A New Simple Multimodal Platform for Home Monitoring of Cardiac Patients through Textile Technology

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Abstract

In the developed countries, healthcare systems are evolving under the pressure of the population ageing, the necessity of reducing the increasing healthcare costs and the availability of new technologies. Telemedicine and eHealth solutions are gaining importance in this reference frame.

Recently we participated in the final validation phase of a wide European Project, Heartfaid, aimed at building an eHealth platform for the remote monitoring and management of patients suffering from chronic heart failure. In this context, we designed and developed a simple multimodal subsystem for the home acquisition and transmission of data collected from the patients, composed of a vest embedding textile electrodes, a touch-screen computer and a UMTS dongle.

In this paper we report the results of this experience where we explored the usability of such a simplified interface for home monitoring of cardiac patients.

1. Introduction

The worldwide growing cost of the healthcare and the availability of sophisticated Information and Communication Technology (ICT) tools fuelled a large number of projects in the telemedicine and eHealth areas, with an increasing focus on the development of the so-called *pervasive health care technologies* [1]. However, in spite of these big efforts, the adoption of advanced ICT tools and telemedicine solutions in clinical practice is still limited, also because of the complexity of the available solutions [2, 3].

In cooperation with the Heartfaid project (FP6-IST-2004-027107 [4]), funded by the European Union, we had the opportunity to test on the field a simple solution, recently developed in our labs, for the home collection of biological data and transmission to a remote server.

The Heartfaid project was aimed at building an ICT platform for the management of chronic heart failure (CHF) patients. The whole Heartfaid platform consisted of a home gateway (for the collection of patient's biological data), and servers for data handling and for providing the caregivers with a knowledge-based decision support system.

The part of the architecture here presented is one of the different implementations of the Heartfaid home gateway and was used in the test site of Milan. The solution is composed of a textile based wearable system named MagIC [5] and a touch-screen personal computer (PC), where a specific software acquires data from the user and sends them to the Heartfaid server through an Internet connection.

In order to facilitate the interaction with patients, particularly elderly people, a *multimodal* interface, making use of a touch-screen and keyboard for input, graphical and audio cues (namely voice directives) for output, was designed and developed. As recently described, this approach might facilitate the accomplishment of complex tasks, with respect to traditional written directions [6].

In this paper, we describe the system with its multimodal interface, and the results of the validation study carried out in the context of the Heartfaid project.

2. Methods

The home platform designed for this validation included the **MagIC System** (for the vital sign acquisition), a **touch-screen personal computer** with a GPRS/UMTS USB dongle (for Internet access and data transmission), and specific **software applications**.

The MagIC System is composed of a sensorized vest (made of cotton and elastan) and a portable electronic board. At the thorax level the vest includes two woven ECG electrodes made by conductive fibers and a textile transducer for the assessment of respiratory movements. Signals are acquired by an electronic board (having weight and size of a cell phone), hooked on the vest through a Velcro strip. The electronic board also detects the subject's movement through an embedded 3-axis accelerometer.

The electronic board is powered by a 3.6 V rechargeable Li-Ion battery, allowing continuous use of the system for more than 60 hours. All signals are stored on a local memory card, and can be simultaneously transmitted via Bluetooth to an external computer.

So far, 150 subjects have been studied with positive results in terms of signal quality, accuracy in the estimation of cardiac rhythm and capability to detect arrhythmic events [7-9].

