Design and Ergonomics of Monitoring System for Elderly

Giuseppe Andreoni[1], Fiammetta Costa[1], Alberto Attanasio[2], Giuseppe Baroni[3], Sabrina Muschiato[1], Paola Nonini[3], Andrea Pagni[4], Roberto Biraghi[4], Roberto Pozzi[5], Maximiliano Romero[1], and Paolo Perego[1]

[1] Design Department, Politecnico di Milano, via durando 38/a, 20158 Milan, Italy
[2] La Meridiana, Società Cooperativa Sociale, Via G. dei Tintori 18, 20900 Monza, Italy
[3] Flextronics Design srl, via B. Gerolamo 27, 20052 Monza, Italy
[4] STMicroelectronics srl, via C. Olivetti 2, 20864 Agrate Brianza, Italy
{giuseppe.andreoni,fiammetta.costa,paolo.perego, maximiliano.romero}@polimi.it, alberto.attanasio@gmail.com, {roberto.biraghi,andrea.pagni}@st.com, {giuseppe.baroni,SabrinaMuschiato, Paola.Nonini}@it.flextronics.com, roberto.pozzi@datamedsrl.com

Abstract. This paper presents the study and the development of a tele-monitoring system with the aim to support elderly people living alone. The intent of our new system is to permanently connect the elderly with their relative and caregivers. The tele-monitoring system allows to continuously monitoring the subjects as they were in a hospital and, in case of anomalies in the health state, automatically share and alarm to caregivers and relatives. The continuous monitoring is done using two different sub-systems: wearable sensors for biomedical data collection and infrared video cameras for fall detection. The main goal of this study is to develop and test the system prototype not only from a functional point of view, but also from the user acceptability and usability point of view. For this reason this studies was based on a parallel development of acceptability and technical issues; this allows to create an ad-hoc tele-monitoring system for elderly,

Keywords: Tele-medicine, Tele-monitoring, Elderly, Wearable devices, Optical monitoring devices.

1 Introduction

Data from Eurostat estimations [1] shows that European population is constantly and progressively aging; in 2012 there are four people in working age for every over 65s; and the prediction shows that they become two in 2060; in 260 the overs-65s is predicted to reach more than 42% of population [2]. These aspects cause an increase in the cost the National Sanitary System has to face; in the last 15 years, the health spending has grown more than twice the Gross Domestic Product (GDP), with an average hospitalization cost for one day which amount to 674€ [3]. With this trend in aging population and costs rising, it is easy to expect a collapse of the National Sanitary System. For these reason many countries are trying to find alternatives and

V.G. Duffy (Ed.): DHM 2014, LNCS 8529, pp. 499–507, 2014.

strategies based on early de-hospitalization and tele-medicine with the aim to reduce costs. Thus many applied research projects focused on home care services based on Information Communication Technology (ICT) systems have been carried out [4][5][6]. Contrarily to other studies, this work targets to develop and test few prototypes not starting from the technology point of view, but from the users.

This kind of systems have the goal of monitoring people, for this reason the human component is fundamental and can not be forgotten during the design of the project; moreover accessibility and acceptability issues of technological system in healthcare are mandatory for success. As Norman [7] said we are now in a mature phase of technology where product has to shift from a technology centered to a user perspective.

Design can offer several tools to develop technological systems which can be handle by users with special needs; furthermore, if the systems include house interactive environment for non-invasive support, an ergonomic approach to design domestic context integrated by technology can solve several problems related to the use of that kind of system by people for whom technology could be a big barrier (social inclusion).

Therefore, the MAMMA (Multimodal Ageing Monitoring and Assistance) project, co-founded by Lombardy Region (Italy) and involving companies, university and health care provider, develops a tele-monitoring system for elderly people to support autonomously living at their homes with a top-down approach starting from acceptability and usability evaluation of the system, the products and the interfaces between humans and devices.

We can summarize the project objective with the following points:

- Low invasively; the measurement has to be efficient and reliable, but it has to be invisible in order to be easily used during daily activity;
- High accuracy in order to read all the possible anomalies (cardiac problem and fall event);
- Plasticity; the system can be adapted to different environment configuration (space flat, two-rooms flat…) and different users;
- Easy to use and learn;
- Connected; the system has to be connectable with different communication system in order to send alarm to caregivers and relatives.
- Low cost.

2 The Monitoring System

The project starts with the aim of monitoring elderly people in their home environment. Many studies show that elderly are subjected to many risk [8][9], from fall to heart complication. In order to record all this different situation, the system needs to be a multi-parametric filter. Our system is so composed by two main parts:

- Videocameras for fall detection;
- Wearable garment or patch for biomedical data recording.

The first subsystem was developed by Flextronics Design srl and it is composed by a patch which collects biomedical data (ECG, body movement, respiration) with the aim to detect heart complications.

