Università degli Studi di Cagliari

DOTTORATO DI RICERCA

Ingegneria Elettronica ed Informatica

Ciclo XXVIII

TITOLO TESI

Conception, design and evaluation of an ICT platform for independent living and remote health monitoring

Settore scientifico disciplinare di afferenza

ING-INF/01 - Elettronica

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Esame finale anno accademico 2014 – 2015

Ph.D. in Electronic and Computer Engineering
Dept. of Electrical and Electronic Engineering
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Dedicated to my family.

Abstract

The current society is dealing with a progressive ageing of the population. Life expectancy is constantly increasing and, at the same time, families tend to have less children than in the past. For these reasons, the global proportion of people aged 60 or over is expected to outnumber the younger age groups. This trend will have a serious impact on the society, since the health related costs will rise, there will be a lack of professional caregivers trained to assist the elderly and more and more people will suffer from chronic diseases that must be treated somehow. To overcome this situation, in the past years many initiatives aiming at increasing the elderly independence were born. The problem in developing technological systems for the elderly is that they are reluctant to try out new systems and devices, so a great emphasis must be put on the design of an acceptable and usable solution. In this thesis, an ICT platform for independent living of older adults is presented. The platform is based on a standard TV and remote control, in order to lower the risk of technology refusal by older people, and aims at offering a rich set of services that include social networking, support, welfare and health. The health aspect is important but not the leading one, since such platform should be first perceived as useful for different aspects of their daily life, and not strictly related to the concept the being old means having health problems. Another aim of the proposed platform is to expand the offered services by involving external service providers, that will exploit the basic functionalities offered natively by the platform. The aspects related to the initial studies that let to the definition of system requirements and technical specifications will be presented, together with some preliminary usability results obtained from several user tests. Starting from mid 2016, the proposed platform will be tested during three field trials in Italy, Belgium and the Netherlands.

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Introduction

The modern society is dealing with a progressive increase of the elderly population. Projections show that, by 2050, the people aged 60 or over will be more than two billions, reaching 21.1% of the total world population. This disproportion between young and old people will also result in many challenges for the society and the health care system: the increase in age-related diseases, like Alzheimer's or Parkinson's and consequently a rise in the number of people unable to live independently, the increase in health-related costs, the shortage of professional caregivers trained to assist the elderly, and a lack of facilities in which the elderly could be transferred in. Since older adults prefer to stay in their homes and, anyway, the costs related to care facilities is often not sustainable for them, the development of services for social inclusion and independent living is of paramount importance to enable the elderly to live in their homes autonomously as long as possible. Recently, there has been a trend in developing ICT solutions in the field of Ambient Assisted Living to give older adults instrument for their autonomous living. Such solutions paves the way to a sustainable social and economic model where older adults develop self-confidence and promote their participation in the community life. These systems often include telemonitoring features aimed at supporting vital signs monitoring from remote. Telemonitoring is nowadays one of the most sought-after approach for patient management, especially for those suffering from chronic conditions. It involves different actors and exploits various technologies for monitoring patients at distance. The main difficulty in developing ICT platform for the elderly is that they suffer from digital divide: they are not used to technologies, as young people are, and often reluctant to learn to try new devices. It is essential to consider usability and acceptability aspects when developing ICT systems targeted to the elderly.

This Ph.D. thesis presents the studies conducted to design an ICT platform for independent living of older adults, focusing mainly on its social aspects and telemonitoring features. After a careful analysis of the platform present on the market and various usability tests with real users, an open platform based on the TV and on the Android operating system has been chosen. The proposed solution combines the potentialities of broadband internet services to the simplicity of TV use. User researches in three European countries allowed to define several important services (healthcare, home monitoring, shopping, communication and social inclusion) to be provided. Another important aspect of the research was the definition of a unique infrastructure in which external service providers could add their services, exploiting some basic functionalities and, in this way, enriching the set of available utilities for the elderly. One peculiarity of the platform is that it includes only services with a well-defined layout and navigation scheme, in order to help the users avoid confusion passing from one screen to another. These design aspects have been translated into guidelines for developing consistent services. The research activities presented in this thesis have been conducted in the framework of an European project.

Thesis overview

This thesis is structured as follows:

- *Chapter 1* describes the context in which this thesis work was born and the current research activities carried out around Europe,
- *Chapter 2* briefly introduces the European project that made this research activity possible,
- *Chapter 3* presents all the research activities conducted during the first year of Ph.D., that led to the definition of system requirements and specifications,
- *Chapter 4* describes the technical implementation of the ICT platform, highlighting the services connected to active ageing and independent living and illustrates the links present between requirements found during system specifications and guidelines followed for the implementation (and to be followed when developing consistent services to be integrated into the platform),
- *Chapter 5* focuses on the remote health monitoring aspects integrated in the system,
- *Chapter 6* presents some preliminary usability results and the implementation plan developed in preparation for the field trials.

Chapter 1

State of the art

1.1 Ageing society

Population ageing is a widespread phenomenon all over the world, resulting from the complex coexistence of many factors, such as the increased life expectancy, the choice of working parents to have less children than in the past and reduced fertility [35]. According to [78], the global portion of older people, aged 60 years or over, increased from 9.2% in 1990 to 11.7% in 2013 and will continue to grow reaching 21.1% by 2050. Globally, the number of older people is expected to reach more than two billions in 2050, for the reasons explained. In Figure 1.2 the trends and predictions of life expectancy, total fertility and number of people by broad age group are shown. Focusing on Italy, that can be a good indicator of the trend of all European western countries, in Figure 1.1 the population pyramids relative to 1950, 2015 and 2050 are shown. As it can be seen in the pictures, in the 1950 the majority of the population was younger than 50 years, while it is projected that by 2050 the number of older adults will overtake the number of younger people.

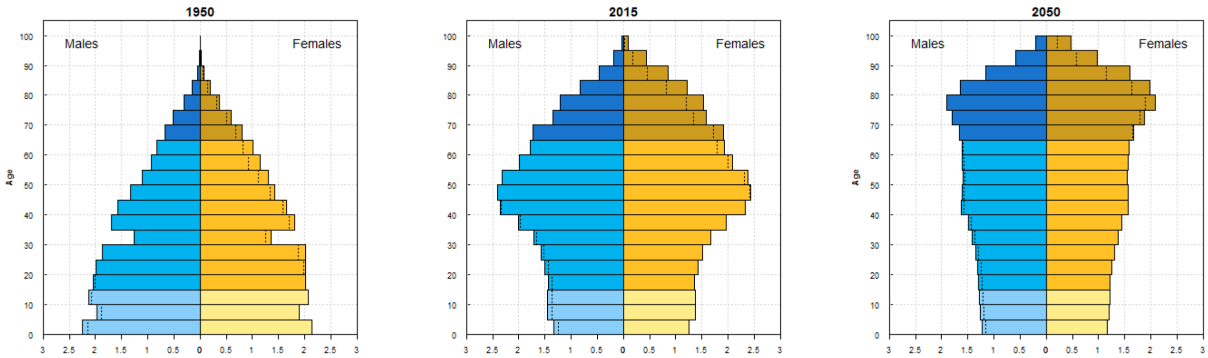
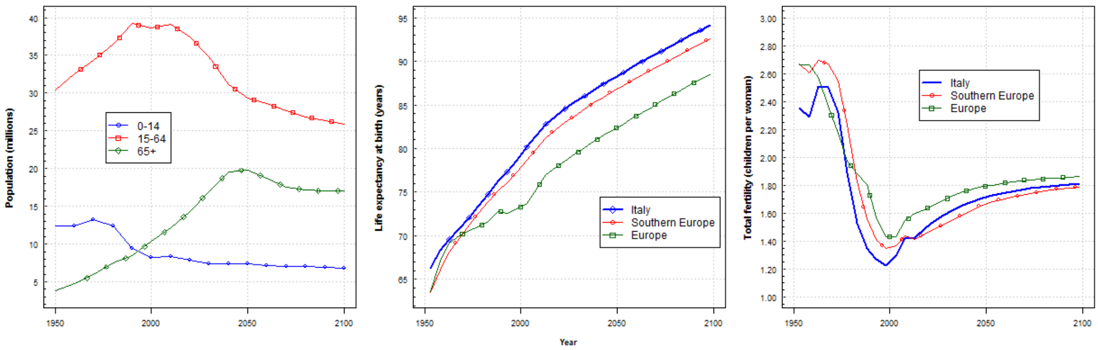


Figure 1.1: Population pyramids (Italy) [77].

Population ageing has major social and economic consequences, since the healthcare expenditure increases along with the populations age because of the age-related diseases and disabilities. In Figure 1.6 is shown, for example, the trend in Italy of elderly people that have at least one chronic disease. As it can be seen, the older people gets, the more likely it is that a certain pathology arises.



(a) Population by age group. (b) Life expectancy at birth. (c) Total fertility.

Figure 1.2: Italian and European demographic profiles [77].

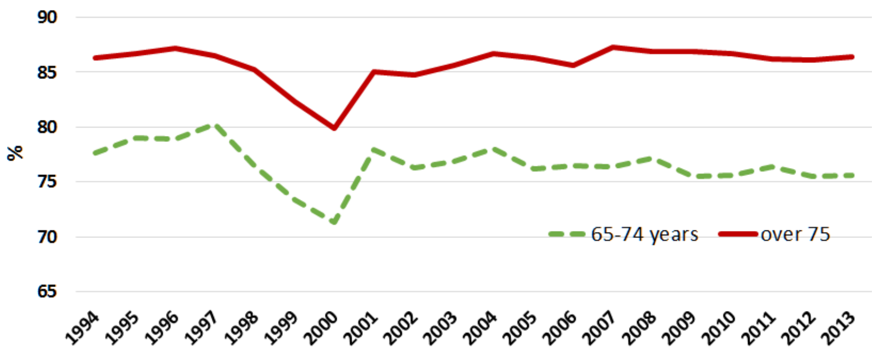


Figure 1.3: Percentage of elderly people with at least one chronic disease (in Italy) [54].

The shortage of professional caregivers and the lack of facilities in which the elderly could be transferred in are exacerbated by the increasing number of older users [72]. Many elderly who live by themselves suffer from isolation for many reasons [56]. With age, many of them suffer from mobility impairments and cannot leave their houses as often as they did before. As time goes by, the sons move out, sometimes in other countries, causing their parents to start living by themselves, older family and friends pass away and these facts lead to the shrinkage of their social networks. Also, there is often a lack of organization of specific social events, their publicity is poor, or it is difficult to access this kind of information.

Information accessibility can be hampered by another major issue that afflicts the elderly: digital divide. Digital divide can be territorial, i.e. lack of access to information and communication technology (ICT) and lack of broadband Internet access, or literacy-related, i.e. the inability to use certain devices. It is extremely important to take into account all these aspects to design and build a useful and user-friendly assistive technology for active ageing.

Population ageing poses new challenges to the National Health Systems, facing the contrasting needs of ensuring good quality services to a growing number of people, keeping under control the associated expenditures [28]. As it can be seen from Figure 1.4, there is a trend that shows how the total health expenditure (THE) is increasing [79] (it has been chosen to take as example the four European countries involved in the project that will be described in the next Chapter). Since the number of older adults that could need health assistance is constantly increasing, this rising trend of the THE could reach worrying levels. A solution must be found to keep under control all these repercussions that affects the society while the population ages. Many project focused on the creation of active ageing and telemonitoring platform have started and are currently being funded, by the European Commission, through the Active and Assisted Living (AAL) Programme [15] or, more recently, through Horizon 2020 [48] Health calls.

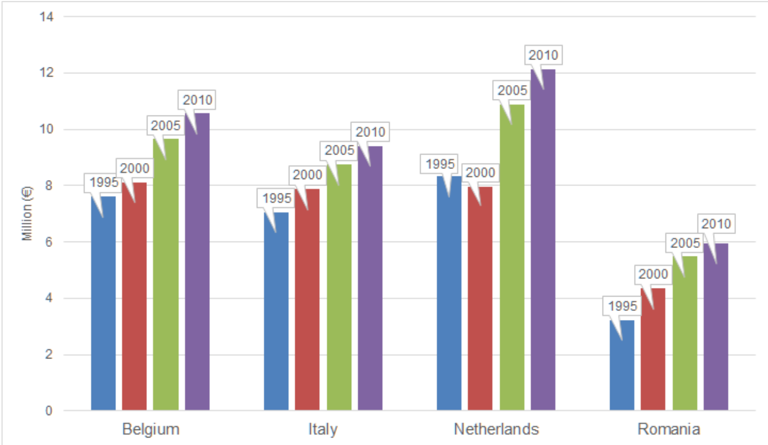


Figure 1.4: Total Health Expenditure (% of Gross domestic product) [79].

1.1.1 The Active and Assisted Living Programme

The AAL programme funds projects in the field of information and communication technology (ICT) for active and healthy ageing since 2008. The programme is co-financed by the European Commission and 19 countries until 2020 for an estimated budget of 700 million of euros.

AAL
PROGRAMME

Figure 1.5: AAL Programme logo.

The objective of AAL is to enhance the quality of life of older adults through the use of ICT. Since 2008, AAL has issued 7 calls for proposals and has funded 154 innovations projects. Almost half of these project partners are small and medium enterprises (SMEs), which are collaborating with user organisations, large enterprises, universities and research organisations in the development of innovative solutions. The topics covered by the programme include management of chronic conditions, social inclusion, mobility of older adults, management of daily activities, support from informal carers (e.g. family and friends) and occupation in life.

The work presented in this thesis was born within a European project funded by the AAL Programme, call 5 that was published in 2012 with the title "ICT-based solutions for (self-) management of daily life activities of older adults at home".

1.1.2 Healthy Life Years

An important indicator that measures the number of remaining years that a person of a certain age is still supposed to live without disability is called the "Healthy Life Years" (HLY). It is used as a functional health status measure and to associate the life expectancy with the quality of life. Since chronic diseases, frailty and disability tend to become more prevalent at older ages, the fact that a population has a higher life expectancy may not imply that their life would be healthier. One of the fact to be considered is whether an increases in life expectancy will be associated with a greater or lesser proportion of the future population living with disabilities. If HLY is increasing more rapidly than life expectancy in a population, then people are both living longer and free of disability. To calculate the HLY indicator, the Sullivan [76] method is used. This method combines mortality and morbidity rates into a single summary measure of a population's health status. Using data available at European Community Health Indicators (ECHI) database [36], the following graphs can be obtained for Italy:

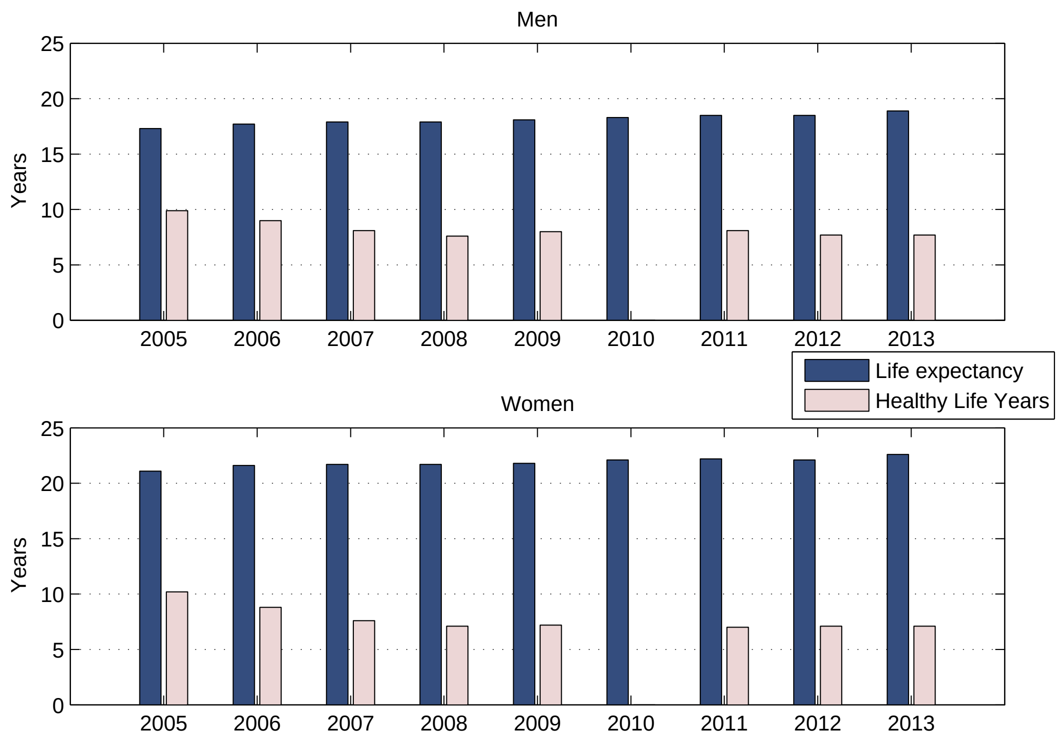


Figure 1.6: Difference in life expectancy and healthy life years for men and women at age 65.

Data regarding life expectancy and the HLY indicator show some interesting aspects. Not surprisingly, life expectancy is increasing, both for men and women and it remains higher for the latter. For example, in 2005, the life expectancy for men and women aged 65 was, respectively, 82.3 and 86.1 (so they were expected to live 17.3 and 21.1 years more), while in 2013 men were expected to live until 83.9 years and women until 87.6 years. The increase in life expectancy from 2005 to 2013 was 1.6 years for men and 1.5 for women. The interesting fact is that while life expectancy is increasing, the number of years to be lived without limitation is decreasing. In fact, a 65 years old man in 2005 could live 57.22% of his remaining years in good health, while in 2013 only 40.74%. Regarding women, they passed from 48.34% to 31.41%. Taking into account only the percentage could be misleading, since it could mean only that life expectacy is increasing at a faster rate than HLY indicator. Looking at the numbers, though, the interesting fact is that the number of HLY decreased over time. In 2005, men aged 65 could live 9.9 years in good health, while in 2013 only 7.7. Women aged 65 could live 10.2 years in good health in 2005, while only 7.1 (even lower than man) in 2013. These findings are worrying, in fact, the HLY improvement is the main health goal for the EU. The European Innovation Partnership on Active and Healthy Ageing (EIP on AHA [1]) aims to increase the average healthy lifespan of Europeans by 2 years by 2020.

1.2 Telemonitoring and Tele-health

Telehealth aims at providing health services directly in the patient's home, exploiting the latest Information and Communication Technologies (ICT) to avoid moving either the professional caregivers or the patients. Beyond the positive effects in terms of cost and comfort, telehealth can be exploited to create new services to the population. In the context of telehealth services, telemonitoring [23] is focused on the process of transmitting/receiving data on a patient's health status from home to the respective health care setting [44]. Even though simple accelerometer-based activity monitors can be used for telemonitoring, the largest part of systems deals with vital signs (such as blood glucose level, blood oxygen saturation (SpO_2), heart rate, non-invasive blood pressure (NIBP), temperature, weight, and so on), up to electrophysiological signals (electrocardiogram, electroencephalogram, and so on) and drugs intake. Home telemonitoring of vital signs can increase the quality of the health service, by promoting the patients involvement in the preventive control of their health status, augmenting their self-confidence and independent living and reducing unnecessary hospitalizations [30]. This approach presents positive reverberations especially for the elderly who live alone.

For example, in Italy, the healthcare system is dealing with the difficult national and international framework of economic and financial crisis: the health sector is still undergoing a reduction in health service supply especially for services paid by the National Health Service (Nhs). In a survey conducted in 2011, the number of hospital beds available for 1000 citizens was found to be 3.4 [54], ranking Italy 23rd in Europe [38], as shown in Figure 1.7. While population ages, there will be an increasing number of health related diseases that could lead to hospitalizations, if not treated in time. Telemonitoring could be a solution to overcome this problem.

Despite the growing number of systems already available on the market to this aim, they present several limitations, including the high cost, the complexity, and the little integration with leisure services.

Age-related chronic diseases, such as type II diabetes, requiring a daily monitoring of vital parameters, can benefit from the adoption of tele-health services. Home monitoring reduces the costs and the discomfort for the patients, guaranteeing an accurate follow-up able to limit the insurgence of severe consequences. This, in turn, limits the health service expenditures and the social costs associated to disability. However, typical home monitoring settings, based on computers or smart TVs, are not aimed at supporting the mobility of the patients. This is in contrast with several real-life situations, when the elderly could be hosted by different relatives during the year, or when they are travelling for the holidays

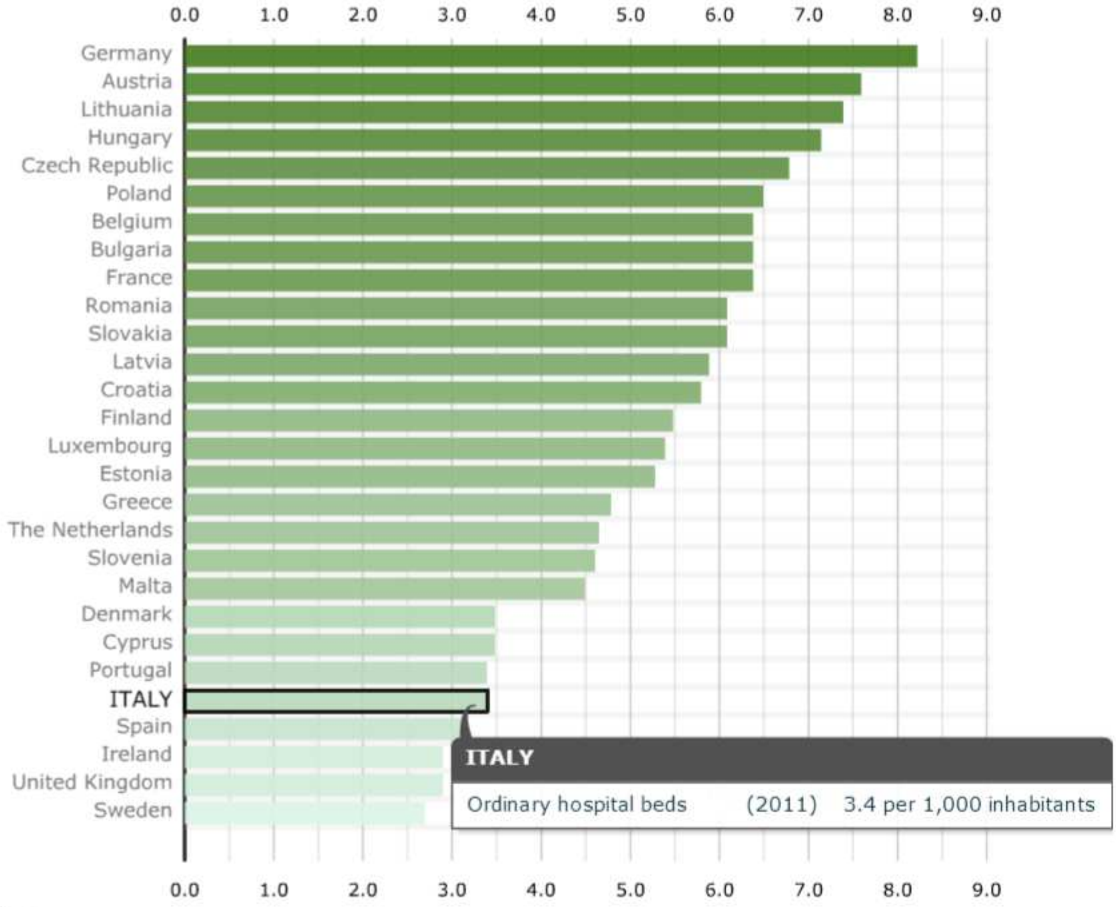


Figure 1.7: Number of hospital beds per 1000 inhabitants, throughout Europe (2011) [54].

or during the so-called medical tourism. In such situations, the tele-health systems shall be able to follow the patients, without perceivable differences for the patients compared to their home settings. Smartphones and tablets represent a natural solution in these cases because they provide internet connectivity, Bluetooth support and the possibility to provide graphical user interfaces with intuitive touch interaction. Despite the large number of healthcare apps developed, only a small number of older adults actually use them [34] [41]. The problem is mainly that they are generally not designed on the needs and technology literacy of the older adults neither marketed for them. Moreover, these remote monitoring apps generally work with a set of specific medical devices from a unique vendor. Overcoming this limit would allow to cut the costs for the acquisition of the system and provide an affordable alternative to other traditional monitoring solutions based on written records.

Digital technologies are changing the way of delivering healthcare services and improving the associated outcomes. The availability of medical wearable devices and the growing number of connected devices (such as smartphones and tablets) enables patients and physicians to access real-time healthcare data and information. Home care and remote monitoring technologies are progressively gaining popularity among people of all ages, in particular among older adults and those living with chronic diseases [55]. Diabetes is one of the most studied diseases where such technologies have been applied in randomized controlled trials [68][71]. For instance, an application for adults with diabetes and hypertension demonstrated the promising utility of the current mobile phones Bluetooth capabilities in facilitating up-linking of home blood pressure monitor readings to the patient's doctor. This enables a subsequent follow-up based on the analysis of such readings [16]. Other applications are integrated into larger models of care organizations and include the use of activity monitoring devices to enable prevention and early detection of health problems. Some of them can include also the tracking of daily caloric intake and exercise performed [57].

1.2.1 Telemonitoring apps

A wide range of applications is nowadays used for monitoring parameters such as body weight, blood pressure, heart rate and blood glucose. For example in [12], Triantafyllidis et al. proposed a personalized mobile health system for supporting heart failure patients in daily self-monitoring of their condition. The system is based on an Android platform and uses a tablet computer and Bluetooth technology to communicate with clinically-validated instruments (a blood pressure monitor, a weighing scale, a pulse oximeter and a bio-patch for continuous measurement of heart rate and activity), according to the proprietary protocol provided by the device manufacturer. The collected data can be reviewed by patients through graphical displays or transmitted to a back-end infrastructure through Internet, enabling healthcare professionals to review the patients' health status remotely.

Another home monitoring system that uses wireless health devices and a mobile application (on the patient's end) integrated with a web dashboard (on the physician's end), is MyHeart [64]. It aims to facilitate the exchange of information pertaining to vitals, symptoms and health risk.

The "Handroid" application was also designed to wireless acquire health information from Bluetooth medical devices and digital media [58]. In detail, it allows to monitoring blood pressure, body weight, BMI (Body Mass Index) and heart sounds by using an Android phone connected to a blood pressure monitor and a weighing scale manufactured by A&D Medical (model UA-767 PBT and UC-321 PBT respectively) and to a digital stethoscope manufactured by Thinklabs Medical Inc. (model DS32a+). Handroid is also able to keep track of daily calorie intake and exercise performed. Other remote monitoring applications that are designed to be used with a proprietary set of products were also reported in [62].

The Withings Health Mate app [6] is the core of multiple Withings products including the Withings Pulse O_2, the wireless blood pressure monitor and the wireless scale. The application is accessed through password authentication and it uploads acquired raw data directly to the cloud storage where the user can review them. The application provides users informative feedback on conditions and reference values. Personal health data can be exported in the form of a CSV file and shared by entering the email address of the person who will receive data. The Health Mate application can also interconnect to external applications using the IFTTT (If This Then That) protocol. Stored data can be shared with partners App such as MyFitnessPal [10] and Runkeeper [11].

The mobile health apps MyVital, Gluco-Smart and SpO_2 designed by iHealth Lab Inc. work with a suite of nine personal medical devices [9]. The MyVital app supports the iHealth Blood Pressure monitors, the iHealth Scales, the iHealth Pulse Oximeters and the iHealth Activity and Sleep Trackers. The measured health information is automatically stored in the app (in easy to read graphs and charts that show changes and trends over time) and can be shared to keep clinicians and caregivers updated on patient's vital status and progress. The iHealth Gluco-Smart app allows measuring and recording of patient's glucose levels by using a portable testing kit and a Bluetooth-enabled mobile device. The SpO_2 mobile app works with the iHealth Wireless Pulse Oximeter to measure and track patient's blood oxygen saturation (SpO_2), pulse rate (BPM) and perfusion index.

1.3 Telemedicine and active ageing platforms

According to the World Health Organization, all over the world, 49% of countries are adopting a mobile telemedicine initiative; in particular, in Europe the percentage increases to 64% and in the Americas to 75%. Mobile telemedicine initiatives taken into consideration included consultations between health-care providers and transmission of a patient's health-related data using mobile devices. In some European countries, mobile telemedicine initiatives for the management of chronic diseases with applications in elderly health and home care are ongoing and there is a great interest in adapting them to ageing populations [80]. In spite of the large number of devices and systems for remote monitoring of vital signs, the real exploitation of these systems for clinical purposes is somehow limited [61]. This is particularly true for the systems targeted towards the elderly. This specific category of subjects is adversely affected by progressive digitalization of the world around them [43]. Being not accustomed to the exploitation of computers and digital devices, these subjects tend to refuse the technology, exacerbating the previous mentioned digital divide [73]. At the same time, despite prevention allows reducing the costs associated to both hospitalization and worsening of the health status of the elderly [75], the healthcare models of several European countries are not ready for the massive exploitation of tele-health solutions. From the user's perspective, the usability and ease-of-access to tele-health systems are obstructed by the lack of technology integration, interoperability, and standardization [49].

