education for special value adding jobs
closed captioning	enablement for people with hearing disabilities
accessibility, remove barriers	barriers can be removed to enable wheelchairs and mobility of disabled persons
high tech assitances	light weight high performance wheel chairs (for sport); electric aids,robotics, robot aids
adaptive switches	to perform simple tasks, precursors of robotic aids
diverse assitive aids	to perform regular works in housholds and at work (cooking, dressing, grooming, etc.)
visual aids	large prints, electronic read (book on tape), talking computer software, tactile assistance
positioning	healthy body position; sport; positioning in wheelchair, at home, school or at work
alternative communication	different forms of communication using the other senses

Table 3. Assistive technologies (slightly modified from NIH/NICHD [16]).

For example, the Individuals with Disabilities Education Act (IDEA, 1997, 2004) states that assistive technologies must be provided for any child if the device is approved to increase, maintain, or improve functional capabilities, assessed by a special service team. All of these assistive devices [15–17], as all health care, help the best if people in need are fully served.

Once again smart city development can learn a major lesson from all of these approaches to help people and children with functional disabilities and from customized appliances. Finding bridges of enablement is also a key for all other citizens in need of help or a job. The lessons tell us that we must provide full help if we can and we must do the same to people without a disability that might be impaired or nonenabled in other ways. Connect the citizens to the city system means that everyone needs fair bargain and a fair and livable chance in life. What if we announce a right or fairness and plain level field for all citizens, or a right to be also integrated into the networks that govern the job markets? No networking should be allowed that only benefits some networkers, everyone must be treated fair and equal, where are the fair chances in universities, schools, or as an applicant and on the job?

Whatever problem we might have with evil exclusive networking, lack of inclusiveness and integration, issues with accessibility to the city, to jobs, to information and data, basically whatever problem or issue it might be, we could agree that it must be reported somewhere. Someone should take care of this but nobody is usually responsible for anything today. However, a smart city could allocate responsibility and would research every new case in order to know how to solve it in all future—if citizens ask for x that solution y is provided.

The assistive technology web interface (**Table 2**) would allow such a reporting and would also integrate all assistive technologies in the narrow sense (**Table 3**) in advanced ICT forms.

All reported customer citizens, a disabled person or even patient problems would professionally research in order to learn which procedures work fine and which solutions are still elusive. A Smart City is a learning organization of a city and needs a learning ICT platform

[11] and infrastructure and responsiveness to all citizens. Screening and a final solution must be given, which can be short term for the citizen, or long-term for the city, as some things will take some time, cannot be done overnight, while previous solutions are instantaneous. Only feedback can help to solve the silent challenges that are million-fold dormant in our societies as nobody has really registered them. But it is of importance to reveal and resolve all silent issues—best early on.

The smart city is more than the sum of its citizens—and the citizens are more than just its parts. Together they form the metacity entity that wants to thrive and evolve some more, the metacity wants to interconnect like nerve cells in the brain and the division of labor makes it possible that everyone can try to give want he or she can do. But the city needs more plans and actions to enable all citizens without conflicts of interests. What if we could do what we can do best? This would benefit smart cities. Still, most of us are hindered to do exactly that.

Smart cities could strive for an enablement of skills by providing platforms [11] and hubs for all sorts of professions: artists, musicians, scientists, writers, engineers, entrepreneurs, innovators, sports, and disabled persons, and much more. This would attract many new talents into the city and can benefit the economy if done right. A smart city should bear a niche and real chance for everyone—a way to make it—and thereby attracts special people that will be beneficial for the city in the long-run, in direct or indirect new ways. Smart cities empower their metacitizens, strengthen the community, bridge all barriers that a citizen faces to have a good life, enable the disabled and enable the blocked citizens, they allow smart feedback to achieve smart city goals and solve social problems. Smart cities are unique places that want to be general great compatible places that also want to be very special too.

Smart cities will further evolve via wide sense and narrow sense assistive technologies, and communication via web interfaces, which could lead to totally new patterning outcomes in cities, if the city fathers, majors, and decision makers will become responsive to citizen input. Citizens will have to trust the new communication technologies and interfaces with the government and city, which will create the need for quality assurance of such ICT systems [11]. Agencies should assure its unbiasedness, neutrality, independence, and a real privacy protection for more fairness as information based decisions patterns all cities [11].

If these important smart city goals will be reached depends on many things, including the historic fatalities, which are still striking today—e.g., a real privacy protection is still elusive.

What else could delay smart city evolution? There is also a flaw in the capitalistic system for common goals and standards. Moreover, the markets have a built-in issue to equilibrate in a semishortage (see **Figure 5**). Subsequently, this shortage situation for less affluent citizens can get better but not always. Shortages for less affluent and poor citizens pose a major barrier to city evolution due to the reasons that there is also urgent and important demand. Economics has forgotten or downplayed the role of equilibrated markets for less affluent people, which is an inherent market failure for all of those how cannot afford what every they importantly need. The utility that would be provided would be very high, let us assume much more than the remaining cost to become affordable: an economics of human inclusion.

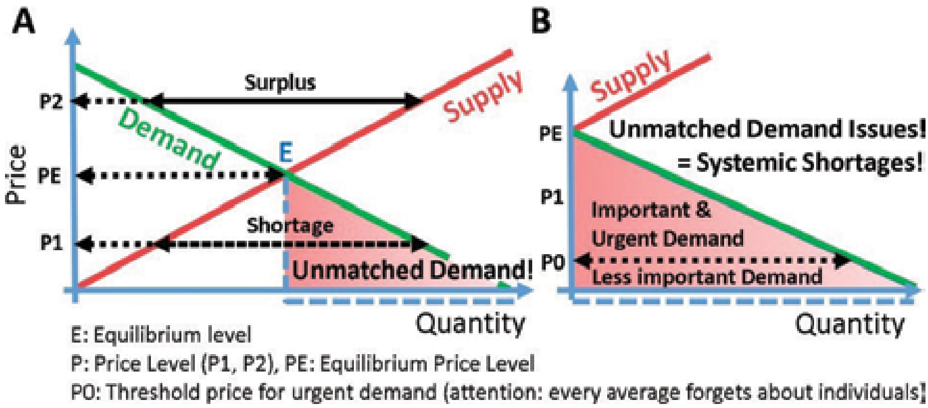

Figure 5. Economical flaws regularly cause shortages that hinder smart city development. Econometrical model, figure legend: (A) at equilibrium prices, demand matches supply only for a percentage of the overall demand. The remaining demand is not served at the given prices, which causes shortages for all demand that can only afford to pay sub-equilibrium prices (<PE). IN this example only the majority of all demand (e.g., 75%) is served but a significant proportion of demand is not met not met (e.g., 25%). But do you want 25% of your citizens to be without something they urgently need like water, electricity, health care, jobs, etc.? (B) No, 100% of all important and urgent demand must be served also below the equilibrium level. If demand follows the curve of few rich and many poor people than the unmatched demand will be the biggest part of it. Unmatched demand happened along the entire pyramid of needs in both the developing and developed world and spreads on the individual level even more. (B) illustrates the starting problem of supply before the prices would fall. Early supply is too expensive at low quantities which hampers economies of scale and scope. Catalysts are needed to bridge bottlenecks to vitalize the economy by matching key demand.

