Designing, implementing and testing an IoT based home system for integrated care services

Exploring the transferability and expandibility of an ICT based integrated care system to respond to the long term daily needs of people with disabilities

Massimiliano Malavasi , Lisa Cesario, Valentina Fiordelmondo, Arianna Gherardini,
Evert-Jan Hoogerwerf, Chiara Lepore, Carlo Montanari, Lorenzo Desideri
Assistive Technology Area
AIAS Bo onlus
Bologna, Italy
mmalavasi@ausilioteca.org

***Abstract*—The purpose of this paper is to describe the design, development and implementation plan for testing the transferability of an ICT based solution for Integrated Care (the ProACT system), originally optimized for older people with multimorbidity, to an enlarged group of users and needs. The transfer trial will be held in Italy and requires the development of a specific expansion of the ICT platform and service protocols. This paper outlines the details of the design, development and implementation plan, including the home IoT based solution. The target participants will be disabled people, informal carers, formal carers, professionals in the health and social domain.**

Keywords— Integrated care · Active Assisted Living · Internet of things · Transferability study

I. INTRODUCTION

Almost every country in the world is experiencing growth in the number and proportion of older people in their population [1]. Multimorbidity, defined as the coexistence of two or more chronic conditions, is certainly one of the main challenges related to increased longevity [2,3]. Emerging evidence reports that multimorbidity increases the risk of having higher healthcare utilization, worse self-reported health status, depression, and reduced functional capacity [4-6]. A more accurate information about users' lives and their vital parameters may promote self-management of chronic health conditions and improve organization of care activities [7,8]. Starting from this scenario, the ProACT project international team has developed a multi domain (home, community, social and hospital) ICT based integrated care system [9,10]. The system is based on cloud services, data analytics and specific Careapps to be used both by final users and carers. The original system includes a kit of personal healthcare devices that, if properly used, can provide more information about the health conditions and daily activities of users with multimorbidity [11]. The system is currently being tested in Ireland and Belgium, while transferability trials in Bologna, Italy, are having an explorative approach and include four groups of users with different user scenarios and needs. The main objectives of the transferability study and trials can be outlined as follows:

1. To collect preliminary information on the usability, accessibility and acceptability of the system;
2. To identify weaknesses and strengths of the system used in specific contexts and within specific use scenarios (also different from the principal users target group);
3. To identify technical, cultural, and personal barriers for the adoption of the system;
4. To evaluate the interoperability and expandability of the system.

Three local social and healthcare service providers participate in the trials: AIAS Bologna, ASP Città di Bologna and Azienda USL di Bologna (the Local Health Trust, LHT). The participants were divided into four user groups: while the first three groups (G1-3) can be included in the main target of ProACT project (older adults with multimorbidity), the fourth group (G4) aims to expand the use to residential long term independent living pathways of people with disability, adding to the assistive technology already in use a state-of-the-art ICT based integrated care service.

II. METODOLOGY

The transferability study is based on four main phases:

T0. The system is localized to the trial region context. The researchers also directly pilot the system for 3 months in order to ensure its proper functioning and reliability in a variety of living contexts.

T1. This phase involves the recruitment of selected participants, the gathering of informed consent and the administration of baseline questionnaires. The system is also delivered and installed within the users' living contexts.

T2. The users use the ProACT system in their daily living environment for a month.

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T3. A comprehensive assessment of the users' experience of the system is conducted using both quantitative and qualitative approaches.

III. SYSTEM ARCHITECTURE DEFINITION AND COMPONENTS

The architecture of the IoT based system specifically designed and developed for the fourth group of users (G4) adapts the original model proposed by ProACT to the specific needs of G4. Home automation and IoT solutions that can easily adapt to the user environment have been identified as "proactive key actors" in supporting a more independent and safe daily living. A key objective was to expand the capability of the integrated care system to gather and analyze the data from the home environment. These data can be significant not only for the safety of the user, but also for his/her sociability and to plan home care. Figure 1 shows a conceptual model of the system developed for G4.