Creating ICT based solutions able to support older adults in different aspects of their lives is, nowadays, a critical challenge in our society. For this reason, the European Union (EU) is funding several initiatives aimed at fostering the development of new ICT services, applications and products in a wide range of sectors, including healthcare, social policy, nutrition, security, mobility and transport. In this section, some examples of research activities, recently funded by the EU will be presented. An example of integration of technologies for health monitoring at home is provided by the four-year Dreaming project [32]. It provides a user-friendly technology, based on health monitoring, alarm handling and a TV-based video-conferencing service, to help the elderly and patients. This system provides a valuable support to both satisfy the users need of continuous care to safely and independently live in their homes, instead of being in a care institution, and to facilitate their social life and contacts with family, friends and caregivers. Another project, Care@Home [40], additionally provides continuous remote monitoring of emergencies and lifestyle changes to manage or reduce risk factors associated with independent living. The project aims at defining an open platform, exploiting the Smart TV as the key front-end device. GeTVivid [27] is another example of a TV-centric platform that aims at stimulating and supporting daily activities at home through a rich set of services. The project is based on the Hybrid broadcast broadband TV (HbbTV) specification. The ELF@Home project [29] proposes a self-care solution capable of generating a personalized fitness program based on the health status and the continuous monitoring of activity level of the users. The system will comprise several parts including wearable activity and biomedical sensors, a simple TV interface for fitness sessions and a computer vision system to analyse fitness exercises execution. Many other works are focusing on training games that could motivate older adults to remain socially and physically active. Long Lasting Memories [21] is an innovative e-health service that combines physical activity and cognitive exercises to prevent mental decline in the elderly. Join-in [25] aims at counteracting loneliness in the elderly by providing a web-browser platform that connects to PCs or TVs to offer multiplayer video gaming, exergames and group exercising targeted at senior citizens.

Chapter 2

The HEREiAM Project

This Chapter features a description of the project, funded by the Active and Assisted Living Programme (www.aal-europe.eu), within which the activities related to this thesis work have been performed. The project "HEREiAM: An interoperable platform for self care, social networking and managing of daily activities at home" started officially on July 1st, 2013 and have a duration of 42 months. The project will officially end on December 2016 (it is ongoing at the time of writing).

Figure 2.1: HEREiAM project logo.

In the following paragraphs, the aim of the project, the planning of activities, the technical infrastructure built and the project Consortium will be introduced.

2.1 Aim of the project

The main objective of HEREiAM is the set-up of an integrated system of communication, interaction and self checking, specifically tailored for older adults. In order to enable them managing many of their activities in their home, the platform offers a TV-based user-friendly solution. TV is present in our homes since more than 50 years and it is now part of our daily life, in particular for older people that already spend much time in watching dedicated programs. In 50 years, many changes happened at technological level but also at user interaction level. For example, in Italy with the switch-off of the analog broadcasting (in 2011) users experienced a change of TV-set or the introduction of an external set-top-box. So, even in this situation, everybody can use a remote control without being afraid of making a mistake in the performance of very basic interactive functions. Directly from their house the elderly is be able to access a set of basic services and utilities, some related to home activities such as self-care and some related to external services such as food shopping, keeping track of events organized by local associations and so on. To overcome the older adults traditional digital divide to use all PC-based ICT systems, HEREiAM provides an user-friendly solution that reduce the technological effort and skills needed to use application running on common PCs or smartphones.

During the first phases of the project, a careful market analysis has been carried out, to understand the best solution to implement a user-friendly TV-based system for the elderly. At first, the Terrestrial/Satellite/Cable Digital Video Broadcasting (DVB-T/S/C) solution has been considered, but the world of technology is changing rapidly and in many ways, so it is crucial to follow the trends in the Consumer Electronics market closely. The analysis carried out during the definition of the specifications, suggested that a different approach was required to end up with a viable/sustainable solution five years after the beginning of the implementation activities. The first solution analysed was based on the use of an interactive DVB-MHP (Multimedia Home Platform) set-top-box or of a new TV set already equipped with DVB-MHP (in case equipped with an external device to insert a smart-card). The Multimedia Home Platform (MHP) is an open middleware system standard designed by the DVB consortium for interactive digital television, used from the very beginning of the DVB-T introduction (2003). The MHP enables the reception and execution of interactive Java-based applications. Interactive TV applications can be delivered over the broadcasted channel, together with audio and video streams. MHP applications can use an additional return internet channel. In 2012, the largest deployments of DVB-MHP were in Italy (DVB-T), Korea (DVB-S), Belgium (DVB-C) and Poland (DVB-S), with trials or small deployments in other countries. MHP was seen as a 'future proof' API that would evolve over time in different versions. Anyhow, during the last years, MHP failed to become a common standard (licence fees, extra effort required from services providers to offer their services in a format compatible with the MHP solution that is limited to the TV use, relevant differences between different producers of set-top-boxes and televisions), its distribution stopped and it never reached several countries in Europe. Due to a such poor diffusion, using an MHP set-top-box for HEREiAM didn't satisfy (fulfil) the need, central for the project vision, of a platform with the following features:

- able to work in all (or most of the) EU countries,
- able to work on most of the set-top-boxes/TV sets,
- able to reach a huge market.

Considering these factors, it was decided to base the HEREiAM system on an Android TV-box. The number of Android Apps developers was large and growing. Android has the benefit of allowing service providers to develop an application that could be delivered across multiple platforms: TV, tablets and smartphones. Thus, this choice simplifies the integration of new third parties interested in offering services on HEREiAM, in terms of finding app developers, and of having the possibility to reuse app already developed for other platforms. The priority was, anyway, to create for elderly users the same user-experience obtained with a more standard DVB-MHP set-top-box.

Thanks to the use of a simple and cheap Android TV-box, an interactive application running on it is displayed on the TV screen. It allows the access to a set of services for the management and improvement of older persons' everyday activities at home. Such services are uploaded and upgraded directly by the platform without any intervention in the users' home.

Through the use of a custom remote control (or other simple custom hardware interfaces), the user can access all the applications interface and services available at home.

HEREiAM is supported by Dedalus (one of the project partners) interoperability platform X1.V1. This is a flexible and structured interoperable platform that allows the integration among various stakeholders (usually in the field of healthcare services) supplied at all levels (enterprise, territory, greater metropolitan area, region). It is based on a service oriented architecture, written in JAVA and compliant with international standards such as HL7, IHE profiles and token SAML based federated authentication. The stakeholders (e.g. services providers, healthcare centers, formal and informal carers, and so on) are connected by the interoperable platform with standard PC and smartphone client terminals.

2.2 Consortium

The HEREiAM Consortium is composed by eight partners from four different European Countries. In this section, the Consortium composition will be briefly described. The Consortium is composed by one University (coordinator and technical partner), two large enterprises (technical and business partners), three small and medium enterprises (end-users and business partners) and two end-users partners. These are the partners involved in the project:

University of Cagliari (UNICA)

UNICA is the project coordinator and the only University of the Consortium. Its role in HEREiAM regards the managing of the project and the conception and development of the software framework at home and the graphical user interface (homepage and a few basic services).

Dedalus S.p.A.

Dedalus is today at the head of a leading national healthcare software industrial group, with many important roles in all public and private health market segments. Today Dedalus is market leader in software systems for General Practitioners and primary care Paediatricians. In HEREiAM, Dedalus develops the interoperable platform (server side of the system) and is responsible for exploitation and marketing activities.

Remedus

Remedus is the Belgian specialist in hospitalization at home. It delivers home care services for patients with chronic and rare diseases based on an approach that combines logistics, education and communication. In the HEREiAM project, Remedus have a central role in the pilot testing in Belgium and The Netherlands and is involved in user-centred design, concept development, system integration, prototype testing, pilot testing, evaluation, exploitation and dissemination activities.

TeamNet International (TNI)

TNI is a Romanian Large Enterprise specialized in the development and implementation of software applications. TNI is among the few private Romanian companies which was involved in the complex research within the FP6 & FP7 of the European Commission. In the HEREiAM project, TNI is one of the technical partners, with Dedalus and UNICA, with a special responsibility and competence in system integration, testing and management of technical development in the project.

Smart Homes

Smart Homes is the Dutch expert centre on home automation, smart living and e-health. It acts as an independent and intermediary organisation in the complex market of technology and ageing, bridging the worlds of technology development and those of end-users and service/care providers. In HEREiAM, Smart Homes is involved in user-centred design, concept development, system integration, prototype testing, pilot testing, evaluation, exploitation and dissemination activities.

KempenLife

KempenLife is a new cooperative of older citizens in the rural area, south-west of Eindhoven. The area encompasses 5 municipalities, Eersel, Bladel, Bergeijk, Reusel-De Mierden and Oirschot, all together with 85.000 inhabitants. The area is a rural area: many small villages, many people living in detached houses in the country side. In HEREiAM, KempenLife represents the Dutch end-users.

Municipality of Cagliari

One of the area of activity of the Municipality of Cagliari is represented by the Social Services that provide elderly people with different services. The possibility to help people to maintain their independence in their own familiar surroundings and to be independent in the management of their day-to-day tasks is one of the aims of our municipality. In HEREiAM, they offer a fundamental contribute to the pilot application in Sardinia, their expertise and help in enrolment of the target group.

Snauwaert-Maes&co

Snauwaert-Maes&co is a Belgian association specialized in co-creation, social innovation processes and project management in care-projects. In HEREiAM, Snauwaert-Maes&co, with its expertise in social care services, contributes to the trials implementation and to the business model development.

2.3 Activities

In this paragraph, the division of activities of the HEREiAM project will be described.

The HEREiAM project is divided in six Work Packages (WP):

- WP1 - Specification
- WP2 - ICT Platform
- WP3 - System integration and verification
- WP4 - Trials
- WP5 - Dissemination, exploitation, standardization
- WP6 - Management

In WP1 the system is specified according to the technologies available and the end-user needs (both primary and secondary), many different cases will be considered to have a broad range of solutions. The activities in WP1 will proceed during the technological development to promptly catch the feedback from users. Utilities available to stakeholders interested to use this platform will be defined. This WP is divided in two different tasks. The first one concerns the definition of requirements needed by possible users and the comparison of different kind of user-interfaces. At the end of this task, the system will be fully defined, also at technological level, in terms of functionalities and interaction. The second task of WP1 will be focus on the identification of a set of possible services for stakeholders. These services will be translated in terms of system utilities/functionalities to be developed. Different kind of stakeholders will be considered.

In WP2 all the components of the system (system at home, the platform, the communication level) will be developed. WP2 is divided in three different tasks. The first one regards the development of all the software installed in the users' homes. The software will be installed in the Android TV-box and consists mainly of: an Android custom launcher application that represents the main screen of the system and provides an overview of the installed services; an Android service running in background that will constantly check for updates, new events and messages to be delivered to the user and represents the mean to exchange information between the Home Level and the Platform Level; different kind of basic functionalities and interfaces to support data transfer from external devices to the apps. The detailed description of the system software will be presented in Section 4.1.2 The second task regards the development of all the hardware operating at home (described in details in Section 4.1.1). The last task of this WP concerns the extension of the interoperability platform, with the implementation a set of web services that will enable the stakeholders (e.g. services providers, healthcare centers, formal and informal carers, and so on) to easily integrate their applications. The description of the development that took place during this task can be found in Section 4.2.

In WP3 all the components of the system developed during WP2 will be integrated and evaluated. This WP is divided in several tasks, two regarding integration and three verification/maintenance of the system. During the integration tasks, all the software developed for the home side will be put in communication with the one developer for the platform side, through custom interfaces and also two existing services offered by external service providers will be integrated in the HEREiAM platform. Regarding the verification and maintenance tasks, the system functions will be tested against all the defined requirement, either functional or non-functional, and the platform will be maintained through some small changes to adapt it to the pilots needs.

During WP4 the HEREiAM platform will be tested on the field. Three different pilots will take place in Italy, in The Netherlands and in Belgium. In each country, 25 elderly will be recruited and will test the platform functionalities, services and user-interface. Each country will prepare a different trial plan, according to what is needed to be tested. At the end of the trials, the information gathered will be retrieved and analysed in order to evaluate the success of the platform. The result of the pilots will be evaluated against the scope of the system in terms of usability, acceptability and usefulness. Such study will use statistics (numbers of connections per day, number of services successfully used and so on) and answers to questionnaires.

In WP5 mainstream opportunities will be produced: identification, planning and designing (feasibility phase) of potential or already implemented pilot sites, with special interest into available data clusters to be managed, technical theoretical testing of tools and platforms, potential practical testing of tools in case of available and ready pilot sites, financial analysis and possible adoptable solutions, validation models of new approaches.

WP6 concerns all management activities, taking into account ethical, techno-ethical and social implications.

2.4 System architecture

Since the TV is the most known and used device by the majority of the elderly, the HEREiAM system has been developed to be used through it. Furthermore, the choice of the operating system fell on Android, in order to facilitate third parties to join the platform and offer their services, being able to seamlessly customize the system to the different regional uses and needs. A simplified scheme of the platform architecture is depicted in Figure 2.2. The system architecture can be divided in three levels: the Home Level, the Platform Level and the Third Party Level. These three levels will be described in the following.

The Home Level, described in Section 4.1, is the part of the system that includes all the components of the platform installed in the homes of the users. It includes all the hardware and software tools operating at home, that will be described more in details, respectively, in Section 4.1.1 and 4.1.2. Each home is equipped with a custom Android TV-box with the system software installed on it, including the main application, that loads a set of basic applications that are stored in a local repository. Some of these core applications work in conjunction with external devices (e.g. telemonitoring devices, sensors and so on) exploiting a Bluetooth or Zigbee interface, according to the selected application.

The Platform Level is the server side of the HEREiAM platform. It includes information regarding user profiles, it contains an external repository of additional applications offered by third parties and a module that manages the users authentication system. In addition, the Platform Level houses a Documental Repository Service (REPO) that allows the storage of data generated by each application in eXtensible Markup Language (XML) document format. The components of the Platform level will be described in more details in Section 4.2.

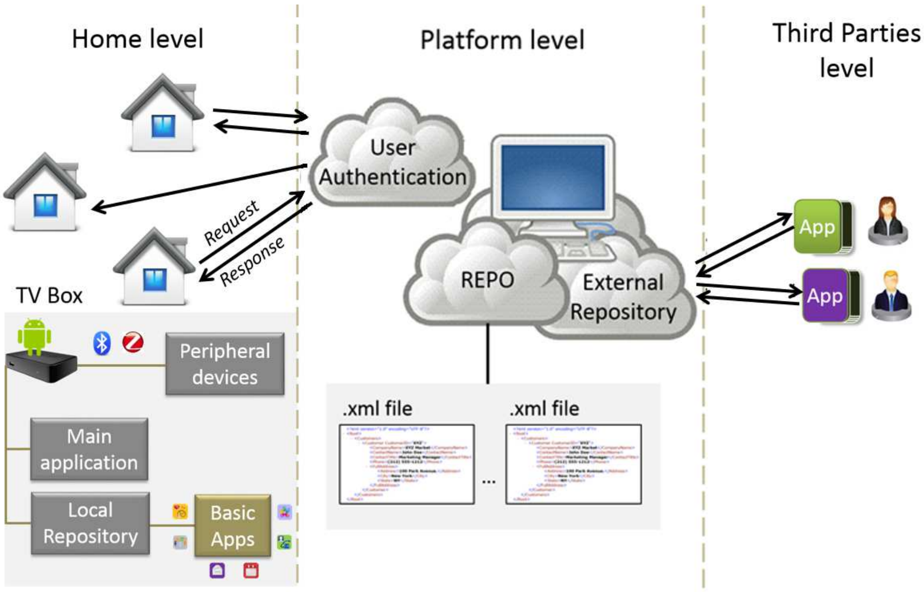


Figure 2.2: Platform architecture.

The Third Party Level, described in Section 4.3, includes all external stakeholders that may join the platform, that are divided in two groups: the ones that already have their own Android application and all the others. The Home Level and the Third Party Level communicate with the Platform Level through a request/response mechanism. Third Parties cannot contact the users directly, each communication needs to be registered and approved by the Platform Level.

In Figure 2.3 are shown the services already included in the HEREiAM platform, that will be described in details in Chapters 4 and 5. The choice of these services is in accordance with "requirement 1: address everyday problems and enhance perceived usefulness" presented in Section 3.5.1.

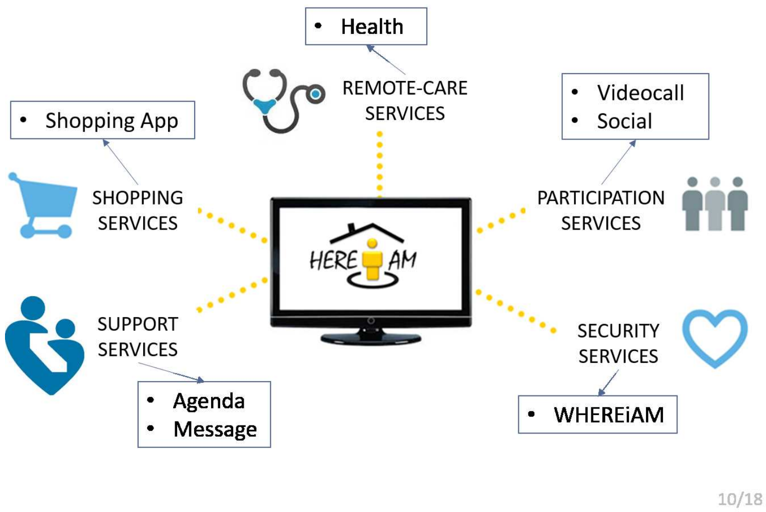


Figure 2.3: Platform services.

2.5 Business perspective

During the research activities of the project, great emphasis has been put on the business related aspects of the system. Nowadays, as explained in Chapter 1, there are a number of different platforms or stand-alone devices that try to fill the gap in the elderly market. It could be said that every platform, pretty much, does the same. The important thing to keep in mind is that, if a real viable solution is not found, there will be huge consequences for the society. When developing such a platform, it is mandatory to understand if the elderly are able to use it, if they are motivated to do so and how this solution can be offered. Specifically, who is going to pay for it? How much? How is it going to be distributed? Many other questions need to find an answer before proceeding with a "blind" development. Aside from user evaluations, the business aspects where constantly taken into account. This was possible also thanks to the AAL, that organized business courses and support actions to help the project Consortium understand how such platforms can have success in the market.

Chapter 3

System specifications and requirements

The aim of the HEREiAM project is to help older adults to stay longer and independent at home by providing an innovative user-friendly technology able to support them during daily life activities. This chapter presents the activities and the key outcomes of the HEREiAM Consortium related to the first period of activities, carried out within workpackage "WP1 - Specification". The goal of these activities was to accurately investigate users' needs, which were the basis for further development in technical specifications. The objectives of the work package WP1, can be summarized by the following topics:

- identification of elderly people's needs,
- assessment of potential services that should be provided to help older persons to live longer independently and safety at home,
- definition of the most effective technical solution to deliver the identified services.

This chapter is organized as follows, after a brief introduction of the characteristics of user needs in Italian urban areas and Dutch rural areas, emphasis is put on which care services can be provided at home (Section 3.2) and on the service platforms already available in the market (Section 3.3). Section 3.4 provides a description of the user sessions performed in the Netherlands and in Italy in order to find out service platform requirements and target group profile. Then, Section 3.5 looks at issues to consider in the development of the HEREiAM platform for an efficient management and control. This includes usability, feasibility and reliability aspects. Lastly, in Section 3.6 the HEREiAM architecture and its technical specifications are introduced.

3.1 User research

The focus for system specification started with the identification of the users and their needs. Identifying the range of people who might be likely to use the HEREiAM platform was a crucial first step. The system was designed for a specific target group of self-sufficient older adults who want to be independent in the management of their daily activities. For this reason, the user research process involved a literature review to determine elders' attitudes, beliefs, desires, and reactions to ICT concepts in the various countries. Moreover, since the platform was designed to be an invaluable resource also for care professionals and for many family members acting as carers for their relative or friends/neighbours, an analysis of secondary user needs was acknowledged as part of this research process. Finally, additional requirements were gathered for people who live in remote areas (the end-user group of the pilot in the Netherlands) and in urban areas (the end-user group of the pilot in Italy). The key questions to take into consideration during the user needs analysis are:

- What are the user needs?
- How are they structured?
- Why, when and where do they exist?

In the following sections, findings from user research studies related to Italy are presented. Studies that were conducted in The Netherlands will be only summarized.

3.1.1 Specific user needs in rural areas - The Netherlands and Belgium

According to the central office of statistics in The Netherlands, the number of Dutch households will increase strongly in the coming decades. From 2010 till 2045, the amount of households in the Netherlands will rise from 7.3 million to 8.5 million, resulting in a higher demand for housing. Part of this need can be fulfilled by making use of rural areas. To guarantee the quality of life in rural areas, it is crucial to have a clear and well-thought vision. Liveableness in rural areas focuses on the health and safety of humans and animals and on a good quality of landscape, nature and environment. The combination of the green environment (nature) and humans (culture) in the rural areas offers opportunities for the agricultural sector, living and housing, tourism and leisure, and non-agricultural business. However, rural areas are also confronted with a wide variety of challenges to fit all these different activities in the peaceful country-life.

3.1.2 Specific user needs in urban areas - Italy

The 68% of Italy's population live in and around urban areas [69] like cities and towns, while only a small part of the population lives in the rural areas, where a lot of farming takes place. The Quality of Life (QOL) of rural elderly population can be better in physical and psychological domains but in terms of availability of public services, employment, shopping, transport, culture and sport facilities as well as space to live, living in urban areas is preferable [37]. Although almost all Italians in the cities live in apartment buildings (with no access to outside spaces or gardens for exercises and recreation) and cannot enjoy nature, spaciousness and quietness, they prefer living in urban environments to benefit social relationships and cultural interactions. It must be highlighted that a great proportion of the Italian elderly is still playing social roles, such as continuing with their economic activities, caring for grandchildren, attending social and cultural events (such as concerts, cinema, museum, theatre and so on), actively participating in regular physical activities, whether individual or organized. For this reason, living in or around the city is of vital importance to seniors.

In an urban area, the social environment provides multiple and diverse types of activities and brings a positive influence on their mental and cognitive health. Investigation of leisure activities and the use of new technologies conducted by Marcellini et al. [39] revealed that elderly urban dwellers are not only more active than their rural peers, but also more technologically minded. Elderly urban people have multiple choices for learning courses and acquire digital skills. Elder learning initiatives are mainly provided by seniors associations and social services centres and focus on computer and Internet use, language courses and recreational activities. To guarantee the quality of life in urban areas, it is crucial for seniors to strengthen social relationships and keep active with productive activities. It is important to provide services that fit these needs in order to fight loneliness and increase their participation in the community.

3.2 Service Definition

The mission of the HEREiAM project is keep European elderly independent at home. Therefore there is a focus on a combination of physical, mental and social well-being to enable older people to manage daily activities and live in their own homes as long as possible. Services must meet needs expressed by older people, giving them a sense of security, a sense of belonging and a feeling of health and well-being at home. Furthermore, services must evolve in order to continue meeting the needs of its users over time and respond to technological changes and advances. HEREiAM is conceived for those who could have difficulty to complete daily activities related to independent living that involve interaction with physical and social environment. These activities include shopping for groceries, preparing meals, contacting family and friends, taking drugs as instructed, monitoring health status, managing appointments and meetings, getting news from TV, radio or newspaper. Elderly needs can vary widely according to both personal (age, mobility impairment, activity level) and living situation (rural or urban areas, country). Even in Europe, a difference between countries in health care, leisure, laws and regulations was noticed. Because of these differences, it is almost impossible to create a general European digital platform for the elderly. On the other hand, in all countries of the European Union, there are several local business or public companies that are working on platforms that cover the needs of the local residents. The power of the HEREiAM platform should exist in standardizing and uniting these local applications. These platforms have to be built on the needs of an individual user, but the relatives, health care professionals and social network should remain the same throughout the platform. Each individual will define preferable services based on personal characteristics and current situation. HEREiAM should provide customized services suitable to individual user needs at the right time. The goal is to develop a general, interoperable platform with a wide variety of services that can be chosen. Doctor visits and nursing, but also services related with home maintenance like hot meal delivery, housekeeping and laundry cannot be replaced by an ICT platform. Nevertheless, some services can support older users to:

- manage a certain task themselves (e.g. telemonitoring),
- order some goods or services themselves (hot meal, groceries and so on),
- stay in touch with their own social network.

Taking into account the fact that the current elderly generation have not grown up with digital technology and assuming that a virtual platform can no longer be ignored in the future care of the elderly, it is necessary to:

- start with the introduction of a virtual platform when the older person is not yet care dependent,
- start with every day and fun things and not just link to the "frail elderly" as this could be stigmatizing,
- involve the environment: carers, health professionals, neighbourhood and so on,
- provide a simple platform with only a few applications that can be expended later and adapted to the degree of dependence on care of the elderly,
- provide a price friendly system: starting with a subscription and the possibility for expansion and additional costs that have be (co)funded by the government.

In the following sections an overview of the services that have been foreseen for the HEREiAM platform is presented.

3.2.1 Healthcare services

For elderly people who want to maintain their independence within the comfort of their own home, health care services might be the ideal solution. All health care practitioners have to be able to log in to a unique multi-disciplinary healthcare application. It is the patient or a counsellor that gives access to this information by using the HEREiAM platform. Safety procedures, as mentioned by the local authorisations, have to be taken into account.

The general practitioners are able to access their patients' data and contact them, if necessary. The patient at home will be able to read the message and, eventually, if the doctor requested an appointment, he/she can schedule it and save it in the HEREiAM agenda.

Different types of devices can be connected to the application: body scales, glucometers, blood pressure monitors, and so on. All data gathered are automatically stored in the patient's electronic healthcare record.

3.2.2 Welfare services

Agenda management

in the HEREiAM platform it is important to foresee an agenda that can be managed by the user or his near relatives, but that also allows synchronisation of appointments of external caregivers. If a conflicting appointment has been made, it is the responsibility of the user to see which appointment has to be moved, and to take action to get it solved. The agenda can be shared with their children of near care givers. Indirectly they can stay in touch with everything their parents do. The HEREiAM platform can be programmed to generate reminders before the next appointment.

Communication services

The social network of the elderly is very important in the context of their care. Spouse, children and neighbours take a very vital role in the caring of the older person. Different kind of communications will be offered by the HEREiAM platform:

- Videocall service - interesting to maintain social contacts, not to build them (especially with children and grandchildren),
- Message service - to link different messages generated by external services with the user at home.

3.2.3 Safety services

Feeling safe is an important item for the well-being of the elderly, since insecurity affects mobility, activity patterns and quality of life. Half of the seniors struggle with insecurity. Falling is still a problem for seniors and this increases with age and with the amount of care they need. This is the reason why these services are very important. In all European countries, there is a well organized infrastructure concerning personal alarm systems. The HEREiAM platform should not provide this service itself, but of course the hardware of the HEREiAM platform could be used to improve the personal alarm services.

3.2.4 Comfort services

When older people start using a digital platform, the services offered must not be based on care-dependent elderly only. Older people have to learn through comfort services (shopping, video calls, games, social networking), so they can get used to the time that they will really have the need to use a system for health purposes. In the following paragraphs, a few services that should be foreseen in a digital platform designed for the elderly.

Shopping and groceries

Elderly people like to do their shopping themselves but, if necessary, they need it to be delivered. The application can communicate with a grocery shop to place an order and arrange delivery. Users can add items to their shopping cart before approving it to be transferred to a shop. It is foreseen the possibility for the users to make a list of favourite products, so they can create a new shopping list easily. As soon as the order is confirmed by the deliverer, the appointment relative to the expected delivery is visualized in the HEREiAM Agenda.

Other additional services

It should be possible to expand the system so it can be adapted to the specific needs of a user. Other optional services can be added to the system on demand of the user. All these appointments can be shown in the HEREiAM Agenda.

3.3 Learn from Dutch Market

Dutch partners in charge of market investigation studied and evaluated a few platform in a R&D phase or already present in the market, to highlight their pros and cons. In this Section a table that summarize the platform taken in consideration will be shown, without going in details, since that was not part of this thesis work.

Service platform	**Device**	**Character**
ABC TV	TV, touch PC, tablet	Market product
Carescreen	Tablet	Market product
Comficare (Van Dorp)	TV, tablet	Market product
CompanionAble	Robot	Research
Connectedcare	PC, laptop, tablet	Market product
Cubigo	Touch PC, tablet, laptop	Market product
Minddistrict E-health platform	Tablet, smartphone	Market product
Life XS	TV, touch PC, tablet	Market product
MiBida	Touch PC	Market product
Mobiserv	Robot	Research
Netcarity	Touch PC	Research
OnsNet	PC, laptop	Market product
Pal 4	Touch PC	Market product
Philips Amigo	TV	Research
Soprano	TV	Research
Vicasa	Touch PC	Market product
Viedome	Touch PC, TV, laptop	Market product
ViePlus	Touch PC	Market product
WikiWijk	Internet service	Market product
ZorgTV Proteion	TV	Market product
Zuster Ria (Techxx)	Internet service	Market product

Table 3.1: Overview of existing Dutch service platforms.

3.4 Learn from Users

Based on the overview of service platforms and current trends presented in Section 3.3, it is clear that finding out how users experience these technologies and whether their findings and opinions match the information gathered from the service platform providers is of emerging importance. Therefore, older adults were invited to evaluate the usability of existing service platforms and to give feedback that would be of interest for the development of the HEREiAM platform. Two user sessions were performed, one in The Netherlands and another in Italy, consisting of a combination of user profiling questionnaires, service platform testing, usability questionnaires and a focus group.

