Wireless ECG based on Bluetooth protocol: design and implementation.

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***Abstract* — The design of portable systems for remote monitoring of cardiac activity is one of the most important fields in telemedicine and telecare. In this paper we present a low cost, portable system with wireless transmission for real time ECG acquisition, archiving and visualization both in a mobile phone and a PC. We have implemented the acquisition module and the visualization tool for the mobile device and the PC.**

I. Introduction

Mobile telemedicine systems are becoming more important all the time, specially in the care of patients that are isolated or travelling, far from a reference hospital. These systems must be embedded in low cost, small devices with a low power consumption, and should have an interface that is usable by the patient.

Incorporating technologies such as bluetooth, GPRS, GSM or Wi-Fi to these systems allows the wireless transmission to health or control centers [1-4].

This paper describes a low cost, portable system with wireless transmission capabilities for the acquisition, processing, storing and visualization in real time of the electrical activity of the heart to a mobile phone, a PDA or a PC.

Several groups [5] have developed applications to monitor the ECG in mobile devices, where the samples have been obtained from standard data bases [6], or they have development the ECG module [7]. Other works [8-10] have proposed techniques for signal processing via software to reduce noise or classify heart pathologies. In this work we describe both the implementation of the acquisition module with wireless transmission capabilities (Bluetooth and GSM/GPRS), and the tool for real time ECG visualization in mobile devices.

The structure is the following. In the following section system analysis, employed technology and development environment are described. In sections III and IV hardware and implemented software will be explained in detail. Results and final prototype, together with the conclusions are shown in section V.

II. SYSTEM DESCRIPTION

The system consists of three modules: the patient's acquisition and processing board (PAP-BT), the medical control unit in the PC (MCU-PC), and the medical control unit in the mobile phone (MCU-MP). See figure 1.

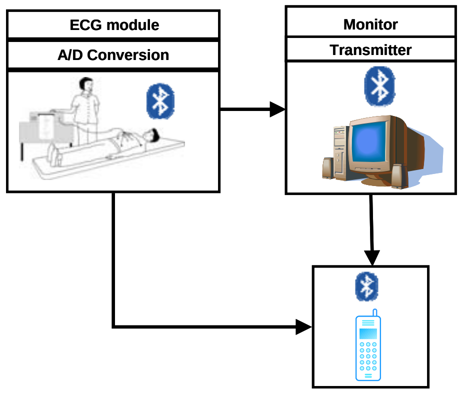

Figure 1. System description

The MCU-PC module is a tool with a user interface that simulates an ECG monitor and offers the following functionalities: Bluetooth communication with the PAP-BT, ECG reception and visualization, and data storage, and GSM/GPRS communication.

The application running on the mobile terminal runs on any mobile phone or PDA equipped with Bluetooth and a Java virtual machine. Its user interface allows communications with other devices, reception of cardiac signals and real-time data signal visualization.

The acquisition module consists of a bioamplifier, a bandpass filter, a microcontroller and a Bluetooth chip for wireless transmission.

A. Selected technology

We have chosen Bluetooth as transmission protocol as it is the one used by most commercial mobile devices. It is a short range technology that allows secure and robust communications, apart from a universally accepted standard, described in [11].

For developing the application in the mobile device we have used J2ME [12], a Java platform oriented to small embedded devices with restricted graphical and computational resources.

The application for the PC was Developer in J2SE, which allows an abstraction from the underlying operating system, and offers a great number of libraries for serial communications, Bluetooth, etc.

B. *Development environment*

The specification, design and implementation of the acquisition module were carried out using OrCAD® [13],P-CAD® [14] y MPLAB® IDE [15].

Java applications were implemented using the Eclipse environment [16].

The Docklight simulation tool was used to test all serial communications. The J2ME-Wireless Toolkit allowed to perform application trials in small devices such as a mobile phone.

III. HARDWARE DESCRIPTION

Our PAP-BT device consists of several functional blocks (Figure 2).

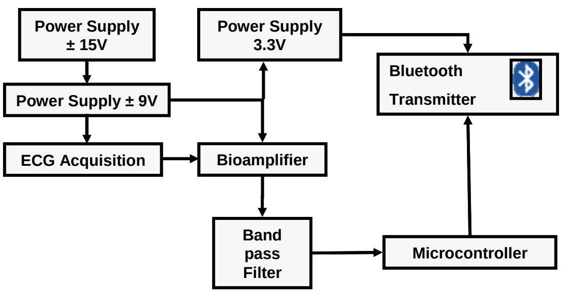

Figure 2. Patient acquisition and processing module

A. *Sensors*

In our ECG we use three electrodes. The acquired signal represents the first Einthoven bipolar lead(Figure 3). By convention, lead I has the positive electrode on the left arm (LA), and the negative electrode on the right arm (RA), and therefore measures the potential difference between the two arms. In this and the other two limb leads, an electrode on the right leg serves as a reference electrode for recording purposes.