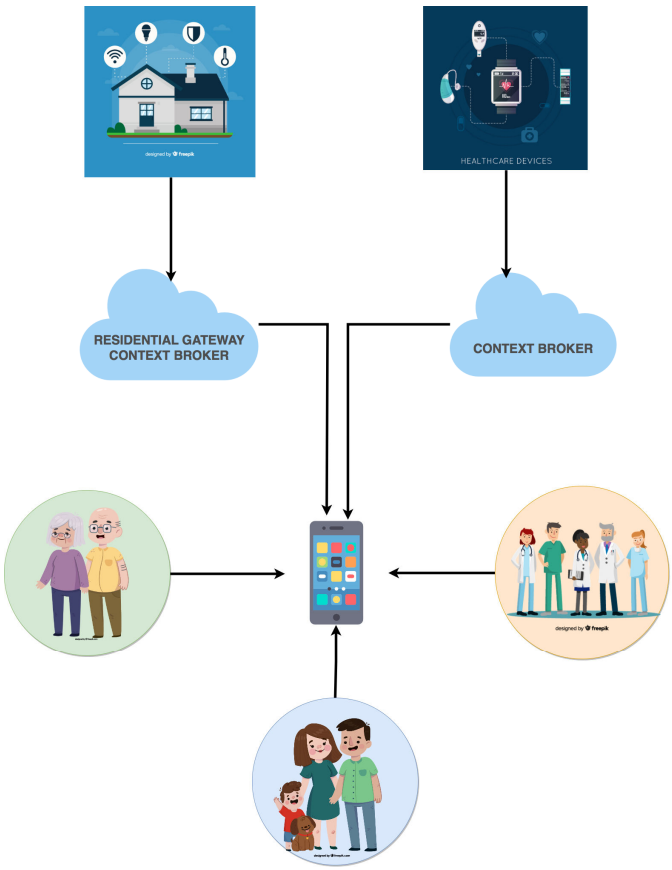

Fig. 1. System conceptual model

A. IoT devices

The initial Focus Groups (unpublished data) revealed a certain skepticism of participants towards the introduction of home automation in their own homes. Therefore, it was necessary to design the system in such a way that it would be the least invasive possible, but at the same time enhancing the potential of the devices to interact with the environment and to improve the daily life of users. The choice of the devices was also informed by the required functional performances, as well by the need to keep the cost of every single IoT kit sustainable for a large-scale implementation in the existing health and social care protocols and services. The fourth main specification was to select reliable products already present in the worldwide smarthome IoT market, in order to ensure a fast and replicable development and implementation of the solution.

The final selected devices for G4 are the following:

- *Smart Lights*: radio controlled lights are certainly one of the least invasive devices present in the IoT market, both from the point of view of the data collected (essentially intensity of light and color) and from the point of view of the concept of bulb itself, which is already present in all houses. Managing environmental light increases safety and autonomy.
- *Motion and presence sensors*: these sensors have been chosen to trigger the smart light when a movement is detected (for example going to toilette at night), but also to collect data and monitor the presence and the movements in a specific room.
- *Weather and air quality sensors*: the weather station provides data strictly related to the environment in which the person lives, both indoor and outdoor. It provides information on temperature, humidity, air quality, barometric pressure and weather forecast. The information gathered can be used to monitor the quality of the living environment and possibly provide advice to the user in order to change her/his behavior (for example, if the system detects low air quality it may suggest the user to open the windows more frequently during the day).
- *Smart camera*: the smart camera detects and recognize faces and consequently social activities and can detect intruders, increasing the security of vulnerable people in frailty condition. It must be emphasized that the camera can be placed in such a way that it points to the entrance door only, in order to be as less invasive as possible during daily activities.

Tables I and II describe some of the devices selected and tested to finalize the ProACT G4 trial home kits.

TABLE I.

