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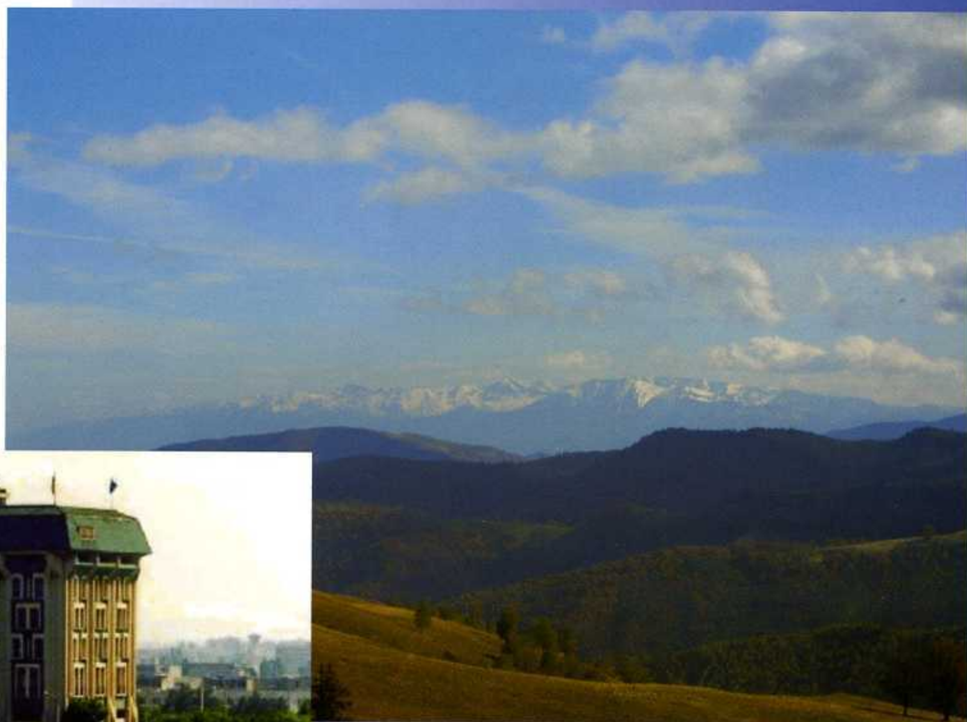

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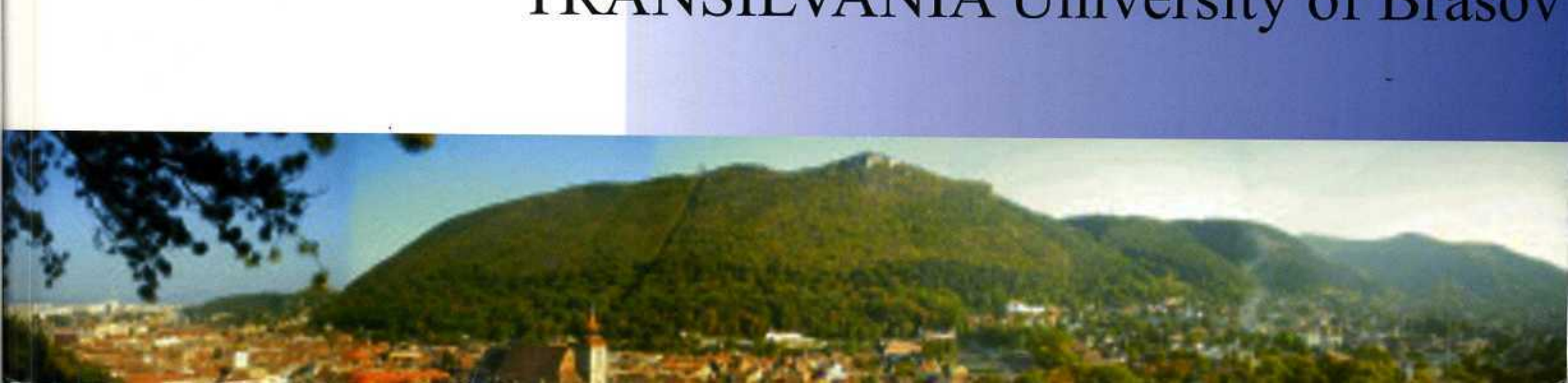

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Patient Remote Monitoring of Biophysical and Biochemical Signals

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Abstract

A remote monitoring system for the vital parameters of the patients with cardiac diseases can save their life by early detecting the bio-signals that can anticipate a dangerous status of the patient. The system's architecture is developed on four layers: (i) sensors and signals' sampling sub-system layer, (ii) preprocessing and filtering sub-system layer, (iii) processing and dangerous events detection sub-system layer, (iv) hospital server layer.