3.4.1 Target group

The HEREiAM project aims at improving the autonomy and quality of life of older adults, providing them with a TV-based platform that enables to access services for self-care, social networking and to manage daily activities at home. The choice for a TV-based system is based upon the familiarity older adults have in using the TV and the digital divide caused by the lack of broadband Internet connectivity in certain areas. Based on these aims, three target groups have been identified:

- in Italy, older adults (65+) living in autonomy, with no severe physical or cognitive impairments,
- in the Netherlands, older adults (65+) with higher incomes living in rural areas,
- in Belgium, older adults (75+) with a Katz [74] score for support dependency of 3 or higher.

3.4.2 Research questions and goals

As described above, the service platform to be developed in HEREiAM will be provided on a TV. Interaction will be done with a standard remote control. The user sessions were organized in order to find out user requirements and user needs. The study aimed at gathering a deeper insight in:

- the user profile of the identified target groups,
- the perceptions of existing service platforms by the identified target groups:
  - the perceived design aesthetics
  - the perceived usability of the menu
  - the perceived usability of the services/applications
- the overall acceptance of a service platform by the identified target groups,
- the user needs for additional services.

3.4.3 Methods

The user sessions with older people were conducted in Italy and the Netherlands (for Dutch and Belgian older adults). The study consisted of two related parts. The first part was focused on gathering demographic and personal information from each participant by means of a general questionnaire (see Appendix A), in order to identify an in-depth profile of the identified target groups and their needs. The second part was dedicated to the evaluation of existing service platforms and to the performing of a number of pre-defined and open tasks. The purpose was to find out what in an obstacle to an effective and efficient interaction with the selected types of interfaces and to identify any usability problem. Furthermore, the study ended with a focus group in which the participants discussed their experiences with the service platforms and provided suggestions for future services and designs. The main focus of the user tests was on:

- user profiles,
- user perceptions,
- design aesthetics,
- usability,
- user acceptance,
- additional user needs.

The studies took place at two locations in Europe: in local elderly association centres in Italy and in the Smartest House of the Netherlands (Dutch & Belgian older adults).

3.4.4 Location and equipment

Location: the Italian user session took place at the conference room of two different local elderly associations operative in Cagliari: "Società di Sant'Anna ONLUS" and "ANTEAS - Associazione Nazionale Terza Età Attiva per la Solidarietà". The test rooms were equipped with the required hardware and software. The Dutch and Belgian user sessions took place at the Smartest House of the Netherlands. This test and demonstration facility looks like a home environment and was equipped with the required hardware and software.

Equipment: in Italy, two existing service platforms were presented and used during the user sessions, one was a TV-based system (KeepInTouch) and the other a touchscreen-based system (Eldy). Additionally, at least one audio-recorder was used for the interviews and focus groups. A digital camera was used to take high-resolution images of the users and user-test setting. In the Netherlands, four service platforms were presented and used during the user sessions with a variety of input and control possibilities. Besides touchscreen-based systems (Viedome, Vicasa and MiBida), also a Digital TV with set-top-box was available at the location to demonstrate and use a service platform (ABC TV).

3.4.5 Measurements

The above mentioned user research questions were answered collecting data by using different measurement instruments and with different data collection modes. During the user sessions the following aspects were measured:

- **user profiles** (measured by a general questionnaire and reported by experimenters). Background information, such as socio-demographic characteristics, cognitive abilities, experience with computer technology were gathered by a general questionnaire, filled in when giving informed consent,
- **user perceptions** (gathered through interviews, questionnaires, and focus groups). An appropriate method to study user acceptance is by means of interviews/focus groups and diary studies. The interview/focus group moderator can elicit in-depth information of the perceptions, opinions, beliefs, and attitudes [70] of users about the system,

- **design aesthetics** (gathered through interviews, questionnaires, and focus groups). Similar to the user perceptions, design aesthetics were gathered during the focus groups, eliciting perceptions on specific and overall design aspects (e.g., colour use, icon design, etc),
- **usability** (gathered through interviews, questionnaires, and focus groups). The interviewed commented on specific UI flaws, but also on their likes about certain aspects of the functionality of the system. The usability of the UI was further studied by means of the (translated) IBM usability questionnaire [60],
- **user acceptance** (gathered through interviews, questionnaires, and focus groups). User acceptance was gathered during the focus groups, eliciting perceptions on the acceptance of specific services and service platforms in general (e.g., in respect to usage, privacy, and so on),
- **additional user needs** were also gathered during the focus groups, eliciting additional needs in respect to the services that were provided by the various service platforms (e.g., need for comfort services, groceries, e-mail, and so on).

3.4.6 Procedure for the evaluations

In both user sessions, participants were welcomed and a plenary introduction (15 minutes) was given by one of the experimenters to introduce the study procedure. It was emphasized that the session aimed to test service systems and not users performances. After this, participants were asked to read and sign an informed consent form. If necessary, participants were supported by the experimenters in filling in the forms. The informed consent stated what was being studied, ensured anonymous analysis, announced that audio and image recordings were going to be made, and made clear to the participants that they could withdraw their consent and cooperation at any given point in time during or after the study. Then, participants were invited to complete well-defined tasks with the platforms, while their behaviours were observed. No extra documentation or user manuals were provided because it was important to evaluate for each platform the interface itself and its intuitiveness. Before starting with the test, users were encouraged to become familiar with the systems for a few minutes. Then, participants were conducted step by step through the execution of tasks assigned and were asked to express their thoughts aloud while interacting with systems. One experimenter sat next to the participant while he/she was performing the tasks (pre-defined and open) and objectively took notes of everything that users said, without attempting to interpret their actions and words. The experimenter noted down all relevant behaviours (including problems encountered) while interacting with the platforms. After performing tasks, participants were invited to complete the Post-Study System Usability Questionnaire (PSSUQ) [60] to provide an overall evaluation of the system they used. The questionnaire contains 19 items that are 7-point graphic scales, anchored at the end points with the terms "Strongly agree" for 1, "Strongly disagree" for 7 and a "Not applicable" (N/A) point outside the scale (see Appendix B for the complete questionnaire). At the end of all user sessions, participants were debriefed and received an information sheet about the goals and following steps within the HEREiAM project. In Italy the user sessions were performed in two days, starting at 15:00 and ending at 19:00. Each participant spent 20 minutes per service platform (total 40 minutes) and 30 minutes on the questionnaires. For each system under test, users were asked to perform a set of specific tasks as described in 3.4.8.

3.4.7 User sessions in the Netherlands

During the user sessions in the Netherlands, four service platforms have been tested: ABC TV, MiBida, Viedome and Vicasa. The user tests were performed in two days, with thirteen user each, from The Netherlands the first day and from Belgium the second. The Dutch users' average age was 71.24 ± 6.88 and the Belgian users' average age was 78.15 ± 4.26. Since this part of user testing has not being performed for this thesis work, it will not be described in details. Findings gathered from those users tests together with the ones that will be described in 3.4.8 helped in the definition of system requirements and technical aspects.

3.4.8 User sessions in Cagliari

November 2013 - first day of testing

Twelve seniors ($M_{age} = 69.72 \pm 6.6$; 3 females and 9 males) members of the local elderly association "Società di Sant'Anna ONLUS" in Cagliari were invited for the testing of two existing service platforms. With the exception of two participants, everyone wanted to try, at least, one of the systems proposed. With regard to educational qualifications, the majority of participants had a high-school diploma, one of them a degree and the rest a primary or a secondary school certificate. Seven of the participants lived together with their partner, two with their children and three people lived alone. Regarding computer and Internet usage, the majority of the participants uses them every day or, at least, every week. A few of them said that they never use them. The answers for PC and Internet are identical, this suggests that when people use PC, the main reason is to go online. Regarding the tablet, the situation is diametrically opposite: almost everybody said that they never use it, only a few of them use it regularly. Eleven of the participants use mobile phone and everybody watched TV on a regular basis (11 daily, 1 weekly). Regarding the health-oriented technology, only a few participants asserted that they use it regularly. Half of them admitted that they never use it.

January 2014 - second day of testing

Eighteen seniors ($M_{age} = 70.83 \pm 5.2$; 12 females and 6 males) members of the local elderly association "ANTEAS - Associazione Nazionale Terza Età Attiva per la Solidarietà" in Cagliari were invited for the testing of the two service platforms. The majority of participants had a high-school diploma (55.6%), two of them a degree (11.1%) and the rest a secondary school certificate (33.3%). Sixteen of the participants lived together with their partner, only two of them lived alone. Regarding computer usage, the frequency of usage was lower than the participants from Sant'Anna (6 never, 1 less than once a month, 2 more than once a month, 1 weekly and 8 daily). Seven participants never use the Internet and one participant reported to have used a tablet. All participants use mobile phones and seventeen reported that they watch TV on a daily basis (1 weekly).

The answers given in the user profile questionnaire are summarized in the following figures. Figure 3.1 shows which ICT technologies are daily used by respondents, while results related to their leisure activities and lifestyle are shown in Table 3.2.

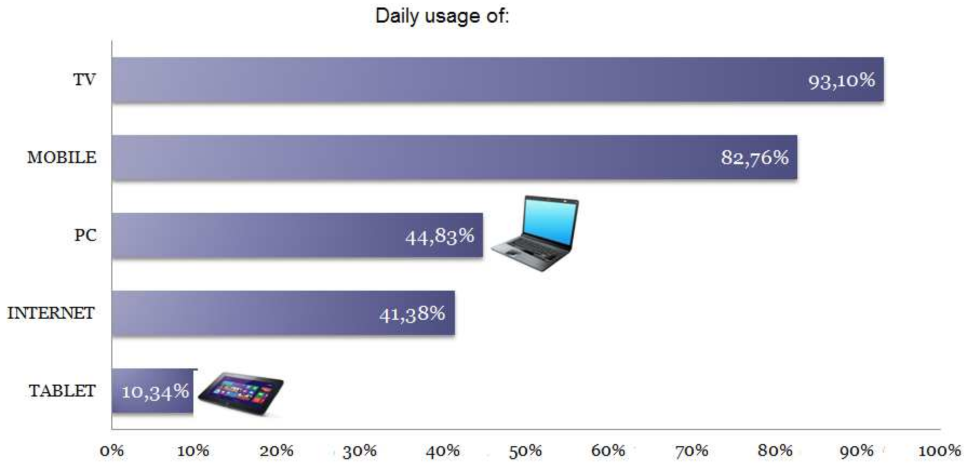


Figure 3.1: User profile questionnaire: daily use of ICT technologies.

How often do you perform the following activities?	Never	Every year	Monthly	Every week	Daily
Go out (e.g., shopping, bus trip, restaurant...) with relative(s)/friend(s)	6.9%	10.34%	20.69%	17.24%	44.83%
Organize social gathering/meals	10.34%	37.93%	24.14%	20.69%	6.9%
Physical activity (e.g., walking, sports, gym...)	17.24%	3.45%	6.9%	27.59%	44.83%
Play card games	67.86%	14.29%	7.14%	3.57%	7.14%
Go to cultural events (e.g., museums, concerts...)	14.81%	33.33%	11.11%	22.22%	0%
Travel	13.79%	65.52%	17.24%	0%	3.45%
Play board games	86.21%	10.34%	0%	3.45%	0%
Craftwork	17.24%	17.24%	13.79%	13.79%	37.93%
Play brain teasers/puzzles	68.97%	6.9%	0%	13.79%	10.34%
Play computer games	72.41%	0%	3.45%	6.9%	17.24%

Table 3.2: User profile questionnaire: results related to the leisure activities

Including the members of two different elderly associations, we had a mixed participant group with variations in gender, age, education, family situation and affinity with technology. Therefore, findings can be applied to the target population. The majority of participants was easily able to complete their tasks quickly and efficiently without any trouble. In general, the participants were enthusiastic about the functionality of the systems and about the added value a service platform could offer them. Various participants were surprised about their skills in dealing with unfamiliar technology. In the following sections, firstly the two different individual service platforms will be described, then, based on heuristic evaluation techniques, the observations and comments from the participants during the user sessions will be reported and, finally, the user friendliness (measured via the PSSUQ questionnaire [60]) of the different platforms will be compared.

KeepInTouch

The first platform that was experimented by the users was KeepInTouch (KIT), a low-cost tele-home-care system based on the Digital Video Broadcasting Terrestrial Technology (DVB-T) [43][42]. The goal of KIT is to give older or disabled people the chance to monitor their blood pressure, heart rate, weight and glucose levels from the comfort of their own homes and to share results in real time with physicians. Since it employs common TV sets, KIT was a good opportunity to explore how successful a TV-based service platform is in its mission to be user-friendly for senior citizens and how it must be improved for better ease of use. The participants were equipped with a TV set receiving the KIT application, a remote control, a sphygmomanometer and a personal body scale. They were invited to do well-defined tasks with the KIT system, while their behaviors were observed. The xlet-KIT application runs directly on the decoder from the selected TV channel. It manages data acquisition and transmission to the remote health center of the patients blood pressure, weight and glycemia records. The graphical user interface available for the KIT care service consists of three main environments (see Figure 3.2). On the top-right corner of the screen, a small area provides the TV program being broadcasted simultaneously by a local channel. On the top-left corner, a larger panel with word balloons helps patients in the process of acquisition and transmission of their physiological parameters. The patient's name, physiological measurements and eventually physician's feedback messages are displayed on the bottom of the screen. The patient interacts with the service by pressing proper buttons on the remote control of the set-top-box remote. The user uses the different colored buttons of the decoder to transmit the results to the remote health center.

Figure 3.2: Screenshot of the KiT Xlet.

Description of the tasks

The trial was carried out using the KIT system, a sphygmomanometer and a personal body scale. Before starting with the test, users were encouraged to become familiar with the system for a few minutes. The user ability to interact physically with the application, focusing on the efficiency of the system has been evaluated.

The goal was to identify any usability problem and determine the users' satisfaction and perceived usefulness in the use of the system. During the test, users were invited to complete the following tasks:

- **measure body weight**. Test users were invited to measure their personal weight and to press the blue button on the remote control to share results with the health care provider,
- **measure blood pressure**. Participants were asked to measure their blood pressure value using the sphygmomanometer and to press the blue button on the remote control to share results with the doctor.

The steps expected for the user to go through in completing task 1 and 2 are shown, respectively in Figure 3.4 and 3.5.

Evaluation based on users feedback

The study involved 14 participants (5 male and 9 female). Ages varied from 63 to 82 years

Figure 3.3: A participant performing tasks with KIT: day 1.

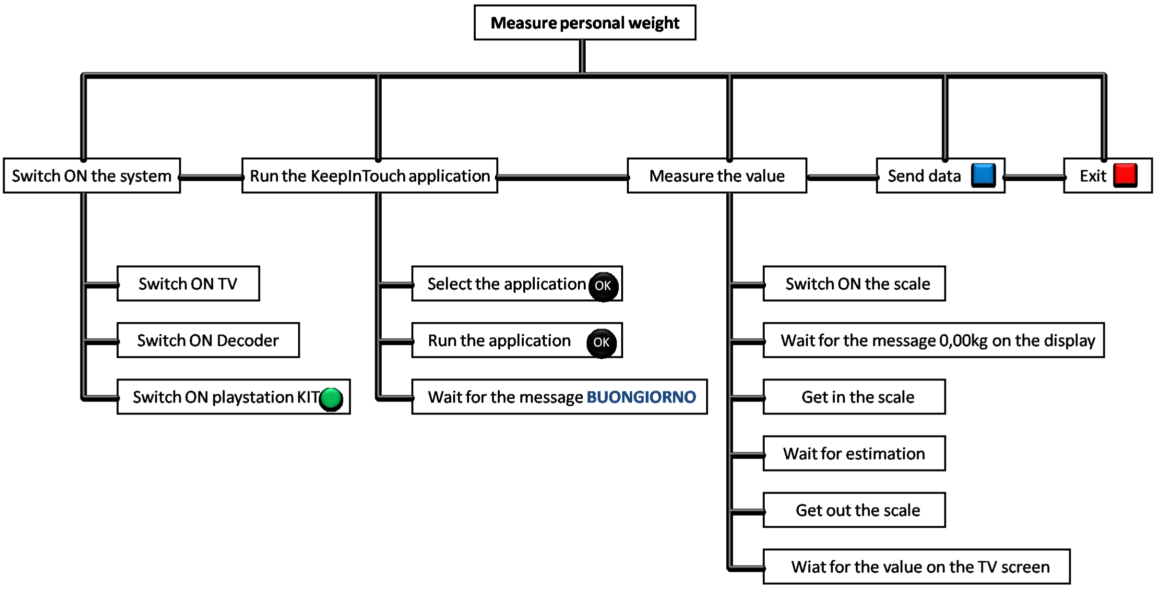


Figure 3.4: Task 1: Measure body weight.

old. All the participants were interested in joining the experiment and in applying what they had seen during the KIT system presentation. Before the test, participants reported that they had familiarity with the use of a remote control but limited experience using colored-buttons. The majority of them had difficulty understanding the relation between color and function reported in the xlet application. Despite that, the 85.7% of the participants was able to complete their tasks quickly and efficiently without any trouble. The majority was very satisfied with the user-friendliness of the KIT system.

Regarding task 1, most of the participants were able to measure their weight and send the results by pressing the blue button on the remote control without any training time. The scale required participants to tap it to turn it on, to wait for two zeros to appear and then to step on it to get their weight recorded. Only one participant (76 years old) had difficulty with this task and needed assistance. Some participants were of the opinion that a wider scale platform should be adopted, to provide more surface area on which to stand.

Although participants were familiar with measuring their blood pressure, some of them had difficulties in placing the cuff and in switching on the sphygmomanometer during the

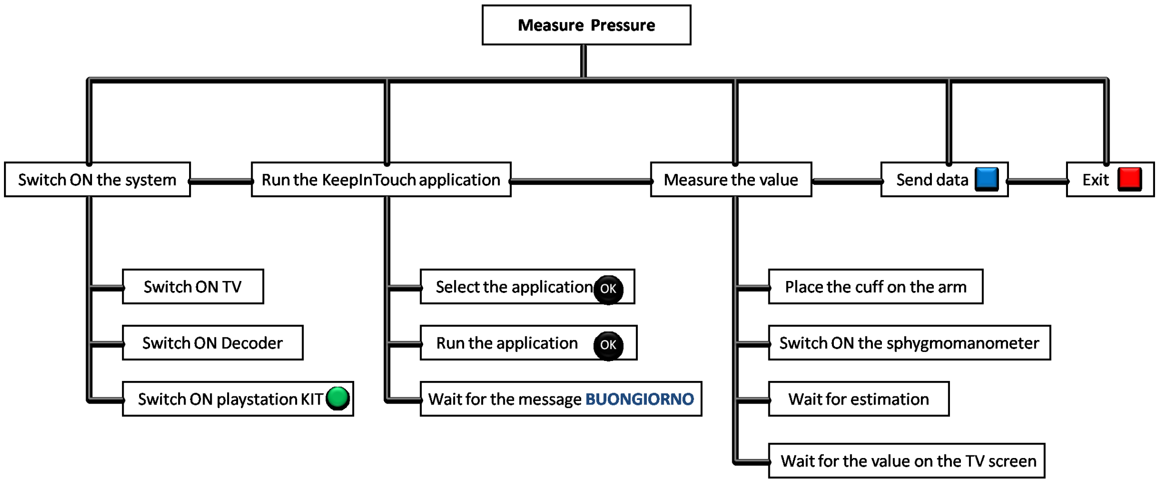


Figure 3.5: Task 1: Measure blood pressure.

task 2. Whenever they attempted to start the measure, the Start button was pressed twice turning off the device. Two participants were concerned because their values were particularly high, they re-checked 2 times and values barely went down.

Figure 3.6: Participant performing tasks with KIT: day 2.

Regarding the KIT interface, some participants didn't like how results were displayed on the TV screen. They were of the idea that an easier interface with less options and graphics (sponsors, Partners' logos and so on) and bigger fonts could be preferable. Some participants were of the idea that the TV screen should be organized in a different way, showing only the results (weight and pressure values) and the options EXIT and OK. The broadcasting of the television program during the use of the system was considered useless by the majority of the participants.

Positive comments

Positive comments from participants about the KIT system:
"I like the idea of reading my weight on the TV screen rather than on the scale display at ground level. I don't have to strain my neck to look down. That's nice" (76 years old, male)
"I think that the possibility to manage my health status at home and to transmit data to clinicians is actually a great alternative to going into the medical office" (70 years old, male)

"I really like this system, it's simple to use." (67 years old, female)
"I think that this platform could give me more motivation to lose weight and stay healthy. If data could be shared every week with a trained specialist, I would be interested." (71 years old, male)

Negative comments
Negative comments from participants about the KIT system:
"I'm not sure that I would use this platform by myself since I'm not entirely comfortable with using it without your supervision" (74 years old, male)
"I get confused if the screen displays the application and a television program at the same time. I prefer to stay concentrate on my task." (63 years old, female)
"It would be really great if there was a way to send data automatically to the doctor any time a value is measured, without using the remote control. I get confused with all these colored-buttons and there are too many information to read on the TV screen" (82 years old, female)
"For the moment I feel good and everything is going well. Why should I measure my blood pressure daily? I don't have a need for it at the present time. I'm not sure that I would use this system." (72 years old, male)

Conclusion
Thanks to the information gathered during the user sessions, a few general conclusions about the KIT system could be draw. Regarding the instrumentation used, it could be better to change the body scale with an automatic one. The one used required participants to tap it, wait for three zeros to appear and then step on it to get their weight recorded; these actions were not very intuitive to perform. The new body scale should be automatic, with no tapping or waiting time. Also, it should be bigger than the one used, in order to make them feel well in balance and not afraid to fall.

Analysing the participants' comments about the KeepInTouch interface, we can state that a few changes are in order:

- the hints given by the virtual nurse appear too big and, according to some participants, unnecessary. It could be useful to change the text or provide suggestions in a different way,
- the streaming of the TV channel during the measurement of the physical parameters is a little bit distracting. It could be better to present it differently or remove it,
- many participants suggested that it would be better to see the data measured in a bigger font size, in order to see them more clearly. Another suggestion is to automatically send the data to the doctor, once the measures are done, to avoid confusion due to the colored buttons. The clearest window could be with only the patient data (name and measures) and the "Exit" button.

Eldy

The second system tested by the elderly was Eldy (www.eldy.eu), a free software package conceived by an Italian non-profit organization and designed specifically for seniors who have little or no computer experience. The goal of the software is to help senior citizens to use

computers and access the internet. Thanks to Eldy, users were able to experience an interface that makes easier to read the latest news, see weather forecast, send e-mails, video-call friends and share photo. Since it is completely free and covers 25 different languages, Eldy software was a good place to start in order to establish how users from Cagliari experienced the usage of a touch screen interface and to understand which services were more appreciated. Users were equipped with a Samsung Galaxy Note 10.1 tablet with the Eldy application installed and they were invited to perform well-defined tasks with it and simply explore it freely, while their behaviors were observed. No extra documentation or user manuals were provided to evaluate the interface itself and its intuitiveness.
The Eldy system includes 9 services, presented as 9 large buttons on the screen, each with a different icon. The simple nine-buttons main menu, called "The Square", has large texts and high color contrasts that makes it easy to see, understand and operate [63].

Description of the tasks

The trial was carried out evaluating the user's ability to interact physically with what was shown on the screen, focusing on the efficiency of the system. During the test, users were invited to complete the following tasks:

- **weather forecast consultation (Task 1)**. Test users were invited to read the current weather conditions of Cagliari, the forecast for later in the day and for the day after. Since the application allows to check the weather forecast for any city in Italy, participants were asked to get information regarding another city, clicking on the bar next to "how is the weather in:" and selecting the city they were interested in. A screenshot of the weather forecast page can be seen in Figure 3.7,

Figure 3.7: Screen capture of the Eldy weather forecast functionality.

- **reading on-line newspaper (Task 2)**. Participants were asked to look for an on-line newspaper (Figure 3.8), clicking the icon News from the main menu and selecting the newspaper they're interested in,

- **writing a text (Task 3)**. Participants were invited to type their name using the touch-screen virtual keyboard.

The steps expected for the user to go through in completing task 1 and 2 are shown, respectively in Figure 3.9 and 3.10.

Evaluation based on users feedback

The study involved 14 participants (6 males and 8 females), from 63 to 82 years old, members

Figure 3.8: Screen capture of the Eldy newspaper page.

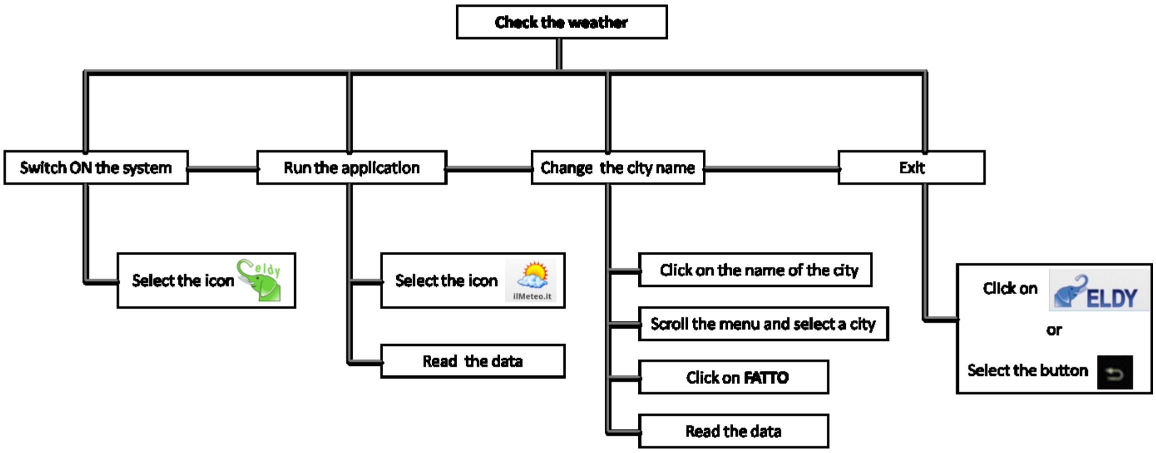


Figure 3.9: Task 1: Weather forecast consultation.

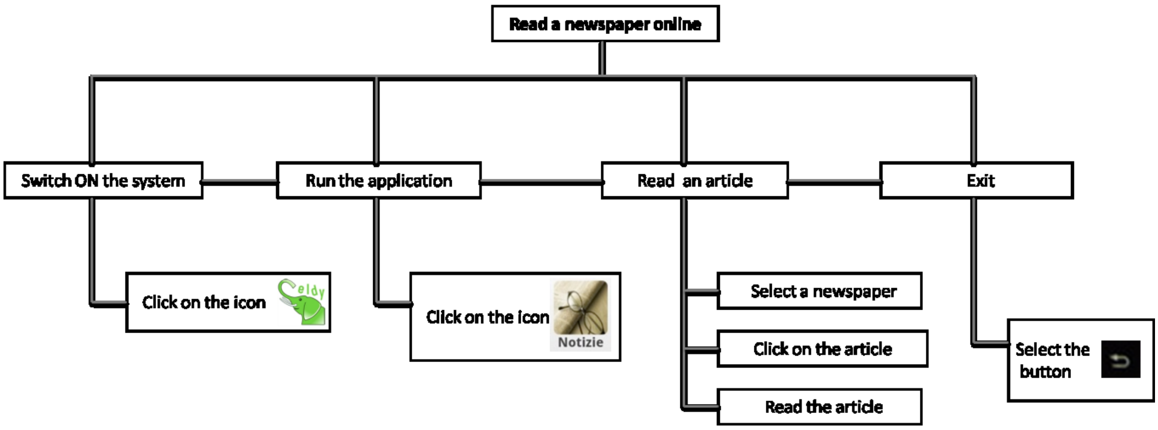


Figure 3.10: Task 1: Reading on-line newspaper.

of local elderly associations, reasonably healthy and with no vision impairments. None of them had ever used tablets before. Participants found the software engaging and helpful. Overall, the majority of them was easily able to handle the touch-screen interface intuitively. The majority was positive about the user-friendliness of the Eldy application. In particular, some users were enthusiastic about the speed with which they can consult weather forecast or keep up on the latest news.

Figure 3.11: Participant performing tasks with Eldy: day 2

Although the interface was perceived as clear, well structured and understandable by participants, some of them had difficulties in selecting one specific city on the touch-screen during the Task 1. Whenever they attempted to scroll down the list of the cities available, the Home button of the tablet was selected and the central home screen was displayed, making it extremely hard to select one city. Regarding Task 2, when looking for newspaper articles some participants clicked on button "Useful pages" instead of "News". The majority of the participants were able to browse through the newspaper external web page but the layout was quite disorganized for them (pages with too many advertisement, links and sponsored stories) and the article content wasn't visible at a first glance. During Task 1 and 2, some participants were complaining that although you can enlarge the font size, the applications do not really adjust the page so you end up scrolling a lot. Lastly, the difficulty with the Task 3 for most participants was to type capital letters on touch screen. Some participants pressed and held (or pressed twice) the shift key before starting typing the first letter of their name and got confused when all capital letters appeared. At the end, some users were more interested in exploring the Poems application, rather than performing the proposed tasks. They were enthusiastic about the possibility of reading poetry and of sharing their poetic works with others.