Catalysis	Catalysts of Smart City Development	Description of Role on Smart City Evolution
Which Catalysis	Communication & Patterning	Finding out what citizens and businesses really need, smart idea and solution finding
Which Catalysis	Bottleneck Identification	Identify major bottlenecks that hinder in cascades subsequent smart city development
How to Catalyze	Economies of Scale, Scope, Time	Can lower the price level -> better coverage of demand and important demand
How to Catalyze	Productivity, Synergies, Technology	Can lower the price level -> better coverage of demand and important demand
How to Catalyze	Smart Subsidiaries, Smart Taxation	Strategically eliminating bottlenecks that hinder wealth/growth
How to Catalyze	Investment in Smart City	Strategically providing attractiveness for citizens and businesses
How to Catalyze	Creation of Non-Business Platforms	Fair opportunity in research, music, art, writing, engineering, architecture, etc.
How to Catalyze	Health Care incl. Aid for Disabled	Health care infrastructure, hospitals, assistive technologies, affordable health care
How to Catalyze	Solution for Market Failures	Public enterprises, public financing of projects, public aid for citizen needs, technologies
How to Catalyze	Smart Entrepreneurship, Start-ups	Lower the market entry barriers for value-adding start-ups (business activation energy)
How to Catalyze	Smart Employment Opportunities	Create enough and diverse jobs for all; enable transferable and sustainable career paths
How to Catalyze	Assistive Technologies	Create awareness and scope; develop importance for disabeled and non disabled persons

Table 4. Catalysts for smart city development including assistive technologies.

Here, a smart city can provide financial help to eliminate shortages of important demand due to unaffordable prices. Whenever demand meets supply an equilibrium price (PE) is believed to be found in the prevailing microeconomic theory [17]. This price (PE), however, will always cause an initial shortage at some quantity. Especially if important or urgent demand is not affordable this can cause bottlenecks for the population; and assistive technologies are also one of the examples, but also food, housing, healthcare, medicine, ICT, infrastructure, and more. When it comes to urgent and very important demand this can cause major blockades for all citizens and halts smart city development; like the sewerage that was maybe too expensive early on, which has caused terrible situations over centuries and millennia and ill citizens. Hence, catalytic switching events are needed (see **Table 4**) to give the starting help the market might need, or the city must manage it, e.g., infrastructure.

One might argue that prices could fall in the future but this does not always happen and the people need urgent or important demand immediately, like water, electricity, jobs, or health. As a result, Smart City cluster management must take care of all of these bottlenecks of "important citizen demand" where supply does not meet demand as it should. Hence, it would be important for macroeconomics and microeconomics to think about the level of.

coverage when it comes to important demand and important supply. What is the percentage of people who will get what they urgently need at a market equilibrium? Often not 100%.

When it comes to important demands and urgent needs, one should strive for 100% of coverage and supply as one cannot wait until the prices will fall, maybe, one day? It can be life-saving, it can be an enablement, it can be food or water, infrastructure, medicine, jobs,

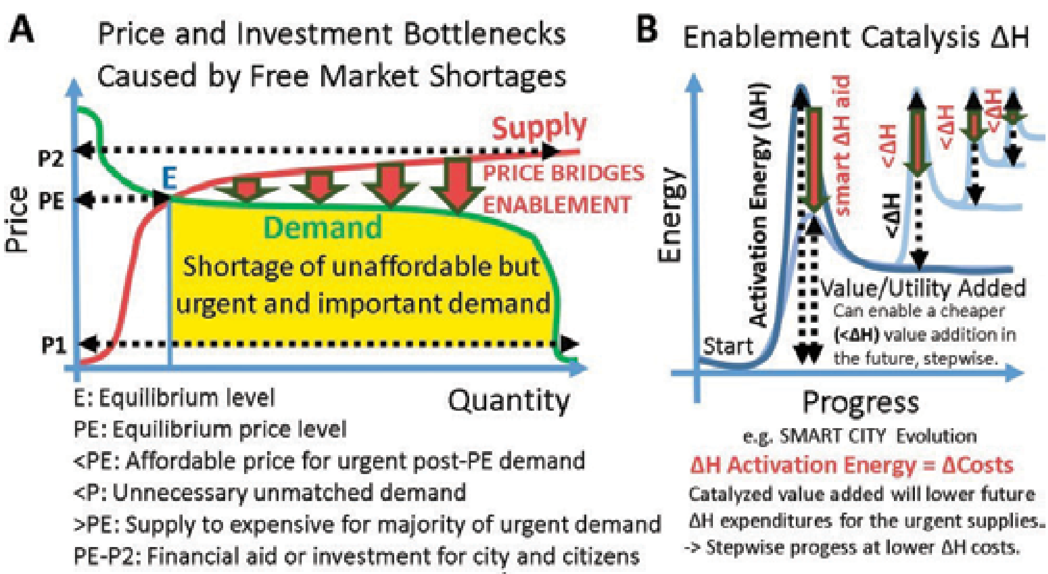

Figure 6. Shortages due to unaffordable supply for the important and urgent demand. (A) Urgent and important demand is a bottleneck for the city, economy, family, or for the individual. At equilibrium level, only a tiny fraction of this important and urgent demand is satisfied. In an economy with only a few rich and many poor people, as given, frequently most of the demand is not matched by supply even under ideal market conditions and even at equilibrium level (see yellow area). A price subsidization or public investment or tax-cut can make the supply available to all and how they are in urgent need of it. Important demand can be very many things, and many are already coved by public expenditures like infrastructure e.g., for smart cities, like financial aid for people with health problems or disabilities, universities, research, water, pollution and waste management, sustainability, social aids or jobs. (B) Progress via enablement is trying to find smart ways to catalyze value added to solve all major bottlenecks—starting with the most urgent ones—which results in new ladders of enablement of faster and cheaper progress (<ΔH′ < ΔH″ < ΔH^n). Such aid becomes required if the markets fail due to market failure an equilibrium, due to other market failures like poverty, monopolies, not enough jobs or too little income. Like in a chemical reaction, progress can be accelerated via smart synergistic catalytic aids that also build on each other.

assistant technologies, and it can be basically everything that the market would underserve. In a networked economy of today, in which consultancies mange all prices and HRs for firms, it becomes implausible that a price might fall soon or that most urgent demands will be met.

"Implementation delay" is one of the hallmarks of smart city and smart economies of today, with centuries of delay in major technologies like the sewerage system, fair insurance, public transportation, and jobs for all without cheating on unemployment numbers. Today's unemployed statistics tend to be systemically embellished, which hinders communication and pattern formation in the country, state, and city, because everybody tends to have the wrong numbers, and politics might use them as the population and media are responsive to the euphemized data. Patterning and communication require correct information. Smart city development needs good decision making and is advanced by smart catalysis (**Figure 6**). Shortages due to unaffordable prices can be bridged via strategic temporary subsidiaries or public corporations and institutes that deliver such services [11] and products at affordable prices (**Figure 6**). The costs of solving a fundamental bottleneck will be a good investment that saves future costs and might benefit the city and economy, and enables cheaper investments in the future, as subsequent bottlenecks are reduced and all build on each other. Patterning catalysts can be grouped into catalytic goals setting and implementation. A list of some common themes is given in **Table 4**. First of all, bottlenecks are solvable via ideal "catalytic investment cascades" to be identified for continuous improvement [1].