We have developed a system able to process all the acquired signals from the patient, able to store them and to inter-correlate them. We have focused on implementing a software able to assure an energetic management of the distribute acquisition system and able to analyze the inter-correlated signals. The evaluation of the different scenarios in concordance with the patient's status and the parameters acquired and processed are the main elements detailed in this paper.

1. Introduction

Cardiovascular affections are a prime cause of mortality and morbidity in Romania. The risk of cardiovascular morbidity and mortality remains high despite the attempts of correcting the cardiovascular risk factors. In the field of cardiovascular pathology the death risk by cardiovascular or vascular-cerebral accident persists even after the patients have left the hospital. By monitoring the health condition of the patients in their environment and by analysis their biophysical and biochemical parameters and trends we bring an essential contribution of prevention of severe diseases or deadly situations.

The remote monitoring system acquires and processes in real time bio-signals (one ECG derivation, oximetry and pulse, temperature, blood pressure and blood glucose concentration of the patient in his environment –at home- . The remote monitoring system's architecture includes four tiers in accordance with the functionality that endowed this system: signal acquisition and monitor-patient interface, pre-processing and acquired data filtering, inter-correlation and intelligent signal analysis, bidirectional remote communication between the monitor and the hospital server. The architecture and also the design of the monitor have developed in the idea to offer a very high versatility and scalability of it and also to be easily and automatically integrated into the communication environment. For that we have used where it was possible standard elements and products (e.g. Personal Digital Assistant –PDA- or Smart Phones –SP, existing blood pressure apparatus –BPA-, and portable glucose monitors –PGM-). We have integrated all of these elements [1].

We also have implemented an on-line, multimodal communication system from monitor to hospital server and also the communication between the hospital server and the patient. Thus, the doctor that supervises the patients can offer on-line emergency advices.

2. The System's Structure and Specific Features for Our Remote Monitoring System

In Figure1 we have shown the five tiers of the monitoring system.

This architecture offers a high versatility, scalability and processing power necessary to implement the continuously acquisition, processing and analysis of the patient status, taking into account not only for the specific morphological and physiological aspects but also for the current status (movement, body position and effort level made by the patient) of patient in order to filter the artifacts that can appear in his quotidian life.