The biomedical wearable device, as shown in fig. 1, is composed by four parts:

- ECG Patch
- Bluetooth Sensor Node
- Gateway receiver
- Server

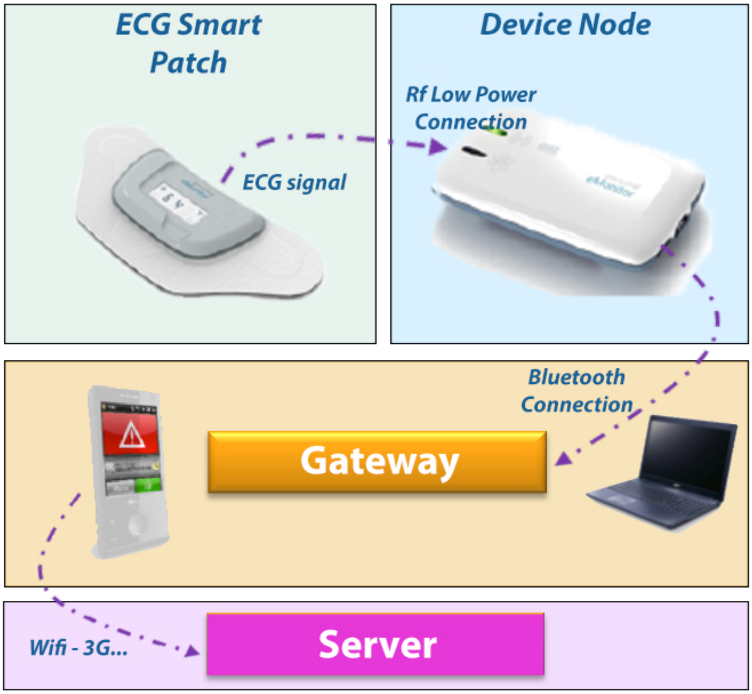

Fig. 1. Diagram of the entire system

The first part consists in the sensitive part: it is composed by the wearable conductive adesive patch and the ECG amplifier. The patch has two electrodes and an adesive part and can be easily attached to the skin as a normal plaster. The amplifier is made by flexible circuit in order to have high wearability and comfort, and it is connected to the patch with four snap button which allow for securely fit the device avoiding noise and interference during ECG signal recording due to device unintended movements.

The acquired ECG signal is transmitted to the second part which consist of the Device Node. The Device Node, because of the dimension, has a bigger battery than the ECG smart patch so that can be used to transmit the entire acquired signal to the gateway via bluetooth. As shown in figure 1, the ECG smart patch communicate with de Device Node via RF connection that is low power in order to save battery consumption; the Device Node instead communicate with the gateway with standard Bluetooth™ 2.0. The node has to be dressed trough a band or has to be placed at a maximum distance of two meters from the Smart Patch. The gateway, depending on whether the elder is in the house or outside, can be a computer or a bluetooth enabled smartphone. The Gateway process signals in order to extract features that can be used by the local intelligence to generate alarms that will be sent to the remote assistant & health management.

The gateway provides also access to data and sanitary services through an ad hoc console with different interaction levels according to the different users: elderly people, relatives, caregivers…

The second subsystem consists of the video monitoring system for fall detection. It consists in a variable number of cameras (that can be webcams or IP-cameras) connected to ethernet (or power over ethernet adapter if ethernet or wifi is not present) to a gateway which in this case is a dedicated PC. The intelligence work locally on this gateway and, analyzing the picture recorded in the house, is able to extract information on the presence of a subject in the room, and communicate an alarm to the assistant & health management over internet. Figure 2 shows in three pictures the capability of the video subsystem to recognize the presence of a body in the room and verify if the subject has fallen.

Both the subsystem are invasive because the wearable subsystem has to be directly in contact with the skin, dressed everyday all the day, while the video subsystem record every instance in the room.

Fo this reason, we conduct a parallel development of acceptability and technical issues in order to allow to tune tele monitoring system on elderly physiological and social needs according to User Centered Design principles.

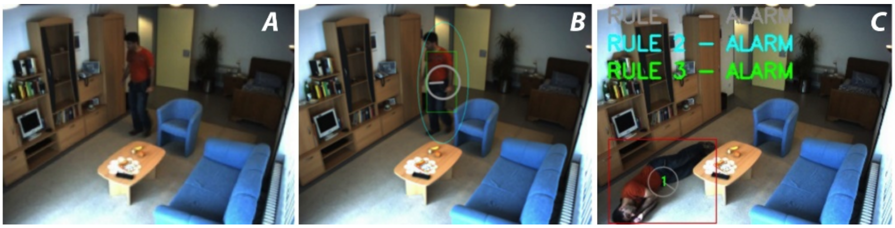

Fig. 2. A. Input image of the camera, B. Processed image, C. Processed image in case of fall detection and generated alarm.