Health care devices		
Producer	***Device***	***Main function***
Withings	BPM	Blood pressure monitor
IHealth	BP5 Feel	Blood pressure monitor

Health care devices		
IHealth	PO3M Air	Pulse oximetry
Withings	Steel Series	Activity tracker, Sleep monitor
IHealth	BG5 Gluco	Glucometer
Withings	Body Series	Weight Scale
Withings	Sleep	Sleep Tracking

TABLE II.

Samarthome IoT devices		
Producer	***Device***	***Main function***
Philips Hue	Hue Bridge 2.0	Bridge
Philips Hue	Hue Motion Sensor	Motion Sensor
Philips Hue	White Ambience	Bulbs
Philips Hue	Dimmer Switch	Switch for manual control
Netatmo	Weather Station	Weather station, CO2 Sensor
Netatmo	Smart door and windows sensor	Windows and doors sensors
Netatmo	Welcome	Smart camera

B. Home automation server – context broker

All the data gathered by the different IoT devices are sent to a context-broker, which saves them in local databases. To perform this task, the development team chose OpenHAB [12], an open source framework for home automation. The choice derives from the versatility of the system, which allows the integration of many IoT devices and remote services, accessible through different user interfaces like dedicated *webapps*, a REST API and cloud services. With OpenHAB it is possible to integrate also other frameworks and smart assistants like Apple Homekit, Google Home and Amazon Alexa, making the system more accessible and adaptable to the single needs. Moreover, it also allows to develop a custom web application based on Angular, which is useful for rapid prototyping and testing.

C. The Care App

All the data collected by the devices and stored on OpenHAB are available to the end user, who can view them through a custom *webapp*. Below some features of the specific CareApp developed for G4 and based on HabPanel, a tool part of the OpenHAB framework:

- *Smart home controller*: it consists of a remote control for the smart home which allows the user to control IoT devices, performing action such as switch on/off the lights and so on;
- *Dedicated camera view controller*: which allows the user to visualize the camera streaming and the log of visitors
- *Sensors Graphics*: this module allows to visualize simple reports of the data collected by the sensors.

D. The CareBot

The *CareBot* was created with the aim of making the existing section of ProACT dedicated to health tips more interactive and engaging for the user. In the original version, developed for the ProACT main trails, the tips and tutorials sections of the app, were based on a classic approach, with sequences of buttons to reach specific pages. This has discouraged some users, less confident in the use of technology. Starting from this feedback, the team decided to create a small chatbot, the *CareBot*, to respond to the need of specific users to simplify this kind of operations as much as possible. A highly user-friendly chat that can guide users towards the search for the requested information is essential for the usability of the system.

IV. CONCLUSIONS AND FUTURE SCENARIOS

The objective of the ProACT G4 transfer trial is to test and demonstrate the transferability and extension of the ProACT system to different contexts where different needs may occur. In the case of G4 this has required the integration of ProACT with an IoT module and a webapp entirely dedicated to smart home functionalities and to explore the strengths and weaknesses of the enhanced system in an integrated care context. At the actual stage a fully functional prototype has been successfully developed, implemented and tested in the lab. The prototype has positively ended mid-term friendly trials and eight kits are ready to be implemented, for the final integrated care trial of ProACT G4, both in single users' homes and in two cohousing facilities. During the trial the system will be evaluated with qualitative and quantitative methods.

We can consider this trial as an intermediate step towards the creation of a single innovative Careapp that can combine health care, social care and smart home environment. This would allow the development of a well-rounded care network with a broader view of the user's health, with the ultimate goal of improving the quality of life and make it possible to extend independent living pathways of people with disability to the domain of self-health management, a domain often excluded by existing assistive technology solution.

Another important aspect that has remained unexplored is that concerning user engagement. Analyzing the Focus Groups output during the previous trials it emerged that some users did not find the system very stimulating to use, causing a lack of motivation in the use of the app. This could lead to the gradual abandonment of the system. For this reason, in the future, the research team is planning to introduce some elements of gamification, which might stimulate people to interact more actively with the devices and the Careapps forming the enhanced ProACT system.

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Icons of Fig.1 designed by Freepick.

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