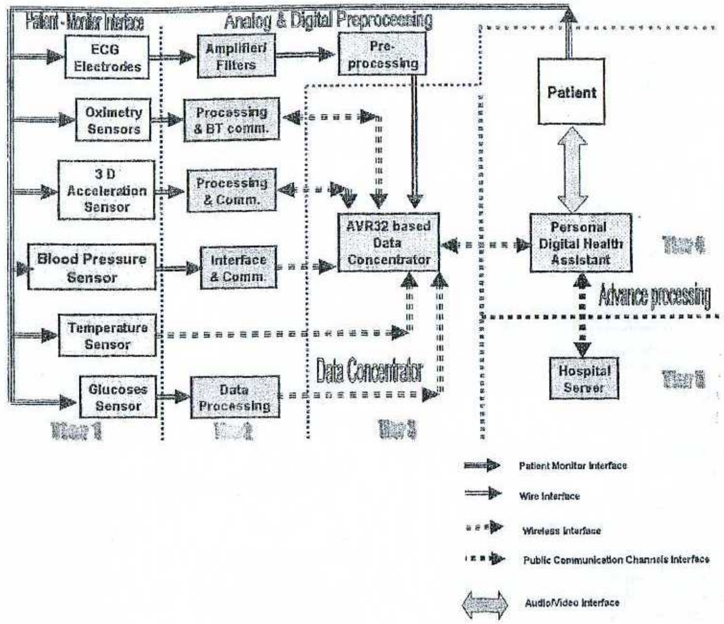


Fig. 1 BIOMED system and Legenda of the interfaces

First tier includes all the sensors placed on the patient: ECG electrodes thought as wearable assemble of Ag /AgCl or stainless steel electrodes. The numbers of derivation that we have established was one, pre-cordial, and we have used SVM methods [3] in order to approximate better the acquired bio-potential. For oximetry we have used the classical method developed by Beer-Lambert, using a dedicated sensor that has a dual LED and a phototransistor (SF-1011N -Nellcor) placed onto the patient's finger [4]. In order to offer an image about the patient's movement status we have developed a movement detection system by using a 3D accelerometer [5]. This sensor is placed as the ECG electrodes on the wearable support applied near of the patient's sterna just to assure the optimal condition for capturing the sterna's vibration. By the help of this sensor we have captured the movements due to the breath and heart (pulmonary and cardiac activities). These signals are important signals that can make easier the detection and classification of other signal records improving the success rate in automatic patient status detection. For the blood pressure we have chosen an existing apparatus and for it we have adapted a serial interface and the Bluetooth transceiver necessary to control the measurements and to collect the blood pressure data – *Ambulatory Blood Pressure Measurements* (ABPM). For measuring the *Blood Glucose Concentration* (BGC) we have chosen an appropriate sensor – *DEXCOM SEVEN* system – that offers a continuously monitor of the BGC for seven days by using for that a single application for the sensor that is placed near of the patient's belly. The BGC system is endowed with a wireless communication channel and the data are being transmitted by using a specific protocol. All the sensors are independently supplied from batteries in order to offer a maximum availability of the system in any conditions and also for commodity application of these on the patient.

The second tier is designed for the signals' preprocessing, data conversion and adapting and, for multiplexed data transfer to the data concentrator. At this level we have made the data filtering, and digitization of the signal for the ECG records, the control and light multiplexing for the oximeter sensor and the filtering of the obtained signals' difference.

For ABPM and BGC we have used the proprietary firmware as preprocessing support and only the communication protocol was modified by adapting it for our system needs.

The third tier we have implemented using an AVR32 microcontroller and the role of this tier was thought to realize the inter-correlation between the ECG, pulse, ABPM, and oximetry and also to generate the trend records for the acquired bio-signals. At the level of third tier we have obtained a very low consumption (~10mA) by using the newest 32 bits microcontroller AVR32UC3, placed onto a belt near to the wearable support of the sensors mounted onto the patient. This microcontroller has advantages such as: 8 different serial communication channels, multilayer high speed bus, and very low power consumption. The AVR32 UC3 CPU is the first 32-bit microprocessor that integrates single-cycle read/write SRAM with a direct interface to the pipeline that bypasses the system's bus to achieve faster execution, better deterministic behavior and lower power consumption. The microcontroller can deliver up to 1.38 Dhrystone MIPS/MHz, running from on-chip flash memory. Between the other advanced features we mention: the DSP arithmetic unit, single-cycle multiply and accumulate instructions and atomic bit or word read-modify-write instructions. The key benefits are high computational throughput, deterministic and real-time control, low power, low system cost, high reliability. A peripheral DMA UC3 controller core can be considered ideal if thinking at its high throughput and it can be also considered as perfectly suited for portable and battery-based applications (performance/power consumption ratio up to 1.08 DMIPS per mW). The rich feature set of the AT32UC3 microcontrollers includes up to 512 KB Flash, up to 64 KB SRAM, Ethernet MAC, Full Speed USB with OTG, 10-bit ADC, SPIs, SSC, two-wire interface (I2C compatible), UARTs, general purpose timers, thirteen pulse width modulators and a full set of supervisory functions.

For the data transfer between third and fourth tier (AT32UC3 CPU and Personal Digital Health Assistant (PDHA)) we have used a Bluetooth channel.

The fourth tier is represented by this PDHA that offers a very good Patient Machine Interface (PMI) and also has a lot of communication channels that can implement the multimodal interface with the fifth tier - the Hospital Server (HS) -.At the fourth level of the system we have conceived the video and audio interface with the patient that offers a large variety of video and audio messages necessary to assure the support for the dialog between the doctor responsible with the supervising of patient's health status being at the HS and the patient that is continuously monitored. Also at this level we have started to develop a set of routines for patient's biological signals analysis and we have started the research with the physicians to find out the correlation between the health status of the patient and the corresponding limits and trends of the evolution for the acquired signals. Using Java 2 Micro Edition (J2ME) [2] we have implemented on PDHA the asynchronous and synchronous communication protocols between the third tier and fourth tier of the system in order to control the interface with the patient and to acquire the data.

The fifth tier is formed by one or more servers that manage the patient. Powerful computers endowed with all the components of Windows 2003 server and SQL server manage the communication between the HS and patient's PDHAs.

Between fourth and fifth tier we have developed a multimodal interface protocol able to choose the optimal solution (from the point of reliability, availability and cost) between the PDHA and HS. The protocol takes into account the following factors: patient's health status, patient's biological signals variations, histogram of the real and virtual signals processed by the system, external conditions such as: existing on the place wireless communication channels (Wi-Fi, WiMAX, UMTS, GPRS, GSM, PSTN or other communication lines near to the patient environment).

