Measurement of the Heart Rate of a Person during Physical Activities

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Abstract: - This contribution examines options for the measurement of a person’s heart rate during physical activities. The main emphasis is being placed on the use of a measuring device for a project called “Fireman – rescuer of the future”. The article describes the most common methods of heart rate measuring and their possible use for the “fireman of the future”. The conclusion is devoted to a design of a device for measuring the heart rate using a method of detection of an R wave of the ECG signal.

Key-Words: - Heart rate, Heart rate measurement, ECG signal, Fireman of the future, Informatics, Physiology

1 Introduction
The heart pulse rate is one of the fundamental diagnostic data used when determining a condition of an organism both at rest and during physical activity. In medicine, the monitoring of the heart rate of patients is most frequently done while they are on a bed. However, hospitals are not the only places where the heart rate is checked. Heart rate monitoring is also used with top sportsmen who optimize their training accordingly. The use of heart rate measurement is also relied on in the “Fireman – rescuer of the future” project. The fireman is to wear special clothing which enables measurements of physiological functions of the body to be obtained. Specifically, the heart rate is one of these functions. The information acquired from individual firemen will be sent on a regular basis to a commander who evaluates it and thus gains a better overview of the physical and medical condition of each one of them. Based on the change in physiological functions that can be recognised, for instance, exhaustion, the increased heart rate may indicate the beginnings of shock caused by internal bleeding. [7]

Therefore, the objective of the paper is to design an operational system for the measuring of the heart rate of the fireman in action.

2 Problem Formulation
The pulse is a pressure wave induced by the expulsion of blood from the left ventricle into the aorta and from there it spreads into peripheral arteries. It is a volume change of the artery. Pulse can be seen and felt by fingers or checked by a device. It is caused by the impact of blood flow on the walls of arteries. These impacts are induced by the left ventricular systole. The pulse is influenced by the aortal valve, the flexibility of the arteries and the vasculature content. [5]

The system of heart rate measuring is primarily intended for firemen – rescuers of the future. Undoubtedly, it can be employed in other fields as well, for instance for sportsmen. For the use by rescue services there are several requirements. Above all, the system must be easy to use; its application must be as fast as possible. Further, it must not restrict the fireman in action and it must be comfortable. If these requirements were not met, the firemen would probably refuse to use this system. The heart rates obtained from individual firemen should be constantly sent to the commander who is to evaluate the data and replace the tired fireman if needed. There is no need for showing the heart rates to the actual fireman as he has no time to deal with this when in action.

For firemen – rescuers the special device for heart rate measurement must be developed. None of the commercially available systems for measuring heart rate is fully satisfactory. They do not meet the requirements of speedy usage, as upon alarm the firemen must dress quickly and go to action. On that account it is impossible for firemen to waste time by placing the measuring system and fixing electrodes. Moreover, all devices for heart rate checking require a direct contact with the body of the fireman. One of the possible solutions to this problem is the system being attached to the body constantly. Nevertheless, it must not restrict the fireman at work and it should
be comfortable. Also, the system must be capable of transferring the obtained data to the commander who evaluates it, which enables him to deploy firemen into action more effectively.

3 Problem Solution

Individual methods of measurement differ only in the way the heart rate is converted on the electrical impulses which are consequently processed and displayed. Generally, it can be stated that a block diagram, see Fig. 1, consists of sensor, amplifier, converter of scanned quantities on pulses, microprocessors for signal processing and display units or chart recorders. [6]

3.1 The method of optical scanning of the heart rate

This method uses variations in light transmission of the tissue when the blood pressure changes. Well perfused tissue absorbs light differently from the tissue that is not perfused. This change is then dependant on the heart rate. Measurements are performed on fingertips. It is possible to use a transmissive method in which there is a source of light from one side of the finger, most frequently in the infrared range of 940 nm of wavelengths, and a photodetector that detects infrared radiation from the other side (usually, it is a photoresistor or phototransistor). Another method that can be used is a reflexion method where there is the source of light and a photodetector placed next to each other on the same side of the finger. [6]

3.2 The method of capacitive scanning of the heart rate

The sensor is in the shape of a ring which is fitted on the finger. This method uses a flexible dielectric capacitor placed inside the ring. The change in the volume tissue causes resizing of flexible dielectrics, which changes the capacity of the capacitor. With the change in the capacity also comes the change in voltage. Based on the voltage it is then possible to determine the frequency of the heart rate. [3]

3.3 The method of the R wave measurement

In order to measure using this method, an R wave detector and an ECG signal are required. The detector signals the QRS complex in the ECG signal. The frequency of the heart rate is then calculated from the R-R interval.

