Real-time monitoring through wearable systems

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Abstract:
Wearable textile-based personal systems have been subjects of research in the last 10 years due to their potentiality in the implementation of ambulatory monitoring for healthcare, protection and safety, and wellness. Progresses in this field, due to a cluster of R&D projects [1] dealing with e-textile and smart fabrics for vital signs and functionality monitoring, allow to move from the phase of feasibility to clinical and statistic assessment. At present stage, real products are on the threshold of prototyping and testing. This poster presents results from the on going R&D activities in the frame of the European projects like Wealthy, MyHeart and Proetex, improvement in the textile platform in term of comfort and functionality, lessons learned and future challenges.

I. INTRODUCTION

II. FROM FEASIBILTY STUDY TO A REAL PRODUCT

In 2002 the FP5 with the Wealthy project (IST-37778) opened a route that allowed to develop new wearable devices able to monitor cardiopulmonary signals. The project was aiming at a feasibility study about sensing functionality of textile material in form of yarns and fibres. The results achieved, the quality of the signals, the potentiality behind this study gave rise to a more ambitious vision leading to new projects like MyHeart dealing with health care applications, and Biotex dealing with further research from the sensors side.

MyHeart (2004-2008) is the largest on going project on wearable textile-based personal health applications, it is currently running under the 6^{TH} FP, IST programme of the EC. It addresses systematically the risks of cardiovascular diseases (e.g. sedentary lifestyle, sleep disorders, stress, weight and acute events by early diagnosis) by empowering citizens to actively improve preventive lifestyle and early diagnosis through wearable textile-based monitoring systems with feedback and interaction to various stakeholders. The project achieved to demonstrate operational systems and in user testing for "activity coach", "take care" and "neuro rehabilitation" concepts as well as to get 200 prototypes for one year clinical trial for “heart failure” concept.

The work proceeds in Biotex with the integration of new type of biosensors on the textile. Here the sensors are seen as textile patches, of relatively small surface. The technology is designed to be later extended to the entire garment.

III. WEALTHY

WEALTHY system is developed as the integration of several function modules, as has been presented in previous works [2]. The main functions of the modules are namely sensing, conditioning, pre-processing, data transmission and remote monitoring.

Sensing module consists of the garment connected with the Portable Patient Unit (PPU), where local processing as well as communication with the network is performed.

The PPU is small and lightweight, only 145g., it is easy to use, with two LEDs and a buzzer for user-warning purpose and a button to let a manual trigger of alarm, data transmission is done over GPRS link. The device is powered by a Li-Ion battery autonomy up to 4 hours with real time streaming of all signals over GPRS

ECG signals are sampled on the PPU at 250Hz where a local processing is applied in order to extract parameters with the highest sampling rate, in a way to compute ECG parameters, such as heart rate (HR) value and QRS duration.

The complete list of the signals interfaced by the PPU is given below:

- Six ECG electrodes configurable in Einthoven configuration (lead I, II and III) and Wilson configuration (V2 andV5). Only one lead is transmitted at a time (for GPRS bandwidth limitation reasons). The ECG lead to be transmitted can be selected remotely by the monitoring center.
- Respiration by impedance measurement
- Up to four I2C skin temperature sensors (monolithic circuits)
- One 3D accelerometers (integrated in the unit)
- Four piezo-resistive strain sensors
- SpO_2 (oximetry) from a commercial device (NONIN) (serial interface and power supply provided)

In order to offer full mobility to the patient or the user, acquired signals are wirelessly transmitted from the PPU to the remote Monitoring System. The communication is based on TCP/IP that is the standard protocol for GPRS communication. All signals are sent in quasi real-time to the Remote Monitoring Centre.

A different version uses Bluetooth connection for short range transmission.

In order to increase the comfort of the garment a design study has been carried out and for each model a prototype has been realized and tested.

The final garment is more easy to wear, comfortable from the thermal aspect as well as from the ergonomics aspect, washable and good enough from the look and feel perspective.

In Figure 1 is shown the old and the new version of Wealthy garment.

Figure 1 Wealthy System, old version on the left, new version on the right

IV. MYHEART

MyHeart is dealing with the prevention and early diagnosis of cardiovascular diseases. The idea behind MyHeart is to apply continuous or periodic monitoring of vital signs, in order to gain knowledge about a person's health status. Aim of this poster is to present the last results of research activity of Workpackage 2, dealing with textile platforms development for Activity Coach (AC) and NeuroRehab (NR).

AC garments provide fabric ECG electrodes and piezoresistive sensor for respiratory activity, fully integrated in a shirt in male and female version, during normal activity and during the physical activity.
The electronics is able to memorize and transmit through the BlueTooth protocol the following signals:
1 ECG lead detected through two fabric electrodes integrated in the clothes and the breathing signal detected by the piezoresistive sensor; the device is monitoring posture and activity level through 3D accelerometer inside the electronic device.
In is shown one of the last version of AC shirt.

