Development of low-cost Hardware supporting Mobile Home–Care

B. Spyropoulos, A. Tzavaras, M. Botsivaly, K. Koutsourakis, E. Koulouris, D. Liargovas

Medical Instrumentation Technology Department, Technological Education Institute of Athens, Athens, Greece

Abstract—**We have developed a home-computer based system, addressing important aspects of the development of contemporary home – care that comprises of first, the employment of low-cost commercially available components, supporting home-care patient's well-being observation, including eventually vital-signs monitoring, and, second, software means for the processing, the evaluation and the targeted transmission of the acquired health-data, together with the home-care patient administration,. The hardware of the system comprises of, first, a custom-made ECG acquisition module, equipped with a RF link between amplifier and PC, second, a Nellcor finger pulse oximetry probe for typical plethysmography based Oxygen Saturation (SpO2) measurements and the estimation of Heart Rate (HR) and Respiration Rate (RR), and third, another custom-made Carotid Sounds (CS) acquisition module, for the extraction of Heart Rate (HR) and Respiration Rate (RR). The acquired row data and trends of SpO2, HR, RR, ECG waveforms, Oxygen Therapy advice etc. are appropriately processed to produce decision supportive data, while they can be easily stored in the home computer and / or transmitted to another location. The transmission can be achieved through wireless point-to-point links, modem and telephone lines on both, landlines and mobile cellular telephone lines, by a designated location through secured paths over the internet and, finally, through two satellite communication links. The pulse oximetry module is employed only if the patient is in need of Oxygen Therapy.**

Keywords— **Homecare, home monitoring, teleauscultation, home ventilation, home CPR.**

I. INTRODUCTION

The continuous evolution, growth and integration of information, communication and electronic technologies, together with the miniaturization of Biomedical Equipment and their merging with Informatics and Medical Decision Making techniques, will eventually alter the way that health care is going to be delivered in the future. The combination of these technological innovations, with the increase of mean life expectance, and the hospital care cost avalanche [1], indicates that the 21st Century Hospital will increasingly encourage home-care and especially Telemedicine supported one. The mission of this emerging Hospital will most probably be completed by a network of various associated Institutions, providing several interrelated types of preventive medicine, care for aged citizens, rehabilitation services for impaired persons and mental health-care programs and, generally, providing care closer to home-care than to rather that of the traditional hospital-care.

Therefore, we have developed a home-computer based system, addressing important aspects of the development of contemporary home – care that comprises of first, the employment of low-cost commercially available components, supporting home-care patient's well-being observation, including eventually vital-signs monitoring, and, second, software means for the processing, the evaluation, and the targeted transmission of the acquired health-data.

II. THE HARDWARE CONFIGURATION

The hardware of the system comprises of, first, a custom-made ECG acquisition module, equipped with an RF link between amplifier and PC, second, a Nellcor finger pulse oximetry probe for typical plethysmography based Oxygen Saturation (SpO2) measurements and the estimation of Heart Rate (HR) and Respiration Rate (RR), and third, another custom-made Carotid Sounds (CS) acquisition module, for the extraction of Heart Rate (HR) and Respiration Rate (RR).

The ECG module is designed to acquire Eindhoven I, II or III leads. The system comprises of a preamplifier circuit, a band pass active filter in the range of 0.5 -150 Hz, an amplifier, an analog to digital converter, and a microcontroller circuit that collects and transmits digitally and wireless the ECG, as shown in Figure 2. The receiver end is composed of a Radio Frequency (RF) digital receiver tuned to transmitter frequency, and a controller that translates digital data to RS232 communication protocol.