Communication and patterning are like planning and implementation (**Table 4**) and will lead to new assistive technologies for all people and specifically for disabled citizens. Some of the key questions that arise in the evolving citizen-city-country communication system are summarized in **Table 5**. Assistive IT network systems could take care of all of our needs.

Finally, assistive technologies and any city aids can be achieved in a centralized public or decentralized private manner and it is very important to find the right choice or balance. In **Table 6**, there is a brief summary given of decentralized and centralized urban patterning, of the more decentralized mobile assistive technologies, the more centralized local assistive technologies, and eventually, an outlook is given about some novelties in this exciting area. Assistive technologies are a very interesting and an outstanding high-tech field of many futuristic cutting-edge novelties that are fascinating not only to technology fans and experts. Assisting the disabled can

Assistive Technologies	Communication	Smart City Pattern
Mobility Aids	Help on demand for all	Higher compatibility with mobility aids, help on demand
Hearing Aids	Help on demand for all	City screens for all people to provide captions with information
Cognitive Assistance	Instructions for all	Streamflow efficient and effective procedures that make sense
Software and Hardware	Interfaces for everything	Enable feedback, interactive environments, safety, transparency
Job Opportunity Pattern	Identify all job potentials	Provide customized jobs for all citizens incl. disabled persons
Health Care System Pattern	Personalized medicine	Personalized health care, learning health care system with TQM
Architecture Pattern	Form follows function follows form	For all citizens including disabled aids (ramps, elevators, screens)
Report an Incident	tell the city what is missing	Smart cities have to learn from every case to stay smart
Solution finding	Which solution is conflict free?	Smart City and Smart Country strive for good solutions for all

Table 5. Communication and patterning for all citizens: technology assistance for disabled citizens can help all citizens, like screens, instructions, designed processes, aids, and more.

Decentralized Urban Patterning	Centralized Urban Patterning
Private households and businesses, potential trend setters	Public institution and public businesses, inclusive planology
Private architecture, private industry, potential city interactions	City planning, overall city architecture and blue print patterns
Principle of self-determination; potential interfaces with city	Principle of subsidiarization and hierarchical responsible planning
Private spaces: private patterns, potential interfaces with city	Inclusive common spaces for families, sigles, young, old; for all
Rich could contribute to city goals; potential joint ventures	Bigger industries and big businesses could cooperate with city goals
Smart housing options for all citizens; affordable living	Assure enough houses at affordable prices; affordable living
Emergency training, citizen engagement; smart city goals	Emergency services; civic inclusiveness, integration, responsiveness
Decentralized: Mobile Assistive Technologies	**Centralized: Local Assistive Technologies**
All assistive technologies to carry around	Accessible urban planning, architecture, digital assistances
Difficulty of urgent demand of unaffordable assistive technologies	Financial aids for local and mobil assistive technologies
Assistive Technology Novelties	**Assistive Technology Novelties**
Novelties: artificial intelligence, robotics, higher interactivity	Novelties: artificial intelligence, robotics, higher interactivity
Smart phone maps for everything e.g. accessible city routes	Online services that provide the information for free
Many optional activities for lonely people, singles, and families	Assured/approved safety, independence and quality of options
Interactive civic and citizen information, segment of one	Assured data safety, good use of information to provide services
Smart phone apps: navigation, information, help, connect	Apps for everything that a citizen might need in life that really help
Augmented reality; world translation in a preceivable way	Augmented reality hubs and software maintenance
Face, head, body, hand tracking/interpreting devices	Face, body, hand tracking communication system
Free rights and free awards for all citizens, uncoupling from money	Regulations for all citizens and assuring that they are all met

Table 6. The big topics of centralization and decentralization, a scientific not political theme.

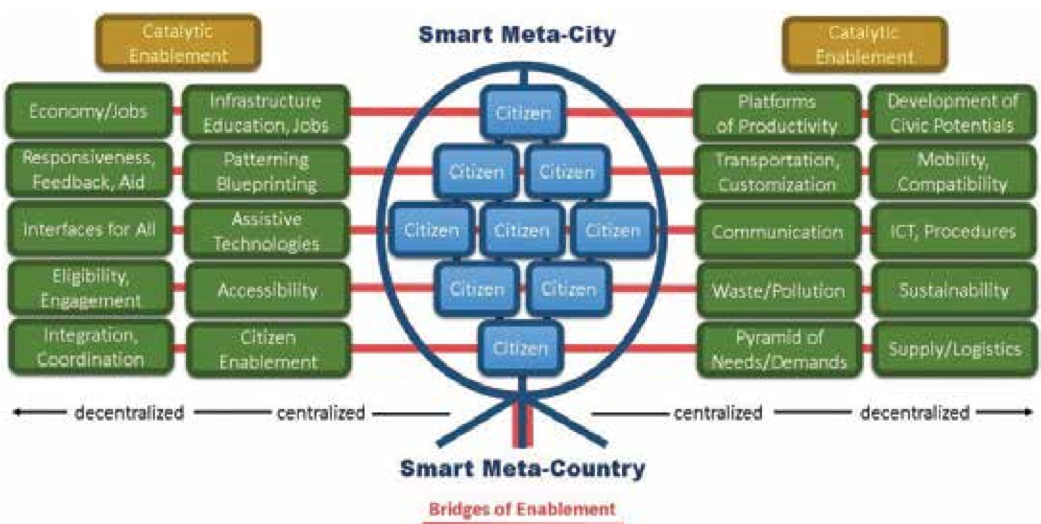

Figure 7. Summary of the smart metacity: catalytic enablement to solve all bottlenecks.

be like a seed that will grow into the enablement of all by extending our senses, our mobility, services, and assisting us in every function that we have in life - like an urban tree of enablement.

They are a key driver of technological progress in robotics, artificial intelligence, cognitive assistance, mobile appliances, augmented reality, virtual reality, human-machine interfaces, cyborg technology, communication technology, image-based interpreting algorithm, and so much more. Assistive technologies will lead in the future to advances in robotics, advances in artificial intelligence, and advances in their interactivity with all sorts of assistive technologies for disabled persons and assistive technologies for all remaining citizens too.

Robotic implants and automated prosthesis are thinkable like entire helping robots, machine-human interface technologies, and early cyborg technology that might be further advanced and could help disabled people to have a more normal and independent life. Smartphones will be performing medical and assistive functions, information, instructions, assistance, robotic control, will control additional devices and instruments or robotics, and more if necessary. Astronaut missions have led to additional inventions and assistive technologies will likewise do. **Figure 7** gives a general overview of smart city evolution: the role of breakthrough catalytic enablement, bridges of enablement, interactivity, interconnectivity, enablement of all citizens, assistive technology, smart metacities with metacitizens, and roles of centralization.

