DEVELOPMENT OF A PROTOTYPE OF A PATIENT'S WIRELESS VITAL SIGNS MONITOR

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Abstract. *In recent years, the development of microelectronics, Internet of Things (IoT) and communication technologies in medical applications provided a good components and solution basis for successful development of wearable devices . These devices are used in different application with goal of diagnosing of pathological states and monitoring of the health status of chronic patients. In this article will be described a prototype of a telemetry system for remote monitoring of patient vital sign parameters (SpO2, heart rate/pulse, ECG, non-invasive blood pressure, temperature).*

Keywords: *vital sign, wireless, NIBP, ECG, IoT*

Introduction

According to the definition of the European Commission, "telemedicine is the provision of medical services using information and communication technologies (ICT) in situations where a medical professional and a patient (or two medical professionals) are not in the same place. It includes the secure transmission of medical data and information in the form of text, sound, images or other forms necessary for the prevention, diagnosis, treatment and follow-up of patients" [1].

Telemonitoring is especially useful for people with chronic diseases (such as diabetes, high blood pressure or chronic heart failure). Many of these patients, often elderly, require regular follow-up due to the long duration of the illness, the nature of their medical condition, and the medications they are taking [1-3].

Telemonitoring supports both patients and healthcare professionals. Its use may allow symptoms and abnormal health parameters to be detected much earlier, even during a routine or emergency consultation, so timely corrective action can be applied before more serious complications occur. It may also lead to less frequent visits to healthcare facilities, thereby improving the quality of life of patients and decreasing loading of healthcare sector, especially in current situation of heavy pandemic and regional instability [1,4-6].

It has been proven that the use of telemonitoring improves the quality of patient care and state of patient health, in particular for chronic patients [6-8]. In the context of a stable aging of human population and a growing burden of chronic diseases, the benefits of wider distribution telemonitoring are seen very clear [7].

As part of state project No. 20.80009.8007.26 "Piloting the application of principles of personalized medicine in conducting of patients with chronic non-transmissible diseases" the author together with colleagues were developed a combined system for remote monitoring patient vital sign parameters, with possibility to monitor gas composition of exhaled air [8]. In order to provide the necessary functionality, the system currently consists of two separate devices, one device for gas analysis, and another device for vital signs.

This paper will focus on the results of the development of a second device - prototype of a remote monitor of patient's vital signs.

Materials and methods

During the project, a compact autonomous prototype for wireless monitoring of patient's vital signs was developed, with remote acquisition of ECG, pulse rate (HR), SpO2, NIBP blood pressure, temperature and respiratory rate.

A full schematic diagram of the prototype is shown on Fig.1:

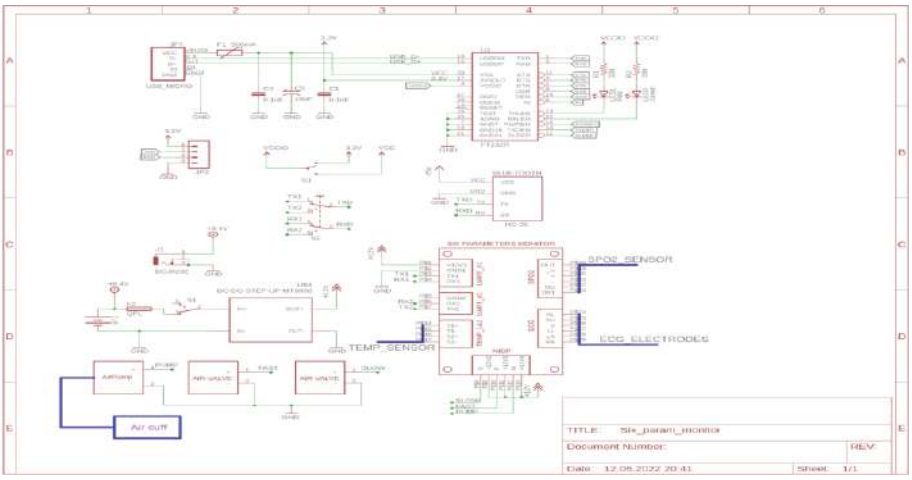

Figure 1. Scheme of the prototype of patient's wireless vital signs monitor

The main components of the prototype are:

(1) Central patient monitoring unit type UN 806;
(2) Boost power converter to power the central module;
(3) USB to UART interface converter;
(4) Bluetooth 2.0 communication module type HC -05;
(5) Lithium polymer battery 8.4 V2400 mAh.