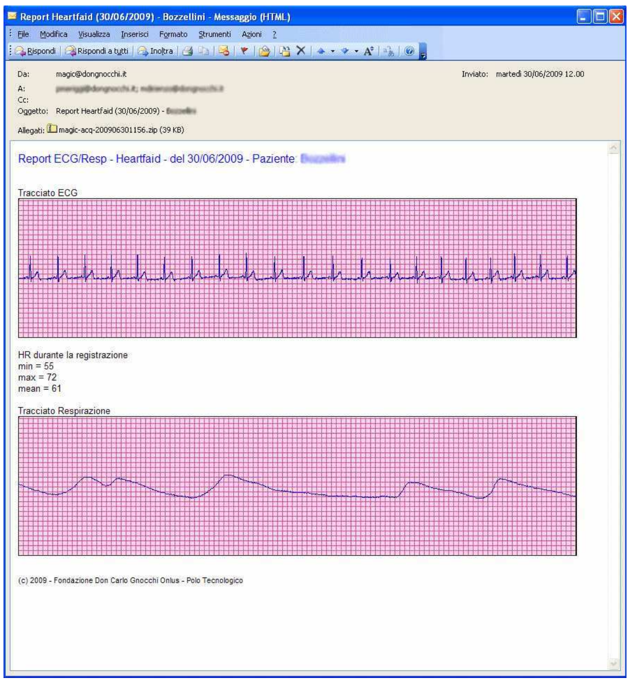

Figure 1 – An email sent by the MHB application, reporting 20 seconds of ECG (upper panel) and respiratory driven movements of the thorax (lower panel).

The selected computer was a low-cost all-in-one touch-screen PC (ASUS Eee Top 1602). Two dongles were used with it: a class 1 Bluetooth USB dongle for the communications with the vest and a GPRS/UMTS USB dongle for the data transmission through the Internet. The PC was equipped with software applications allowing the user to operate the device just through the touch-screen. For the Heartfaid project, however, an external keyboard was also required to input specific numerical data derived from additional medical devices.

The software suite of the system was composed of the following applications:

- *The Nurse@Home (N@H) and the VestServer (VS) applications*. They have been both developed at the Foundation for Research and Technology - Hellas in the context of the Heartfaid project. The first application is the home communication endpoint of Heartfaid architecture which sends the patient's data to the remote Heartfaid Server; the second application allows the transmission of the MagIC data to the N@H.
- *The MagIC Heartfaid Bridge (MHB) application*. This is an updated version of a software package previously developed at the Don Carlo Gnocchi Foundation, for the monitoring of data coming from the vest. This software has been customized in order to automatically manage the data acquisition and transmission to the VS. The application also sends an email containing a report of the MagIC data to a number of predefined caregivers. As illustrated in Fig. 1, the email includes plots of the first 20 seconds of the ECG and respiratory movement recordings and an attached file containing the entire 3 minutes of acquired data.

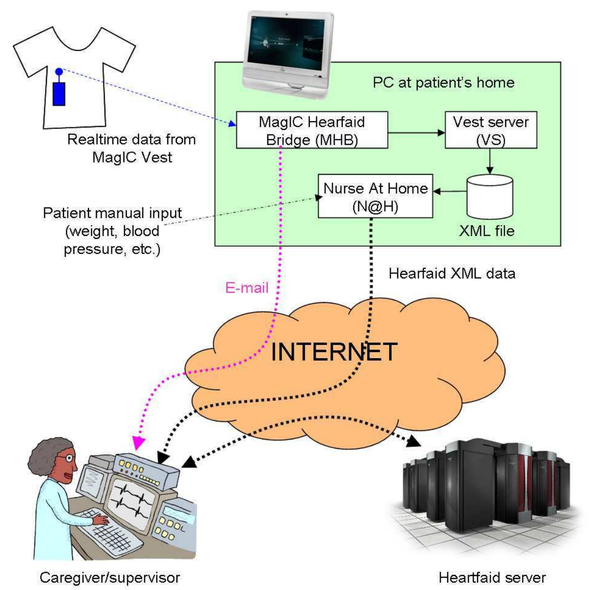

Figure 2 – Overall architecture of the system implemented for the home monitoring of CHF patients and the related information flow.

The architecture and the information flow of the whole system are illustrated in Fig. 2. Patient's data reach the Heartfaid server in two ways: automatically from the vest through the MHB and VS applications (via a TCP/IP socket connection), and manually, via the keyboard, through the N@H procedure. Collected data are sent by the N@H via Internet to the Heartfaid server, while, as mentioned above, MHB sends to the caregiver(s) an email containing a report of the data acquired by the MagIC vest.

The MHB application is automatically launched at the home gateway startup. It manages all the data acquisition steps, and activates the N@H and the VS procedures. The interaction with the computer via MHB is referred to as *multimodal*, because the user is prompted both visually (via written messages on the screen) and acoustically (via audio messages through a text-to-speech engine), and information are provided to the system via the vest, the touch-screen and the keyboard.