3. Conclusions

Smart city development builds bridges of enablement for all of its citizens, matches their overall and individual demands, and enables assistive technologies and key communication among the citizens, the city, and government that responsively resonates and patterns the future city. Learning smart cities increasingly makes use of assistive technologies in the widest sense and narrow sense to enable all of their citizens. Catalysts of smart city development are needed whenever the free market does not provide a satisfactory solution on time to catalyze various aids or to reach higher stages. Assistive technologies will drive innovation in the field of robotics, artificial intelligence, digitalization, transportation, and also cyborg technologies and advances in many other fields like smartphone technologies.

Maslow's pyramid of citizens needs will stay the main orientation for smart cities and all citizens including the needs disabled, aged, young, unemployed, troubled, or poor persons. New ICT and web technologies can assure a faster and more informed progress toward more functioning, comprehensive, assistive, healthy and nice city patterns, better reciprocal communication and more autonomy and independence of all, and the collective of citizens. If done right and if the new level of personal information is not misused against citizens, such assistive ICT technologies [7] could boost smart city evolution by better coordinating and integrating all of the efforts and by finding a smarter way in which supply fully matches demand and assuring everyone gets the assistive technology help needed. By improving our help for people with disability, cities and countries can also learn how to improve the lives of all citizens by finding the right bridges of enablement and assistive technologies for everyone everywhere and by assuring sustainable career paths and good city lives for all. An "ongoing" but not trivial future work and important case study is the advancement of what is called "e-governance" [12, 18] by the new IT and ICT fields of "e-inclusion" [19]. Assistive technologies are high-tech drivers for many new innovations that create jobs, and smart cities and assistive technologies can best grow in a socially

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sustainable environment with a good communication and understanding of all decisive circumstances—so we should incentivize more efforts on common grounds to unleash our smart potentials and dreams.

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To Use or Not to Use: The Design, Implementation and Acceptance of Technology in the Context of Health Care

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Abstract

Technology in general, and assistive technology in particular, is considered to be a promising opportunity to address the challenges of an aging population. Nevertheless, in health care, technology is not as widely used as could be expected. In this chapter, an overview is given of theories and models that help to understand this phenomenon. First, the design of (assistive) technologies will be addressed and the importance of human-centered design in the development of new assistive devices will be discussed. Also theories and models are addressed about technology acceptance in general. Specific attention will be given to technology acceptance in healthcare professionals, and the implementation of technology within healthcare organizations. The chapter will be based on the state of the art of scientific literature and will be illustrated with examples from our research in daily practice considering the different perspectives of involved stakeholders.

Keywords: technology use, technology acceptance, human-centered design, healthcare professionals

1. Introduction

In order to face the challenges of demographic changes [1], i.e., an aging population and the high prevalence of chronic diseases, smart digital solutions are promising. However, implementing technological innovations in the domain of health and well-being has been found to be difficult [2, 3]. Difficulties in the implementation at scale are related to barriers at three levels: a macro level, such as market readiness and national policies [3, 4], a meso level, in which industry and health service readiness are main themes [3]. The focus of this chapter is on technology adoption at the third level, that is, the micro level, which is the level of the actual user. Assistive technology has two main user groups, i.e., healthcare professionals and patients/clients. Therefore, we will discuss issues around technology adoption in general *and* with specific focus on healthcare professionals, as they are usually facilitators for the uptake of technology in care practices. In Section 2, we will first discuss challenges in the design and implementation of assistive technology, including the vision of human-centered design, followed by theories on technology acceptance *in general,* and the readiness of technology uptake of healthcare professionals. In Section 3, we will present some examples of recent practice based research to illustrate the presented theories and elaborate on the perspectives of different stakeholders and their mutual relationships in the use of technology in health care.

2. Challenges in the design and implementation of technology in health care

2.1. Human-centered design of assistive technology

In order to ensure an optimal match between the technological product or service and the person who will use it (or is otherwise affected by the technology), it is important that all stakeholders are involved in the whole process of design, development and implementation. Over the last decades involving users and other stakeholders already in the design of new products and services has become standard and is commonly denoted as human-centered design [5, 6], participatory design [7], or co-design [8, 9].

Central in any human-centered design approach are the following aspects: empathy, collaboration and experimentation [5, 6]. *Empathy* is our ability to see the world through the eyes of someone else, to see what they see, feel what they feel and experience things the way they do [10]. The ability to be empathic is vital in order to not project one's own preconceived ideas to the design of new products and services, but really incorporate the (sometimes latent) needs and wishes of the people designed for. Empathizing with the users, understanding them and bringing them along in the design process are essential basic principles of any human-centered design process.

Collaboration. The challenges in our current society (also for the design of new assistive technology) are so complex that they cannot be solved by a single designer. Instead, they require a design team consisting of specialists with different backgrounds, not only interaction designers or industrial designers, but also psychologists, engineers, business people, care professionals and the intended users.

Experimentation. When solving complex issues it is unlikely that the design team will come up with the optimal solution at the first guess. Therefore, experimentation is central in the human-centered design process. The process entails multiple cycles of ideation, refining and improving the design, allowing the design team to have multiple ideas, to try out various approaches, to be creative and to arrive at successful solutions more quickly. Very early in the design process a first prototype of the design is built and tested. Watching users interact with the prototype and asking them what they think and experience while using it, provides relevant feedback on the basis of which improvements can be made to the design. This learning-by-doing approach to design allows new ideas to be tried out without running too much risk. It ensures that the design optimally matches the wishes and needs of the users.

Human-centered design will lead to products and services that better match the needs and wishes of the users, and thus will be purchased easier and create more impact. Moreover, involving patients and care professionals as well as other stakeholders in the development process, also creates more support among them for the product or service. When they play a role in the development process, they will be more inclined to act as ambassadors and to stimulate others to use the product.

In the human-centered design process three main phases can be distinguished: the *inspiration phase*, the *ideation phase* and the *implementation phase* [6]. Each human-centered design process will go through each of these three phases at least once. However, the process is not always sequential, rather it may consist of several iterations of going back and forth through the different phases while rethinking and refining the design, based on feedback of the people designed for.

The *Inspiration phase* is about empathizing with the people designed for, getting to know them and trying to understand what they feel, think and experience. In this phase the design team will be talking to people and observing them in their own context.

In the *Ideation phase* creative solutions are generated for the design opportunity that has been identified in the inspiration phase. Still early on in the design process, one or two of the most promising ideas will be concretized into a prototype. The prototypes are tested and feedback is collected from users, which will be the basis for another iteration of refining the idea, prototyping and testing.

In the *Implementation phase* the end product or service is developed and put to use with real users. In this phase the product or service is also evaluated: does the product do what it is supposed to do, is it effective? In the implementation phase it becomes apparent whether the technology is accepted by the users or not.

2.2. General models explaining the use of technology

In this section *general* models that explain factors and circumstances influencing the use of technology, are presented. Although mostly developed within general workplace situations, they can also help to understand acceptance of assistive technologies in specific contexts, e.g., within healthcare situations.

With the exponential growth of the use of technology in several domains, specific models have been developed to explain technology use. The most important and well known models are the Technology Acceptance Model (TAM) [11] and the Unified Theory of Acceptance and Use of Technology (UTAUT) [12]. The core of the TAM is the perceived *usefulness* and *ease of use* of the to be used technology. In several domains, up to 40% of the variance of the intention to use technology in several domains, including health care, is explained by the TAM [13].