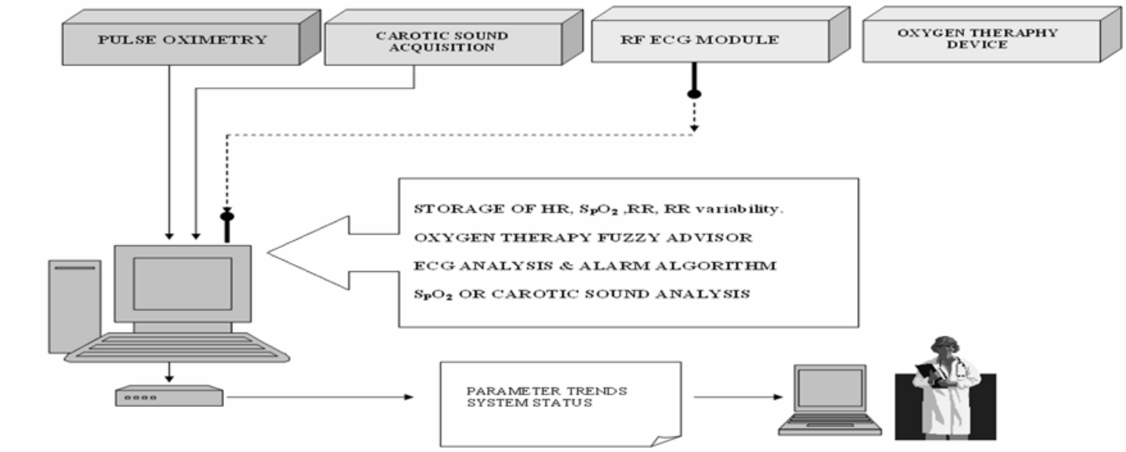

Fig. 1: The overall monitoring hardware block diagram.

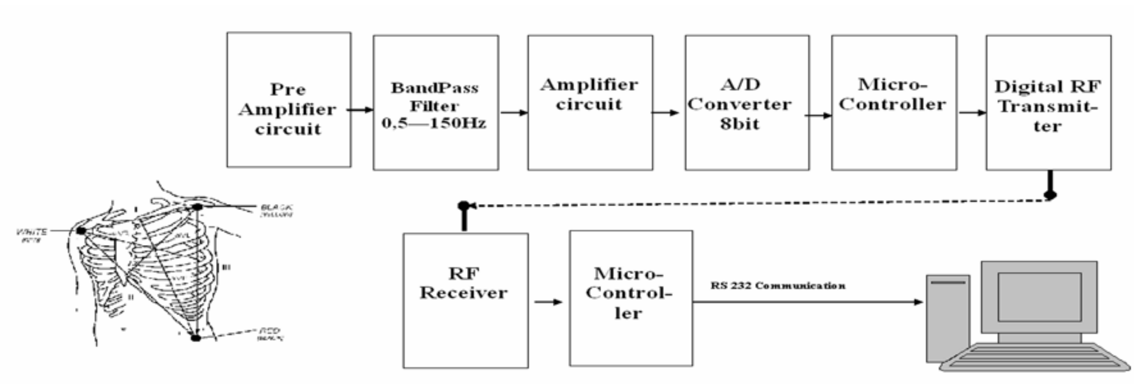

Fig. 2: ECG module block diagram.

The Pulse Oximetry module measures non-invasively light absorbance of arterial blood as a basis of determining arterial oxygen saturation. It measures absorbance at two distinct wavelengths: Red light (660nm) and Infrared light (990nm), and distinguish the concentrations of two different absorbers (Hb and HbO2 respectively), as shown in equation 1:

$$S_pO_2 = [HbO_2] / ([Hb] + [HbO_2]) \times 100 \quad (1)$$

The Ratio of Ratios (R_{OS}) is a variable used in calculating oxygen saturation based on the above mentioned two-wavelength Arterial Blood absorbance, and is presented in equation 2:

$$R_{OS} = \ln(R_L / R_H) / \ln(IR_L / IR_H) \quad (2)$$

Here, R_L and R_H are the maximal and minimal readings of the Red-light intensity, and IR_L and IR_H for the Infrared-light intensity accordingly. The Oxygen Saturation module returns the data to the computer for further processing.