Positive comments

Positive comments from participants about the Eldy software:

"This device offers some fun and entertaining apps that might keep me busy at home. I'm very interested in submitting my poetic works in this system and receiving comments from other users. I think it would be fun." (72 years old, male)

"I'm a limited computer user but this tablet seems to be very easy to work with. I would use it daily to read the newspaper." (70 years old, female)

"No more cables? Great." (72 years old, female)

"I like these larger icons that makes it easier to see the different choices you can make." (80 years old, male)

"I like this interface to check the weather because it doesn't have too many dialog boxes popping up" (70 years old, male)

"I will be recommending this device to my wife who wants to use the computer/Internet, but is easily frustrated with the whole thing and she is afraid to try." (75 years old, male)

"This is something that I can actually function and use." (63 years old, female)

Negative comments

Negative comments from participants about the Eldy software:

"I had to scroll the menu a lot to change city in the weather application. It would be too annoying for me." (71 years old, male)

"I'm okay with the touch-screen, but I'm not sure if I want to use it all the time. It seems to

require good control for gestures. It would be tiresome." (72 years old, female)
"I like pushing buttons, I don't like the touch screen." (80 years old, male)
"Honestly, I have no need for these services right now." (70 years old, male)

Conclusion

Analysing the results of the test regarding the Eldy system, it was possible to evaluate the participants' appreciation to the services offered by the system. They appreciated very much the "Poetry", "Weather" and the "News" services. The thought of having a reading activity to perform as a diversion during the day was considered a very nice idea by the majority of the participants. Speaking about additional services, some of them reported that they would also like the possibility to have games to play, even though in the questionnaire very few of them affirmed to play card, board or PC games. Regarding the possibility of having grocery delivered at home, everyone affirmed that they would much rather going shopping by themselves than order it, because they see the shopping activity as a pleasant way of going out, meet and talk to other people. The same concept applies to the e-prescriptions: they prefer to go to the physician in person, because it is an excuse to spend a few hours with other patients.

Usability results

Despite the claimed user-friendliness and the overall positive feedback by the group of expected users about Eldy, compared to KIT, the two platforms mark very similar usability scores on the PSSUQ. As we can see in Figure 3.12, both platforms scored highly on the scale, their scores fall above the average score of 4 and there were no significant difference between them.

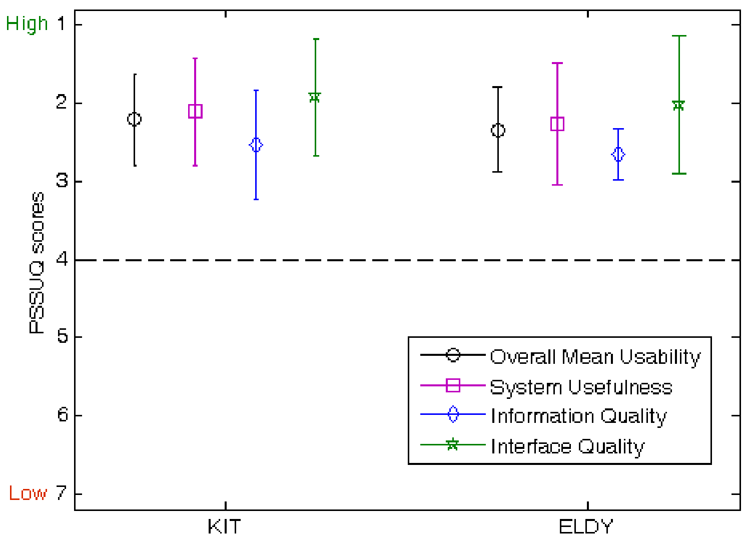


Figure 3.12: PSSUQ mean usability score.

3.5 System requirements

Keeping in mind the analysis of the state of the art and of the user test sessions carried out both in Cagliari and in The Netherlands, the following general requirements and principles for a sound and effective design have been identified.

- The consideration of age-related changes in perceptual, motor and cognitive abilities is required to guarantee accessibility. However, awareness of the importance of these aspects must be coupled with the acknowledgement of the importance of the compensatory processes that older people develop to adapt to the changes, and by the crucial role played by motivation, affection, and experience ("learning by doing") in supporting them.
- Acceptance of IT technologies is a complex and multifaceted issue. Drawing from theories of ageing and from the user sessions findings, one of the primary goals of the design should be to turn technology into something "familiar", i.e. artefacts that are perceived as belonging to their own world, that fit into their daily practices, and that can be interpreted and used exploiting common and practical knowledge acquired through experience. "Familiarity" knocks down two main barriers to the accessibility to, and acceptance of, digital technologies: the lack of perceived advantages of the technology and the perception of a negative trade-off between the investment of personal resources required and the expected benefits.
- The design should be grounded on the affective and aesthetic value of artefacts besides that on efficiency-oriented principles, and should consider the specific meanings and values associated to the home, e.g. the role of the home in maintaining identity and independence.

In this section, a few of the requirements that have been identified during user tests will be listed.

3.5.1 General requirements

- **Requirement 1: address everyday problems and enhance perceived usefulness**
  - ☐ Description: make sure that new technologies fit in the daily lives of the older adults correlates to their daily activities, so that the users see the usefulness. Platform that can host a wide variety of services where the older adult can choose from, ranging from comfort services, welfare, safety and care. Platform can vary in complexity according to the needs of the older adult.
  - ☐ Rationale: user studies show that reluctance to explore new technology in elderly people is due not only to a lack of skills but, above all, to a lack of perceived advantages and benefits. When older adults see the added value of new technologies, they are willing to do an effort to get used to it.
- **Requirement 2: make use of familiarity-based design**
  - ☐ Description: Technologies should look familiar to the user or appeal to familiar features.

- The platform should be offered on a TV, a device where almost all older adults are familiar with.
- The system, but also user manuals, should make use of words, phrases and concepts that are familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

☐ Rationale: familiarity-based design can lower the threshold in trying and accepting new technologies. What is new, unexpected or unknown is perceived with suspicion, concern or awe. Providing a device that looks familiar could prevent rejection.

- **Requirement 3: design for the living room**

☐ Description: the living room is a common space in the house used by different people for a wide variety of purposes, ranging from social activities, entertainment and relaxation. The system should fit well this atmosphere.
- Avoid movable objects with wires, to maintain tidiness and to avoid as much as possible additional risks for falls or occupation of (already reduced) available domestic space.
- The GUI appearance should not be stigmatizing.

☐ Rationale: what is of added value for one person is not necessarily for others. Each individual has different skills and needs. Each individual should experience both perceived usefulness and perceived usability.

- **Requirement 4: design for reduced physical and cognitive abilities**

☐ Description: design of interaction interfaces should take into account sensory changes, motor difficulties and cognitive decline.
- Readability of information. Make use of large font sizes, strong contrasts and fonts that are suitable for either an interface or a manual (eyesight).
- Sounds have to be loud and not abrupt.
- Avoid complex hierarchical structures. The information structure has to be as linear as possible, restricted to maximum three levels, in order to minimize the number of steps to reach a given screen.
- The interface must look tidy and organized. Avoid clutter and decorative elements that serve no functional goals, since it distracts users from necessary information.
- All elements of the interface should be clear and unambiguous. Graphical rendering of digital objects should use a stylized rather than a realistic way.
- Use animations sparingly and purposefully. Quick animations are difficult to perceive. Animations should be smooth and slow. Give users the time to read and respond. Avoid messages that appear automatically.

☐ Rationale: insufficient adaptations to age-related changes leads to difficulties in dealing with technology, frustration and,possibly to rejection.

3.5.2 GUI requirements

- **Requirement 5: design a GUI specifically for presentation on a TV display**

- ☐ Description: TV displays have a higher contrast and saturation levels than computer monitors. Therefore it is important to take into account some guidelines when working with solid colors:
  - Use pure white (#FFFFFF) sparingly. It causes vibrancy or image ghosting. Instead use #F1F1F1.
  - Avoid bright whites, reds, and oranges. It cause bad distortion.
  - Make sure that the GUI looks nice in various display modes that TVs have (standard, vivid, cinema/theatre, game, and so on).
- ☐ Rationale: older adults are familiar with TVs as a qualitative and reliable mean. When the GUI of a TV platform is perceived as substandard, people might lose their confidence in TV technology.

- **Requirement 6: minimize the complexity of 10 foot UI's**
  - ☐ Description: on a TV, the viewable area should display less information overall, and what's there should focus on a confined set of tasks. The goal of 10 foot user interface design is to make the user's interaction as simple and efficient as possible, with few buttons while still having an intuitive layout, in terms of accomplishing user goals.
    - Keep it simple and restricted to a minimum of core buttons.
    - Keep all content "above the fold" and fully viewable on the screen without scrolling down.
  - ☐ Rationale: keep the interface as simple, tidy and user-friendly as possible, in order to make the learning curve less steep.

- **Requirement 7: take into a viewing distance of 10 feet (3 meters)**
  - ☐ Description: all GUI elements, i.e. menus, buttons, text fonts, and so on, are theoretically ergonomically large enough to read easily at a distance of 10 feet (3 meter) from the display.
    - Digital objects should be distant enough one from the other to be perceived as different objects.
    - Break text into small chunks that can be read at a glance, and limit paragraphs to no more than 90 words. Keep line length at about 5-7 words per line. Never go shorter than 3 or longer than 12.
    - Avoid lightweight fonts or fonts with both very narrow and broad strokes.
    - Target body text needs to be around 21pt on 720p and 28pt on 1080p. Text smaller than 18pt on 720p and 24pt on 1080p should be avoided.
    - Remember that light text on a dark background is slightly easier to read on TV (compared to dark text on a light background).
  - ☐ Rationale: the living room, the TV in particular, is associated with entertainment and relaxing. The user is in "couch mode". An easy interface that does not demand much effort to use is required to fit this atmosphere.

- **Requirement 8: navigation should be TV-originated**
  - ☐ Description: by connecting interactivity to TV, the development of design must bear the TV characteristics and viewer's baggage and customs in mind.

- TV screen space is plentiful on the sides, but vertical space is precious (even more on wide screen TV's). Therefore, it is best to only use side category navigation rather than top navigation. Even more fancy is to include navigation as an overlay.
- Avoid visual pollution. Relevant information can be lost when covered by interactive elements like menus or buttons.
- Vertical scrolling, while fundamental on a desktop browser, may not be as appealing on the TV UI. Scrolling can appear less seamless, and important information may be hidden below the fold if users do not recognize that more content exists off-screen. A better approach is to make use of horizontal layouts and visual transitions between pages of content.
- Segments of your page can scroll vertically to reveal new content.
- Present onscreen "arrows" to indicate that more content exists, as well as how to reach it.
- Keep in mind the characteristics and limitations of standard hand-held remote controls with respect to usability.

☐ Rationale: older adults are used to watching TV as a passive viewer. Making the TV an interactive medium is a challenge to fit computer functionalities into an existing TV, and into the way older adults deal with TVs.

3.5.3 Remote control requirements

- **Requirement 9: design a remote control ergonomically**

  ☐ Description: older adults experience problems with respect to sensory changes and motor difficulties. Therefore it is important to take into account human factors for the design.

  ☐ Rationale: a remote control that is difficult to handle will cause frustration and can cause rejection of the system.

- **Requirement 10: minimize the complexity of the remote control**

  ☐ Description: older adults experience problems with respect to the complexity of existing remote controls. Therefore it is important to take into account some guidelines.
  - Minimize the number of buttons.
  - Avoid button combinations.
  - Provide a simple solution for text input.

  ☐ Rationale: a complex remote control leads to uncertainty and reluctance.

- **Requirement 11: offer appropriate feedback**

  ☐ Description: proper feedback mechanisms simplifies the usage of technology.
  - Immediate feedback.
  - Multimodal feedback: visual feedback on the TV and auditive or haptic feedback on the remote control.

  ☐ Rationale: a complex remote control leads to uncertainty and reluctance.

- **Requirement 12: make remote control interaction consistent**
  - ☐ Description: to lower the learning curve it is important to use the same interaction for the platform and all the services. In this way you can control all services, when you know how you control one.
    - Every action must have the same effect in every context.
    - Consistent match between TV display and remote control.
  - ☐ Rationale: consistent interaction lowers the effort needed to learn using the platform and the different services. This leads to shorter learning time, smaller threshold to start using new services, and more time to enjoy the platform added value.

3.5.4 Configuration and personalization requirements

- **Requirement 13: an open platform with a wide variety of services to choose from**
  - ☐ Description: the service platform should be a general platform offering some basic functionalities and a large set of services varying in goal and complexity. The user can choose him or herself which services to access.
  - ☐ Rationale: the better the platform and the services meet the requirements of an individual older adult, the higher the chance for accepting new technology.
- **Requirement 14: develop an overall user profile**
  - ☐ Description: for each older adult using the system a user profile needs to be developed and stored in the system containing information like contact details, age, location, social network, health condition and limitations, skills, interests and preferences, allergies, and so on.
  - ☐ Rationale: when the system has access to personal information, the system can better fulfil the user's needs and wishes.
- **Requirement 15: a customizable interface, for the platform and the services**
  - ☐ Description: an interface that can be personalized according to sensorial and motorical abilities (described in the user profile). For example larger font sizes and increased contrast ratios for people with decreased eyesight.
  - ☐ Rationale: the better the platform and the services meet the requirements of an individual older adult, the higher the chance for accepting new technology.
- **Requirement 16: link services to a database of personal information**
  - ☐ Description: based on user profiles, it is possible to personalize services to the user, in order to suggest interesting services, tailor services to the user, and even avoiding risks.
  - ☐ Rationale: tailoring the platform to customer needs and preferences automatically lowers the workload for the client and the carers. Besides, when the platform better fits the client's needs and preferences, they are probably more inclined to accept and use it.

- **Requirement 17: enable remote configuration and personalization**
  - ☐ Description: informal carers, volunteers or organisations should be able to configure and personalize platforms remotely through a web-admin page.
  - ☐ Rationale: by enabling remote configuration and personalization, it is easier and quicker to make changes to the platform when needed.

3.5.5 Privacy and security requirements

- **Requirement 18: environmental stability**
  - ☐ Description: the HEREiAM equipment itself, but also installing and maintaining it should not hamper the stability of the home environment.
  - ☐ Rationale: stability of the home environment is of particular importance. Introduction of inappropriate technology into elders' home can dramatically alter their life, especially if the installation is time-consuming and disruptive (e.g. users private space may be even too limited to permit PCs).
- **Requirement 19: privacy and informed consent**
  - ☐ Description: data should only be exchanged for the benefits of the user. Besides, clients need to be aware and understand what data is being sent out of the house and to whom.
  - ☐ Rationale: older people lack the expertise to estimate correctly the risks of their online behaviour. Therefore, they need to get protection and guidance.

3.6 Technical Specifications

The primary objective of the HEREiAM technology is to integrate all services specifications and at the same time, meet users needs, preferences and expectations. The HEREiAM Consortium has examined existing platforms and compared design alternatives based on the requirements presented in the previous section, in order to achieve the optimal solution for implementation. HEREiAM will take advantage of the open-source accessibility of Android technology to provide its users with innovative care and social services that allow them to continue living in their homes and maintain their independence. The technical specifications identified and implemented during the development of the platform will be described in details in Chapter 4.

Chapter 4

The HEREiAM platform

This chapter provides an overview of the HEREiAM ICT platform that empowers elderly people to access a rich and extensible set of personalized services through the TV set (following requirement 2, Section 3.5.1. The HEREiAM solution is based on an open and flexible platform that allows the integration of third-party services, via defined interfaces. The platform consists of different but meshing modules which form a powerful tool for all the actors involved: senior citizens, informal caregivers and third party service providers. The chapter is organized as follows: in Section 4.1 both the hardware and software components at home side will be described, in Section 4.2 modules included in the HEREiAM Service Level (Server side) will be reported, in Section 4.3 third party services that have been integrated (or are under integration at the time of writing) in the HEREiAM platform will be presented and, finally, in Section 4.4 the link between identified requirement and implementation will be described.

4.1 HEREiAM platform home-side

The Home-side of the HEREiAM platform is the part of the system that includes all the hardware and software tools operating at home, that will be described more in detail in the next paragraphs.

4.1.1 Hardware components

The hardware that the users will install in their homes includes mainly:

- Android TV-box
- Remote control and Flirc receiver
- Personal smart card and smart card reader
- Webcam
- Medical devices (if needed)
- Custom PIR sensors (if needed)

Processor	Quad Core Cortex A9r4
GPU	Octo-Core Mali 450
Memory	2GB DDR3
Internal Storage	16GB eMMC
Wireless connectivity	802.11ac Dual Band Wi-Fi (2.4GHz/5.0GHz), Bluetooth 4.0
OS	Android KitKat 4.4.2
Video output	HDMI 1.4b, up to 4K @ 30fps
Audio output	HDMI 1.4b, 3.5mm stereo jack, optical SPDIF
Peripheral interface	Gigabit Ethernet (10/100/1000Mbps), SD/MMC card reader, support HDMI-CEC, USB 2.0 port x3, OTG port x1, microphone jack, headphone jack, IR receiver
Power	DC 5V, 3A

Table 4.1: MINIX X8-H Plus characteristics.

This section presents in details all the hardware components of the HEREiAM platform, present in the users' homes. The medical devices and their integration with the HEREiAM platform will be detailed in Chapter 5, where the complete telemonitoring framework included in the system will be presented.

Android TV-box

The HEREiAM system is installed in a custom device that the user should perceive as a standard set-top-box. An Android TV-box was chosen for its main useful features, low cost and easy installation and maintenance. The Android TV-box is connected to the TV through the HDMI port and to the Internet (wireless or wired depending on the possibility of each home). From the wide range of TV-boxes present in the market the MINIX X8-H Plus, which characteristics are described in the next table, has been chosen:

The main reason why the MINIX X8-H Plus TV-box was chosen is its support for the HDMI-CEC standard. The CEC, once the HEREiAM system is turned on/off, allows the automatic switch of the TV video source from the DVB source to the HDMI source of the HEREiAM system and vice versa, without having to manually select the video source from the remote control. This function will empower the users that owns an HDMI-CEC compatible TV to have an even more simplified system. The flexibility of the MINIX X8-H Plus allows the integration of all the external modules used by the HEREiAM platform. The Bluetooth module will allow the connection with the telemonitoring devices (see Chapter 5), the USB ports will be used to connect the universal IR receiver Flirc and the other receivers/devices used to communicate with all the application installed (e.g. external webcam used for the Videocall App).

Remote control

To use the HEREiAM system, the only input device needed is a standard remote control. The HEREiAM custom remote control, developed following the requirements identified during the system specification definition (see Section 3.5.3) is shown in Figure 4.1.

Figure 4.1: Custom HEREiAM remote control.

Figure 4.2: Flirc.

As it can be seen, it only has the four arrow keys to navigate between elements of the screens, the four colored buttons, yellow, green, blue, red, to make decisions (e.g., green = accept, red = reject), the TV and HEREiAM button, respectively to turn on a TV channel and turn on the HEREiAM system, the OK button to select elements of the screen, the BACK button to return to the previous screen, the INFO button to start a video tutorial from every screen of the system, the HOME button to go back to the HEREiAM homepage and the volume buttons. The remote control can be used thanks to the Flirc IR receiver, described in the next paragraph. The remote control developed respects all requirements identified and described in Section 3.5.3.

Flirc

Flirc is an "intelligent" IR receiver that allows to reconfigure the buttons of any standard remote control in order to give them a specific function. With an easy first configuration, it is possible to associate the custom remote control to the HEREiAM platform. Flirc is a very small, low cost, USB device that is inserted in one of the USB ports of the Android TV-box and allows the system to translate IR commands coming from the remote control, converting them in instructions that will be interpreted by the HEREiAM system.

PIR sensors

The platform includes options to monitor and evaluate the users' lifestyles in order to predict safety problems, paying attention to the privacy issues reported by several elderly during informal interviews and focus groups, completely reluctant to accept any video monitoring device at home. For this purpose, for the users who want to use a home monitoring system, custom PIR sensors will be installed in each room of the house; this sensors will register the passage of the user (taking into account if he/she is entering or leaving the room) to evaluate unusual behaviours. These sensors will communicate with the TV-box using the ZigBee protocol, sending the data collected and transmitting them to the server side of the platform, to make them available to interested third parties. The data are accessible through a custom Android application, called WHEREiAM, or a web interface (still in development phase).

Figure 4.3: PIR sensor.

The PIR sensors send the data collected to the Android TV-box wirelessly, using the ZigBee protocol (2.4GHz, 40m indoor, 250Kbps). To be able to receive the data, a custom ZigBee receiver (shown in fig. 4) will be connected to a USB port of the TV-box. An Android service, running in background, will send a data request via USB to the PIR sensors at predefined times (e.g., once a day, once a week or more frequently), according to each user configuration, and will read the data received.

Figure 4.4: USB receiver.

To develop an Android service able to communicate with a USB device, the USB Host APIs must be used. A description of these APIs and the steps to be implemented to connect with a USB device are described, respectively, in Sections 5.2.1 and 5.2.2.

Personal Smart Card and Smart Card reader

To login into the system and to be able to use all the HEREiAM services, the Android TV-box is connected to a USB Smart Card reader supporting the CCID (Chip Card Interface Device) protocol. The CCID protocol allows a smart card to connect to different devices (PCs, tablets and so on) via a card reader using a standard USB interface. The personal smart card contains user id and password of the HEREiAM user and, inserting it into the smart card reader, the user will be automatically authenticated into the system. The selected smart card reader and smart card type are, respectively, the ACR38U-N1 Pocket Mate [?] and the ACOS3 microprocessor card , both from Advanced Card System Holdings Limited (ACS) [13] vendor.

The selected ACS reader supports the ACS Android Library, that is a collection of methods and functions allowing application developers to build smartcard based application in the Android platform [14].

4.1.2 Software components

This section presents all the software components of the HEREiAM platform included in the Home level. The software framework is based on the Android operating system. The home software installed in the Android TV-box is written in Java and consists mainly of the system main application, in form of an Android custom launcher, an Android service running in background that handles various events that will be described hereafter, and the system applications out-and-out.

Main application

The main application, whose interface is shown in Figure 4.5, represents the HEREiAM homepage and provides an overview of the installed apps. The custom launcher is programmed in order to display only the project approved apps and hide all the other Android system ones. The HEREiAM homepage is composed of:

- a title bar at the top of the screen, where the project logo and current date and time are always shown;
- a dedicated spot for various system notifications;
- a scrolling grid with all the installed services, at the bottom of the screen.

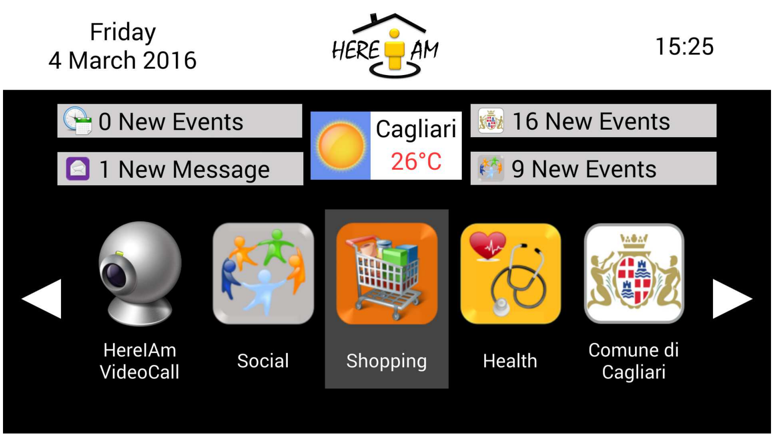


Figure 4.5: Main application interface.

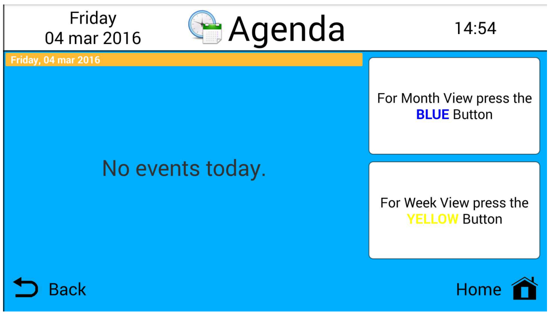


Figure 4.6: Example of daily view with no events scheduled.

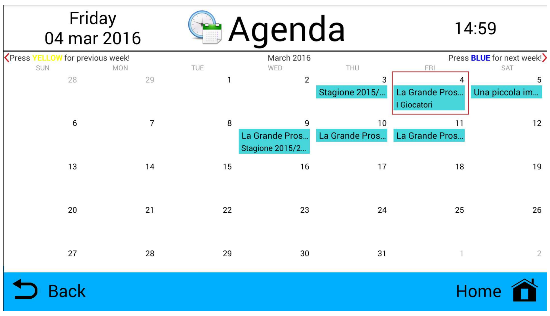


Figure 4.7: Example of monthly view.

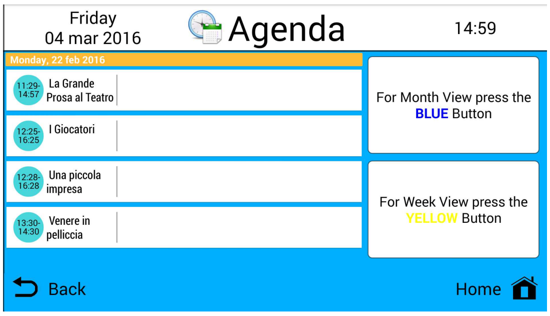


Figure 4.8: Example of daily view with some events scheduled.

Figure 4.9: Example of weekly view.

On the title bar, the current date, project logo and current time are always shown. The widgets below the title bar contain system notifications and are configurable according to the user preferences, memorized in a specific file (User Preferences) saved in the server side of the platform, described in Section 4.2. Using the left/right arrow keys on the remote control, users can move the scrolling grid of apps to select the one they want to open. The selection frame always stays in the middle of the scrolling grid, while the icons move. To open the selected application, users have to press the OK button on the remote control.

Basic functionalities: Agenda

The Agenda App lets users at home schedule personal appointments (such as a doctor's appointment with date, time and location of the meeting) and reminder notes (check vital parameters, make a phone call at a certain time, and so forth). The item on the agenda can be added by a system application or by the elderly caregivers through Google Calendar. When a user opens the Agenda App he will be shown the Agenda main screen with the daily events (Figures 4.6 and 4.8). The user will have the possibility to switch the daily view with other views: the monthly (Figure 4.7) or the weekly view (Figure 4.9). On the Agenda Main Screen the user can select an event to view its details. At this point he will be able to Dismiss or Postpone the event. If the user decides to dismiss the reminder, the task is not removed from the agenda, but the user will not get any further notifications for that task. The Agenda App is connected to the Google Calendar service through the server level of the HEREiAM platform, in order to synchronize events.

The Agenda application has been developed by Teamnet.

Basic functionalities: Videocall

As the name suggests, the videocall app allows users to make video calls. The underlying technology is based on the open source framework Linphone (http://www.linphone.org/). Once a user opens the VideoCall app he/she will be registered in background. The registration service will communicate with the Videocall cloud services in order to get a valid SIP account for the current user. Once this step is done, the app provides the user with his/her contact list (requesting it to the server, through the serviceproxy) in order to allow the user to create a video call with one of his/her contacts. In Figure 4.10 is shown the main interface of the Videocall app.

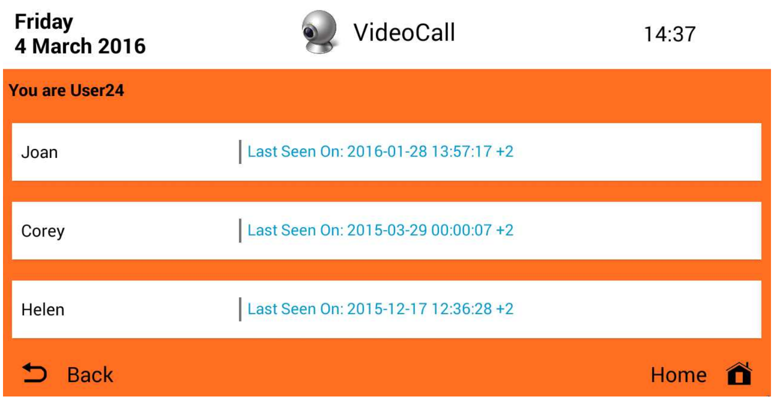


Figure 4.10: Videocall main screen.

If the user selects one of the contacts, a video call will be initiated. The receiver will be notified with a dialog containing the name of the caller and an "Accept" and "Reject" options. If the receiver responds to the video call, a new window will be shown both to the caller and the receiver where they will be able to see each other. From there the users can close the video call or switch camera, if the device has more than one camera available. This application has been developed by Teamnet and Dedalus.

Basic functionalities: Message

The Message App is used by all the HEREiAM applications and by external users, authorized to use the platform, to exchange messages with the HEREiAM users. The main interface of the Message App (shown in Figure 4.11) will be a window showing all the categories of applications able to generate messages. When a new message of a certain category is present, inside the icon of this category will appear a notification showing the numbers of unread messages.