In UTAUT [12, 14], the TAM was further refined into a model that could explain up to 70% of the variance of the acceptance and use of technology. The UTAUT not only includes ease of use (redefined as 'effort expectancy') and usefulness (redefined as 'performance expectancy') as explanatory factors, but also social influence. These three factors influence behavioral intention and thus, indirectly, use behavior. Apart from that, facilitating conditions are defined, which directly influence use. Finally, a set of five moderating factors are distinguished, being gender, age, experience (with technology) and voluntariness of the use of the technology (**Figure 1**) [12].

Of these factors, *performance expectancy*, is the strongest predictor. Performance expectancy refers to the degree in which a person expects technology to be helpful for doing a job. *Effort expectancy* indicates how easy a person thinks that the technology is in its use. *Social influence* refers to the degree in which an individual thinks important others think he or she should use the technology [12]. *Facilitating conditions* are supportive infrastructures (both organizational and technical) that facilitate the use of the technology.

2.3. Technology acceptance and implementation in healthcare organizations

In the adoption of assistive technology, the views of many stakeholders influence the ultimate successful implementation of technology and the delivery of technology at scale. In this section, we will describe the perspective of healthcare professionals (Section 2.3.1) and we will describe the Normalization Process Theory as the theoretical framework to explain how individual professionals within healthcare organizations understand and integrate new technologies into their own daily practice (Section 2.3.2) [15, 16].

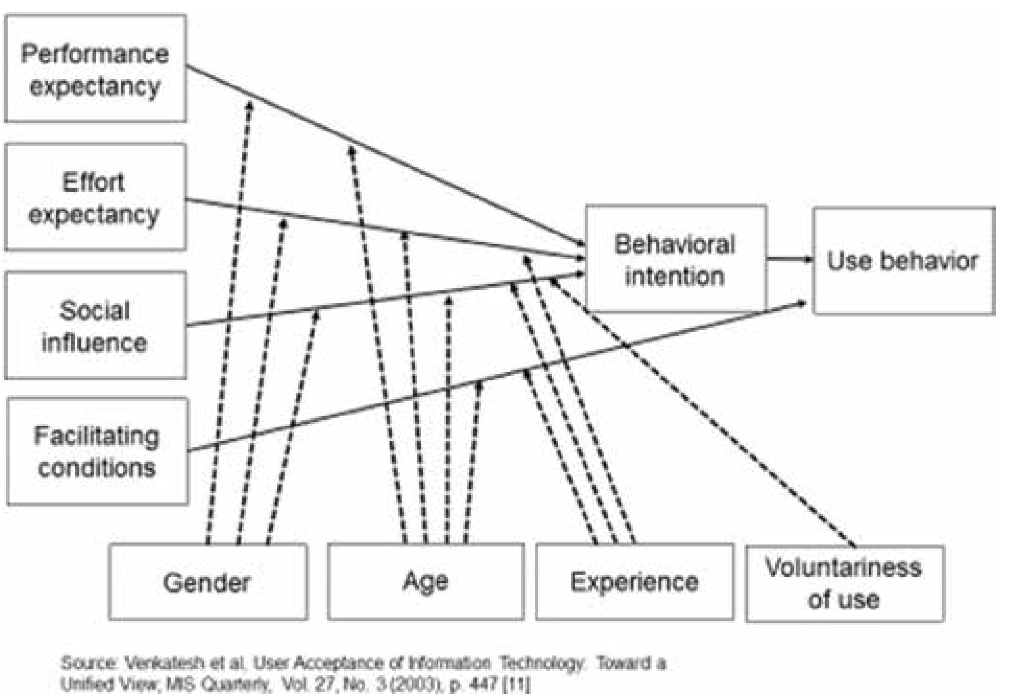

Figure 1. The Unified Theory of Acceptance and Use of Technology (UTAUT) [12].

2.3.1. Acceptance by individual healthcare professionals

Many healthcare professionals working in healthcare practice nowadays, do not consider technology routinely as an important solution for health problems [17]. Several factors can explain this often problematic adoption of technology [18]. One main factor is the fear that technology interferes with the relationship with the patient [18]. Care professionals worry about, e.g., the quality of the contact with patients through eHealth. Professionals who are familiar with this form of caregiving, are far more positive, although they approve contact with a 'well-known' professional in a blended construction over purely digital relationships, e.g., exclusively via a call center [19].

Another important barrier for the uptake of technology in healthcare practice is the change in work processes that it requires. In practice, new technologies are often introduced as pilot projects [18]. These projects are in most cases temporary, and therefore they are not integrated into daily routine. As a consequence, professionals perceive these new technologies as something extra on top of their work, thus mainly increasing their work load. EHealth technology is also considered to cause additional responsibilities rather than provide an opportunity to do the care work in a more efficient manner. For instance, the introduction of telemonitoring in the care practice for patients with chronic heart failure poses the question of responsibility between patients and professionals: who is responsible for which data and how and when should one react [20]?

The reconsideration of patient-professional relationships is another barrier, closely related to the issues concerning changed work processes and responsibility. The use of self-monitoring technology leads to a shift towards patients' self-management, which leaves professionals worried about patient safety. Especially with vulnerable patients, professionals are hesitant to rely on technology and prefer face-to face contact [21].

Finally, technical issues interfere with the uptake of technology by healthcare professionals, such as interoperability, installation issues, and user friendliness [22].

There are also factors that facilitate the implementation of technology by healthcare professionals. Facilitators of technology uptake are the so called 'clinical champions', enthusiastic ambassadors and leaders of innovations within an organizations [18, 23]. Apart from leadership, also training and support of professionals are important, in order to develop confidence in the technology and the accompanying changes in work process and role [22, 24]. Finally, involving relevant stakeholders in the *design* of technology, especially patients or citizens and healthcare professionals, improves the adoption of technology and facilitates the process of implementation and transformation into self-management by patients [18, 22]. In Section 3, 'human-centered design', we will elaborate on this topic.

2.3.2. Implementation of technology within healthcare organizations: normalization process theory

As described in Section 2.3.1, there are many factors influencing the intention to use and the actual use of assistive technologies by care professionals. In this section, we will describe the dynamics of technology use in health care explained by a sociological theory, the Normalization

Process Theory (NPT) [25], in which these, partly interdependent factors, can be summarized into a framework.

NPT describes what actually happens in practice, not the behavioral intention for using a (technological) innovation. The NPT comprises four constructs, being: *Coherence, Cognitive participation, Collective action* and *Reflexive monitoring* [15, 26].

Coherence is the extent to which professionals working together with the technology attribute the same meaning or importance to the system; do they have the same values or ideas about the (new) system and are they aware of changes in their individual work processes?

Cognitive participation refers to the work that is done to enhance the engagement and involvement of all relevant stakeholders and their motivation to stay involved. This means that great effort has to be taken, especially at the start of a program, to invest in good leadership and ambassadors, and the continuous involvement of everybody.

Collective action means what is actually done in practice while working with the technology, to facilitate the use of it. Several factors play a role here, e.g., financial support or time investment and sufficient management support. Also a workable system, a good help-desk and other technical support, as well as training, is crucial. And, most importantly, transparency on responsibilities of all involved professionals.