3 Methodology

As described in the previous chapter, the parallel development has been conducted with the aim of a user centered design. In our hypothesis, if it is possible to provide technologies to elderly people and if they accept them, then it will be easy to use it for environment and social improvements. For this reason we focus the first part of the research on usability [10] and acceptability [11] evaluation.

The first study has been conducted on elderly people in small protected apartments in the Oasi San Gerardo, located in Monza (Italy).

The study goal is to collect information about the real user needs and at the same time, check acceptability. Since this study as been conducted in the first stage of the development, the products did not exist yet; for this reason the first ergonomic study has been conducted using Wizard of Oz techniques [12]. Mock-up of the products have been manufactured and provided to the elderly people. A first Focus Group has been carried out before the acceptability test with the aim to explain the project to elderly, relatives and care givers. The mock-up consist into four products:

- Smart patch product;
- Smart t-shirt product [13];
- Camera monitoring system;
- Forniture with embedded video monitoring system.

These fake products, organized in two subsystem (t-shirt with smart forniture and smart patch with camera) have been used by two male elderly (respectively 85 and 89 years old) both for five days. Figure 3 shows the two subsystem tested.

Fig. 3. The two subsystems Mock-up for monitoring test of elderly at home

After two weeks another Focus Group has been performed to collect information about the test experience highlighting pros and cons. Using the methodology of Focus Group it was possible to gain informations also from elderly who haven't used the system. The configuration of the two monitoring products and devices has been designed according to the result of this previous ergonomics analysis.

The parallel development allowed ST Microelectronics and Flextronics to define systems' architecture and the base of user interface. After this phase, using the data acquired during focus groups, a strong laboratory activity was developed in order to optimize the performances and the reliability of the wearable platform, improving RF communication, power consumption and the usability of the relevant sensors (smart patch and device node). A dedicated activity has been performed on ID/User Interface with the aim of choosing the most comfortable material and the best technology to be used for better wearability and end user usability.

During the hardware and software development, algorithms for signals and video analysis have been design; these algorithms extract some features from signals and video which can be used to generate alarms. The alarms are generated by the gateway locally (both on personal computer if the aged subject is in the home, and on android based smartphone if the subject is outside). The generated alarms are than sent to the Server that is part of the remote assistant & health management service.

After this development phase, the project has been carried out through three different functional tests.

The first one has been conducted by technicians in the Oasi San Gerardo on two subject to test the wearable system.

This test has been realized using a Smart Patch, a Device Node, an android smartphone as gateway, The test has been attended by two elderly, a 92 years old healthy male who lives with his younger wife take care of him; a 82 years old widow with some ambulation problem due to the femur rupture six month earlier. Before the test technicians has explained to the elderly subject how to dress up the monitoring system. Figure 4 shows the quality of the signal acquired during the test with the smart patch.

After checking the system work properly, the second test has been carried out on the gateway software. The software has been developed following the user requirements collected during the focus groups. For this reason there is a different user interface depending on the user who uses the gateway. For this test we have used a PC-Gateway to collect signals and generate alarm. We also use a PC-based server and an other smartphone which simulate the relative smartphone for alarm receiving. The gateway allowed also to generate a false alarm in order to test the server and to verify the operation of the connection between the server and the relative mobile phone.

Figure 4 shows the signal acquired during the test of the wearable monitoring system in the PC-Gateway user interface for care givers.

The last test has been conducted on the video monitoring system. This test has been divided in two parts:

- a technical test in the STMicroelectronics laboratory;
- a test in the Oasi San Gerardo with real user.

The first test had the aim to verify the capability of the system, algorithm and intelligence to generate alarm in case of fall detection. The test has been done using 34 video files at a resolution of 1024x768 px and with a frame rate of 15 fps of fall occurred in controlled environment. The files come from the Hannover Database [14]

The algorithm and local intelligence in the PC-gateway has an accuracy of 93%. Table 1 reports the results of this test.

Fig. 4. PC-Gateway user interface

Table 1. Test results on fall detection algorithm

Numbers of falls in the used video	15
True positive fall detected	14
False positive fall detected	2
False negative fall not detected	1
Precision of the fall detection algorithm	93.3%

The test on real users has been carried out in three rooms of the Oasi San Gerardo. The three room are respectively a studio flat, a two-room flat and a big common room. Testing the system in this three different room allow us to try different type of cameras (Webcam Logitech C905, Network STMicroelectronics Camera and Axis M1011 Network camera) with different configuration. In the studio flat we use a single two Logitech Webcam cameras (because forniture hide a part of the room). Figure 5 shows the image from the image camera configuration.

4 Results

As shown in previous chapter in this studies two different kind of research have been carried on: an ergonomic study and a technological studies.