Each message will be an .xml document contain various parameters, like:

- message title and message text: auto generated, depending on the application that is sending it,
- message type: parameter that will allow the identification of the application that is generating the message. This information is necessary to be able to interpret correctly the content of the text, that varies from one application to another (e.g., one application could generate only messages containing plain texts, while others can include an event to be inserted in the agenda),

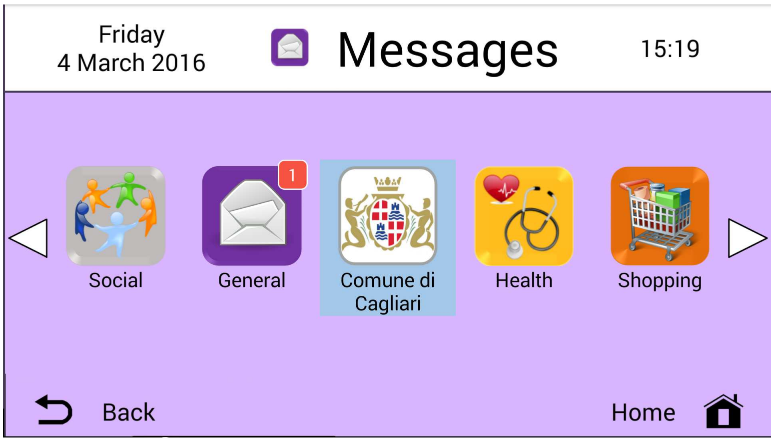


Figure 4.11: Message main screen.

- message data: optional, depending on the application that is sending it,
- date and time,
- message priority: optional,
- sender,
- other optional parameters.

Inside the HEREiAM homepage, there is a Message widget that checks for new messages at specific time intervals (e.g., every minute, every hour or at a frequency specified by the user).

Basic functionalities: App Store

The main scope of the AppStore is to provide end users with the ability to discover and use new apps. There are two parts of this service: the Android app and the Cloud services with the Cloud web platform. The Cloud service facilitates administrators and registered third parties to use the Cloud web platform to upload new apps in the system and create and modify information about their uploaded apps (description, category, icon, screenshots, etc.). After a new app is uploaded on the platform, it will only be made available to end users after it is verified by a HEREiAM administrator, since it must meet the system requirement that will be discussed in Chapter 4.4. The Android AppStore will provide recommendations for new apps based on the user's preferences and previously installed apps. Whenever there are changes to the list of apps that should exist on the system (changes made through the Cloud web platform), the Android AppStore app will install or uninstall apps accordingly on the Home side platform.

This application has been developed by Teamnet.

Basic functionalities: ServiceProxy

All HEREiAM platform services described in the following paragraph are accessible via internet to every authorized application. To simplify the work of Android application developers, including Third Parties that need to call remote HEREiAM services, there is the ServiceProxy

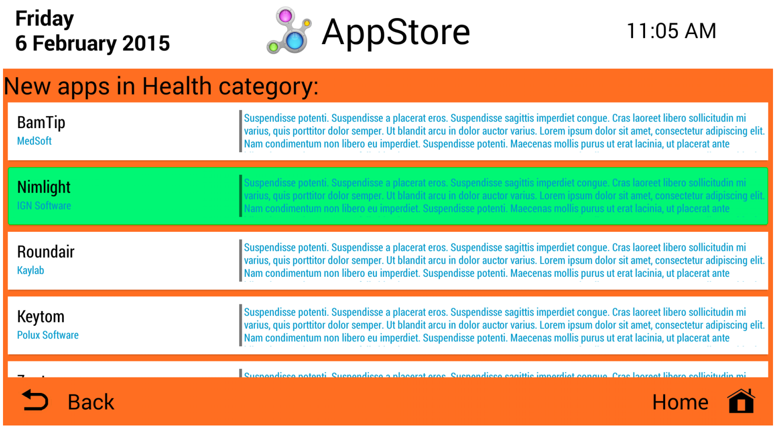


Figure 4.12: App store screenshot.

component that will be pre-installed in the Android TV-box. ServiceProxy component is implemented as an Android Service and it does not provide any user interface. All apps that need to consume a HEREiAM platform service, have to bind to ServiceProxy and to invoke the connect(clientid, clientsecret) interface. If and only if they are successfully connected, then they are allowed to invoke remote HEREiAM services, without worrying about user authentication and authorization, because the ServiceProxy handles the associated activities, through the embedded smartcard library. The only requirement for each App is to provide the couple of application credential clientid and clientsecret that uniquely identify the app, and that have to be kept secret. To get the application credentials, the App providers have to request them contacting a HEREiAM system administrators and specifying the desired access policies:

- the services to be consumed,
- the set of resources on which to obtain authorization,
- for each service the operations on which to obtain authorization.

In the following figure a schema of the ServiceProxy with the list of service interfaces is shown.

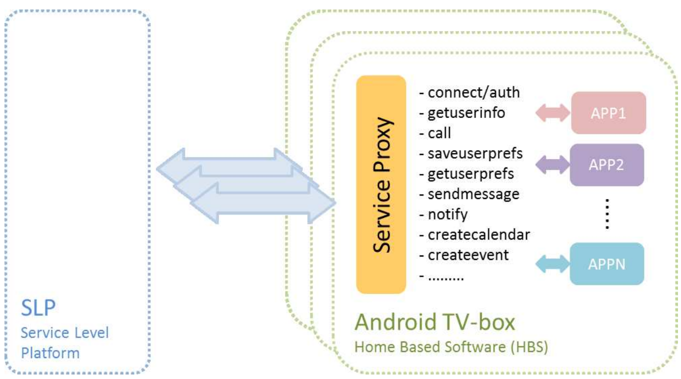


Figure 4.13: The ServiceProxy with service interfaces.

The Service Proxy components, in execution on Android TV-boxes at the citizen home, communicates with remote Service Level Platform using HTTPS protocol via Internet.

4.2 HEREiAM Service level platform (Server side)

The HEREiAM Service Level Platform has been built according to a fully Service Oriented Architecture (SOA) to guarantee a lightweight integration between different systems involved. Service orientation is an architectural style, that is an approach for splitting complex environments into well defined, formally specified functions (service contracts) based on the activities they perform (services) and there is an orchestrator to coordinate the overall process workflows. The HEREiAM Service Level Platform (SLP in the following) exposes a set of web services to support interactions among HEREiAM basic functionalities, and also future third party applications and web portals. The schematic overview of the HEREiAM SLP software architecture is shown in the Figure 4.14.

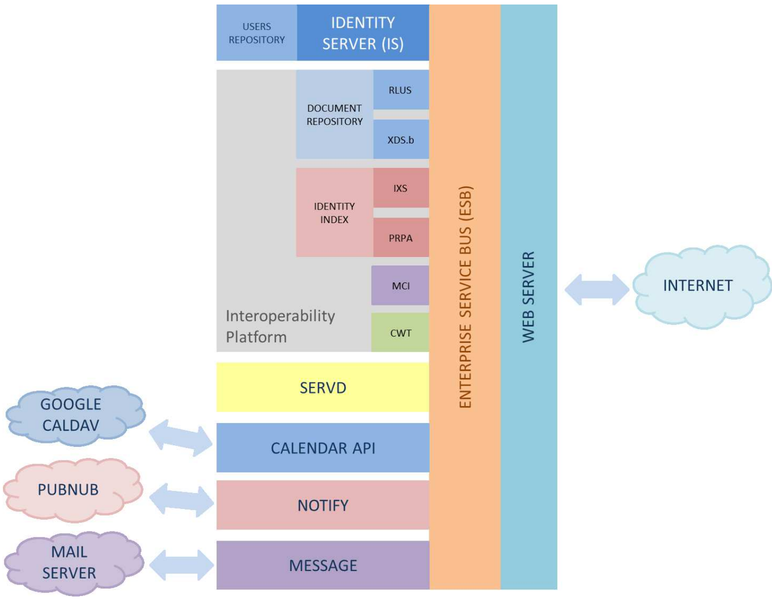


Figure 4.14: Architectural schema of HEREiAM SLP software components.

Implementing a best practise to improve socket handling/system stability and to improve security, a Web Server has been configured to be the unique access point to requests coming from internet. The Web Server implementation chosen for HEREiAM is the Apache HTTP Server [20]. All HEREiAM web services and all new services that will be developed in the future are orchestrated by an Enterprise Service Bus (ESB). The ESB implementation selected for HEREiAM purposes is WSO2 ESB [7], an open source ESB rich of features and standards compliant, which is the access point for all web services; WSO2 ESB handles message routing, mediation and distribution to destination services. Moreover, the ESB has the important role to mediate the service access authentication and authorization, via the integration with the WSO2 Identity Server (IS) [8] that is another WSO2 product included in HEREiAM SLP. WSO2 IS has been selected for the following reasons:

- it is open source,
- it implements REST security with OAuth2.0 [3] and OpenID Connect [4],
- it supports role-based access control (RBAC),
- it supports fine-grained policy based access control via XACML.

OAuth2.0, which is a RFC6749/RFC6750 standard, and the OpenID Connect identity layer on top of it, are widely adopted, since they are light and easy-to-use interoperable protocols for authorization flows: their adoption is especially suitable for the HEREiAM project where the type and the number of the future application providers is not known. For the same reason it is necessary to have a fine-grained and dynamic control on access policies for services and resources, particularly in the case of private information (e.g. personal data, clinical information and reports...); the adoption of eXtensible Access Control Markup Language (XACML), its data flow model and its policy modelling language will support the fulfilment of these requirements.

4.2.1 The Interoperability Platform

HEREiAM interoperability platform supports the citizen centred cross-enterprises document sharing, since it is based on the IHE standard integration profile XDS.b (Cross-Enterprises Documents Sharing) and natively incorporates a multi-repository/registry architecture.

Document management

The document management operations inside the interoperability platform are performed according to the registry/repository pattern by the Registry (XDS.b box in Figure 4.14) and Document Repository components. This latter module stores documents in a database specialized for handling large collections of (possibly large) XML documents. It natively supports a hierarchy-oriented data model, which is particularly suited for storing documents and which is able, through simple configuration activities, to support, query and validate any XML structured document like CDA2, XDW and so on. In the HEREiAM project, to better support document management and interoperability based on documental approach, service interfaces conformant to emerging standard HSSP Retrieve, Locate and Update Service (RLUS) [5] have been exposed (RLUS box in Figure 4.14). These services have been generalized to support not only clinical documents, but also other documents needed in the HEREiAM domain. Examples of documents in the HEREiAM context are user preferences (as defined in sec:reqconf, requirement 14), to be retrieved and managed by authorized applications, and other structured documents containing information that have to be shared with other systems. RLUS interfaces are based on the key concept of Semantic Signifier, which is the basis for document generalisation. Quoting the normative documents "the purpose of the Semantic Signifier is to separate the generic functional capabilities of RLUS from the semantic content. In this way RLUS can support different information objects and different metadata sets in a flexible and consistent interface". Semantic Signifiers are used to specify the different types of content that can be accepted by RLUS interfaces and it is the reference for the RLUS query system. In HEREiAM SLP, the following semantic signifiers have been defined:

- rlpnotes: RLP documents containing measurements and observations;
- rlpuserprefs: RLP documents containing user preferences as couples of (key, value);
- cda2report: generic clinical reports that adheres to the IHE Clinical Document Architecture (CDA2) standard;

- cda2phmr: clinical documents that adheres to the CDA2 Personal Healthcare Monitoring Report (PHMR);
- xdw: documents that adheres to the IHE specification for Cross-Enterprise Document Workflow (XDW);
- xthm: XDW Workflow Definition documents for Tele Home Monitoring (XTHM).

The HEREiAM Document Management service, which has been called "REPO" service, includes Document Repository, RLUS and XDS.b components, as shown in Figure 4.14. The Repo service is a basic service for HEREiAM SLP: both the Measures Management service "Sens" and the User Preferences Management "Prefs" rely on REPO service to store observations and measurements collected by devices and sensors at the elderly home, and to store application and user preferences parameters, respectively. Considering the list of Semantic Signifiers reported above, rlpnotes semantic signifier has been configured for the "Sens" service, while rlpuserprefs semantic signifier has been configured for the "Prefs" service. The other RLUS semantic signifiers defined, i.e. cda2report, cda2phmr, xdw, xthm and the XDS.b family of services, are specific for the eHealth domain and can be used to establish a two-way connection between the HEREiAM platform and the National Health Service, allowing the exchange of information to support a better involvement of the citizen in the management of his/her own health, thus improving the so called "empowerment of the patient". For example HEREiAM could provide to the clinical case manager of the elderly citizen, access to patient's vital sign monitoring data via a PHMR document, or, on the other side, could provide to the citizen direct access to laboratory exam results contained in a CDA2 report.

Identity management

The identification management system of the platform is composed by the Identity Index module and two families of services, namely the Identity Cross-Reference Service (IXS) and the Patient Identifier Cross-Referencing (PIX)/Patient Demographics Query (PDQ) service. PIX/PDQ IHE Integration Profiles are specific for healthcare domain; they could be useful in case of integration of eHealth services owned by third-party service providers. Concerning HSSP-IXS, it is based on a set of web services with a simple and generic interface to uniquely identify various kinds of entities (e. g. people, patients, providers, devices and so on) within disparate systems owned by a single enterprise and/or across a set of collaborating enterprises. IXS is intended to allow for the resolution of demographics and other identifying characteristics (traits) to a unique identifier. A standard interface for accessing and maintaining entity identification information allows systems and applications to have consistent means of indexing data related to an entity. As a consequence, IXS provides a robust and complete means for defining, updating and generally managing identities, along with the associated set of identifying information, which maybe an arbitrarily simple or complex information structure. These sets may be anything from a single class with a set of attributes (or traits) up to a complex constrained information model with many classes. This information structure is referred to as a semantic signifier. The semantic signifier defined in the HEREiAM SLP has been called xcard: it is based on the xCard [53] XML representation of vCard [52] standard file format for electronic business cards, and it implements identification of citizens, caregivers and HEREiAM third-party service providers. IXS will be used not only to identify users, but also relations among them (such as relatives, neighbours, formal and informal carers, and so on), so it has been decided to implement only the version 4.0 of vCard, because of the RELATED property introduced in this version. This is a basic feature for HEREiAM purposes, since it allows to define the "neighbourhood" of a citizen, which is composed by all entities (people and service providers) able to interact with him/her.

Master Code Index

The Master Code Index (MCI) service supports the management of code systems and terminologies. Semantic interoperability is the ability to correctly translate the information exchanged among systems which use different encoding vocabularies in a meaningful and accurate way, in order to produce useful results as defined by the end users of all systems involved. To achieve semantic interoperability, all systems must defer to a common information exchange reference model. Coding values stored and managed through MCI are uniquely identifiable set of valid concept representations; concept may vary from a simple flat list of codes drawn from a single coding system, to complex expressions drawn from multiple coding systems. In the healthcare domain the MCI is a basic service in order to guarantee the interoperability: a typical example is diagnosis encoding that, even referring only to standard encoding, has different representation in SNOMED CT and in ICD10. Other, more generic, examples could be the encoding of gender (e.g. "masculine" could be "1" in some systems "M" in others, and so on), the encoding of job, and many others. At the time being, this service has not been used yet, but it will play a fundamental role for future integration of third party service providers.

4.2.2 Calendar API

The personal calendar is an useful citizen service, that allows the HEREiAM compliant applications to create events such as visits reservations, appointments (e.g. with citizen's general clinical manager, with shopping aid people), or also to add entertainment event, plan therapy administration, and so on. For management and synchronization of citizen calendar, the HEREiAM will rely on the Google Calendar service and more specifically on the Google CalDAV [2] protocol implementation and on the iCalendar (.ics) standard file format. Google offers to developers the Google Calendar API also, that is a Google proprietary REST API to display, create and modify calendar events, it was preferred to use the API supporting the CalDAV standard protocol, which is widespread adopted and is less bound to the Google calendar implementation. Using these API, HEREiAM app developers can:

- create, delete or check the existence of a calendar,
- share calendars between different users,
- insert events using the iCalendar or xCal data structure,
- delete events,
- query events via CalDAV query structure.

The Calendar API creates all users calendars on a HEREiAM Google account suitably created for this purpose that is hereiamproject.org@gmail.com, so it is not needed for each

HEREiAM user to have a Google account; however, if the HEREiAM user has his/her own Google calendar, it is possible to share it with HEREiAM platform.

4.3 HEREiAM platform Third Party-side

4.3.1 Services integrated: medical and nurse care

As we age the chance of having medical complications increases significantly. This means an important part of the elderly has a need for medical care. The HEREiAM platform therefore should be able to host applications of organizations with a focus on health care. Since healthcare is organized differently in different countries and regions, the implementation of what is needed as a medical care functionality in the HEREiAM platform will depend on the region. The biggest difference will be in the processing of the data gathered in the HEREiAM platform. That's why the medical application should be owned by a regional healthcare organization that can do the follow up.

Health App

The Health App is part of the telemonitoring framework included in the HEREiAM system. All the details regarding telemonitoring features integrated, including a thorough description of the Health App and its principles can be found in Chapter 5.

RemeCoach App for Remedus

As a company focused on healthcare in Belgium, Remedus developed a smartphone application to make it possible for patients to be monitored and coached. This Android app features a daily schema with the different to do's a patient has on one day for the follow up of his health. Examples of these to do's are medication intake, blood pressure registration and input of certain symptoms. The results of these registrations are monitored by healthcare workers on the RemeCare web application and are bundled and visualized for the different responsible care givers. This Android app is now offered to patients on a smartphone. To reach an elderly target audience, the transition of the smartphone app to the HEREiAM platform on TV became into scope. The intelligence of the actions a patient needs to complete is part of the RemeCare system. The RemeCoach app visualizes the available actions in a daily schema and sends the captured data to RemeCare. To keep the RemeCoach app as simple in use as can be, to reach a broad audience of patients, only the actions for that day are visualized. By only making a limited set of actions available, the interface can also be very simple in use. This makes the integration of the RemeCoach app in a platform for elderly more straightforward. The same limited set of functionalities can be translated to the TV screen. Views available in the RemeCoach app:

- Daily schema: this contains the actions available for a patient on that day.
- Registration screen: after selecting a task to be completed, this task opens and gives the possibility to make a registration. The type of registration that is required (numeric, qualitative, long answer type, short answer type) determines the view that is used for this particular task.

- Occasional registrations: next to the daily schema, a patient can also choose to make an occasional symptom registration. The list of the available occasional registrations is accessible by a button on the daily schema. After selecting a task the same method of determining the correct view is used as for the daily schema.

4.3.2 Services integrated: participation services

The risk of becoming socially excluded is widespread among older people, particularly among those who have a decline in health status and are dependent on care and support. Municipalities are major players in the provision and coordination of social services, but there is also a large number of non-profit associations committed to promoting the active participation of older persons in social life. The range of services and activities is very rich and diversified because each territory has its specific needs and resources, but the common challenge is to maintain senior citizens healthy, productive and involved in their communities.

Social app for the Municipality of Cagliari

The Municipality of Cagliari has an official website that contains general information, news and resources for residents but also a selection of things to do in the city area like events, festivals, concerts, exhibitions, elderly friendly activities and more. In the next figure is shown the homepage of the Municipality of Cagliari website.

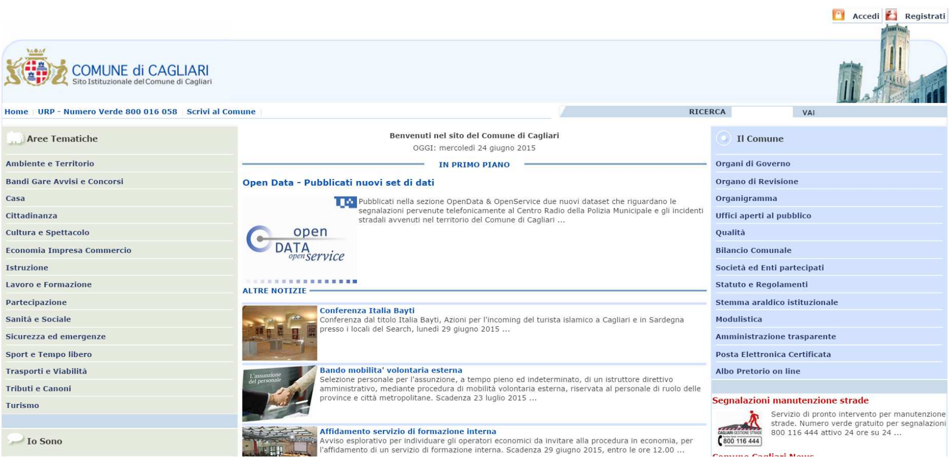


Figure 4.15: Municipality of Cagliari website.

The social application developed in collaboration with the Municipality of Cagliari is a window that shows the news and events published in the Municipality website in a user-friendly way in the HEREiAM users' TV-screens. The Municipality of Cagliari App can be divided in four main elements: LocalService, Widget, Database and all the rest of the application with its activities and handlers. The main component of this application is its Service part. It deals with reading the Municipality of Cagliari website and extract the information that allows to identify the presence of the newest events and news published. These informations are stored in the Database that makes them available to the app's activities. The Widget communicates directly with the Service, from which it receives the total number of events and news to be visualized in the HEREiAM Homepage.

The App includes the following activities:

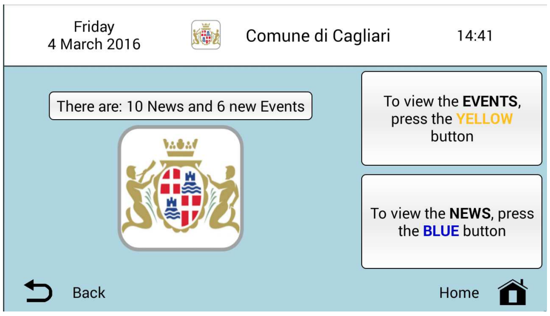


Figure 4.16: Municipality of Cagliari app homepage.

Figure 4.17: Municipality of Cagliari app event categories.

Figure 4.18: Municipality of Cagliari app event list.

Figure 4.19: Municipality of Cagliari app event details.

- MainNewsOrEventsActivity: this is the main activity of the application (interface shown in Figure 4.16). Inside this activity are visualized the number of unread news and events and the user can choose between reading the news or the events, using respectively the blue and yellow buttons on the remote control. Pressing the yellow button, the ListActivity is started, pressing the blue button the MainMoreEventCustomActivity is started.
- MainMoreEventCustomActivity: this activity, using the scrolling list loop, shows the categories in which the list of events is divided (interface shown in Figure 4.17). Selecting one of the elements of the list, the ListActivity will start.
- ListActivity: through this activity, the news or the events read in the Municipality of Cagliari website can be visualized (interface shown in Figure 4.18). They are related to the elements present in the database that allow to identify the read or unread items. Once one of the element of the list is selected, the ElementActivity will start.
- ElementActivity: activity that shows the details of the news or the events previously selected. The element is processed through a specific handler and visualized in a predefined way (correct font size and subdivided in several pages, if the content exceeds one page length). If the element is an event, the EventDetailActivity can be started. Moreover, once the news or event are opened, inside the database the element will be updated as "read".
- EventDetailActivity: this activity shows in details title, location, date and time of the selected event (interface shown in Figure 4.19). From this activity it is possible to insert

the event in the Agenda starting an intent and, once the event had been inserted, it is possible to start another intent to share the event with another end-user that has the Message and Municipality of Cagliari apps. Finally, the activity keeps listening for the sending confirmation or error from the Message App.

To develop an app as adaptable as possible, the possible icons, the categories and the links of the news and events present in the Municipality of Cagliari website are saved in a database inside the HEREiAM WebService and not directly inside the app. From this database are read and used from the application. Furthermore, since the structure of the website may change and as a consequence the handlers should too, the items read are processed by a pre-processing handler present in the HEREiAM WebService that is called by the application handler. The pre-processing handler reads the lists, news or events from the Municipality website and gives to the application handler the information gathered. In this way, only the pre-processing handler inside the WebService will be updated, but the one inside the application will remain the same.
In the next figure is shown the flow chart of the Municipality of Cagliari App.

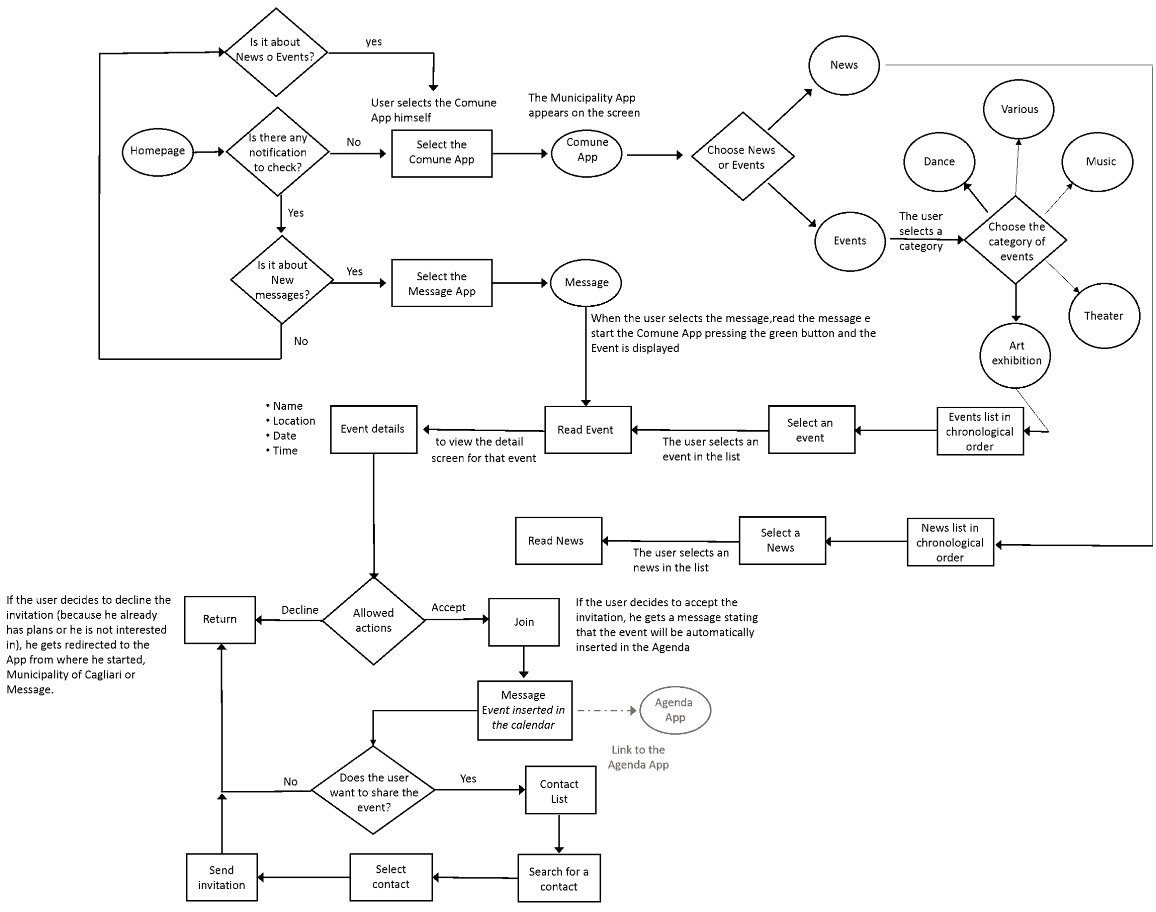


Figure 4.20: Flow chart of the Municipality of Cagliari App.

App and Web Portal for the promotion of news and events

To allow the promotion of local news and events, a dedicated web portal, whose interface is shown in Figure 4.21, has been developed. This service has been created for entities (with or without an existing website) that want to present news and information about their local activities in a digital way. Accessing the web portal, using the username and password assigned by the HEREiAM platform, each entity will be able to view the events and news already published, modify them or insert new ones filling the pre-compiled form. They will be asked to choose a title of the event, the location and time and they will have the possibility to insert its description. The user at home will use the Social App to view the event in a custom way.

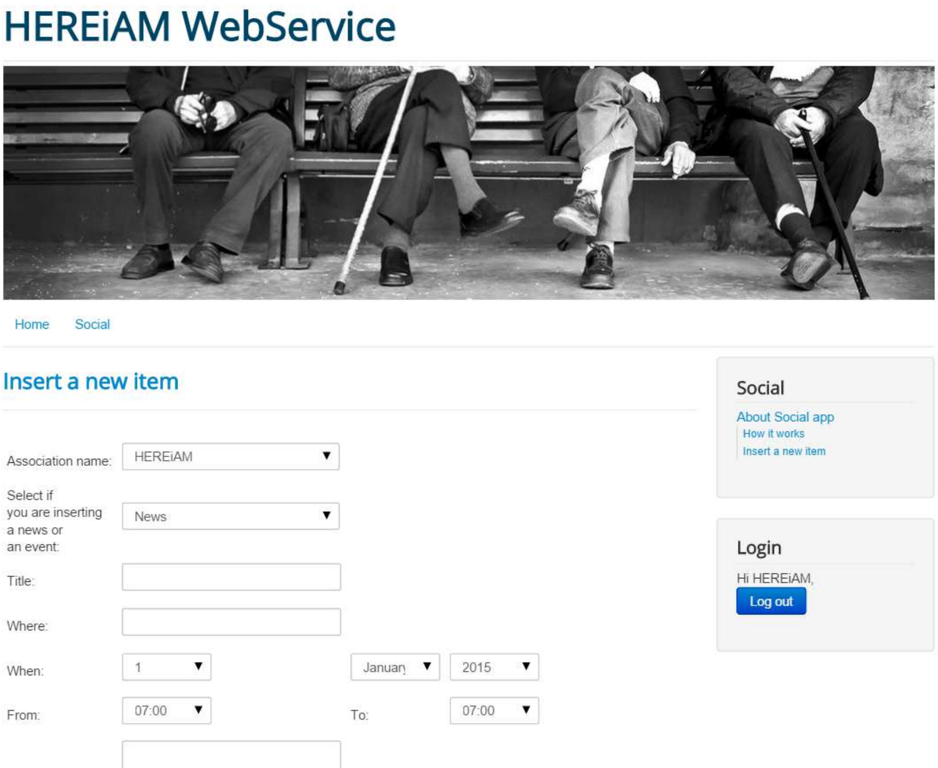


Figure 4.21: Interface of the web portal.