Reflexive monitoring is the final construct of the NPT, which in practice is often forgotten or neglected. It refers to the evaluation after implementation of the technology: has it brought what was expected for all stakeholders, what are elements that need improvement, are all stakeholders still involved?

3. Examples of practice-based research

3.1. Introduction

In this section, we will show examples from recent research at Fontys University of Applied Sciences, nursing faculty that illustrate the theory presented in Sections 2 and 3 and add practice based knowledge to these theories from a multi-perspective view. As has been illuminated in Section 2, the uptake and use of technology in health care, can be explained by several general models such as MAO, TAM, UTAUT and the Normalization Process Theory. It was pointed out that the strongest predictor for the use of the technology is the degree in which the user expects technology to be helpful for doing a job (performance expectancy). Users of technology in the context of health care are mainly healthcare professionals, care recipients but also significant others such as managers and next of kin.

Since in the adoption of technology in daily practice the views of the users of technology are critical, we aimed to expand the knowledge on users' views on the impact of technology. Apart from considering factors such as usefulness and ease of use, and changes in professional roles and care processes, we also explicitly wanted to include the patient-healthcare professional relationship and also refer to important others who are close to patients. It is important to acknowledge that technology can change relationships between healthcare professionals and care recipients and their loved ones [17, 27]. These changes can create opportunities for new and meaningful connections between them, but they also pose moral questions that may interfere with successful implementation of technology in practice.

Research questions formulated were:

1. How does the introduction of new technology change relationships between healthcare professionals, service users and significant others?
2. What values and beliefs do healthcare professionals, service users and significant others have, related to technology?
3. What kind of dilemmas arise when using technology, for instance when technology interferes with certain values?

3.2. Methods

Nine studies focusing on the implementation phase were carried out, aiming to expand our knowledge on the impact of technology in care and wellbeing and how it contributes to the relationships between different stakeholders. We collected evidence, in and from practice, related to the personal perspectives of healthcare professionals and primary service users (patients, citizens, clients) as well as significant others (managers, next of kin), with regard to the use of assistive technology. Three different applications of eHealth were involved: telecare, telemonitoring and the use of surveillance technology.

A qualitative design, using interviews, as well as focus groups, was used. This enables revealing subtle changes in relationships and is helpful in exploring beliefs and values of healthcare professionals and service users. In each study data from interviews and focus groups were audio recorded and transcribed verbatim, with the interviewer keeping additional field notes. Member check was carried out by means of summaries to assess the researchers' understanding and interpretation of the input of the participants. Data were analyzed using thematic analysis by Braun and Clark [28]. In order to generate initial codes, in each project two researchers coded the transcripts independently. One of the researchers had not collected data and acted as peer reviewer to warrant trustworthiness. Once all data had been initially coded, the different codes were sorted into potential themes. After construction of concept themes, the themes were refined based on the criteria that all data within themes should cohere, while there should be clear and identifiable distinctions between themes [28]. In the last phase themes were defined by describing the meaning, the scope and content in a couple of sentences.

3.3. Telecare

Five qualitative studies focused on the beliefs and values about, and experiences with telecare for, mostly elderly, people who live independently at home.

Telecare in these studies involved real-time contact between a home-dwelling service user and a healthcare professional using a display screen with an audio-visual connection (see **Figure 2**). The service offered practical support, such as medication intake, or cues for day structure, exercises, reminders for toileting or food intake, as well as emotional support with respect to symptoms of depression. Data in these studies about telecare come from interviews with 36 healthcare professionals, 31 service users and nine managers. The level of experience of the respondents with telecare varied (**Table 1**).

Figure 2. Impression of telecare.

Topics	Experience with telecare within the organization	Method	Population
Experiences with and beliefs about telecare	Over 10 years of experience	Semi-structured interviews with healthcare professionals and service users	Seven healthcare professionals and eight service users
Hopes, fears and expectations about telecare	No experience with telecare	Two focus groups with healthcare professionals and semi-structured interviews with service users	Fourteen healthcare professionals and five service users
Experiences with and beliefs about telecare	Experience varies between organizations (from no experience till over 10 years of experience)	Semi-structured interviews with managers	Nine managers
Experiences with and beliefs about telecare	4 Years of experience with telecare	Semi structured interviews with healthcare professionals and service users	Six healthcare professionals and eight service users. Of these respondents four healthcare professionals and four service users had experience with telecare
Experiences with and beliefs about telecare	2 Years of experience with telecare	Semi structured interviews with healthcare professionals and service users	Nine healthcare professionals and 10 service users. Of these respondents four healthcare professionals and eight service users had experience with telecare

Table 1. Qualitative studies on telecare (between 2015 and 2017).

First of all the results revealed that the introduction of telecare does change relationships between healthcare professionals, service users and significant others. Results showed that telecare influences relational connectedness between healthcare professionals and service users, but also the distribution of control within that relationship. The results showed the potential of telecare to strengthen relational connectedness or at least respondents claimed that personal contact between healthcare professionals and service users and significant others did not necessarily suffer from telecare. According to service users it could even help them in engaging more with significant others, who live at a distance. This connectedness is illustrated by a respondent who claims that '*FaceTime is easily accessible and feels less distant compared to making a telephone call*'. Also interviews with healthcare professionals illustrated that the interaction using telecare was experienced as real with the argument that '*it forces to make eye contact*'. Also healthcare professionals mentioned that telecare offered the opportunities for '*reassuring service users at a distance*' or '*having short conversations*' which were seen as helpful in preventing loneliness. It was however remarkable that beliefs differed depending on whether telecare was already used in practice or not. Healthcare professionals who had not used telecare were much more skeptical about the possibilities to realize values such as compassion, compared to practitioners who already used it.

With regard to values and beliefs, related to telecare, it was reported by most service users who used telecare that they felt more safe thanks to telecare, e.g., it offered an alternative for '*having to open the door late at night*'. Moreover, service users claimed that it made them feel safe that there always was someone for them to call when they needed it. Other values that were identified when using telecare were autonomy, freedom and dignity. Some service users and healthcare professionals claimed that '*people may experience a higher degree of freedom since it allows them to call for support whenever it fits their needs and agenda*'. It was argued that because telecare provides flexibility one can take into account the preferences, needs and values of each individual and those who care for them.

Notwithstanding the perceived opportunities for strengthening relational connectedness and enhancing safety, some difficulties and dilemmas were noted in practice. For example, respondents noted that although, telecare offered possibilities to service users to exercise some control of their own agenda, fixed schedules set by the healthcare professionals was still common practice. Another dilemma that appeared concerned an issue about who is responsible for the safety of a client. It was remarkable that especially healthcare professionals voiced the need to use telecare for supervision of their clients. As one professional stated: '*taking care of a patient is one of our core values, with this technology we are able to regularly check up on a person*'. Although healthcare professionals appreciated that telecare allowed them to regularly check up on a person, for example to make sure that medication was administered in the right way, some service users expressed that they did not like 'unsolicited supervision' if it was not agreed upon with them. So this raised the dilemma whether using telecare for the sake of reassurance of the safety of service users, is really in line with values of autonomy.