The Carotid Sound Acquisition module is based on the arterial blood flow sound waveform, acquired by the stethoscope. The sound is captured with the aid of a microphone fitted to the stethoscope acoustic path, and then directed to the PC sound card input, as shown in Figure 4. Although the system's architecture is simple, and the implementation cost is minimal, the performance is very good, allowing not only for the acquisition of Heart Rate and Respiration Rate waveforms, as shown in Figure 4, but, furthermore, for full-scale tele-auscultation, in quasi real time mode. Obviously, other irrelevant bodily sounds and external noises may influence the recording.

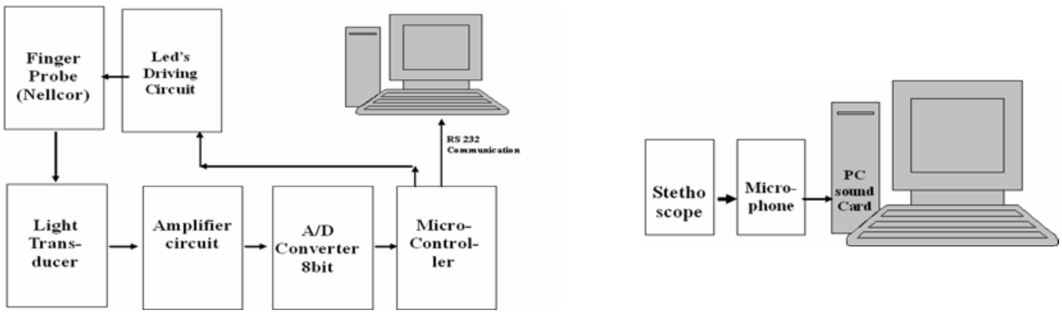

Fig. 3: The Pulse Oximeter module (left), and the Carotid Sound Acquisition module (right) block diagrams.

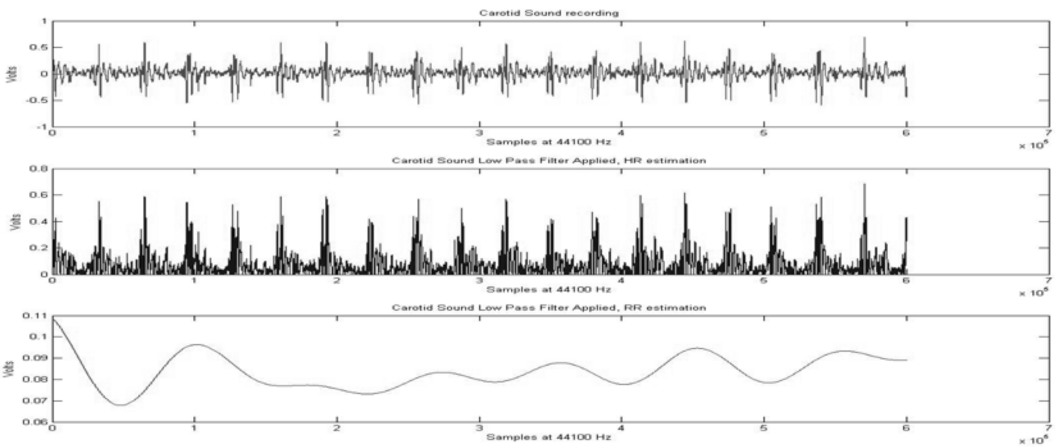

Fig. 4: Heart Rate and Respiration Rate waveforms acquired through the Carotid sound acquisition module.

III. PROCESSING, EVALUATION, AND TRANSMISSION OF THE ACQUIRED DATA

The acquired row data are appropriately processed to produce decision supportive data. The ***ECG waveforms*** and the corresponding ***Heart Rate (HR)*** are directly exported from the ECG module, while HR can also be obtained directly from the Carotid Sound acquisition module. ***Respiration Rate*** can also be estimated directly from the Carotid Sound acquisition module, or be extracted by employing frequency analysis and filtering of the original Photo-plethysmography [3] signal (PPG). PPG taken from finger tip extends from 0.001Hz to 6Hz, with the DC content removed, and the range 0.5 – 2.0 Hz is related to the mean heart rate. The data has been collected in quasi real time mode, and undergone Fast Fourier Transformation in the frequency domain, by employing standard MatLab software. The estimation of Respiration Rate and Heart Rate respectively, was based on the identification of the local frequency peaks, in the ranges 0.01 - 0.50 Hz and 0.5 - 2.0 Hz.

