Designing a mobile cardiac monitor

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Abstract. The mortality associated with cardiovascular diseases is increasing every year. Especially high its risk levels in the Arctic and the High North areas. It is necessary to continuously monitor cardiovascular patients in order to prevent sudden death among them. The development of a portable diagnostic monitoring device is what is seen as able to contribute to this task. We have developed a prototype of the device and tested it. The device is portable. It can transmit data to a computer. The data is recorded continuously, indicating the beginning of the crisis and its course. The device can be connected to a smartphone to send emergency signals to health care facility. The signal is sent automatically and carries information about the location of the patient and their condition, allowing doctors to provide services in timely manner.

1. Introduction
In the modern medicine, cardiovascular diseases represent an acute problem. The mortality from cardiovascular pathologies is constantly increasing. Millions of new cases are registered annually, and half of all deaths is associated with this or that blood circulation pathology. Cardiovascular pathologies are what reduce the size of working population. Their rates are only increasing every year [1].

The need arises in monitoring the condition of cardiovascular patients in order to provide for timely preventive measures. Helpful in this regard is electrography, which, however, is not without downsides. Firstly, it is impossible to monitor patients during long time and continuously. Secondly, recording electrical potential difference is a difficult task. Thirdly, it is difficult to analyze, in prompt manner, the long paper tapes of the recordings. Also, the question arises as to data storing. You can use an oscilloscope to eliminate the above disadvantages. To deal with these downsides, one can make use of an oscilloscope – an oscillograph designed to monitor electrocardiograms. It allows for continuous receipt of data during unlimited time intervals. The data is provided visually on the monitor screen. The main disadvantage of this method is that it fatigues the staff responsible, keeping the operators “glued” to the monitors. Also, documenting the visualized information can be very difficult.

The effort of monitoring the patient's condition and reducing the risk of sudden death from myocardial infarction can be contributed by portable cardiac monitor design. It improves the quality of diagnostics and treatment of cardiac patients, while also facilitating the non-stoop monitoring of the patient's condition. A great achievement in the development of cardiac monitors is cardioscopes capable of storing data in their internal memory. Such cardioscopes provide an image of the patient's electrocardiogram in real time, which is especially important in a critical situation.

Many of the modern medical monitors are improved, automated cardioscopes. These monitors allow for unmanned monitoring of cardiac activity and can be integrated into complex systems for
monitoring severely ill patients. The devices are suitable for long-term, continuous monitoring. For daily monitoring purposes, small-size devices (cardiophone, Holter, etc.) are used, designed to take electrocardiograms without a doctor. Such devices are either issued by health care institutions or bought by patients with their own money. Their price, together with the accompanying software, is quite high, so the devices are not affordable to many.

The main objective of our work is to design a simple, compact and, in the first place, cheap device for remote monitoring. Only if it is cheap, can it become available to patients. Important to mention is the monitoring process should be non-stop. The solution lies in portable cardiac monitor design, small-size enough so that it does not interfere with patient’s daily tasks. Such cardiac monitor should not be a full-fledged medical device. It should monitor the patient's heart condition and diagnose pre-critical and critical conditions. If patient’s condition be recognized as pre-critical or critical, the cardiac monitor communicates a signal to the health facility, informing it of the condition and location of the patient. Geo-positioning constitutes an important part of the signal. When in critical condition, patient may fail to call the ambulance before losing consciousness.

Our analysis of cardiac monitors market has revealed the need in a more compact and easy to use design – the one capable of monitoring cardiac activity on a non-stop basis, not episodically; sending the emergency signal to health care facility; and transmitting data to the receivering device in automatic mode.

2. Materials and methods

The operating principle of a cardiograph is based on reading electrocardiosignals sent by the electrodes attached to patient’s skin. The electrocardiosignals are converted into frequency-modulated or code signals. The converted data is transmitted via a radio channel to smartphone. The electrocardiosignals are analyzed in the monitoring. At the same time, the device allows patients to see their electrocardiograms and pulse on the screens of the device in real time.

To obtain a cardiogram, the electrodes need to be attached to patient’s chest and limbs. The electrical activity signals are communicated via the standard bipolar leads developed by Einthoven [2]. This method consists in detecting the potential difference between two points of the electric field, that are located on the limbs, far from the heart – on the right and left arms, and left leg. For a more detailed picture, additional bipolar leads can be used.

The developed design is an integrated signal processing unit. It is capable of performing in conditions of strong interference. A set of sensors and electrodes for data acquisition is selected depending on the purpose of monitoring.

The electrodes-to-cardiomonitior connection scheme uses of a three-wire principle. The converter is an AD8232 chip-based module RC039. The radio unit incorporates a circuit plate with in-built AD8232 chip, a 3.5-mm plug connector (cable to electrodes), LED indication, and a pin connector for connecting to the Arduino.

AD8232 chip is developed by Analog Devices, Inc. [3] as an economical component of the analog input circuit of the heart rate monitor. This chip has a compact size and uses 20 percent less energy than its counterparts, which allows it to be used in a variety of health monitoring applications. Readings are taken with the use of common self-adhesive electrodes with push-button fixation of cable connector.

The device converts electrical signals into digital ones. Then the digital signal enters the microcontroller. Please see the cardiac monitor design on the diagram below (Figure.1).
Figure 1. The potential communication scheme.

After the microcontroller receives the digital signal, it converts the data into *.txt format and sends it via Bluetooth to the output device in real time. The settings are saved in the flash memory of the microcontroller in *.txt format. The smartphone and PC have dedicated software compatible with the design. In critical situation, the smartphone sends notification via the radio network to the health facility. (Fig.2)

Figure 2. Data communication to output unit.

The data coming to health facilities from multiple cardiac monitors will foster the need in a shared database to group patients according to various criteria, which, in turn, will lead to more efficient data processing and analysis, and will allow for developing recommendations to reduce the risk of mortality from cardiovascular diseases.

3. Results
The developed prototype is a small-sized, 3D printed box. Its housing was designed using FreeCAD, a parametric three-dimensional editor enabling 3D models and their drawings. (Figure.3).
Figure 3. Cardiac monitor housing design.

Inside the housing is a platform with all the essential components of the device – Arduino nano, AD8232 module, Bluetooth, SD card. On the lid of the device, there are two screens showing patient’s pulse and cardiogram in real time. The side faces of the housing have apertures for the SD card and mini USB port for PC connection. (Figure4).

Figure 4. SD card and mini USB apertures.

Installed with software interface, the PC displays patient's cardiogram and cardiac rate. The settings menu allows the operator to change dimensions of the cardiogram on the screen. It is possible to set the heart rate threshold. (Figure5)
Figure 5. Sample PC software interface.

For more convenient use of the device, electrodes and wires are attached to special belts. Their length is adjustable and suitable for all bodily compositions. (Figure 6). Placed in special case, the cardiac monitor does not cause discomfort.

Figure 6. Belts with electrodes.

A number of cardiograms were taken using the device design. (Figure 7). It transmits the data in a continuous stream for more accurate analysis. Work is in process to improve the device so that it stops recording ambient noise.
4. Conclusion

The device represents a tool for monitoring patient’s cardiac condition. Theoretically, it allows to reduce the risk of death from cardiac diseases and to improve cardiac patients follow-up.

The developed cardiac monitor design is convenient for monitoring cardiac activity on a day-to-day basis, causing no discomfort to the patient.

The device can be used in biomedical engineering as a means for measuring electrical potentials in the brain or the eye muscles.

Our further work on the device targets a sound signal component to alert the patient in case of an emergency such as detached electrode or low cardiac rate.

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