3.4. Telemonitoring

One qualitative study focused on the service users' and healthcare professionals' experiences with telemonitoring in care practices. In this study telemonitoring was used for monitoring the clinical status of people suffering from heart failure.

The telemonitoring with regard to heart failure concerned pilots of two different hospitals which took place in 2012 (H1) and 2015 (H2) respectively (see **Figure 3**). In both pilots the telemonitoring enabled the service users daily self-assessment of blood pressure, weight, pulse rate and oxygen saturation. Data were sent to a central server, via a tablet or PC. Patient data were compared by dedicated software to parameters set by healthcare professionals. If data passed a threshold, the system activated an alert, which was shared online with the service user and the healthcare professionals. For example when blood pressure data was outside the parameters, the system would generate an alert and the service user was asked to answer some additional questions. The alerts and additional information from questions, was also sent to the healthcare professionals, allowing them to identify potential risks and to take action. The idea was that on the longer run, trends found in the data set can provide more detailed insights in the development of the disease and allows to advice on future disease management and intervene in a more pro-active manner. In pilot H2 telemonitoring offered additional functionalities such as video interaction, a chat modus and an educational content to support patients' self-management.

In this study, in-depth interviews were held with six service users (age 64–77) using telemonitoring for heart failure. Two service users had participated in pilot H1 for 1,5 years and four service users had participated in H2 for 3 months. Moreover three healthcare professionals (two nurse practitioners and one nurse specialist) of H1 and H2 were interviewed.

The results showed that the introduction of telemonitoring, comparable to what was found for telecare, seemed to change relationships between healthcare professionals, service users and significant others. According to the results from the studies it created opportunities for improving engagement, not only between healthcare professionals and service users but also between the latter and their next of kin. Also, the contact between healthcare professionals and service user in telemonitoring via a display screen, was experienced as 'real' contact. As a

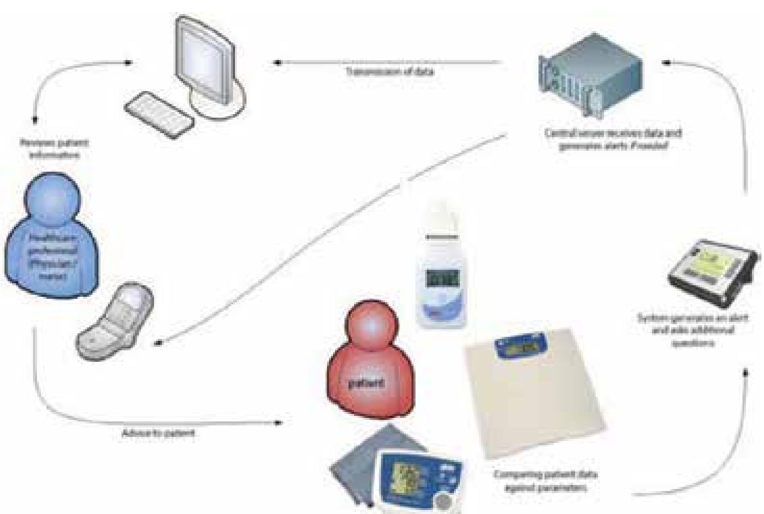

Figure 3. Telemonitoring the clinical status of people with heart failure in H1.

healthcare professional remarked '*Actually you make more eye contact when using a display screen then when someone is actually in your office*'. According to one of the service users, the feedback of the telemonitoring system, such as *'charts of data'* added to the understanding of the next of kin who claimed that it had helped her *'to learn more about my husband's disease'* (next of kin). It was explained that *'diagrams or graphs make it more visual what is going on'* and thereby can act as an enabler in the communication between service users and next of kin.

With regard to values and beliefs, telemonitoring was associated with enhanced feelings of safety among service users. All the service users who were interviewed appreciated the reassurance of feeling constantly '*watched over by care professionals*' and mentioned feelings of security and safety '*knowing that I am constantly being monitored*' (service user). Finally, healthcare professionals claimed that telemonitoring enabled service users '*to be in the lead*'. As one healthcare professional stated '*it stimulates consciousness, such as 'I gained some weight, what is the reason?*'. This was supported by quotes of service users, *'These daily charts show me when I need to take action, such as this physical effort was too high or that food was too salty'.*

Despite these benefits, telemonitoring also showed some *dilemmas*. With respect to the relational connectedness, interacting using a display screen in telemonitoring had its limitations according to healthcare professionals. For example they did not perceive this device appropriate for discussing difficult or emotional topics such as '*financial problems, aspects around sexuality or about bringing treatment to an end'.* More important, professionals claimed that although telemonitoring could enable self-management, in practice this did not always happen. As a professional stated '*its success in the end depends a great deal on people who are willing to take responsibility for their own part instead of passing it on to their caretaker*'. In many cases service users adopted some practical tasks such as measuring, but remained dependent on the expertise of the healthcare professionals to interpret the data and actually manage their disease. In other words: the ownership of the self-management agenda was led and controlled by the healthcare professionals and not by the service users themselves. This surfaced the dilemma on sharing responsibilities.

3.5. Surveillance technology

Three qualitative studies focused on the experiences of healthcare professionals and service users and their families in care practices when using surveillance technology for people living with dementia. This research took place in two different nursing homes and in residential care and also involved residents living independently at home. Types of surveillance technology included: tag and tracking systems such as GPS and the use of motion sensors (fall detection).

The use of a GPS system was initiated recently in a nursing home as a pilot to enhance service users' independence and freedom of choice (see **Figure 4**). As a pilot the GPS system was offered to service users who lived in a nursing home, who had mild dementia but also experienced agitation in the enclosed space of the nursing home and who were expected to benefit from exploring new spaces outside the nursing home. The use of motion sensors had been implemented in a nursing home for some years to enable remote monitoring of fall incidents. Recently, in a pilot, a sensor had also been used for some service users with mild cognitive impairment living independently.

Figure 4. An example of a GPS device (photo: Angela Aprea).

In these studies six in-depth interviews were held with residents living at home together with eight family members. Apart from that 12 focus groups with three to six participants were conducted with healthcare professionals in long term residential homes and in residential care.

With respect to relationships between healthcare professionals, service users and significant others, there was insufficient information in the data to identify any changes which were consistent throughout the data. However, concerning values and beliefs, the results showed that healthcare professionals, service users and there next of kin certainly valued surveillance technology for offering opportunities to enhance autonomy and independence of a person. For example the use of GPS was considered as very helpful to enhance freedom for those who experience agitation in a closed environment. As a nurse practitioner quoted 'O*ne person usually felt very restless and behaved aggressively towards healthcare professionals and other residents. Since the introduction of the GPS he makes long walks and drinks his coffee at the station. When he returns he seems contented and is physically tired'*. Similar to the use of GPS, using motion sensors (for fall detection), was valued by healthcare professionals for offering autonomy, in the sense that a person could live independently '*being watched over*'.