The results after the ergonomic study show a reluctance on the part of elderly to adopt a system that can help them to prevent accident and call for help. If the subject have no cardiac problem, he/she refuses to use wearable monitoring system; the same thing happens for fall monitoring, it the aged subject never had falling episode, they don't want to install such system in their apartment.

For example, after the final focus group, only two over 20 elderly accept the entire system, 7 of the could accept the system only if personalized (wearable device wearable in a different way, different monitoring eg. temperature…).

The subject prefer normal videocamera because the adoption of special forniture could be very difficult because of house's different configurations.

Contrarily to what was expected, all the subject show no problems using video surveillance devices that record images of their daily life.

Regarding the wearable system, the answer reported during the focus group highlight a small preference for the smart patch respect to the smart t-shirt/bra; the subjects prefer something easy to dress and which do not affect everyday life (the subjects do not need to change their garment).

The technological studies show a good performance an reliability of the wearable monitoring system; the quality of the single led ECG signal is good enough to extract HR easily. The subjects who tested the wearable device had no difficulty wearing the patch. However the test lasted only few days was and the wearability should be verified also on a longer time period.

Regarding the tele-monitoring system we verified that one camera per room is generally enough, through more cameras it is possible to reach higher precision since the algorithm has detection difficulties when the subject falls in front of the camera.

An accelerometer integrated in the wearable device and connected with the camera could be applied to improve the accuracy of the system and could be used to detect falling accidents also outside the home.

5 Conclusion

The technical goal regarding the capability of the camera system to detect falling accidents and the capability of the patch to collect and send biomedical data has been reached and verified in real environment, although the caparison and integration of the two different data sets is much more difficult.

We also verified that elderly people preferences cannot be given for granted and it is very important to apply specific user research techniques in each project involving this user group.

The integration of early acceptability tests and subsequent technical development allowed to chose adequate solutions and tune the tele-monitoring system on elderly physiological and social needs according to User Centered Design principles realizing prototypes fully accepted by users.

Further researches will be needed to scale the system in modular parts according to users specific need and to face practical problem as the integration of ICT in existing home.

References

1. Report on demography. In: 2012, for every person aged 65 or older, there were 4 people of working age in the EU27. Eurostat (2013)
2. Marsili, M., Sorvillo, M.P.: Previsioni della popolazione residente per sesso, età e regione dal 1.1.2001 al 1.1.2051, Istituto Nazionale di Statistica, ISTAT, Roma (2002)
3. European Commission. Directorate-General for Economic, and Economic Policy Committee of the European Communities. The impact of aging on public expenditure: projections for the EU-25 Member States on pensions, healthcare, long-term care, education and unemployment transfers (2004-50). Office for Official Publications of the European Communities (2006)
4. Mahmud, K., Lenz, J.: The personal telemedicine system. A new tool for the delivery of health care. Journal of Telemedicine and Telecare 1(3), 173–177 (1994)
5. Brownsell, S.J., Bradley, D.A., Bragg, R., Catlin, P., Carlier, J.: Do community alarm users want telecare? Journal of Telemedicine and Telecare 6(4), 199–204 (2000)
6. Jenkins, R.L., McSweeney, M.: Assessing elderly patients with congestive heart failure via in-home interactive telecommunication. Journal of Gerontological Nursing 27(1) (2001)
7. Norman, D.A.: The invisible computer: why good products can fail, the personal computer is so complex, and information appliances are the solution. MIT Press (1999)
8. Tinetti, M.E., Williams, T.F., Mayewski, R.: Fall risk index for elderly patients based on number of chronic disabilities. The American Journal of Medicine 80(3), 429–434 (1986)
9. Lloyd-Jones, D., et al.: Heart disease and stroke statistics—2010 update A report from the American Heart Association. Circulation 121(7) (2010)
10. Jeffrey, R., Chisnell, D.: Handbook of usability testing: how to plan, design, and conduct effective tests. Wiley. com (2008)
11. Jordan, P.: Designing pleasurable products: An introduction to the new human factors. CRC Press (2000)
12. Maulsby, D., Greenberg, S., Mander, R.: Prototyping an intelligent agent through Wizard of Oz. In: Proceedings of the INTERACT 1993 and CHI 1993 Conference on Human Factors in Computing Systems (1993)
13. Perego, P., Moltani, A., Andreoni, G.: Sport Monitoring with Smart Wearable System. In: PHealth 2012: Proceedings of the 9th International Conference on Wearable Micro and Nano Technologies for Personalized Health, Porto, Portugal, June 26-28, vol. 177. IOS Press (2012)
14. Debard, G., et al.: Camera-Based fall detection on real world data. In: Dellaert, F., Frahm, J.-M., Pollefeys, M., Leal-Taixé, L., Rosenhahn, B. (eds.) Real-World Scene Analysis 2011. LNCS, vol. 7474, pp. 356–375. Springer, Heidelberg (2012)