The main characteristics of the UN 806 module are listed below:

- Six measured parameters HR, ECG, BP, S p O2, Temperature, RR (respiratory rate);
- Working with 3, 5 or 12 ECG leads;
- Three patient modes: adult, paediatric, neonatal;
- Five working modes of measurement, including automatic and manual mode;
- Defibrillator discharge protection.

The MT3608-based step-up power module converts the battery voltage to a standard +12V voltage to power the UN 806 module.

The USB-UART interface converter based on FT232RL ensures the negotiation of communication protocols when the instrument is connected by cable to a PC running software such as Ecg View 1.0 and NIBPTEST-English-v1.2.

The communication module provides Bluetooth 2.0 wireless transmission to a personal PC or Android smartphone with running software. At the next stage, it is provided to connect the communication module for wireless data transmission to the Cloud server.

All the above modules were mounted in one housing, which has the necessary connectors, indicators and switches for the operating mode, the appearance is shown on Fig.2:

Figure 2. External view of prototype of patient's wireless vital signs monitor

Detailed technical characteristics of the measured parameters are given in Tab. 1.

Table 1

Prototype Specifications

Measured parameter	Meaning
Systolic pressure	40~270mmHg (Adult), 40~200mmHg (Pediatric), 40~135mmHg (Neonatal)
Medium pressure	20~230mmHg (Adult), 20~165mmHg (Pediatric), 20~105mmHg (Neonatal)
Diastolic pressure	10~210mmHg (Adult), 10~150mmHg (Pediatric), 10~95mmHg (Neonatal)
Pressure measurement accuracy	± 3 mmHg , Resolution 1 mmHg
SPO2 / Heart rate	0~100% , accuracy ±2 % / 30-250 , accuracy ±2 bpm
General parameters	3, 5 or 12-channel ECG signal; ST segment analysis Calculation of heart rate; arrhythmia analysis; electrode status indication
Detailed parameters	Gain ±0.25…±2V / mV Heart rate (HR): 15 ~ 350 beats per minute Accuracy ± 1% or ± 1 bpm, resolution 1 bpm. Sensitivity > 200 µV/peak, input impedance > 5 MΩ Input isolation 1500 VAC ECG signal range >5mV/peak; signal filter from 0.05 to 100 Hz Input amplitude ： -2.0mV~2.0mV Arrhythmia Analysis (ASY , VF / VTA , CPT , RUN , BGM , TGM , ROT, VPB , TAC , BRD , MIS , PNC , PNP)
Respiratory rate	Waveform 1 channel; respiratory rate 7-120 beats per minute Resolution 1/min; error 2 beats per minute Base resistance 500 - 4000 Ohm; measurement range 0.5 - 3 Ohm
Body temperature	Number of channels - 2; measuring range 0-50 °C Resolution 0.1 °C; measurement accuracy ±0.2°C

The appearance of the prototype with connected sensors is shown on fig. 3:

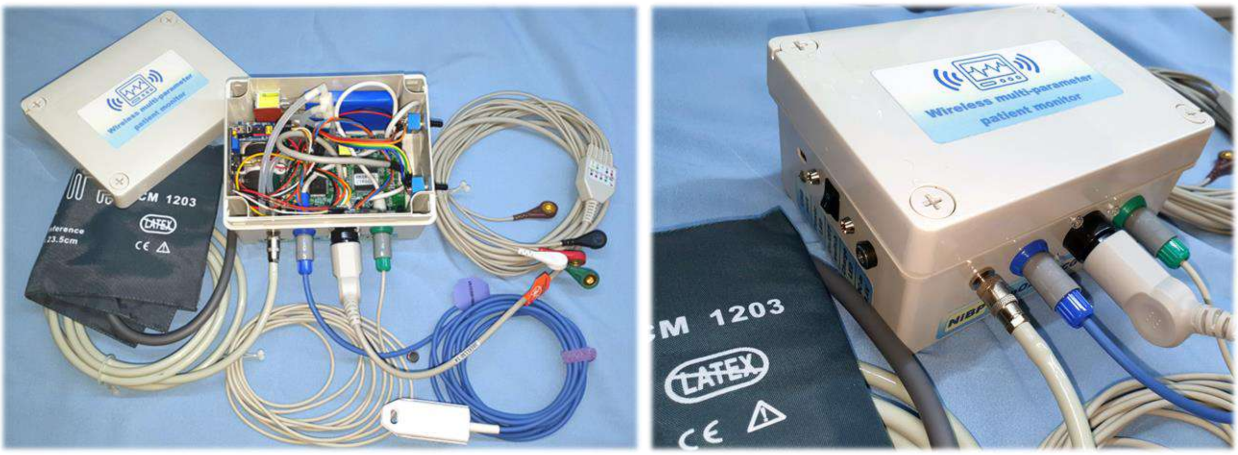

Figure 3. Appearance of the prototype

Connection to the prototype was carried out using a Bluetooth module HC-05 with a power output of 2.5 mW, through a Bluetooth 2.0 type communication protocol , which provides "transparent" operation of the physical COM ports of the prototype and virtual COM ports on a personal computer based on Windows 7, where in the future evaluation software was launched to receive data from the prototype.