4.3.3 Services integrated: comfort and security services

At the time of writing other two services have already been integrated in the system: the Shopping App and WHEREiAM. Both will be described in the next paragraphs.

Shopping App

Being able to do shopping is an important part of living independently. It is also a chance for the elderly to get out of their houses and meet other people. However, some unpredictable events, like bad weather conditions, shot-term disability/illness, traffic congestion or strikes, may prevent them from being able to do the shopping or hamper it. The shopping application is a window for local supermarkets that will allow them to sell their products and deliver them directly in the users' homes. The shopping application will be able to include different shops, both local small shops and big supermarkets chains. At time of writing, technological partners are investigating with service providers how they would prefer to interact with the platform. The following interaction modes have been already identified:

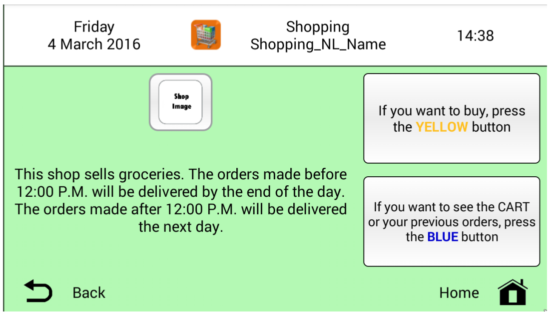


Figure 4.22: Shopping app store details.

Figure 4.23: Shopping app products categories.

- By creating and sending a structured file containing all information;
- By manually entering all information into a form using a dedicated web portal (feasible only for small shops with limited number of products).

The application main page will contain the list of the shops that have been integrated in the HEREiAM system. From this page, the users will be able to select the shop they prefer and enter in the shop page, where there will be a list of its products (with names, pictures, prices and, eventually, daily offers). At this point the users will be able to compile a grocery list, specifying the products names, quantity and other details, according to the shop configuration. To have an updated list of products, each shop will take care of uploading its list in our server every day (or depending on their preferences). To transmit the order, an e-mail will be auto-generated (without the users' interaction) and sent to the selected shop. A confirmation message from the shop will be sent to the users and received through the Message app, and the time and date of the delivery will be saved in the Agenda.

WHEREiAM

The HEREiAM system, linked with the above described PIR sensors, is able to collect data regarding user's movement inside the house thanks to a service installed in the Minix. This service deals with the communication with the PIR sensors installed in the house and the collection of the data. Once the user enters or exits a room, the PIR sensors will alert the service that will collect, parse the data and send them to the server side, using the ServiceProxy.

The data will be accessible for relatives or caregivers, authorized by the system, through an application developed for Android smartphones, called WHEREiAM. Turning on the application, the relative will immediately know in which room the elderly is (or if he/she is outside). Clicking on on room, it's possible to have information on all the time the older user entered in that room, and for how long.

4.4 Guidelines for integrating services

In this section will be highlighted the links between the requirements identified during the first phases of the project, and presented in Section 3.5, and the app design guidelines followed during the development of the system. The guidelines followed became part of a document, called "guidelines for developers", that provides rules and guidelines for Third Parties who want to interact with the HEREiAM's ecosystem of applications, services and content. It should be considered as a quick-start handbook containing necessary instructions and information to easily manage the following tasks:

- obtain credentials for the HEREiAM platform (authentication process),
- obtain access to a specific service of the HEREiAM platform,
- develop applications for the HEREiAM AppStore.

The structure of the document starts explaining how the HEREiAM Server-side services are accessible by Third Parties Android apps, then it continues describing how a document list can be obtained from the Server and how information can be sent to the Server to be stored. The document finishes with a first set of rules and guidelines that will assist Third Parties in developing Android applications for the HEREiAM platform (layout and remote control use). In this Chapter, only the guidelines directly linked with requirements presented in Chapter 3 will be described.

4.4.1 Layout

HEREiAM activities' layouts follow a precise scheme. Each activity must be "full screen", so it is necessary to hide both the navigation and the notification bars. As shown in Figure 4.24, the layout is divided in three main parts: top_layout, content_layout and bottom_layout.

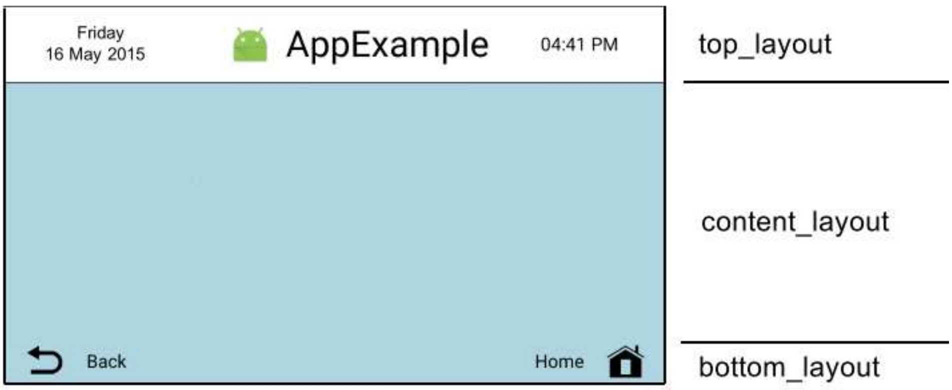


Figure 4.24: Activity layout scheme.

The total weight of the activity layout is 8 (weightSum="8"), 1.6 of which belongs to the top_layout and 1 to the bottom_layout. The remainder is for the activity's contents. The bottom_layout is always the same for each activity and it contains the Back and Home icons. Inside the top_layout there are always the current date and time, respectively on the left and on the right. In the middle of the top_layout there is the name of the application and its icon. The text containing the name of the application may vary, for example including also the name of the current activity, but the size of the text must not be less than 30-35sp. Inside each activity it is good practice not to reduce the text size below 30sp.

Regarding the content_layout, three scenarios that will be described in the next paragraphs have been explored.

As it can be seen, this layout is in accordance to requirement 4 (Section 3.5.1) for the following aspects:

- large font sizes,
- interface tidy and organized without unneeded contents,
- graphical rendering of the home and back icon stylized.

Requirement 5 (Section 3.5.2) has been also taken into account for the following aspects:

- the color of the title bar is not pure white,
- verified the GUI for various display modes,

First scenario: coloured buttons

The first scenario deals with the using of the coloured buttons of the remote control (red, green, yellow, blue) to express a choice, for example starting a new activity or a particular action. The possibility to use a button must be well highlighted describing its action inside a dedicated frame. This layout is useful during scenarios in which it is necessary to make a choice only between two options (e.g., "if you want to perform action 1, press the yellow button" or "if you want to perform action 2 press the blue button"), or in scenarios in which the user needs to agree or disagree with something (e.g., "if you agree with this action press the green button", "if you disagree with this action press the red button").

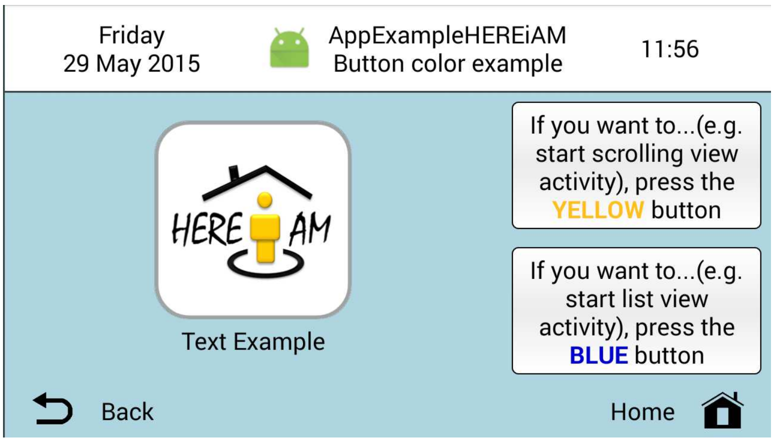


Figure 4.25: Colored buttons layout.

This layout is also in accordance to requirement 4 and 5 for the same reasons explained earlier. Plus, requirement 6 (Section 3.5.2) has been taken into account for the following aspects:

- simple interface and restricted to only 4 possible actions (yellow, blue, back and home),
- all the content is fully viewable on the screen without scrolling down.

Requirement 7 (Section 3.5.2) has been followed for these aspects:

- digital objects distant enough to be perceived as different,

- line length at about 7 words per line, with no more than 90 words total,
- target body text size respected.

Second scenario: scrolling list loop

This layout is useful when the user needs to make a choice between three or more options. The HEREiAM Homepage uses this type of layout. It is composed by a list of elements that are visualized through an horizontal scroll of the list, using the right and left arrow keys on the remote control. The focus of this list stays in the middle and so the selectable item is always the one displayed in the centre of the list. In order to use this layout, the library "ScrollingIconListLoop_UNICA_EOLAB_HiA_v2.0.jar" must be added to the application. Inside the content_layout of the activity it is enough to add the following LinearLayout:

```
<LinearLayout
            android:id="@+id/scrollingListLoopLayout"
            android:layout_width="0dp"
            android:layout_height="wrap_content"
            android:layout_weight="8"
            android:layout_gravity="center_horizontal|center_vertical"
            android:gravity="center"
            android:orientation="horizontal"/>
```

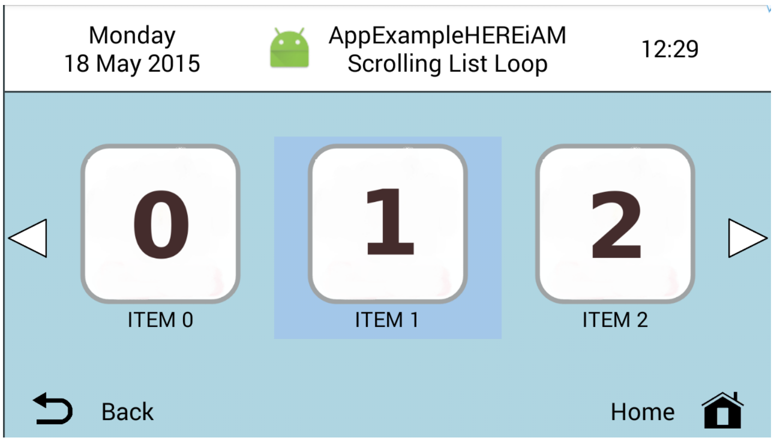


Figure 4.26: Scrolling list loop scenario.

Beside already mentioned requirement, this layout is in accordance with requirement 8 3.5.2) for the following aspects:

- horizontal scrolling with visual transitions between pages implemented,
- onscreen arrows to indicate that more content exists and how to reach it.

Third scenario: list

The last scenario explored applies to lists which elements are composed by long texts or to lists with more than three elements. For elements which are composed by a long text and with icons not crucial to understand their meaning but only visually explicative (e.g., a

Figure 4.27: List layout.

closed or open letter to indicate an unread or read message), we use a normal List Layout, like the one in Figure 4.27.

For elements that are composed by a long text or multiple text labels and a more detailed icon, we currently use an enhanced List Layout, like the one in Figure 4.8.

With a list containing some many elements it was impossible to respect the requirement of the horizontal scrolling, but almost all the others are still respected.

4.4.2 Animations

For our applications, it is necessary to use some animations passing from one activity to another. Inside the HEREiAM Launcher, inside the "onPause()" there is this line:

```
overridePendingTransition(R.anim.grow\_fade\_in\_center,
    R.anim.shrink\_fade\_out\_center);
```

For all the following activities, inside the "onCreate()" there must be:

```
overridePendingTransition(R.anim.slide\_in\_right, R.anim.slide\_out\_left);
```

and in the "onPause()":

```
overridePendingTransition(R.anim.slide\_in\_left, R.anim.slide\_out\_right);
```

The animation used are in accordance to requirement 4 (Section 3.5.1), since the animations are used sparingly and purposefully. The animations have been programmed to be smooth and slow to give users the time to understand what is happening.

Chapter 5

The telemonitoring framework

The HEREiAM platform involves three main actors: the user, the stakeholders and the service providers (that can be considered stakeholders too). The user is the elderly, that could be a patient or no, i.e. could be or not affected by chronic/acute diseases. Nevertheless, the elderly condition suggests some vital signs monitoring regardless the apparent health status. In the user's home, the TV-box is connected to the internet in some way (wireless LAN, Ethernet, internet key, etc.), receives user's inputs from a dedicated remote control and displays the graphical user interface (GUI) on the TV screen. It is able to manage data acquisition from different Bluetooth or USB medical devices. Upon user interaction with the App, medical data can be locally collected on the TV-box, formatted to be compliant with the service provider, and sent to the stakeholders. External stakeholders and service providers, registered and authorized to use the platform, are enabled to access these data in order to offer their services (e.g. general practitioners feedback, telehealth consults, risk assessment and so on), through the Health Portal, a dedicated web interface (described in Section 5.4).

The telemonitoring framework included in the HEREiAM system exploits an asynchronous store-and-forward approach, which is known to be scalable[33] and more sustainable than real-time ones, also promoting patient self-management [31]. Due to the chosen paradigm, it relies on a traditional client-server infrastructure, where a central server hosting the database is accessible by several clients, each of them being a front-end for the medical devices in charge of performing the measurement of the required vital signs in the patient's home or a caregiver computer to monitor the subjects' health condition. Rather than building the telemonitoring server software architecture from scratch as in several works in the literature, we used the commercial product X1.V1 (from Dedalus), designed and developed to support technical and semantic interoperability among the Healthcare information systems. It includes several features, archiving, cross-referencing, profiling and notification management. Natively implemented in compliance with the Integrating Healthcare Enterprise (IHE) standards (www.ihe.net), it conforms to the Cross-Enterprises Document Sharing (XDS.b), the Patient Identifier Cross-Reference (PIX), Patient Demographic Query (PDQ) and the Document Metadata Subscription (DSUB) integration profiles [51]. Remarkably, all these features, as well as the compliance with the current regulations, are unlikely to be present in a proof-of-concept implementation, as for the largest part of scientific works in the field, even though they are fundamental, especially in the healthcare field.

In order to ensure functional interoperability and scalability, a Service Oriented Architecture (SOA) approach was chosen. From an information management point of view, the platform follows a documental approach, i.e. it is based on the production, exchange and sharing of "documents":

- documents are produced in machine readable structured formats, namely in eXtensible Markup Language (XML) format;
- documents contain all information content needed to represent the subject state;
- each document, through a set of metadata, determines the owner, the context, the purpose and the responsible of both the document and its content.

These aspects were deeply analysed in Section 5.3.

5.1 Bluetooth Medical Devices

Bluetooth medical devices present the advantages of an intrinsic electrical insulation from the hardware module in charge to collect, display and forward the acquired measurements. This is common to other wireless protocols such as Zigbee, but the reduced interoperability and diffusion in terms of end-products (both medical devices and receiving one, such as smartphones, tablets, computers, etc.) led the work to be focused mainly to Bluetooth.

Interfacing a Bluetooth (medical) device with an external (Android) platform requires two main steps: (i) establish a link with the device, being able to exchange data with it, and (ii) properly decode the gathered data in order to extract the useful information. The latter problem, partially simplified by the most recent Bluetooth profile, is crucial for the specific application because it is responsible for data integrity. This aspect has particular relevance in telehealth, because of the nature of the information.

The Android operating system includes Bluetooth support, through the Bluetooth Application Programming Interfaces (APIs) [18], to allow the user to connect and exchange data with Bluetooth devices. In the following, an overview of the classes and interfaces present in the classic Bluetooth APIs as well as a description of Bluetooth profiles will be presented. Despite Android, since API level 18, includes also the support for the Bluetooth Low Energy, this technology will not be described, since not used in the development. Android API level is used to identify the compatibility with the Android platform in use: it is a progressive number (the higher the more recent), and it has no direct relationship with the Android version number.

5.1.1 Bluetooth Classes

The Android Bluetooth APIs allow discovering other Bluetooth devices, querying the list of bonded ones, creating Radio Frequency Communication (RFCOMM) channels and finally connecting and transferring data. All these APIs are available in the android.bluetooth package. The most useful classes and interfaces are listed below.

- BluetoothAdapter. Added in API level 5, this class represents the local Bluetooth Adapter present in the device. It is the starting point to perform all Bluetooth interactions (e.g., discovering devices, instantiate a specific device and create the communication channels). To get the BluetoothAdapter it is necessary to call the static method *getDefaultAdapter()*, that returns the default local adapter, or null if Bluetooth is not supported on the device in use.

- BluetoothDevice. Added in API level 5, this class represents a remote Bluetooth device. It can be instantiated, starting from the BluetoothAdapter class, using a known MAC address, calling the method *getRemoteDevice(String address)*, where address is the Bluetooth MAC address of the remote device. The list of Bluetooth devices in range can be found discovering devices with the BluetoothAdapter (*startDiscovery()*) or it is possible to query the list of bonded devices through the *getBondedDevices()* method. Once a BluetoothDevice has been obtained, it is possible to open a BluetoothSocket to communicate with it, calling the *createRfcommSocketToServiceRecord(UUID)*.

- BluetoothSocket. Added in API level 5, this class represents the interface for a Bluetooth socket communication channel. The Bluetooth socket supported by Android is the RFCOMM, a connection-oriented, streaming transport over Bluetooth (known also as SPP). Once a Bluetooth socket is opened, to connect with a remote device the method *connect()* must be used. This call will block the application execution until a connection is established or until an exception is thrown (in case a connection failure has occurred). Once the socket is connected, the input and output streams can be created, by calling respectively the *getInputStream()* and *getOutputStream()*. The two classes generated are:
  - InputStream - a readable source of data.
  - OutputStream - a writable sink for bytes.

- BluetoothServerSocket. Added in API level 5, this class represents a Bluetooth server socket that listens for incoming connections from remote devices. To create a server socket, starting from the BluetoothAdapter, it is necessary to call the *listenUsingRfcommWithServiceRecord("name", UUID)*. A device exposing the corresponding service name and UUID will be able to send a connection request that the server socket can retrieve using the *accept()* method. Once connected, a BluetoothSocket communication channel will be opened.

- BluetoothHealth. Added in API level 14, it is the class that represents a Health Device Profile (HDP), described in 5.1.2.

- BluetoothHealthCallback. Added in API level 14, it is an abstract class, used to implement BluetoothHealth callbacks. It is used to inform the application about changes in registration state of the Health application, through the *onHealthAppConfigurationStatusChange(...)* method, and about changes in channel state, through the *onHealthChannelStateChange(...)*.

- BluetoothHealthAppConfiguration. Added in API level 14, it represents an application configuration that the Bluetooth Health application will register to communicate with the remote Bluetooth health device starting from the BluetoothHealth, through the *connectChannelToSource(BTdevice, BTHealthAppConfiguration)* method. When the communication between application and remote device is over, it is necessary to close

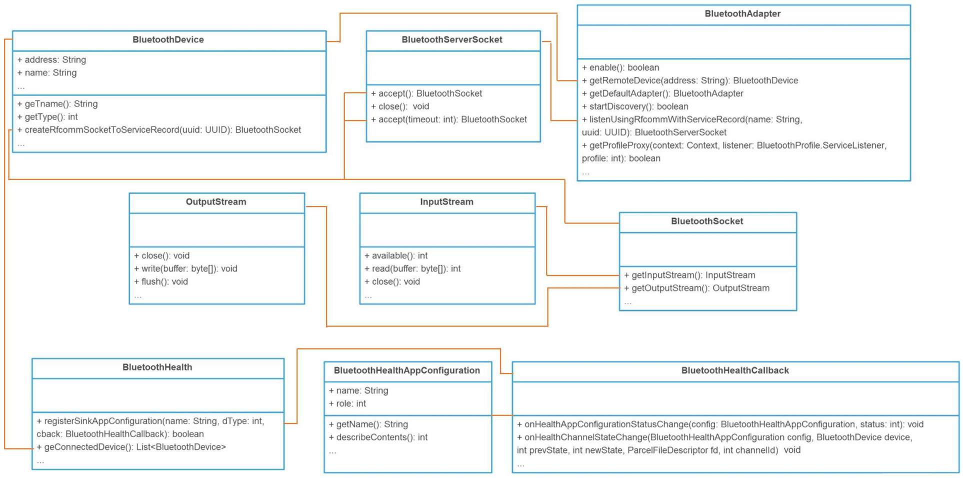


Figure 5.1: Bluetooth class diagram, as for the development of the Android App.

the health channel by calling the *disconnectChannel(BTDevice, BTHealthAppConfiguration, channelID)* method and unregister the application configuration calling the *unregisterAppConfiguration(BTHealthAppConfiguration)* method.

Other two important parts of the Bluetooth APIs in Android are the following interfaces:

- BluetoothProfile. Added in API level 11, it is an interface that represents a Bluetooth Profile (described in Section 5.1.2).

- BluetoothProfile.ServiceListener. Added in API level 11, it is an interface used to notify the BluetoothProfile clients about their connection (*onServiceConnected(...)*) or disconnection (*onServiceDisconnected(...)*) to the service.

The last Android Bluetooth classes, that have not been used in this work, are the BluetoothClass, the BluetoothHeadset and the BluetoothA2dp.

In Fig. 5.1, a simplified Bluetooth class diagram is shown.

5.1.2 Bluetooth Profiles

A Bluetooth *profile* is a wireless interface specification for Bluetooth-based communication between devices. Profiles specify general behaviours that Bluetooth enabled devices use to communicate with each other. Each profile contains, at least, information on dependencies on other profiles, suggested user interface formats and specific parts of the Bluetooth protocol stack used by the profile [24]. There are many different Bluetooth profiles describing just as many types of applications or use cases for devices. Among them, the Serial Port Profile (SPP) and the previously introduced HDP, that are widely used in medical applications [67].

SPP

SPP is used to replace wired serial ports. It is based on the RFCOMM protocol, which emulates the serial cable line of an RS-232 serial port. Since medical data are not sent in a standardized way over an SPP connection, SPP based medical devices require a customized

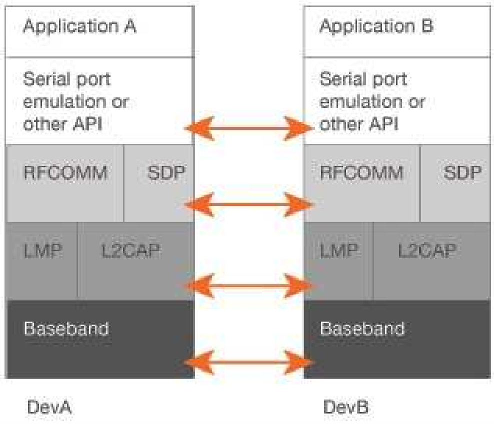


Figure 5.2: SPP Bluetooth profile stack.

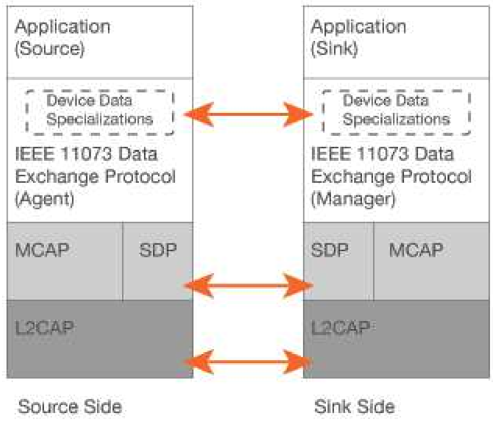


Figure 5.3: HDP Bluetooth profile stack.

software to read their data and interpret them correctly. As a result, two Bluetooth medical devices from different manufacturers cannot work with each other, since they likely use different data formats. In Figure 5.2 is shown the SPP Bluetooth architecture. The Service Discovery Protocol (SDP) module has the role to discover and make connections with other Bluetooth devices. It is used to discover which profiles each device supports, and what parameters must be used to connect to it. The Baseband, the Link Manager Protocol (LMP) and the Logical Link Control and Adaptation Protocol (L2CAP) are the Bluetooth OSI (Open Systems Interconnection) physical layer and data link layer. The LMP controls and negotiates all aspects of the operation of the Bluetooth connection between two devices, the L2CAP allows the transmission of upper layer data packets.

HDP

HDP is an application profile that defines the requirements for qualified Bluetooth Healthcare and Fitness devices implementations. It was created in 2008 by Medical Working Group (MEDWG), part of the Bluetooth Special Interest Group (SIG), in cooperation with Continua Health Alliance, to standardize the way medical data is transmitted over Bluetooth. At the same time, IEEE was developing the Personal Health Devices standard, IEEE 11073 [50], to create the guidelines for medical device interoperability and data exchange. The combination between HDP mechanism for connection establishment and data exchange over Bluetooth and IEEE 11073 standard for data exchange between medical devices has the big advantage to be vendor independent, because each device of the same type (i.e. blood pressure monitors, scales, thermometers, oximeters, blood glucose meters), will use the same data format, so HDP provides a standard framework for communicating medical data across devices. The HDP Bluetooth architecture is depicted in In Fig. 5.3. The Source is the application that transmits data, while the Sink is the receiving one. The Multi-Channel Adaptation Protocol (MCAP) has the function of defining the method by which data connections are established between two devices. The SDP and L2CAP modules have been described in Section 5.1.2.

5.1.3 Integration of Bluetooth medical devices

Nowadays, the majority of Bluetooth medical devices still support SPP profile, but HDP is being adopted more and more by health devices manufacturers [46]. In this work, we integrated and tested several medical devices from A&D Medical. The reason for selecting a specific producer is that, for SPP devices, it is necessary to know the low-level proprietary protocol details to interpret the acquired data. This information is provided under signed Non-Disclosure Agreement (NDA) and, for a scientific exploration, it has no sense to acquire the protocol for any device from any vendor on the market. However, the modular approach followed here allows decoupling the synchronization protocol and the low-level data transmission, changing only the latter when changing SPP device. On the contrary, for HDP devices, this step is not necessary since low-level protocol details are standardized for a device family (e.g., for all the sphygmomanometers) even though they are obviously different for devices from different families (e.g., sphygmomanometers and thermometers). Nevertheless, only minor modifications are needed in order to support different families. Remarkably, Android introduced support for HDP starting from version 4.0, beyond the already supported SPP. This opportunity has been exploited in our platform to support both SPP and HDP medical devices that could be present in the patients' homes.

In the presented framework, the following devices have been integrated:

Weight scale	Resolution (g)	Capacity (Kg)	Memory	Protocol
UC-321PBT	100	200	40	SPP
UC-321PBT-C	100	200	25	HDP
UC-355PBT-Ci	100 or 200 (>100 Kg)	250	200	SPP and HDP

Table 5.1: Body scale characteristics.

Sphygmomanometer	Pressure range (mmHg)	Pulse range (bpm)	Memory	Protocol
UA-767PBT	20-280 (±3)	40-200 (±5%)	40	SPP
UA-767PBT-C	20-280 (±3)	40-200 (±5%)	25	HDP
UA-767PBT-Ci	20-280 (±3 or ±2%)	40-180 (±5%)	200	SPP and HDP

Table 5.2: Sphygmomanometers characteristics.

These selected devices, as shown in the tables, can store up to 40, 25 and 200 measurement respectively for PBT, PBT-C and PBT-Ci series and send them in succession once a Bluetooth connection is established. To help the user avoid confusion if old measurements are displayed in the TV screen before the current one, their memory size have been reprogrammed to 1; in this way, only the current measure will be uploaded and presented to the user.

PBT series connection

The A&D PBT series only supports the SPP profile, the SDP for Bluetooth device discovery, and it works in Master Mode (the medical device starts the connection process). Since the device initiates the connection after the measurement is completed, the Android application must act as a server, opening a Bluetooth Server Socket to listen for incoming connections from the device. The steps to follow to implement the Android connection process are the following [18]:

- Open a *BluetoothServerSocket* by calling the *listenUsingRfcommWithServiceRecord-(String, UUID)*: the parameter "String" is an identifiable name of the device, in our case is given from the manufacturer; the parameter "UUID" (Universally Unique Identifier) is a standardized 128-bit format for a string ID, used to uniquely identify information. For SDP supporting devices, the UUID is always *00000000-0000-1000-8000-00805F9B34FB*.
- Start listening for connection requests by calling *accept()*: when successful, *accept()* will return a connected *BluetoothSocket*.

Once these steps are successfully completed, the device and the application are connected, the socket communication channel is open and the application can read the medical data, interpreting them according to the communication protocol given by the manufacturer. Since the medical data reading has been decoupled from the connection, thanks to a modular software approach, changing the vendor, only the module implementing the vendor-specific reading protocol needs to be replaced, whereas the other parts can be preserved.

PBT-Ci series connection

The A&D PBT-Ci series supports both the SPP and the HDP profile, the SDP for Bluetooth device discovery and it works both in Master and Slave ode. It was chosen to use it in Master Mode, in order to use the same scheme applied for PBT series.

PBT-C series connection

The A&D PBT-C series only supports the HDP profile and the SDP for Bluetooth device discovery. The steps to follow to implement an Android HDP application process are the following [18]:

- Get a reference to the *BluetoothHealth* proxy object, calling *getProfileProxy()* with a *BluetoothProfile.ServiceListener* and the *HEALTH* profile type to establish a connection with the profile proxy object.
- Create a *BluetoothHealthCallback* and register an application configuration (*BluetoothHealthAppConfiguration*) that acts as a health sink.
- Connect to the health device and start reading data, interpreting them using a health manager which implements the IEEE 11073 specifications relative to the specific device.