Despite the perceived opportunities of surveillance technology the interviews also revealed some dilemma's which interfered with certain values. For example, with respect to the use of GPS, a recurrent dilemma surfaced around conflicting interests between the value of autonomy on the one hand and the value of safety on the other hand. Although healthcare professionals indicated the use of GPS could enhanced personal freedom, autonomy and dignity for the service users, our study also showed that healthcare professionals felt reluctant to actually facilitate the use of the GPS device. For example an advanced practice nurse confessed that she *'had witnessed a care professional blocking a door with a laundry basket to prevent a resident from going outside'*. The nurse had argued that she valued autonomy of the resident but she also felt responsible for his safety. The interviews also showed that the next of kin '*often like the idea of more freedom for their loved ones'* but at the same time they express their unwillingness to give consent for the use of the GPS system because of the perceived risks, e.g.: *'If she loses her day structure, we can start all over again. It is okay as it is right now, more freedom will make her head spinning'* (next of kin). As this quote illustrates there may not only be conflicting values between different stakeholders, but also tensions in practice between espoused and enacted values.

Another dilemma identified in the use of GPS related to roles, tasks and specifically the responsibilities of healthcare professionals and service users when using this technologies. Quotes such as '*What if he runs away*? *It would be my fault*' (next of kin) or '*If I give consent and something happens, who is to blame then*?' (next of kin) or '*I think there is too little attention to discuss the risks between care professionals and next of kin* (nurse)', illustrate that responsibility is an issue that needs attention.

Another dilemma that was identified in using surveillance technology was about practicality. This was often an issue and showed the need for tailor-made solutions of health technology. It was found that although motion sensors were valued by healthcare professionals for guarding the patients' safety, in some cases, it seemed to compromise the service users' personal freedom or dignity. Especially when the health of service users deteriorated, it was found that the technology failed to offer practical solutions for the issues for which they were used. For example a resident became restless, every time she approached the door, because '*of an alarm that went off*' (nurse). Another example is about an elderly person, who had deteriorated lately, '*who confused the fall detection sensor with a cuddly toy and took it to bed*'.

3.6. Discussion

To conclude on the first research question as to how relationships change between healthcare professionals, service users and significant others by introducing technology, on the positive side, the results indicated an enhanced engagement when assistive technologies, such as telecare or telemonitoring are being used. Notably, professionals and service users who had experienced using these systems associated it with relational connectedness. This corresponds with literature about the positive relation between professionals' views on technology and their experience with this form of caregiving [19]. Nevertheless, although this result is hopeful, the fear that technology interferes with the relationship with the patient, has also been reported [29, 30]. According to Pols [31] relational connectedness by telecare only applies if there is already 'confidential', personal contact. One of her findings was that a strange and unknown person encountered through a webcam, became even stranger, maybe even scary or intrusive, whereas when as the webcam communication and support was added to an already good relationship this friend or trusted carer would become even closer, intensifying the relationship. She concluded that telecare magnifies the characteristics of the already existing relationship between users by imposing a relational distance that fits best with intimate contacts. 'Knowing the care recipient' is considered essential for signaling and decision making in the care relationship and missing non-verbal signals and the impossibility for 'physical touch' in telecare can make this contact more superficial.

Concerning the second and third question, as to what are the implications of technology on values, the findings showed the potential strength to respect the values and beliefs of individuals and to enhance autonomy and self-management of service users. However it also showed several dilemmas arising from conflicting interests. As has been reported in earlier studies [17], these conflicting interests act as a barrier to use technology in practice. After all, according to the Normalization Process Theory (NPT), coherence in values is one of the conditional factors for actual use. First of all the results showed dilemmas around responsibility. The findings showed that what is expected of technology, is not always realized. For example the research on telemonitoring showed that not every person is able or willing to take responsibility for their own healthcare. Secondly, there are dilemmas related to autonomy, privacy and dignity, and safety and control. For example potential conflict was attributed to telecare: (service user) autonomy and (healthcare professional) control. Moreover, with regard to surveillance technology, competing values around safety versus autonomy were described. On the one hand use of surveillance technology with movement sensors (such as GPS) or video surveillance was seen as enhancing personal freedom and autonomy of persons living with dementia. On the other hand it confronted care professionals with issues around guarding the patients safety. Also, some technology was found to have a negative impact on the individuals' privacy and dignity or to hamper personal freedom. These examples show that whilst technology claims to increase the autonomy of service users, it may also compromise their feelings of dignity. Moreover, it challenges healthcare professionals, service users and their significant others to re-consider the weight given to valuing service users' physical safety above other (psychological, social and spiritual) values such as autonomy and freedom of movement [32, 33]. In other words it is important to acknowledge that technological innovations can cause the phenomenon of competing values within healthcare, not only between different stakeholders' groups, but also *within* groups and individuals. These results correspond with literature on surveillance technology for persons living with dementia in which intra-personal/professional conflicts were identified [33–36]. This highlights the need and the difficulty of realizing engagement and involvement of all relevant stakeholders in the implementation of technology in daily practice, which refers to the construct of cognitive participation in the NPT, and elaborates on this construct by including other stakeholders apart from healthcare professionals.

Finally the results showed dilemmas around practicality: improper use of surveillance technology and the need for tailor made solutions disclosed a paradox. In the pursuit of greater safety, this safety was rather impeded by the use of new technologies than improved. One could argue that the examples around practicality illustrate the importance of acknowledging human-centered design of assistive technology. It underlines the necessity to pay attention to the *inspiration phase,* to understand what service users feel, think and experience, the i*deation phase* in which prototypes are tested and refined after feedback is collected from users, and the i*mplementation phase* in which the final product or service is evaluated, to test the impact of the technology when it is used in care practices. Finally the examples showed that the condition of collective action of the NPT to actually facilitate the use of technology in practice, was not realized. This draws special attention to one of the facilitating conditions of the UTAUT model: the realization of supportive infrastructures (both organizational and technical).

The described dilemmas arising when using technology in healthcare, confront us with the need to explicate choices: what do we value most, and in what situation? When using technology, roles, tasks and responsibilities of healthcare professionals and service users should be made explicit and agreed upon between all stakeholders involved. Also there is a need to regularly/continuously evaluate changes to the care relationship and the perspectives of different stakeholders (cf. reflexive monitoring) during its introduction and thereafter [37].

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4. Conclusion

The integration of assistive technology into healthcare practice is not only dependent on the intention to use a (technological) innovation but also relates to role and process changes. In health care, professional roles are based on values inspired by personal relations between healthcare professionals and patients or service users. Therefore, for technology to be applied in a successful manner the perspectives of different stakeholders during and after the introduction of technology should be identified and evaluated.

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Conflict of interest

We declare no conflicts of interest with respect to the research, authorship, and/or publication of this paper.

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Cities are the places where the greatest technological advances will take place in the near future, and important efforts are being directed towards autonomy and independence for each and every citizen. However, these efforts are rarely coordinated or integrated among governments, citizens, and private firms. In this book, assistive technology solutions are approached considering the smart cities scenario. The book discusses how assistive technologies can be adapted to this new reality. In fact, several challenges arise, stimulating the evolution of current technologies, relying on ubiquitous sensing, big data, and anytime/anywhere access and control. The book presents research under development, not necessarily with consolidated results. Even though the idea of smart cities is still not a recognized concept in most countries, its relevance and application are spreading rapidly.

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