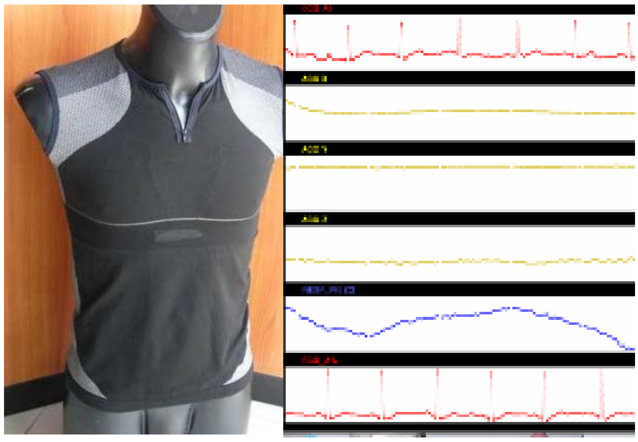

Figure 2 MyHeart AC prototype, on the left; signals gathered from the AC system on the right.C

In the frame of NR, a prototype of shirt able to acquire information about the movement of the joints of the upper limb through 29 textile sensors spread on a shirt. The system can monitor shoulder, elbow and wrist joints. The use of this sensing garment allows patients to continue the rehabilitation training at home or in un surveyed environments, after the intensive rehabilitation period. During the project the shirt prototype has been realized in different versions in order to improve comfort and wearing feeling [3].

Final version of NeuroRehab product concept has been realised by printing through the serigraphic process 29 sensors and 33 connections directly on the fabric patterns. The design evolution comes out to avoid the difficulty to locate the sensing patches during the manufacturing process.

Fabric patterns have been printed by positioning the strain sensors mask according the final location and then the patterns have been sewn to realize the garment. In order to insulate the strain sensors from the skin the inner of the garment have been lined with a breathable fabric.

Figure 3 On the left: The final version of NR prototype; on the right: on the top a detail of the zip on the height of wrist and on the bottom a detail of insert of a breathable fabric

The final version includes a zip on the height of wrists, while the pocket for the electronic device has been moved to the other side of garment to increase comfort and wearability, as shown in Figure 3.

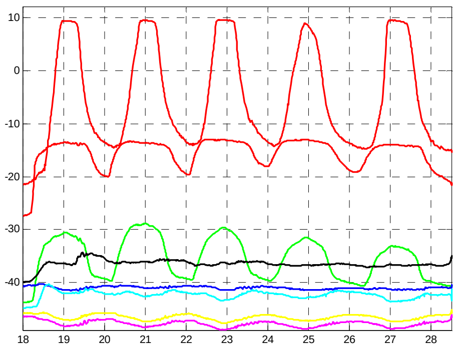

Figure 4: Elbow flexion signals from NR prototype

V. BIOTEX AND PROETEX

BIOTEX project (IST-NMP-2-016789, started in August 2005, still in progress) has a clear technological character, willing to serve biosensing needs by developing new biochemical textile sensors. In this project, biochemical sensors for physiological parameters are studied.

PROETEX (IST-4-026987, started in February 2006, still in progress) is an IP with the goal to build a textile platform where all the monitoring, communication and power management devices are integrated into fully functional wearable and can directly communicate with each other and with ambient planning and management systems.

This IP is a continuation and logical extension of the road map for smart textiles developed in the projects Wealthy, MyHeart and Biotex

The goal of the project is to improve the safety and efficiency of emergency workers by empowering them with wearable sensing and transmission systems that monitor their health, activity, position and their environment during such risky situations.

In the frame of this project several prototypes with different functionalities will be developed [4]:

- Inner Garment
  - o Heart rate
  - o Breathing
  - o Core Temperature
  - o Pulse Oximetry (SpO2)
  - o Dehydratation
- Outer Garment
  - o GPS location
  - o Temperature of the environment (air)
  - o Motion sensor (posture and activity)
  - o Heat flux (fire fighter garment only)
- Patch for Victim
  - o Heart rate
  - o Breathing
  - o Core Temperature
  - o Pulse Oximetry (SpO2)
  - o Blood pressure
  - o CO saturation
- Shoes
  - o Exochemical sensors

An example of the prototypes realized by Smartex for Proetex inner garment is showed in the following figure.

Figure 5 Proetex prototype of the inner garment

This prototype is able to monitor an ECG lead, core temperature and respiratory activity.

VI. CONCLUSIONS

Wearable textile-based personal systems have shown to be a solid innovative tool for the implementation of ambulatory monitoring for a variety of different applications. The knowledge gained in this research field in the last decade allows to foresee for the future a new generation of sensing and active textile platform exploitable in human and environmental interfaces.

VII. REFERENCES

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