A Fuzzy logic algorithm [4] was designed and implemented, by employing Mat Lab software, to support Oxygen Therapy management, accepting as input the Oxygen Saturation (S_pO_2), the Heart rate (HR), and the Respiration Rate (RR) data, acquired by the described system. As internal indicator of the efficiency of oxygen therapy, Oxygen Saturation over time (dS_pO_2), has been considered, serving as an evaluative factor, of the patient's condition. The pulse oximetry module and the associated decision support are employed, only if the patient is in need of Oxygen.

The detection of shockable Ventricular fibrillation (VF) and malignant ventricular tachycardia (VT) and the closest responder alerting, for high risk patients, is achieved by employing two different techniques, introduced earlier by some of the authors [5]. The techniques employed are first, the Image Analysis Technique, according to which the ECG record is considered to be an image, divided into a number of equal regions of interest (ROI), and second, the Cumulative Probability Distribution Function (CDF) and the coefficient of Skewness (SKEW) CDF-SKEW techniques.

The data transmission can be achieved through wireless point-to-point links, modem and telephone lines on both, landlines and mobile cellular telephone lines, by a designated location through secured paths over the internet and, finally, through satellite communication links.

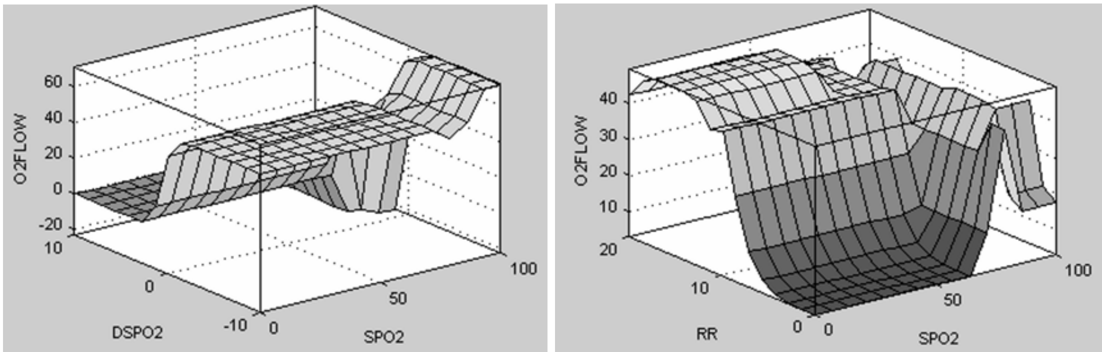

Fig. 5: Graph surfaces of input parameters versus system's output.

IV. HOMECARE ADMINISTRATION

The developed system comprises allows for the creation of a typical Continuity of Care Record (CCR) [6] that contains the appropriate demographic and administrative data, as well as the relevant clinical information that are necessary for the recording and the follow up of the home-patient. The CCR is an ASTM E2369-05 standard for an electronic form for patient transfer, referral, and discharge. Rather than a complete patient record, the CCR is designed to provide a snapshot in time containing the pertinent clinical, demographic, and administrative data for a specific patient. It is actually a way to create flexible documents that contain the most relevant core clinical information about a patient, and to send these electronically from one provider to another or to provide them directly to patients. The system is intended to be used upon the transition of a patient to homecare, although it could actually be used in any case of transition or referral.

The sections forming the CCR include, first, patient and provider information, second, insurance information, third, information regarding the patient's current health status, that is the recent care provided, and fourth, recommendations for future care (care plan).