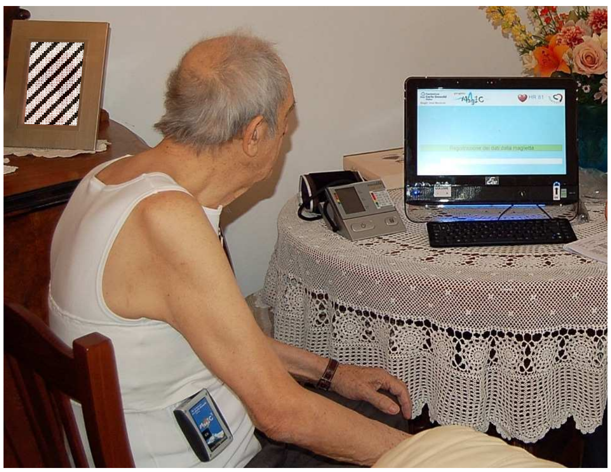

Figure 3. One of the patients during the monitoring session. Note the MagIC vest and its pocket-size acquisition unit in the lower left, the blood pressure monitor in the center and the touch screen PC in the upper right.

Three patients (age 63, 72, 83 yrs), suffering from heart failure and recently discharged from hospital, were enrolled in the validation phase of the Heartfaid platform in the Milan test site. Validation procedures were thoroughly described to patients, who gave their written informed consent to participate.

After a two-hour training, the system was installed at the patient's home and tested. Patients were then asked to follow the protocol reported in Table 1, every day in the morning before 10:00, for 30 days (Figure 3).

From the information provided to the Hearthfaid platform by the home monitoring system, caregivers were able to see on a website the data collected by patients. Moreover, every day caregivers received a report of the patient cardiorespiratory conditions directly on their PC, through the emails automatically sent by the MHB application.

Table 1. Protocol provided to the patients.

1	Measure blood pressure twice (by an external automatic oscillometric device), body weight (by a normal scale) and breathing rate (by counting the number of breaths per minute).
2	Write a diary, reporting the measurements performed.
3	Turn on the touch-screen computer (automatically launching MHB and the N@H applications)
4	Wear the MagIC vest, and acquire data from the vest for three minutes according to the instructions provided by the MHB software.
5	Fill in the fields of the N@H computerized questionnaire and the N@H measurement fields not automatically provided by the system (e.g. blood pressure).
6	Activate data transfer from the home gateway to the Heartfaid servers though the Internet, by pressing the "*Send*" button on the N@H user interface on the screen.
7	Turn off the device and unwear the MagIC vest.

3. Results

All patients entirely complied with the assigned protocol. They found the smart garment comfortable, and the platform easy to use. They also reported to feel themselves "*safely supervised*" and even asked to continue the monitoring for a longer period. Because of these requests, one patient extended the monitoring period for additional 20 days. The multimodal interaction with the platform has been reported by all of them as simple and effective for the purpose.

No on-site technical support has been requested. The system behaved correctly in 85 out of the 90 planned sessions (94%), while in 5 cases a second session was required due to UMTS traffic congestion. In only three sessions (3.3%), caregivers asked the patient (by a phone call) to repeat the acquisition, because of artifacts. All the data were correctly provided to the Heartfaid server via the N@H.

Cardiologists found the quality of the signals to be adequate for a remote daily check of the patient's health condition. Moreover, they considered email an efficient mean for an asynchronous and direct visualization of patient's ECG data.

4. Discussion and conclusions

The high patient's compliance and the large number of sessions performed allowed us to evaluate the methodological aspects related to the integration of smart garments, touch-screen computer and multimodal user interaction , different software applications (MHB, N@H, VS) and UMTS/GPRS connection to the Internet.

The positive results we obtained support the use of this architecture for prolonged home monitoring of heart failure patients.

These promising observations should now stimulate studies on the impact of this telemedicine approach on patients' quality of life, the health care costs and cardiovascular events rate, through large scale randomized outcome trials of sufficient duration.

Acknowledgements

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