The steps described in this section can be applied not only to the A&D PBT-C series devices, but also to all the medical devices supporting the HDP profile.

5.2 USB Medical Devices

Despite the wireless connection presents important advantages over the wired ones, wired device are also present on the market, especially those not presenting applied parts. Safety issues are generally taken into account by the device manufacturer, through the use of isolation amplifiers or USB galvanic isolation modules. High-end devices, such as biopotential recorders, could also use optic fiber cables (and USB adapters) for the same purpose. Supporting on the same platform both wired and wireless devices extends the application scope, making the system more flexible.

Android supports two modalities of USB connections: USB Host and USB Accessory mode. In USB Host mode, the Android device acts as Host whereas in USB accessory mode the external device does. The support for both modalities have been added starting from Android API level 12. In USB Host mode, the Android device powers the external devices connected to it and is able to enumerate them. Since in the presented framework a device that could act as host was used, only the characteristics of this modality will be described in the following.

5.2.1 USB Host classes

All the USB Host APIs [19] are available in android.hardware.usb package. In this paragraph, an overview of all the classes present in the USB Host APIs, as used for the App development, will be presented.

- UsbManager. This class allows accessing the connected USB devices and communicating with them. For instance, using the *getDeviceList()* method, the application will have a HashMap containing all the USB devices connected and will be able to select the UsbDevice needed. Before communicating with a USB device, the application must ask permission to the user. For this purpose, a broadcast receiver must be created. This receiver listens for the intent broadcasted when the *requestPermission()* method is called and, if the user gives the consent, a connection can be established. With the *openDevice(UsbDevice)* method, it is possible to open a UsbDeviceConnection.

- UsbDevice. This class represents a USB device connected to the Android device. Each UsbDevice has one or more USB interfaces and each of them has different endpoints. With the methods associated to this class it is possible to retrieve information regarding device model, ID, class, protocol, vendor ID, product ID and number of interfaces. Using the *getInterface(interfaceNumber)* method, it is possible to obtain an UsbInterface.

- UsbInterface. This class represents an interface of a USB device. Each device can have one or more interfaces, which define different functionalities. Like the UsbDevice class, it has various methods through which is possible to retrieve the characteristics of that specific interface, like number of endpoints, interface ID, class and so on.

- UsbEndpoint. Represents an endpoint of an interface. The endpoints are the channels used to by USB devices to exchange data. Each interface usually has more than one endpoint, each of which has a specific direction (input or output). The direction can be retrieved through the *getDirection()* method, that returns 0 or 128, respectively for output and input endpoints. Another important attribute is the type of endpoint, that can be control, bulk, interrupt or isochronous. Each type of endpoint is used for different purposes, for example, interrupt endpoints are used to transfer small amount of data, while bulk endpoints for large bursty data.

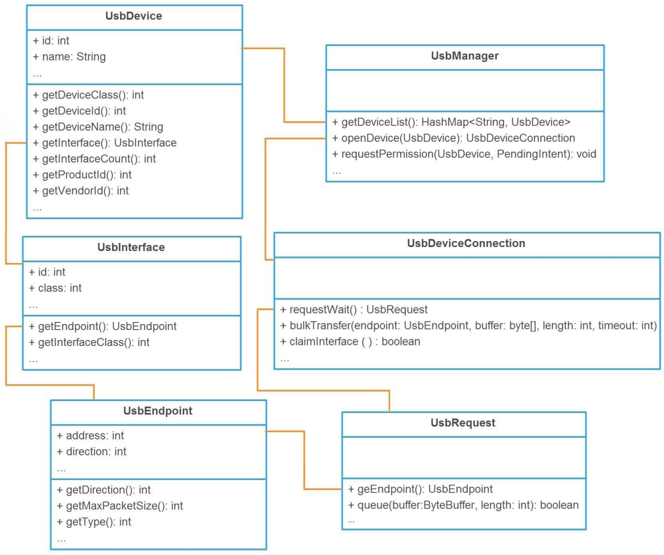


Figure 5.4: USB class diagram, as for the development of the Android App.

- UsbDeviceConnection. This is the class used to connect and exchange data through USB devices endpoints. An instance of this class is created, starting from an UsbManager, by calling the *openDevice(myDevice)* method, passing it the selected UsbDevice. Before sending/receiving data from a specific endpoint it is necessary to request access to that endpoint interface, by calling the *claimInterface(UsbInterface, ...)* method. Once these steps are performed, it is possible to exchange data, using the appropriate method associated by the endpoint type (e.g., bulkTransfer, controlTransfer and so on.

- UsbRequest. A class that represents a request to read or write data on a specific bulk or interrupt endpoint.

- UsbConstants. This class contains all the constant referred to USB. These correspond to definitions in linux/usb/ch9.h of the Linux kernel (e.g., USB_TYPE_CLASS, USB_DIR_IN, USB_ENDPOINT_XFER_BULK and so on).

In Figure 5.4, a simplified USB class diagram as used in this work is shown.

5.2.2 Integration of USB medical devices

Despite the largest part of medical devices for personal vital signs monitoring presents a wireless PC connection, some of them exploit a USB one. The integration of these devices into the system allows expanding the functionalities of the HEREiAM platform significantly. To this aim, the support for the portable SAT-300 finger pulse oximeter by Contec Medical System has been integrated. It is a medical device class IIa, compliant to the CEE 93/42 directive and battery powered. It supports USB communication through a mini USB-USB cable but has also the ability to transmit data wirelessly, using its USB transmitter and receiver included in the box. This configuration allows improving the patient's safety, at the same time introducing all the advantages in terms of comfort of a cordless device. SAT-300 measures the SpO_2 and the heart rate. Among the data transmitted, there is also the possibility to see the pulse wave signal (plethismogram). The SpO_2 measurement ranges from

35% to 100%, whereas the pulse ranges from 30 to 240 bpm. The SpO_2 accuracy is ±2% in the interval between 70%-99% (unspecified for saturations lower than 70%). The HR accuracy is ±2%bpm or ±2%. The SAT-300 has the ability to register and store up to 24 hours of data.

To use the device in wireless mode, the manufacture provides two wireless links, one transmitter and one receiver, than integrate a Universal ISM Band FSK Transceiver (IA4421) to transmit/receive the data wirelessly and a USB to UART Bridge (CP2102) to allow the USB communication. Connecting the oximeter wireless link to a USB port of the Android TV-box, the telemonitoring application is able to connect with the device and receive the data, as will be described in the next paragraph. The oximeter, once turned on, starts sending data immediately, without any external intervention.

To connect to the oximeter and start receiving data, the application uses some classes of the USB Host API but it also needs the correct drivers to be able to communicate with the CP2102 USB to UART bridge. For this purpose, we exploited the open driver library for communication with Arduino and other USB serial hardware on Android (github.com/mik3y/usb-serial-for-android), developed by Mike Wakerly. The steps necessary to perform a connection and read the data coming from the SAT-300 pulse oximeter are the following.

- In the application manifest file, insert the
  <uses-feature android:name="android.hardware.usb.host"/>
  element, to declare that it uses the android.hardware.usb.host feature.
- Get a UsbManager, calling the *getSystemService(Context.USB_SERVICE)* method.
- Get a list of USB devices connected by calling the getDeviceList() method.
- Obtain the correct UsbDevice filtering it, for example, using its product ID or vendor ID (respectively 60000 and 4292 for the CP2102 bridge).
- Request permission to connect to that device, as explained in Section 5.2.1.
- Start a connection with the device calling the *openDevice(myDevice)* method.
- Use the open library to get drivers and ports of the device and connect to the correct port using the *myPort.open(connection)* method.
- Set the correct parameters for the communication (baud rate, stop bits, parity) and start reading data. The device sends packets of five bytes, among which the oxygen saturation and the heart rate.

The Health App

The interfacing with the medical devices, both Bluetooth and USB, is managed by the Health App, one of the services installed in the user's TV-box. The App general layout is compliant to the HEREiAM layout, with the white title bar at the top of the screen, the current page content in the middle and the bottom bar with the Back and Home icons.

Starting from the application main screen, shown in Figure 5.5, the users simply need to select the medical device they want to use, choosing between sphygmomanometer, weight scale, pulse oximeter or glucometer (not yet integrated), in order to start the measurement process. In the central area of the page, there is a scrolling grid of medical devices icons to be selected. Using the left/right arrow keys on the remote control, users can move the scrolling

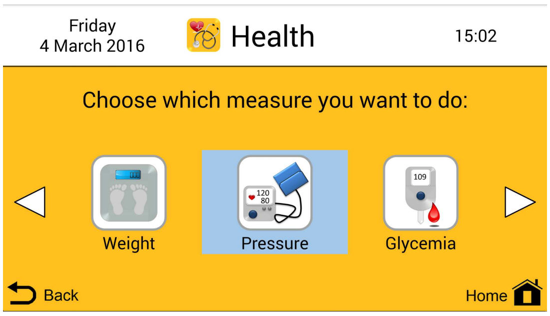


Figure 5.5: Health app homepage.

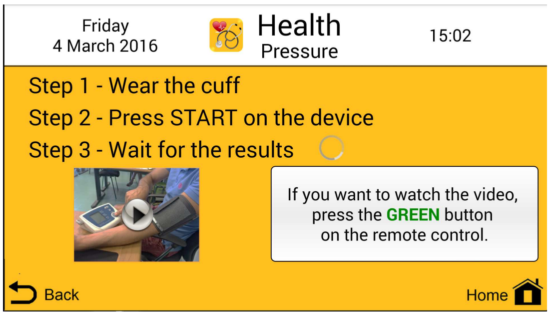


Figure 5.6: Health app measurement page.

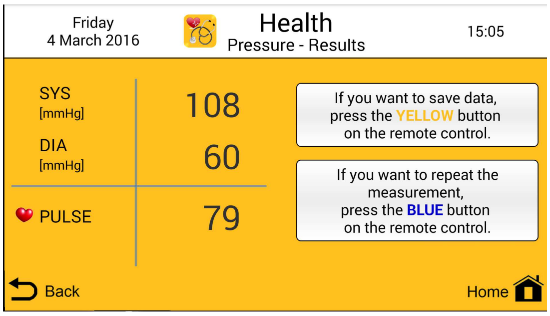


Figure 5.7: Health app results.

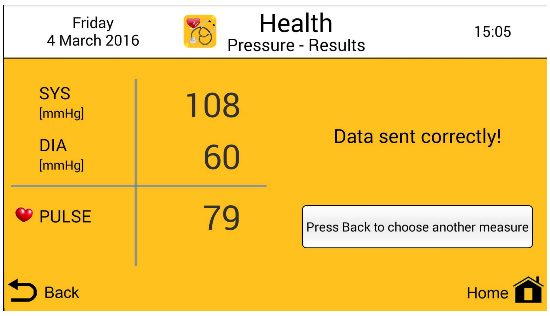


Figure 5.8: Health app confirmation message.

grid of medical devices icons and, pressing the OK button, they can select the measurement to perform. Once the chosen device has been selected, the measurement screen will appear. Such a screen presents a brief list of instructions conceived to support the users during the measurement process. For instance, Figure 5.6 refers to the blood pressure monitor measurement screen.

Once the measurement is completed, the medical device sends the data to the application, which displays them automatically in a new screen (an example is given in Figure 5.7). After reading the results, and checking the coherency with the embedded display of the medical device, the user can choose between repeating the measurement (pressing the blue button on the remote control) or saving the data and send them to the the HEREiAM server (pressing the yellow button on the remote control) through a dedicate ServiceProxy, described in 4.1.2. The data can be retrieved from the server through a dedicated web interface, the Health Portal (described in Section 5.4), by the users' general practitioners, which in turn will be able to send them feedback. The TV-box installed at home will conveniently receive the feedback to be visualized through a dedicated message application (described in Section 4.1.2), and a notification will be sent to the user.

The Health App includes the following activities:

- Health main activity: activity that visualize the medical instruments to be selected. It is finished right after the next one is started. From this activity, the following three can be started: SfigmoActivity, ScaleActivity, GlucoActivity and PulsoActivity.
- SfigmoActivity: activity that deals with receiving the data coming from a sphygmomanometers. It takes care of the connection process with the device and the receiving

of the results. The application remains inside this activity until some data are received. At that point, it automatically triggers the starting of the SfigmoResulsActivity and it is finished.

- ScaleActivity: activity that deals with receiving the data coming from a weight scale. It takes care of the connection process with the device and the receiving of the results. The application remains inside this activity until some data are received. At that point, it automatically triggers the starting of the ScaleResulsActivity and it is finished.
- GlucoActivity: under development. The activity will be identical with respect to Sfigmo and Scale activities.
- PulsoActivity: activity that deals with receiving the data coming from the pulse oximeter. It takes care of the connection process with the device and the receiving of the results. The application remains inside this activity until some data are received. At that point, it automatically triggers the starting of the PulsoResulsActivity and it is finished.
- SfigmoResulsActivity: activity that visualize the results obtained from the sphygmomanometers. From this activity, it is possible to go back to the SfigmoActivity or to start the SfigmoSendActivity.
- ScaleResulsActivity: activity that visualize the results obtained from the body scales. From this activity, it is possible to go back to the ScaleActivity or to start the ScaleSendActivity.
- PulsoResulsActivity: activity that visualize the results obtained from the pulse oximeter. From this activity, it is possible to go back to the PulsoActivity or to start the PulsoSendActivity.
- SfigmoSendActivity, ScaleSendActivity and PulsoSendActivity: activities that deals with the communication with the platform server side. First, the SaveDataXml class is called, to create the appropriate document containing the data and then they are sent through the Service Proxy. From these activities it is possible to go back, respectively to SfigmoActivity, ScaleActivity and PulsoActivity and, after the data are sent correctly, it is possible to go back to the Health main activity.

In the next figure is shown the flow chart of the Health App with the blood pressure measurement example.

5.3 Communication with the Server

The presented Health App can properly work as a personal health care device, extending the functionalities of the medical devices at home, certified for measuring the vital signs of interest. In order to support a telemonitoring scenario, the Health App send the data collected to the HEREiAM server side, according to the current regulations.

As already discussed in Section 4.2, the original X1.V1 has been extended to support interoperability among more heterogeneous systems, including the Android TV-box where the Health App runs. Taking into account the constrained resources of this kind of platforms,

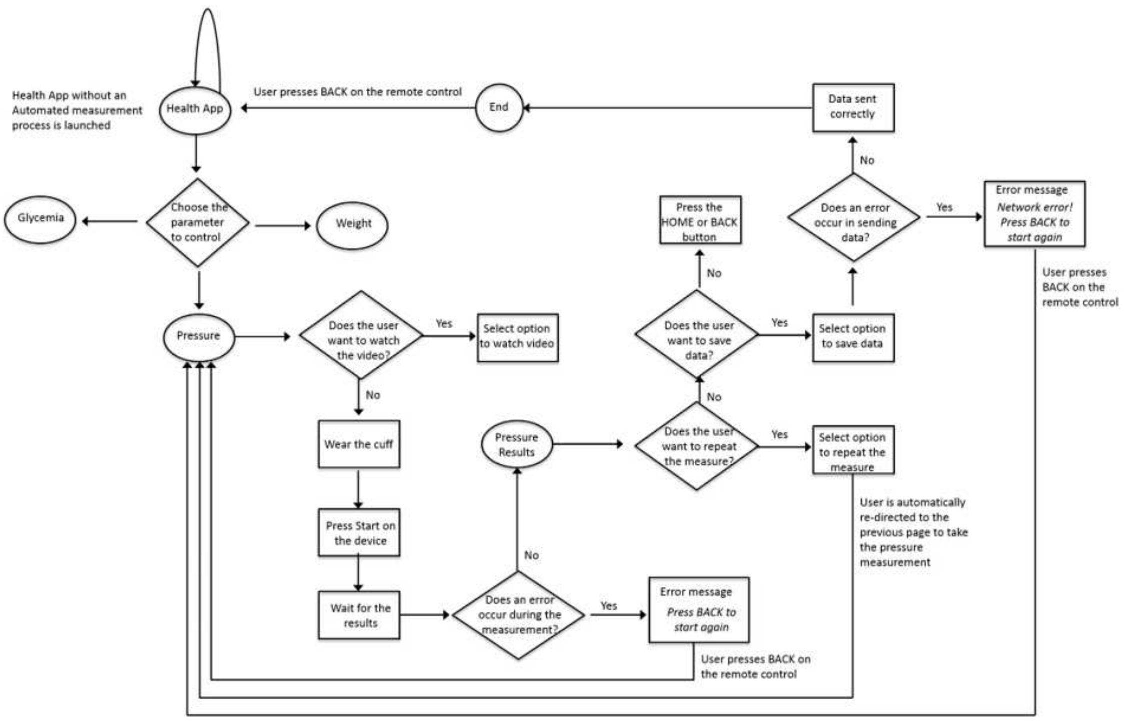


Figure 5.9: Flow chart of the Blood pressure measurement process.

a simplified services interfaces layer, mainly based on the services interfaces specified and standardized in the Healthcare Services Specification Program (HSSP), has been developed. By exploiting this services layer, the HEREiAM platform integrates the following services:

- Documental Repository Service (REPO).
- Measures Management Service (SENS).

REPO represents the core component, and uses the HSSP Retrieve, Locate, and Update Service (RLUS) [66]. RLUS realizes a basic set of create, read, update and delete (CRUD) capabilities and location for generic information resources management, standardizing the way in which the resources are exposed and consumed. SENS is based on REPO and offers the possibility to store and retrieve the vital signs of the patients, measured and collected through the medical devices installed at home, thanks to the Health App running on the Android minicomputer. To this aim, Health App bundles the measurements taken from the connected medical devices into a Rest Lightweight Protocol (RLP) document. RLP is a simple and flexible proprietary format to send information from the patient's home exploiting a limited resources hardware.

To ensure interoperability, allowing to share and exchange measurements information with other systems (such as Electronic Health Record (EHR) systems, or also Personal Health Record (PHR) systems), it is necessary to convert measurements into a widely known standard format. To do so, the SENS service, on the basis of a set of input parameters, builds a Personal Healthcare Monitoring Report (PHMR) [47]. The PHMR is an XML document derived from the Clinical Document Architecture (CDA), and it is a Health Level Seven (HL7, www.hl7.org) draft standard for trial use (DSTU) document format. The information carried by the PHMR may have multiple characteristics, including:

- representation of measurements captured by devices;
- representation of notes, summaries, and other kinds of narrative information that may be added by caregivers or by the users themselves;
- representation of graphs that may be added by intermediary devices that represent trends of users' health.

The PHMR documents are published in their turn on repository, via REPO service, making them available to be searched and viewed by authorized users such as physicians using their software systems integrated with the HEREiAM platform.

5.4 The Health Portal

The Health Portal is the web interface, created for general practitioners, used to visualize the data generated and saved by the elderly through the Health App. It has been designed to be simple and intuitive, with only the important information highlighted. Opening the Health Portal, the general practitioners sees the login page. Using Username and Password provided by the system administrator, the login process will be performed and the user will be redirected to the main page: the patient selection page. From this web page, shown in Figure 5.10, the general practitioners can view the list of their patients that use the Health App, select one of them, select the type of measurement and the time range.

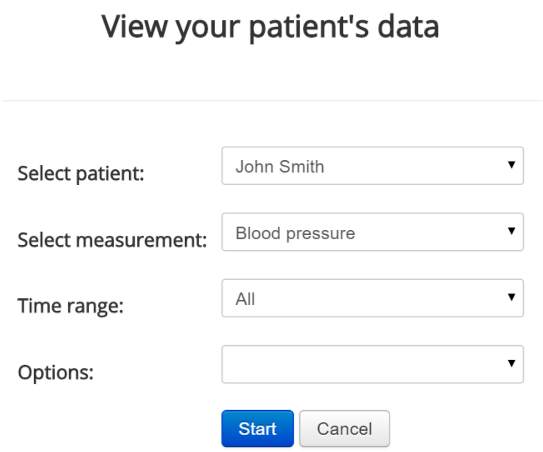
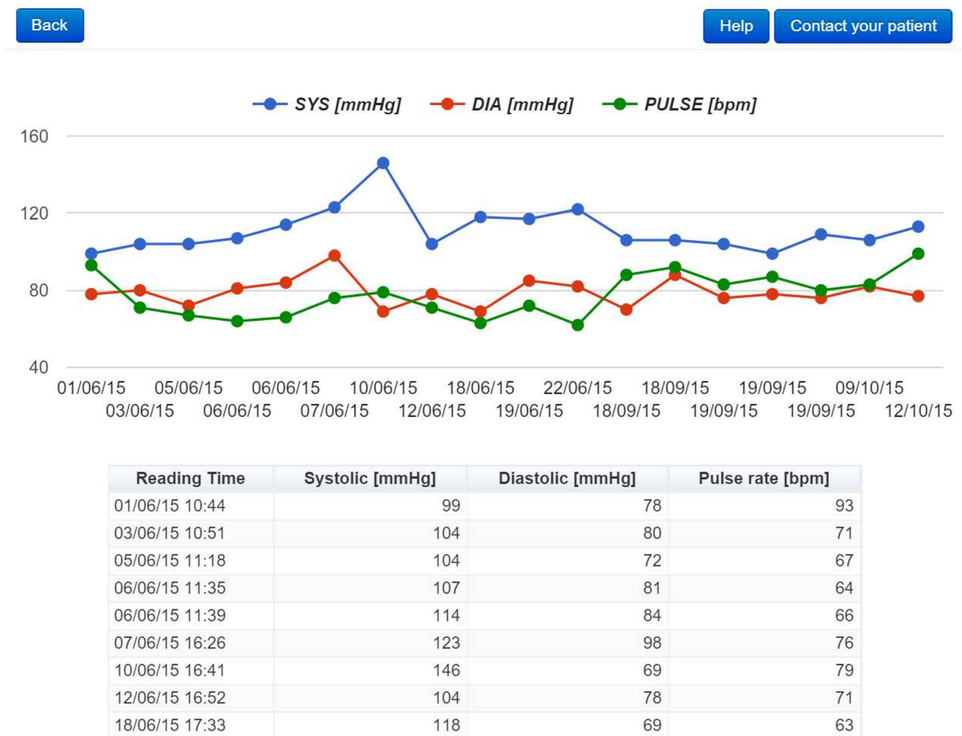


Figure 5.10: The Health Portal patient selection interface.

After the selection, the system performs a query to the database, uploading the results on a new web page (e.g., Figure 5.11 shows the example of blood pressure records).

This page presents a line chart useful to visualize the trends of records over time, usually more significant than the single measurement, and a table containing the details of each one. From this web page, the general practitioners are able to send a message to their patients, clicking on the "Contact your patient" button. The presence of the message will be notified to the elderly at home through the Message app (described in Section 4.1.2)

Preliminary usability tests with elderly patients and general practitioners to evaluate the proposed telemonitoring framework (Health app plus Health Portal) been conducted at the end of 2015. The results are described in Chapter 6.



Reading Time	Systolic [mmHg]	Diastolic [mmHg]	Pulse rate [bpm]
01/06/15 10:44	99	78	93
03/06/15 10:51	104	80	71
05/06/15 11:18	104	72	67
06/06/15 11:35	107	81	64
06/06/15 11:39	114	84	66
07/06/15 16:26	123	98	76
10/06/15 16:41	146	69	79
12/06/15 16:52	104	78	71
18/06/15 17:33	118	69	63

Figure 5.11: The Health Portal data visualization interface.

Chapter 6

Platform evaluation

The HEREiAM system will be tested on the field through three different pilots, one in Italy, one in the Netherlands and one in Belgium, starting from June 2016. The last development activities are still ongoing at the time of writing but, in the meantime, some preliminary usability tests of the HEREiAM system and, in particular, of the Health App and Health Portal have been conducted. In this chapter, the results of the preliminary usability tests will be presented and, finally, the trial implementation plan that have been defined for pilot testing in the three countries will be described.

6.1 Usability tests with elderly users

In this section two user test sessions that have been performed in order to evaluate the HEREiAM platform and improve its technical aspects will be presented. The first one took place in September 2015, with six elderly people that tested three different services developed at that time and the second one took place between October and November 2015, with a total of 35 participants (28 older adults and 7 general practitioners), that testes the telemonitoring service integrated in HEREiAM (Health app and Health Portal, see Chapter 5).

6.1.1 HEREiAM services usability test

The usability test that will be described in this section have been conducted in the Social Policy Department of the Municipality of Cagliari. The test was structured in the following way; first, the experimenter described the functionalities of the system, then the users were invited to explore and use freely three applications, performing the following tasks:

- Comune di Cagliari - users were invited to read a news or an event of their choice,
- Shopping - users were invited to fill in their shopping basket and place a fake order,
- Health - users were invited to explore the application and perform a blood pressure measurement with the help of the experimenter.

After the test, all participants answered two questionnaires, the System Usability Scale (SUS) [26] and one expressly developed for the Health App.

The SUS questionnaire is composed of 10 questions with a scale from 1 (strongly disagree) to 5 (strongly agree). To obtain the total score, first each item contribution must be summed in this way: for odd questions, the score contribution is the users' answer minus 1, for even questions, the score contribution is 5 minus the users' answer. The total obtained must be then multiplied by 2.5 to have a scale from 0 to 100 (instead of one from 0 to 40).

The second questionnaire is composed of 14 questions and uses the same 5 points scale of the SUS, to avoid confusion. The purpose of this questionnaire was to evaluate each graphical and operational aspects of the tested applications, in order to improve them. The questions included in the self-created usability questionnaire are shown in Table 6.1. They have been selected in order to evaluate mainly two aspects: the graphical appearance of the applications and their easiness of use. The evaluation of the first aspect included questions related to colors, fonts and information visible on the screen; the easiness of use aspect was investigated with several questions assessing how easy it was to navigate between the different screens of the applications.

User sample and results

The users selected by convenience sampling by the Municipality of Cagliari (Social Policy Department) for the preliminary usability test was composed by 6 women, with and average age of 75±3 years. Three of the participants had a primary school certificate, two a lower secondary school certificate and one a 4th grade certificate. Half of them lived by themselves whereas the other half lived with one of their sons. With respect to interaction with technologies, it was asked how they felt about their knowledge of the Internet and how often they used it. Three user believe that they have a good or high knowledge of Internet, whereas the others only average or low. Four out of six use Internet less than 1 hour per week, one between 1 and 5 hours and one more than 5 hours.

Usability questionnaire results

All the participants were able to easily perform the required tasks and, at the end of the test, they all compiled the questionnaires. The results collected from SUS mark an overall score of 84±9, whereas results and questions of the custom questionnaires are shown in Table 6.1.

Question	Mean	Std
The graphical aspect of the application is pleasant and appropriate	4.3	0.5
The language used is easy to understand	4.7	0.5
The meaning of the icons is intuitive	4.2	1.2
The fonts used are easily readable	4.8	0.4
The important informations are clearly highlighted	4.5	0.6
The colors are easily distinguishable	3.5	1.6
I am always aware of where I am during the navigation	4.2	0.4
It's easy to get lost using the application	2.7	1.2
The information on how to proceed to the next step are clear	4.5	0.6
The way contents are organized helps finding the information needed	4.5	0.6
Moving from one page to another has been confusing	1.2	0.4
There is always an easy way to go back to the previous page	4.7	0.5
Using the application with the remote control is easy	4.7	0.5
There are too many steps to complete the tasks	1.3	0.5

Table 6.1: Questions and results of the custom usability questionnaire.

Analysing the results of the SUS and the custom questionnaire, the overall users' opinion of the system was good. Some interesting suggestions were given, especially regarding color combinations inside a few application screens. These suggestions have been taken into account in the refining of the platform.

6.1.2 Health App and Health Portal evaluation

To evaluate the developed application, usability tests with a group of older adults have been organized. The tests have been conducted in a family doctor medical practice and the participation to the study was entirely voluntary. The usability test has been structured in the following way:

- presentation of the application performed by the experimenter,
- task 1: blood pressure measurement performed by the experimenter,
- task 2: body weight measurement performed by the elderly user,
- usability and demographic questionnaires administration.

No sensible data has been gathered during the tests, in fact, to perform the weight measurement, the users weighed a bottle of water instead of themselves. After trying the application, all participants filled in two usability questionnaires, the System Usability Scale (SUS) [26] (described in 6.1.1) and the Post-Study System Usability Questionnaire (PSSUQ) [59].

The PSSUQ consists of 19 questions (see Appendix B), with a scale from 1 (highest result) to 7 (lowest result), addressing different aspects of the system. It gives four different results: the *Overall User Satisfaction*, the *System Usefulness*, the *Information Quality* and the *Interface Quality*. The overall user satisfaction is calculated by taking the average of question from 1 to 19, System Usefulness by taking the average of question from 1 to 8, information quality by taking the average of question from 9 to 15 and interface quality by taking the average of question from 16 to 18.

After the usability questionnaires, the elderly users were asked to fill in an anonymous demographic questionnaire, to gather information about their sex, age, education level and interaction with technology, in particular, regarding how often they used TV, mobile phone, tablet, computer and technologies to measure their health status.

User sample

The user sample was composed by 28 older adults, 14 males and 14 females, with an average age of 78.86±5.59. Regarding their education level, 3 had a primary school certificate, 22 out of 28 had a high school diploma and the other 3 had a university degree. The results of the questions related to their interaction with technology are shown in Table 6.2.