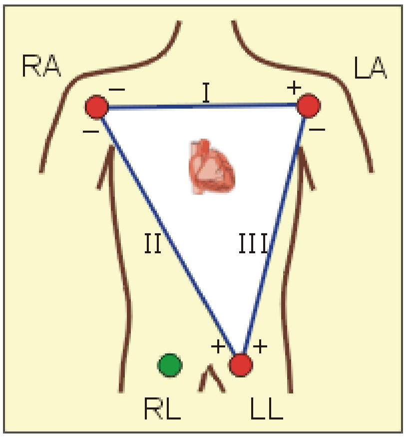

Figure 3. Einthoven's triangle

B. *Bioamplifier*

The low values typical of the ECG acquired by the sensors (values between 1 and 3 mV) require the use of an amplifier with a gain of 1000, a bandwith between 0,05 and 200 Hz and a CMRR greater than 110 dB.

B. Signal conditioning

This module consists of a band pass filter to eliminate the continuous component and high frequency noise.

C. *ECG signal digitizing.*

A PIC16F876 microcontroller is used for analog to digital conversion. This device is low cost (5€) 8-bit CMOS Flash Microcontroller based on RISC technology with 10-bit multi-channel Analog to Digital converter. The signal frequency can reach 200 Hz, so we have selected a 500 Hz sampling frequency, with an 8 bit resolution, as provided by the microcontroller. Extension to 12 bits to fulfill the requirements of telematic emergency services [17] is striaght forward by choosing a microcontroller with a 12 bit converter.

D. *Bluetooth wireless transmission*

The Bluetooth module used was the BISM II chip from EZURIO [18] (Figure 4).

Figure 4 BISM II Bluetooth module from Ezurio

Both the microcontroller and the Bluetooth chip are involved in this process. Packets that contain signal information are sent to the chip, using their USART module as interface. Any device connected via Bluetooth to the PAP-BT board can thus receive them in real-time.

IV. SOFTWARE DESCRIPTION

The software developed can be divided into two levels: low level software associated to the microcontroller, and high level software for the applications in the PC and the mobile phone.

A. *Low level software: Microcontroller*

The microcontroller has been programmed to perform the following functions: capture and digitize the ECG signal, establish the connection to the Bluetooth phone and send the data.

This Bluetooth module allows provides an API for communication through the AT level, freeing the programmer from implementing the complete Bluetooth stack.

The steps taken by the microcontroller can be divided into the following stages:

i) The Bluetooth configuration is initialized: the device is set as visible, authentication functions are activated, a serial communication service is activated and it is assigned a name “TEST ECG”. This name will be shown in the mobile phone when it connects to the PAP-BT module.

ii) Start to search for devices offering the service “SPPTestECG”. This service will allow us to monitor the patient’s ECG.

iii) Once connected to the mobile device, the information about the type of signal and the size of the data packet is sent. Packets sent have a size of 100 ECG values. Five packets are sent every 2 ms.

B. Medical Control Unit: Mobile Phone

The application for embedded devices, such as mobile phones or PDAs offers a service in the SPP port of the device via Bluetooth, named “SPPTestECG”, that will alow us to monitor the patient’s ECG in real-time.

The application has been Developer using the Java platform for embedded devices, J2ME. The Bluetooth communication was programmed using the Bluetooth API (JSR 82). Binaries were obtained using the J2ME Wireless Toolkit.

To access this service from the PAP-BT board, the user selects the “BTMovilECG” application in the phone. Our software starts the SPP service encapsulated in a *url* that will show the type of service available to Bluetooth devices, and what type of device is offering the service.

C. Medical Control Unit: PC.

This application monitors the patient’s ECG signal, receives the data and visualizes them, storing them if the user requires it. It also allows communication with other embedded mobile devices. A possible application of this tool is to receive ECG data in the hospital from an emergency unit.

The user interface is shown if figure 5.

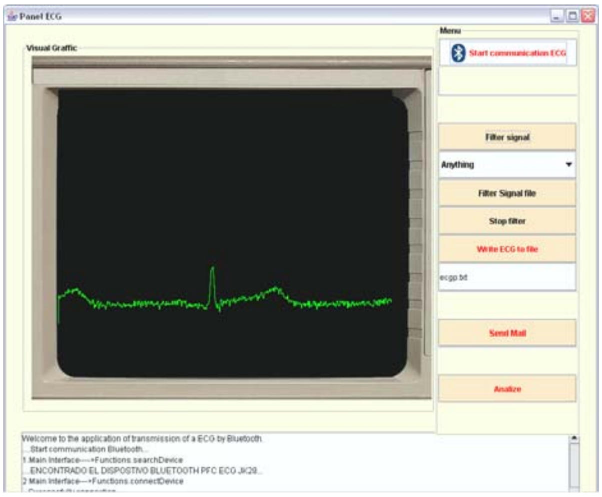

Figura 5. PC interface

The application was Developer on the J2SE platform. For wireles communication we have used the Java Bluetooth communication stack.

Through the user interface, a user can observe the ECG signal in real-time. The application has the following functionalities:

- Communication via Bluetooth with the acquisition board
- ECG visualization
- ECG storage
- Sending the ECG signal to other devices.
- Log window to visualize all the events as they happen.