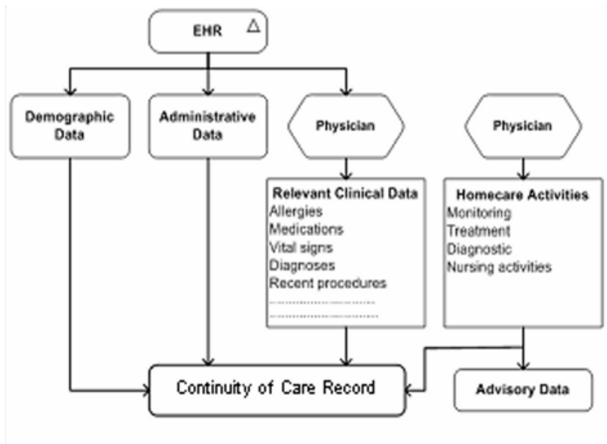

Fig. 6: Flow-chart of the Administrative module.

The CCR is designed to be technology and vendor neutral for maximum applicability. It must be developed on the extensible mark-up language (XML) platform in order to offer multiple options for its presentation, modification, and transmission. Through XML, CCR can be prepared, transmitted, and viewed in a browser, in an HL7 - CDA compliant document, in a secure email and in any XML-enabled application.

The widespread use of the CCR will improve continuity of patient care, enhance patient safety, reduce medical errors, reduce costs, enhance communication and exchange of health information and standardize patient care information across healthcare providers. It is actually anticipated that CCR will facilitate and stimulate more rapid

Electronic Health Record (EHR) development, as an essential and simple building block. The typical–CCR module can either collect the necessary data from an already installed EHR system, or can allow for the user to enter the data manually by filling special forms. In any case, the user decides which parts of the patient's medical record (electronic or paper) are the most significant ones or are the necessary ones for the description of the current health status of the patient and should be included in the CCR.

V. Discussion

The on-going testing of the system shows that it is able to contribute to an effective, extremely low-cost, and based on commercially available technology, home – care package solution, supporting not only well organized nursing care, but further, a structured total Patient Supervision and Treatment home-care approach.

Acknowledgment

This work is part of:

1. A project co-funded by 75% from European Union and 25% from the Greek Government under the framework of the Education and Initial vocational Training Program "Archimedes".
2. Project "Athena", which is funded from the Research Committee of the Technological Education Institute of Athens, Greece.

References

1. Spyropoulos B, Botsivaly M, Tzavaras A, Nikoloudakis G, Balabanis I, Karagiannis N, Limnou I Acquisition of cost-data for Surgery and Intensive medicine to be employed for drafting a DRGs hospital reimbursement system in Greece. Proc. of EMBEC 2005 - 3rd European Conf. on Medical & Biological Engineering, Prague, Czech Republic, 2005.
2. Webster J. G., "Design of Pulse Oximeters", Medical Science Series, 2003.
3. Kamal A. A. et al., "Skin photoplethysmography – a review", Comp. Methods & Programs in Biomedicine, vol.28, (1989) p 257-269.
4. Tzavaras A., Spyropoulos B., Botsivali M., Gatsios K., Koufakis A. Multivariable Fuzzy Logic Advisory System. Proc. of EMBEC 2005 - 3rd European Conf. on Medical & Biological Engineering, Prague, Czech Republic, 2005.
5. Botsivaly M., Koutsourakis K. Spyropoulos B. A quasi real time Biosignal Acquisition processing and Transmission System. 4th European Symposium on Biomedical Engineering, Patras, Greece 2004.
6. ASTM www.astm.org : E2369-05, Standard Specification for Continuity of Care Record.

Address of the corresponding author:

Author: Prof. Dr.rer.nat. Basile P. Spyropoulos
Institute: Technological Education Institute of Athens Medical Instrumentation Technology Department,
Street: Ag. Spyridonos and Dimitsanas Street, Egaleo
City: Athens 12210
Country: Greece
Email: basile@teiath.gr