We have organized the prioritization of the messages transferred between PDHA and HS as a result of continuously patient status monitoring as following:

- *normal status* that means the parameters monitored are in the normal domain of variation);
- *alarm status* (case when one or more signals or virtual signals –inter-correlated signals) exceed the normal limits of variations) and,
- *emergency status* (when one or more parameters present values that endanger the patent life.

The BIOMED TEL system is designed so that depending on the status of the patient and it will react according to specific settled strategies. Thus if the monitor, result of biological signals monitoring, will detect a *normal stage* he will acquire the biosignals and will process its in order to detect the variations of patient health status, will compress the data acquired on local storage devices (PDHA), and in the period when the cost of data transfer to HS is lowest will transfer these data to HS in order to update the history of patient health evolution on HS. If the detected status of the patient is an *energency status*, the BIOMED TEL system will start to transmit in realtime, continously all the biosignals acquired from patient to the HS and also will accept to send from HS to PDHA doctor's advices.

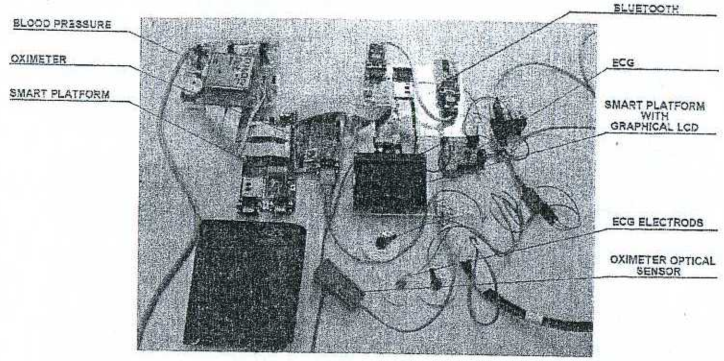


Fig. 2 The testing FCBs of the BIOMEDTEL system

The doctor is found behind the server (HS) and he will heve the full responsability related the energency therapy adopted including the decisions to alarm the public heath services to go and help the patiens at home.

3. IMPLEMENTATION AND EXPERIMENTAL RESULTS

In Figure2 we have shown the sensors and their corresponding acquiring and preprocessing systems [6].

By using the ECG acquiring system we have obtained the waveform presented in Figure 3. This waveform is corresponding to a resting ECG record.

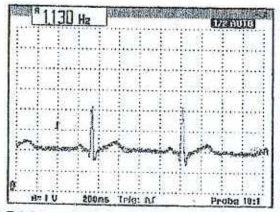
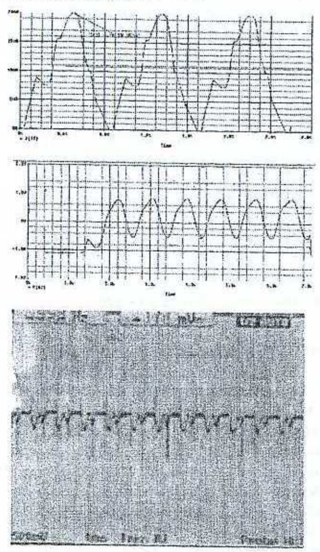


Fig. 3 ECG record obtained with our implemented system while resting [7]



(a)

(b)

(c)

Fig. 4 Oxymetry simulated waveforms (a, b) and experimental result obtained from our system (c) [8]

For the oximetry we have simulated and after that we have implemented the whole data acquisition channel. The simulations and also the real acquired signal are presented in fig 4. As we have shown the real signal presents a saturation of the amplified signal as a result of the high level of light illumination corresponding at the oximetry sensor (Nellcor).

For that reason we have designed and implemented a digital automatic gain adjustment for the light illumination. Thus, by using the preprocessing system based on ATmega128 microcontroller we have designed the corresponding program that implements the automatic gain adjustment [9]. In Figure 5 we have presented the flow diagram of this solution.