The maximum distance of reliable signal transmission and reception was about 8 meters.

To assess the performance of this unit, specialized software for a PC based on MS Windows, implemented as a complex of the following programs:

- **NIBPTEST-English-v1.2** for measuring blood pressure and pulse rate
- **Ecg view v1.0** to measure all other parameters

The appearance of the working screens of the program in working condition - on Fig.4 :

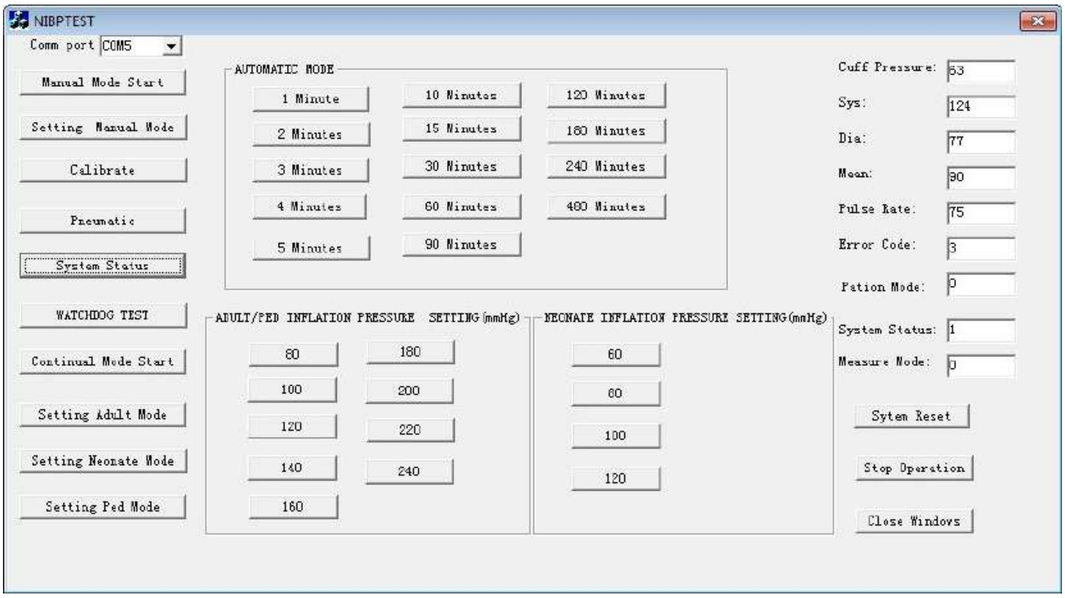

Figure 4. Appearance of the program NIBPTEST - English - v 1.2

According to the screenshot, the following parameters were measured at the time of testing:

- Cuff . pressure (residual pressure in blood cuff) = 63 mmHg;
- Sys . (systolic pressure) = 124 mmHg;
- Dia . (diastolic pressure) = 77 mmHg;
- Mean . (medium pressure) = 90 mmHg;
- pulse rate (pulse rate) = 76 bpm.

The following photo of the working screen of the **EcgView v1.0** program shows ECG lead curves, measured values of the temperature sensor +36.3. ° C , SpO 2 parameter values - blood oxygen saturation equal to 98% and measured pulse rate equal to 75 beats/min.

Figure 5. Appearance of the EcgView program v1.0

Conclusions

As a result of this work, the concept of a system for wireless monitoring of patient's vital signs was developed. Methods for practical monitoring of bioparameters were identified and implemented; transmission of remote data by wireless methods was done. The physical prototype of the system was build. The primary assessment of the functionality of prototype was carried out by connecting to a human person and measuring the main bioparameters.

Our system has an advantage of using of pre-approved OEM patient module, resulting reliable measurements, according to existing standards in medical industry. Having multiple measurements modes, different patient profiles, automatic and manual modes prototype could be used in different clinical applications.

Acknowledgments.

This work was supported by the project 20.80009.8007.26 "Piloting the application of the principles of personalised medicine in the conduct of patients with chronic non-communicable diseases" within the State Program (2020-2023), contracting authority: National Agency for Research and Development, Republic of Moldova. The author of the work expresses his gratitude and deep appreciation to dr. prof. Victor Sontea, for useful comments and advices during project and work under current article.

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