V. RESULTS

The acquisition, processing and Bluetooth transmission module (APA-BR) was designed and implemented in a 5 x 4 cm prototype (figure 6). The acquired signal represents the first Einthoven bipolar lead [19]. The use of other leads or the incorporation of more electrodes has been contemplated in the design.

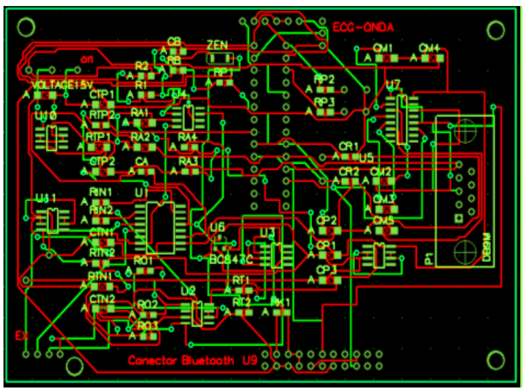

Figura 6. Acquisition board layout

Bluetooth communication has been carried out succesfully (Figure 7).

Figura 7. ECG visualization in the mobile phone

VI. CONCLUSIONS

We have developed a low cost system for ECG acquisition and visualization in mobile devices which is easy to install for a patient, as well as for a physician with little previous knowledge. Its design allows for easy technological updates and further development to provide more intelligence to the system. Incorporating technologies such as Bluetooth and GSM/GPRS, and the devlopment of software tools both for a computer and for mobile devices enables a large range of application scenarios. Future research includes connection of the PC application to a hospital database, and hardware processing of the ECG signal for automatic detection of pathologies.

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REFERENCIAS

[1] C. H. Salvador, M. P. Carrasco, M. A. G. de Mingo, A. M. Carrero, J. M. Montes, L. S. Martin, Cavero, I. F. Lozano, J. L. Monteagudo, "Bluetooth Telemedicine Processor for Multichannel Biomedical Signal Transmission Via Mobile Cellular Networks", *IEEE Trans. On Information Technology in Biomedicine.*, vol. 9, n.1, March 2005.

[2] http://www.mobihealth.org/

[3] M.Elena, J.M. Quero, C.L.Tarrida, L.G.Franquelo, "Design a Mobile Telecardiology system using GPRS/GSM Technology". Proceeding of the Second Joint EMBS/BMES Conference. Houston Octuber 2002.

[4] J. Dong, H.Zhu, "Mobile ECG detector through GPRS/Internet". Proceeding of the 17th IEEE Symposium on Computer-Based Medical System (CBMS'04)., 2004.

[5] J. Rodríguez, A. Goñi, and A. Illarramendi, "Real-Time Classification of ECGs on a PDA," *IEEE Trans. On Information Technology in Biomedicine.*, vol. 9, no. 1, March 2005.

[6] http://www.physionet.org/physiobank/database/

[7] S.L Toral, J.M. Quero, M.Elena, L.G.Franquelo, "A Microprocessor based system for ECG Telemedicine and Telecare".. The 2001 IEEE International Symposium on Circuits and Systems, 2001. ISCAS 2001. 6-9 May 2001 Page(s):526 - 529 vol. 4.

[8] J. C. Pérez, G. Andréu García, V. Eck, C. Sastre Mengual, M. LLorca Alcón, "Reducción del ruido en señales electrocardiográficas mediante la transformada de Wavelet", Departamento de Informática y computadores de UPV, Departamento de Cibernética, Czech Technical University in Prague.

[9] I. Romero Legameta, P.S. Addisson, N. Grubb, CE Robertson, KAA Fox, J.N. Watson, "Real-Time Classification of ECGs on a PDA," *IEEE Trans. On Information Technology in Biomedicine.*, vol. 30, pp. 565--568, 2003.

[10] R. Istepainan, R. García, A. Alesanco, S. Olmos, " A Novel Real-Time Multilead ECG Compression and De-Noising Method based on the Wavelet Transform" *IEEE Trans. On Information Technology in Biomedicine.*, vol. 30, pp. 593--596, 2003.

[11] http://www.ieee802.org/15/

[12] A. F. Quintas, "Bluetooth J2ME Java 2 micro edition manual de usuario y tutorial", Madrid: Ra-Ma, 2004.

[13] http://www.orcad.com

[14] http://www.altium.com/pcad/

[15] http://www.microchip.com/

[16] http://www.eclipse.org

[17] I.Widya, P.Vierhout, V.Jones, R. Bults, A. van Halteren, J.Peuscher, D,Konstantas Telematic "Requirements for a Mobile and Wireless Healthcare System derived from Enterprise Models".ConTEL'03 (7th International Conference on Telecommunications) 11-13 June 2003; Zagreb , Croatia

[18] http://www.ezurio.com/products/bism/

[19] "Medical Instrumentation. Application and Design" J.G.Webster.. John Wiley¬SONS,INC. Third Edition