	Every day	Every week	More than once a month	Less than once a month	Never
TV	96.4%	3.6%	0%	0%	0%
Computer	89.3%	10.7%	0%	0%	0%
Mobile	25%	7.1%	10.7%	17.9%	39.3%
Tablet	3.6%	14.3%	3.6%	0%	78.5%
Technology for health	53.6%	14.3%	10.7%	7.1%	14.3%

Table 6.2: Interaction with technologies

Usability questionnaire results

The results of both questionnaires are encouraging. The results collected from SUS marked an overall score of 85.75±12.83 over 100. The four different results generated by the PSSUQ questionnaire are shown in Figure 6.1.

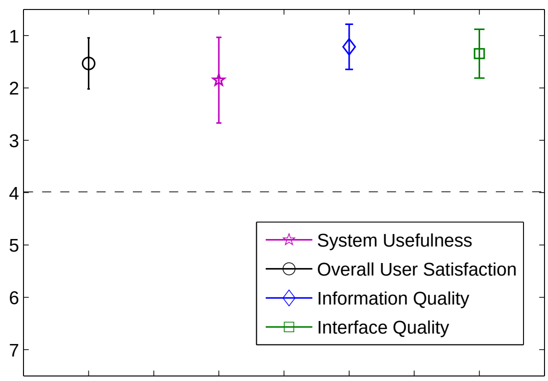


Figure 6.1: PSSUQ results.

As it can be seen from the figure, all aspects evaluated with the PSSUQ obtained a high score, in the range from 1 to 2, being 1 the best possible score. The users indicated that the best aspect of the system were the information present on the screen to help them perform the measurement or moving from one screen of the application to the other. The aspect that marked the lowest score (1.85, still a high overall result) among the four was the System Usefulness. This aspect was clearly related to the fact that many of the interviewed elderly do not feel the need to constantly monitor their health status.

6.2 Interviews with general practitioners

From the GP's side, the Health Portal usability was evaluated. Voluntary practitioners have been asked to:

- watch a short video explaining the working principle of the overall HEREiAM system and the Health App in particular (elderly side),
- watch a short video describing the Health Portal web site (GP side),
- explore the Health Portal web site, choosing one patient from the list and viewing his/her data trends (real data taken from one of the researchers have been used),
- compile two usability questionnaires and a semi-structured interview.

The usability questionnaires that have been chosen were the Website Quality (WQ) questionnaire [17] and the WebQual 4.0 questionnaire [22]. To facilitate the interviews, the three questionnaires were uploaded online using Google Forms [45].

The WQ is composed by 25 questions (see Appendix C), with a scale from 1 (strongly disagree) to 7 (strongly agree). This questionnaire has the aim to evaluate four different aspects of a website: technical adequacy, content quality, specific contents and appearance. Technical adequacy is calculated by taking the average of question from 1 to 9, content quality from 10 to 15, specific contents from 16 to 20 and appearance from 21 to 25. We ruled out two questions, related to customer policies and services) because not applicable to the Health Portal website.

The WebQual 4.0 questionnaire was created originally in 2000 (WebQual) and now it has been updated up to version 4.0. It is composed by 23 questions (see Appendix D), with a scale from 1 (strongly disagree) to 7 (strongly agree). The WebQual 4.0 evaluates three different aspects of a website: usability, information quality and service interaction. Usability is calculated by taking the average of question from 1 to 8, information quality from 9 to 15 and service interaction from 16 to 22. Question 23 regards the general evaluation of the website in consideration.

The semi-structure interview is composed by 12 open questions, conceived with the help of the department of Psychology of the University of Cagliari. It includes the following present in Table 6.3.

6.2.1 GPs sample and results

The general practitioners sample was composed of 4 females and 3 males (41±13 years old), selected by convenience sampling in the districts of the city with the largest number of elderly people.

The results obtained from the WQ questionnaire are shown in Table 6.4.

Question
1. Do you often use IT to manage your patients?
2. Can you estimate the percentage of your older adults patients living by themselves?
3. Do you think it's important to monitor the trends of physiological parameters like blood pressure, glycemia and body weight in elderly patients? (Never, often, sometimes, if they suffer from specific pathologies...).
4. In an ideal scenario, when work hours are not stressful, do you think you would monitor these data more often?
5. In your current situation, if you had the possibility to use an instrument like the one shown in the video, would you use it for its purposes? (Briefly explain)
6. From your point of view, one particularly positive aspect (or more) of this system?
7. From your point of view, one particularly negative aspect (or more) of this system?
8. Based on your experience, which professional figure should monitor the patient through such service? The general practitioner or others?
9. In your opinion, such service should be charged? If yes, how should pay and how much?
10. Would you improve the patient's side of the system? How?
11. Would you improve the doctor's side of the system? How?
12. If an automatic software to analyse the trend of data and send you and the patient a message (via e-mail, text, app notification...) would be available, would you find it useful? Do you think it could increase the adoption rate among physicians?

Table 6.3: Semi-structured interview for general practitioners.

	Mean	**Stdv**
Technical Adequacy	6.063	0.312
Content Quality	6.167	0.167
Specific Content	5.762	0.218
Appearance	6.086	0.163

Table 6.4: Website Quality results (scale from 1 to 7).

As it can be seen from the table, all four aspects evaluated by the WQ questionnaire marked a high score (the questionnaire scale is from 1 to 7), especially the content quality of the website. The aspect that scored the lower result among the four is the specific content. This result is easily explainable, since the Health Portal is very simple and essential and it does not include many contents, except the required ones.

In Table D.1 are shown the results of the WebQual 4.0 questionnaire. The three aspects evaluated marked an high score, as the overall satisfaction. The results are very similar than the ones obtained with the WQ questionnaire, as expected.

	Mean	Stdv
Usability	6,089	0.106
Information quality	6.122	0.192
Service interaction	5.735	0.344
Overall	6.286	0.488

Table 6.5: WebQual 4.0 results (scale from 1 to 7).

Regarding the semi-structure interview, in the following a summary of all the answers obtained is presented:

- Question 1 - Four out of seven GPs declared that they often use IT system to manage their patients, two declared that they do not use them and one said sometimes.
- Question 2 - Two GPs said that 30% of their patients are elderly living by themselves, one said that she is able to estimate the percentage (without reporting the actual number) and the remaining four declared that they are not able to make this estimation.
- Question 3 - Five GPs consider always important monitoring the listed physiological parameters, while the remaining two only if they are linked with a specific pathology.
- Question 4 - They all agree that they would monitor this kind of data more often, if they had less stressful work hours.
- Question 5 - All seven GPs declared that, in their current situation, they would like to use an instrument like the Health Portal. The reasons they added in favour of the use of this system are: it is practical, efficient, it gives useful information, it allows a prompt check of the patients and it allows the GPs to stay in contact with the patients and always be reachable. The negative aspects highlighted are: the fear that many patients and physicians may not use it often and that many elderly would not be able to use the application to collect physiological parameters.
- Question 6 - These are the following positive aspects indicated by GPs: easiness of use (5 GPs), possibility to follow the patients over time (2 GPs), detailed information (2 GPs) and prompt communication with the patients (2 GPs).
- Question 7 - These are the following negative aspects indicated by GPs: none (3 GPs), the elderly may find the system hard to use (2 GPs), a regular monitoring is often not accomplished by patients (1 GP, specifying that this problem was unrelated with this particular system) and the fact that a measurement is not indicative if not linked with a specific medical case.
- Question 8 - All agree that the GP is the main figure that should use this system. Other actors indicated are: other specialists, depending on the case (2 GPs), geriatrician (1 GP) and informal care givers (1 GP).
- Question 9 - All the interviewed GPs declared that this system should be given for free to the elderly by the Health National System.

- Question 10 - Four GPs declared that the patient's side of the system should be improved adding more physiological parameters and informing the patients of its real utility, while the remaining three declared that, in their opinion, it is not necessary to improve it.
- Question 11 - Three GPs declared that the doctor's side of the system should be improved adding more physiological parameters and other three declared that they didn't think it was not necessary to improve it. One stated that, even using this system, a doctor should not stop visiting his/her patients regularly.
- Question 12 - Regarding the last question, all seven agree that if such software existed they would use it.

6.3 Pilot tests implementation plan

The evaluation activities with older adults can be divided into two stages, pilot testing and field trials, which are designed to investigate different aspects of the system. Before introducing the final HEREiAM solution in the real lives of older adults during the field trials, it is important to improve the quality of the technology based on preliminary evaluations with a team of gerontologists and interface designers and with a limited number of older adults. First, the HEREiAM technology and in particular the graphical user interface (GUI) will be, in 3 iterations, evaluated by a team of user-system interaction experts. The system will be evaluated with interface design heuristics [65], guidelines for 10 foot interfaces and expertise in technology for the aged in mind. Second, a small number of older adults will be involved during pilot testing in Italy, the Netherlands and Belgium. The goal is to investigate how older adults use and experience the HEREiAM system, and solve crucial usability issues before the system is implemented in a real life setting. During the field trials, the HEREiAM solution will be introduced in the real lives of 75 senior citizens. The trials aim to demonstrate and evaluate the impact of the developed AAL solution on the elderly citizens' life in their daily environment, i.e. at home, and have the ambition to verify the added value for them and their informal carers.

Before asking older adults to use the HEREiAM solution in their daily lives, it is important to guarantee a sufficiently high quality level. In this regard, a round of pilot testing will be organized in between the heuristic evaluation study and the planned field trials (starting from June 2016). Besides usability, pilot testing will also focus on the attractiveness of the GUI, perceived usefulness of current services and ideas for future functionalities. Pilot tests will be a combination of observation during actual use of the platform, individual questionnaires and a group discussion. These tests will give insight in whether the platform fits the needs of the target group, their knowledge, skills and limitations. Besides, experiences and preferences will be gathered with regards to the use of TV for this kind of service delivery. The outcomes of the pilot testing will serve as input for a final iteration in technical development before the field trials will start.

In this Section, the pilot testing plan will be briefly introduced. This stage will be the last iteration before the real field trials, so, results gathered from it will be extremely important for the last development phased.

6.3.1 Target groups

For the pilot tests organized in Italy 6-8 respondents will be invited, according to the following target group description:

- older adults (65+),
- able to live independent, with or without help of family carers,
- living in urban neighbourhoods.

For the pilot tests organized in the Netherlands 6-8 respondents will be invited, according to the following target group description:

- older adults (65+),
- higher income,
- living in rural areas.

For the pilot tests organized in Belgium 6-8 respondents will be invited, according to the following target group description:

- older adults (65+),
- taking at least one medication daily,
- living in Flanders.

6.3.2 Research questions and goals

The main goal of the pilot tests is to study how older adults perceive the use of the HEREiAM platform in general, and which problems the users are confronted with. The focus is threefold: first, the usability of the HEREiAM system (TV screen GUI and remote control) is examined. Second, first impressions about the design aesthetics and attractiveness are collected. And third, perceived usefulness of current services and needs/wishes for extra services are investigated. In this way, the pilot tests aim at gathering a deeper insight in:

- Perception of the HEREiAM platform
  - Perceived usefulness of the overall platform and individual services
  - Perceived usability of the overall GUI and individual services
  - Perceived design aesthetics of the overall GUI and individual services
- Overall acceptance of the HEREiAM platform
- Need for additional services

6.3.3 Procedure for the evaluations

The pilot test will start with a plenary introduction, followed by a round of three individual session. To conclude the pilot test, respondents come back together for a final group discussion.
At the start of the pilot tests, respondents will be welcomed with a plenary introduction to the project and a brief description of the test objectives and procedure. It will be emphasized that the session aims at testing the HEREiAM platform and not users' performances. Before the start of the actual tests, respondents are asked to introduce themselves and read and sign an informed consent. The informed consent states what will be studied, ensures anonymous analysis, announces that audio and image recordings are going to be made. After the plenary introduction, parallel sessions are organized in an individual setting. Respondents will perform 3 assignments with a different focus, being usability, aesthetics and functionality. After finishing one task, respondents will rotate and perform the other 2 assignments.

Assignment 1: Usability

Each respondent will be invited to use the HEREiAM platform, while being observed by a researcher sitting next to him. No extra documentation or user manuals will be provided to be able to evaluate the intuitiveness of the HEREiAM platform interface. Before start testing, respondents will be encouraged to become familiar with the system for a few minutes. Afterwards, respondents are asked to execute some pre-defined and open tasks and to express their thoughts out loud while interacting with the system. The experimenter objectively take notes of everything that respondents say, without attempting to interpret their actions and words. The experimenter notes down all relevant behaviour (including problems). After performing all the tasks, respondents will be invited to fill out a platform questionnaire to provide an overall evaluation of the system used. Researchers' notes and questionnaire data will help the Consortium in refining the HEREiAM system.

Assignment 2: Aesthetics

Different service platform GUIs (screenshots) are presented to the older respondents. They are asked to rank the different GUIs according to which one is most appealing and which one seems most user-friendly. After that, the HEREiAM GUI is demonstrated, and the respondent can report his thoughts about the look and feel. To conclude the assignment, respondents will be asked to design their own interface, and explain the design decisions made. For this task, the respondents can use creative materials like pencils, paper, scissors, ruler, and so on.

Assignment 3: Functionality

Respondents receive a set of cards describing the different HEREiAM services. They are asked to rank the different services according to usefulness on the one hand and preferred functionality on the other hand. In addition, they have to think about which services should be directly accessible from the home page. After evaluating the currently available HEREiAM services, the respondents are asked to think about other services that could increase the added value of HEREiAM. In this respect, they receive a short questionnaire to score other service opportunities, and to propose three extra services themselves and explain the functionality.

Group discussion

After finishing all three assignments and a short break, the respondents come back together for a final group discussion. It will be discussed how they have experienced using the HEREiAM platform. Next, perceived usefulness and the use of TV will be evaluated in group, in order to get a good insight in overall acceptance and willingness-to-pay. Another interesting topic is how the older adults see the organization and support for the roll-out of such a service platform. The benefit of a group discussion is the combination of different opinions and ideas, and the argumentation respondents will use.

Conclusions and future steps

The research activity described in this thesis and carried out during the three year of the author's Ph.D. has been focused on the conception and design of an ICT platform, based on the TV, for independent living and remote health monitoring of elderly people. During the first year, researches on the implications of the ageing society, ICT solutions present in the market and usability tests with different group of elderly people led to the definition of the requirements and the technical specifications of the presented system. The identified requirements were related to general functionalities of the platform, services to be offered, aspect of the GUI, system interaction, configuration and privacy issues. With all the requirements in mind, the platform was developed in terms of hardware components, software components and central server. The system software consists in several basic functionalities (agenda management, videocall, message exchange) and in some applications developed to enrich the set of services offered to the elderly. The presented platform is modular, being able to integrate external services that comply with the system requirements already mentioned above. Telemonitoring features were added to the platform through an application able to connect with different Bluetooth medical devices and save the data in the server side of the platform, were they will be included in the patient's electronic health record. Through a custom web interface, the health data can be retrieved and visualized by the user's family doctor (or his/her caregivers), allowing the exchange of feedback between older adult and health professionals, by exploiting the Message basic service.

A preliminary evaluation of the platform, with particular emphasis on its telemonitoring features, has been performed. Elderly users aged 65 or over were invited to test the system and evaluate it through several usability questionnaires. Although the user sample was small, the preliminary usability results are encouraging and the comments given by the users helped in improving some criticality at user interface level. The general practitioners' side of the telemonitoring framework was also evaluated. Several family doctors explored the dedicated web front-end and gave their opinion on the interface and the system itself.

Three field trials are about to start in Italy, Belgium and The Netherlands, with 25 users each. Data gathered during the six months of the trials will help understand the real usability of the platform, which services are most used and which are abandoned and, in general, the perceived usefulness of such system.

The architecture of the ICT platform presented in this thesis has unique features with respect to other similar products, since it is an open and modular system, able to expand the set of offered services, while maintaining its internal consistency. The users will have the possibility to install new features without being afraid, since all the new services will be similar to the others in terms of layout and navigation scheme with the remote control. Even if the system includes telemonitoring features, its primary goal is to offer participation, entertainment and support services, so the user will not perceive this platform as stigmatizing. At the same time, if at some point the health capabilities should be needed, the user will be able to exploit them, being already accustom to use the whole system and its services. On the other hand, if the elderly user already suffer from a certain disease, like diabetes, hypertension or other common pathologies among older adults, the telemonitoring features can be seen as a mean to stay in touch with the physician and feel constantly monitored.

Choosing the Android operating system will facilitate the transition between a TV-based system and a portable one. The elderly of today may have difficulties in using mobile devices, but it is of paramount importance to keep in mind that society is evolving and the proposed solutions must be able to follow both population changes and market trends. The proposed system has the advantage of being easily modified to be used on mobile devices (smartphones and tablets). Currently, the tablet version of a few of the service proposed is being developed.

Regarding future steps, other than the ones mainly related to the project, the developed system could be used to study custom alerts mechanism in different areas. Being already able to store different vital signs, one possible application could be the detection of anomalies in data trends, to alert the physician in case of parameters out of range. Since the health application has been developed in order to easily integrate new devices, integrating, for example, an activity tracker, it could be possible to use data mining to identify the user's activity patterns in relation with his/her health status. Linking also the information gathered from the PIR sensors installed in each room, the analysis could be extended further to include a mechanism to encourage the older adults to be more active, promoting an healthier lifestyle. Once all these information are put together, it is possible to rethink the system and make it even more tailored to the single user, proposing activities and events he/she might like, depending on the lifestyle identified. Once the field trials will start, all these planned activities will be carried out involving more users, to be able to apply data mining techniques.

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List of Publications Related to the Thesis

Published papers

Conference papers

- S. Macis, D. Loi, G. Angius, D. Pani, L. Raffo, W. Rijnen and H.H. Nap, *Towards an integrated TV-based system for active ageing and tele-care*, in Atti Quarto Congresso Nazionale di Bioingegneria, GNB2014, Pavia, Italy, June 2014 (Relation to Chapter x)
- S. Macis, D. Loi, D. Pani, S. La Manna, V. Cestone, D. Guerri and L. Raffo, *Home Telemonitoring of Vital Signs Through a TV-based Application for Elderly Patients*, in Proceedings of the 10th annual IEEE International Symposium on Medical Measurements and Applications (MeMeA2015), Torino, Italy, May 2015. (Relation to Chapter x)
- S. Macis, D. Loi, D. Pani, W. Rijnen and L. Raffo, *A TV-based ICT Platform for Active Ageing, Tele-care and Social Networking*, in Proceedings of the 1^{st} International Conference on Information and Communication Technologies for Ageing Well and e-Health (ICT4AgeingWell2015), Lisbon, Portugal, May 2015. (Relation to Chapter x)
- S. Macis, D. Pani, D. Loi, A. Ulgheri and L. Raffo, *A Telemonitoring Framework Designed for Elderly Patients*, in Proceedings of the 12th IASTED International Conference on Biomedical Engineering, Innsbruck, Austria, February 2016. (Relation to Chapter x)

List of Publications Unrelated to the Thesis

Published papers

Journal papers

- M. Crepaldi, S. Macis, P. Motto Ros and D. Demarchi, *A 0.07 mm^2 Asynchronous Logic CMOS Pulsed Receiver Based on Radio Events Self-Synchronization.* IEEE Transactions on Circuits and Systems - I: Regular Papers, vol. 61, no. 3, pp. 750-763, 2014.

Posters with published proceedings

- S. Macis, G. Angius and L. Raffo, *A Wearable Device for PPG Acquisition and Continuous Detection of Sleep Apnea Episodes,* in Atti Gruppo Elettronica 2014, Cagliari, Italy, June 2014.

Appendices

Appendix A

Demographic questionnaire

1. **Personal data**
   1.1. Participant code #:
   1.2. Gender:
      - ☐ Male
      - ☐ Female

   1.3. Date of birth: __/__/__
   1.4. Nationality:
   1.5. Education:
2. **Interaction with technologies**
   2.1. How often do you watch TV?
      - ☐ Never (go to question 2.3)
      - ☐ Less than once a month
      - ☐ More than once a month
      - ☐ Every week
      - ☐ Every day

   2.2. How long do you watch TV per week, on average?
      - ☐ Less that 30 minutes
      - ☐ Between 30 minutes and 1 hour
      - ☐ Between 1 and 3 hours
      - ☐ More than 3 hours

   2.3. How often do you use the mobile phone?
      - ☐ Never (go to question 2.5)
      - ☐ Less than once a month
      - ☐ More than once a month
      - ☐ Every week
      - ☐ Every day

2.4. For what purposes do you you the mobile phone?

☐ Phone calls
☐ Text messages
☐ Agenda
☐ Internet
☐ Photos or videos

2.5. How often do you use the computer?

☐ Never
☐ Less than once a month
☐ More than once a month
☐ Every week
☐ Every day

2.6. How often do you use tablet?

☐ Never
☐ Less than once a month
☐ More than once a month
☐ Every week
☐ Every day

2.7. How often do you use Internet?

☐ Never
☐ Less than once a month
☐ More than once a month
☐ Every week
☐ Every day

2.8. Do you use technologies to evaluate your health status (e.g., blood pressure measurement, glycemia...)?

☐ Never
☐ Less than once a month
☐ More than once a month
☐ Every week
☐ Every day

3. **Leisure activities**

3.1. What kind of activities do you perform mainly during the day?

☐ None
☐ Passive activities at home (watching TV)
☐ Active activities at home (reading or performing manual activities)
☐ Outdoor activities

3.2. Where do you have your social interactions, mainly?

☐ I don't have social interactions
☐ I meet people around, when going out (streets, bar, doctor)

- ☐ I meet people in public offices (community centers, elderly associations)

3.3. How often do you go out (shopping, trips, restaurants...)?

- ☐ Never
- ☐ Every year
- ☐ Every month
- ☐ Every week
- ☐ Every day

3.4. How often do you organize social gatherings (meetings, social meals...)?

- ☐ Never
- ☐ Every year
- ☐ Every month
- ☐ Every week
- ☐ Every day

3.5. How often do perform physical activities (walking, sports, gym...)?

- ☐ Never
- ☐ Every year
- ☐ Every month
- ☐ Every week
- ☐ Every day

3.6. How often do play card games?

- ☐ Never
- ☐ Every year
- ☐ Every month
- ☐ Every week
- ☐ Every day

3.7. How often do go to cultural events (museums, concerts...)?

- ☐ Never
- ☐ Every year
- ☐ Every month
- ☐ Every week
- ☐ Every day

3.8. How often do you travel?

- ☐ Never
- ☐ Every year
- ☐ Every month
- ☐ Every week
- ☐ Every day

3.9. How often do you play board games?

- ☐ Never
- ☐ Every year
- ☐ Every month

- ☐ Every week
- ☐ Every day

3.10. How often do perform craftwork?

- ☐ Never
- ☐ Every year
- ☐ Every month
- ☐ Every week
- ☐ Every day

3.11. How often do you play brain teasers/puzzles?

- ☐ Never
- ☐ Every year
- ☐ Every month
- ☐ Every week
- ☐ Every day

3.12. How often do you play computer games?

- ☐ Never
- ☐ Every year
- ☐ Every month
- ☐ Every week
- ☐ Every day

3.13. Are there different activities you like to perform? If yes, which ones?

4. **Social situation**

4.1. How frequently do you socially meet people that are not related to you (friends or neighbours)?

- ☐ Never
- ☐ Less that once a month or during holidays
- ☐ Between one and three times per month
- ☐ Once a week or more
- ☐ Every day

4.2. How often do you talk on the phone with your family or friends?

- ☐ Never
- ☐ Once a week
- ☐ More than once a week
- ☐ Once a day or more

5. **Familiar situation**

5.1. Whom do you live with?

- ☐ Alone
- ☐ With my husband/wife
- ☐ With __ children

- ☐ With __ grandchildren
- ☐ With son/daughter in law
- ☐ With brother/sister
- ☐ With a caregiver
- ☐ Other ________

5.2. Do you see your close relatives often or, at least, as often as you'd like?

- ☐ I never see them
- ☐ Sometimes I feel sad because they don't visit often
- ☐ Sometimes I feel sad because they visit often
- ☐ I am happy even if they don't visit often
- ☐ I am happy because I can see them as often as I want

5.3. How often do you see your non-close relatives?

- ☐ Never
- ☐ Less that once a month or during holidays
- ☐ Between one and three times per month
- ☐ Once a week or more
- ☐ Every day

Appendix B

Post-Study System Usability Questionnaire

Question	Strongly disagree						Strongly agree
1. Overall, I am satisfied with how easy it is to use this system	1	2	3	4	5	6	7
2. It was simple to use this system	1	2	3	4	5	6	7
3. I could effectively complete the tasks and scenarios using this system	1	2	3	4	5	6	7
4. I was able to complete the tasks and scenarios quickly using this system	1	2	3	4	5	6	7
5. I was able to efficiently complete the tasks and scenarios using this system	1	2	3	4	5	6	7
6. I felt comfortable using this system	1	2	3	4	5	6	7
7. It was easy to learn to use this system	1	2	3	4	5	6	7
8. I believe I could become productive quickly using this system	1	2	3	4	5	6	7
9. The system gave error messages that clearly told me how to fix problems	1	2	3	4	5	6	7
10. Whenever I made a mistake using the system, I could recover easily and quickly	1	2	3	4	5	6	7
11. The information (such as on-line help, on-screen messages and other documentation) provided with this system was clear	1	2	3	4	5	6	7
12. It was easy to find the information I needed	1	2	3	4	5	6	7
13. The information provided for the system was easy to understand	1	2	3	4	5	6	7
14. The information was effective in helping me complete the tasks and scenarios	1	2	3	4	5	6	7
15. The organization of information on the system screens was clear	1	2	3	4	5	6	7
16. The interface of this system was pleasant	1	2	3	4	5	6	7
17. I liked using the interface of this system	1	2	3	4	5	6	7
18. 18. This system has all the functions and capabilities I expect it to have	1	2	3	4	5	6	7
19. Overall, I am satisfied with this system	1	2	3	4	5	6	7

Table B.1: PSSUQ questionnaire.

Appendix C

Website Quality questionnaire

Question	Strongly disagree						Strongly agree
1. The Health Portal looks secured for carrying out transactions	1	2	3	4	5	6	7
2. The Health Portal looks easy to navigate through	1	2	3	4	5	6	7
3. The Health Portal has adequate search facilities	1	2	3	4	5	6	7
4. The Health Portal is always up and available	1	2	3	4	5	6	7
5. The Health Portal has valid links (hyperlinks)	1	2	3	4	5	6	7
6. The Health Portal can be personalized or customized to meet one's needs	1	2	3	4	5	6	7
7. Web pages load fast in the Health Portal	1	2	3	4	5	6	7
8. The Health Portal has many interactive features	1	2	3	4	5	6	7
9. The Health Portal is easy to access	1	2	3	4	5	6	7
10. The content of the Health Portal is useful	1	2	3	4	5	6	7
11. The content of the Health Portal is complete	1	2	3	4	5	6	7
12. The content of the Health Portal is clear	1	2	3	4	5	6	7
13. The content of the Health Portal is current	1	2	3	4	5	6	7
14. The content of the Health Portal is concise	1	2	3	4	5	6	7
15. The content of the Health Portal is accurate	1	2	3	4	5	6	7
16. In the Health Portal, one can find contact information (e.g. e-mail addresses,phone numbers, etc.)	1	2	3	4	5	6	7
17. In the Health Portal, one can find firm's general information (e.g. goals, owners)	1	2	3	4	5	6	7
18. In the Health Portal, one can find details about products and/or services	1	2	3	4	5	6	7
19. The Health Portal looks attractive	1	2	3	4	5	6	7
20. The Health Portal looks organized	1	2	3	4	5	6	7
21. The Health Portal uses fonts properly	1	2	3	4	5	6	7
22. The Health Portal uses colors properly	1	2	3	4	5	6	7
23. The Health Portal uses multimedia features properly	1	2	3	4	5	6	7

Table C.1: Website Quality questionnaire.

Appendix D

WebQual 4.0 questionnaire

Question	Strongly disagree						Strongly agree
1. I find the Health Portal easy to learn to operate	1	2	3	4	5	6	7
2. My interaction with the Health Portal is clear and understandable	1	2	3	4	5	6	7
3. I find the Health Portal easy to navigate	1	2	3	4	5	6	7
4. I find the Health Portal easy to use	1	2	3	4	5	6	7
5. The Health Portal has an attractive appearance	1	2	3	4	5	6	7
6. The design is appropriate to the type of site	1	2	3	4	5	6	7
7. The Health Portal conveys a sense of competency	1	2	3	4	5	6	7
8. The Health Portal creates a positive experience for me	1	2	3	4	5	6	7
9. Provides accurate information	1	2	3	4	5	6	7
10. Provides believable information	1	2	3	4	5	6	7
11. Provides timely information	1	2	3	4	5	6	7
12. Provides relevant information	1	2	3	4	5	6	7
13. Provides easy to understand information	1	2	3	4	5	6	7
14. Provides information at the right level of detail	1	2	3	4	5	6	7
15. Presents the information in an appropriate format	1	2	3	4	5	6	7
16. Has a good reputation	1	2	3	4	5	6	7
17. It feels safe to complete transactions	1	2	3	4	5	6	7
18. My personal information feels secure	1	2	3	4	5	6	7
19. Creates a sense of personalization	1	2	3	4	5	6	7
20. Conveys a sense of community	1	2	3	4	5	6	7
21. Makes it easy to communicate with the organization	1	2	3	4	5	6	7
22. I feel confident that goods/services will be delivered as promised	1	2	3	4	5	6	7
23. Overall view of the Web site	1	2	3	4	5	6	7

Table D.1: WebQual 4.0 questionnaire.