However, interferences which occur in daily life, cause problems. For instance, the interference caused by breathing occurs at frequencies ranging from 0.15 to 0.6 Hz. The electrode potentials caused by motion of the scanned person range from 0.6 to 1.5 Hz. Interference of power supply networks are of 50 Hz while interference by myopotentials ranges from 20 to 500 Hz. When measuring the heart rate the majority of such interferences can be suppressed by a suitable filtration. QRS complex lies at the frequencies of around 12 Hz where the interference is low. [4]

3.4 The method of acoustic scanning of the heart rate

The acoustic manifestations of the heart are referred to as heart sounds generated by the activity of the
heart. It is a very simple method in principle. A microphone is placed on the body of the scanned person and the acoustic signal is converted into an electrical signal. After processing the signal it is converted into pulses. The complex processing of the signal is a disadvantage as there are many interferences, such as breathing, heart murmurs and predominantly movements of the scanned person. [3]

3.5 The method of impedance scanning
During this method changes of impedance induced by the change in blood volume in between two electrodes or by electrical impedance of the chest caused by the heart activity, are recorded. However, the disadvantage of this method is that during physical activity when the stroke volume increases the results of measurement differ noticeably when compared to invasive monitoring. [3]

3.6 The use of individual methods
For firemen – rescuers the measurement of the R wave by means of the ECG signal obtained by electrodes seems to be the most suitable. Both optical and pressure sensors would obstruct during the action as they are usually attached to the finger. The fireman needs both hands free to do the job. Impedance scanning is inappropriate due to its inaccuracy during physical activity.

3.7 The location of sensors
There are several possibilities where to place the sensors. There is no need to scan the entire ECG by means of 12 electrodes. The electrodes located in a chest belt near the heart are enough. One of first such systems was developed by Finish company Polar. Their product Sporttester was intended for sportsmen who wanted to increase the effectiveness of workouts (see Fig. 3). It comprises of the chest belt and a wristwatch. Information is transferred wirelessly from the chest belt to the watch, which enables the user to see the maximum and average heart rate, training time, burnt calories and proportion of fat per exerted energy.

Nowadays, there exist chest belts which do not send information to the watch but to the smart phones using Bluetooth wireless technology. [8]

3.8 The design of the heart rate sensor
The heart rate sensor intended specifically for the firemen - rescuers of the future, could have similar parameters as the chest belt made by the Polar company. However, it will be necessary to make the device as small as possible so it is comfortable and light while putting no restrictions on firemen and their other equipment. One of the possibilities of how to speed attaching the chest belt up is to sew it into the clothing that is worn by the fireman that comes in direct contact with the body. Furthermore, this device should be waterproof; if sewn in the cloth it must withstand washing. Another reason for water resistance is the relatively high level of perspiration of firemen in action.

3.9 The block diagram of the heart rate sensor
The ECG signal obtained from the sensors must be filtered out first; for this a band pass filter with marginal frequencies of 14 to 25 Hz is used in which the most significant spectral components of the R wave are included. The medium frequency of the band-pass filter should therefore be approximately of 12 to 15 Hz with a bandwidth of around 10 Hz. The signal amplification is performed in order to achieve positive values of the signal as well as further enhancement of R waves. The value that is to detect the required R wave is set in the threshold detector. According to [7], the size of the threshold value is usually set at 40 % of the maximum of the QRS complex.

The peak detector represents an algorithm for searching R wave peaks. The algorithm goes through the signal, component by component and the result is a vector that contains only peaks of the R-wave, as isolated points. The microprocessor then calculates the interval among these isolated points and recalculates the distance to the time domain. The signal that is processed in such a way is then
sent by a transmitter to the commander who evaluates the data. Fig. 4 depicts the block diagram of the designed sensor for the heart rate using the R wave detector. [1]

![Block diagram of the R wave detector](image)

**4 Conclusion**

The objective of this paper was to design a device for the measurement of the heart rate during physical activities. Such a device would find its application both with sportsmen in optimizing their training plans as well as in the project of the fireman – rescuer of the future. In latter case, the device would be a part of the smart clothing which is to monitor physiological functions of the fireman in action. Having examined possible methods of measuring of the heart rate, the detection of the R wave out of the ECG signal was evaluated as the most applicable because all other methods were prone to interference or restricted the fireman at his work. From the perspective of the sensors, the chest belt was chosen as it is less likely to limit the fireman in comparison with other methods. Also, the chest belt meets the requirements of simplicity of use as no electrodes must be attached to the body prior to dressing for action. Following further research of the implementation of the designed device is expected.

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