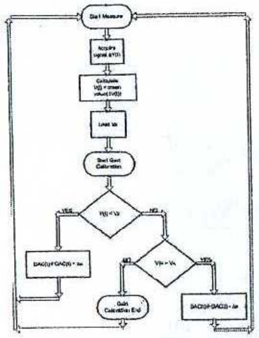


Fig. 5 Flow diagram of the AGC (Automatic Gain Control) Programme implemented with our digital loop

For the blood pressure channel we have used the commercial product Visomat® comfort 20/40 (UEBE-Germany) that is a fully automated upper arm blood pressure monitor that inflates the cuff automatically to the extent required for the individual user by real fuzzy logic. It was awarded with the quality seal of the German Hypertension Society and validated in clinical tests in accordance with DIN EN 1060/4 norms. We have designed a specific interface from the LCD display of the apparatus and we have serialized the data measured by the apparatus and also we have adapted the manual buttons at our designed serial interface by using our ATmega128 data acquisition system. Thus we have not affected the accuracy and functionality of the apparatus. We have implemented the wireless interface using LMX9838 module.

4. Conclusions and Future Developments

With our implementation we have fulfilled the requirements related to the precision and the sampling rates requested by a patient remote monitoring system. Our implementation ensures *accuracy*, *stability* and timely *availability* of portable remote patient monitor. By rational division of the system in subsystems, we have provided for each of them the *adequate power supply*. By choosing as required information flows, the *appropriate communication channels* between the subsystems of our BIOMED TEL system we have created the *premises* for the development of the *advanced and distributed processing software*, a mandatory step in order to reach a high precision and quality of patients' remote monitoring.

By organizing our distributed system on five tiers we have generated the possibility for the remote monitor to dynamically adapt and balance the processing power in order to satisfy the necessities to alarm, and act especially in case of emergency situations.

The two main objectives that we have reached: the acquisition of the ECG, ABPM, BGC, vibration and oximetry and the implementation of a new multimodal protocol for communication between PDHA and HS.

The future work will be focused on the processing of the acquired bio-signals and finding out the inter-correlation that are important for defining the hyperspace dimension for different kind of diseases and also the evolutionary algorithms that will provide the adaptation of BIOMED TEL monitor at the extremely large variety of situation that will meet in practice [10].

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Energy Management System Based on Supercapacitors used for Starting of Internal Combustion Engines of LDH1250 Locomotives and Charging their Batteries

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Abstract

The paper presents a new implementation of an energy management system that replaces the existing one on LDH 1250HP locomotive. Easley this system can be adapted for all kind of vehicles, hybrid or electric. The topology of the energy management system, the models considered for charging the batteries, the performance obtained for the start of Internal Combustion Engine are detailed into the paper. Using supercapacitors in the energetic circuit and a control system based on a microcontroller we successively switch on into the circuit of DC starting motor of ICE the voltage from supercapacitors and after from batteries. In order to avoid the discharging of batteries we designed and implemented an intelligent sensor that will detect the start of ICE and will switch off starting circuit ending the ICE start process. The current solutions use lead batteries which are supra-dimensioned in order to insure a reliable start of ICE and also to avoid the reduction of batteries life time. Using our new solution the inherent current spikes that appear during the starting process of ICE are strongly suppressed and the start of ICE became more reliable. Our solution was verified using a half of initial batteries capacity with excellent results.

1. Introduction

Nowadays the important changes of the climate at global level and depletion of fossil resources require from the human society a rapid and strong assembly of measures able to generate a drastically reduction of energy consumption. An important step towards this goal consists in the fuel consumption and engine pollutant reductions. Our application came to improve the actual locomotive starting system and to integrate all the functionalities related producing and using of electric energy, as an integrated system on locomotive.

Thus, that result is an increasing of overall efficiency of energetic processes that take place on vehicles [1].

The majority of vehicles use the lead-acid (L-A) batteries as power supplies for starting the ICE engine and after that, the starting process provides the electric energy necessary on vehicles. The starting process is critical because requests from batteries important peaks of power that induce an over-dimensioning of the batteries and also affects its life time. The possible damages produced due to starting shocks are difficult to be evaluated and as consequence these facts induce an important reduction of the system's reliability.

The evolution in the domain of nano-technologies has determined important improvements of the parameters of the super capacitors that become more appropriate to fulfill the requirements related to the maximum current, power and energy density. Thus appears as mandatory to introduce on vehicles a management of energy system and applications inclusive for those related to starting of ICE and other transitory processes [2].

Combined solutions, L-A batteries and super capacitors, appear to be the optimum compromise in terms of energy economy, materials, size and cost (including maintenance costs) [1]. While for batteries, starting becomes difficult at low temperatures, by using the combined solution, the battery will be protected and this fact significantly improves ICE starting. By providing intelligent and adaptive switching of the electric starter, energy source between supercapacitor and battery, the characteristic