

OBTAINING THE PHYSIOLOGICAL DATA USING THE PHOTOPLETHYSMOGRAPHIC METHOD

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Abstract: The activity of the cardiovascular system is very important for the overall health of a human being. The Photoplethysmographic method is an effective tool of assessing the activity of the heart. The method is based on recording changes in blood volume in the blood vessels of the individual. The report presents a non-invasive way to obtain physiological data using a created device based on the Photoplethysmographic method. The created device consists of a photodetector, infrared light-emitting diodes, and small pulse rate sensors. The proposed portable device has been tested with three types of interfaces. The received data from the Photoplethysmographic device is transmitted to a personal computer and stored for further processing.

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Introduction

The recording of electrical activity of the heart over time (electrocardiogram, ECG) has been used in recent decades with success in monitoring and diagnosing various types of conditions and illnesses. The need to attach several electrodes to the human body causes some inconvenience and is not particularly suitable for frequent and long-term patient monitoring. In these cases, a PhotoPlethysmoGraphic (PPG) method may be used to monitor the heart's operation. The PPG method is suitable for the study of individuals who are not in the condition of physically rest. Photoplethysmography is an optical measurement method used to record changes in blood volume in blood vessels. The blood flow has a pulsating character and the resultant pulse wave can be detected in different parts of the bloodstream. The method uses a light source and a photodetector for recording the intensity of the light stream that has passed through or is reflected by the biological tissue. The luminous flux intensity varies depending on the changes in blood flow at the site where the measurement is performed.

The purpose of this article is to describe the basic principles of the PPG method and to present a portable device created by the authors to obtain PPG signals.

Literature review

A description of the essence of the photoplethysmograph method and its application is given in the work of some modern researchers, such as Allen (2007), Tamura et al (2014), Webster (2009) and Yoon et al (2009). The PPG method is a recognition of the pulse wave, by means of graphs, taken in different areas of the human body. An algorithm for the rapid detection of the pulse wave was created by Bulgarian authors Nenova et al (2010) and Nenova-Baylova (2011). The algorithm includes a high-frequency filter with a 0.5 Hz bandwidth, acceleration with first zero at 7.5 Hz, detection of maxima and minima, criterion for the validity of the growing front, and an evaluation of the likeness of the current rising front to previous valid fronts. Non-invasive methods for investigating arterial rigidity and elasticity the walls of the blood vessels, by examining the time of the pulse wave propagation are an object examined by Nikolova (2008).

Principle of Action of Photoplethysmographic method

The Photoplethysmographic method relies on the use of a pulse light (by registering changes in the volume of blood flow) and the amount of oxygen in the blood. Light interacts with the tissue in which it is and performs different optical processes: distraction, takeover, reflection, crossing and fluorescence. According to Iliev (2011) the volume of blood contained in the blood vessels, the movement of their walls, the orientation of the red blood cells are factors that influence the light falling on the photodetector.

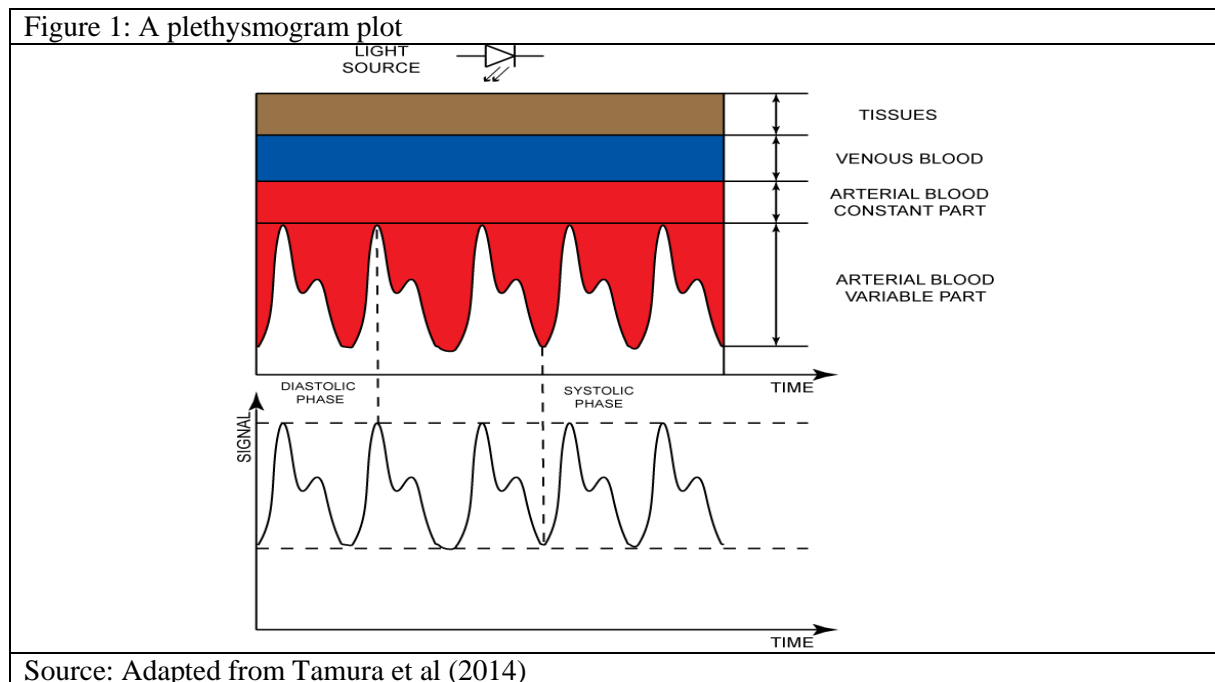
The interaction of light with tissues has a complex character. Anderson et al (1981) examined the optical properties of human skin as well as hthe interaction of human skin with light. As a result of these studies, the authors conclude that the smaller the wavelength, the greater the absorption of

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pigments in the skin. Water absorbs the light in the ultraviolet spectrum and in the far infrared range of the spectrum. The red light and light from the near infrared end is less absorbed, which is why the light of this length is used in the PPG method. The blood absorbs light more than the tissues, hence the increase or the reduction in volume may be determined by the corresponding reduction / increase the registered light.

Figure 1 shows a plethysmogram plot. It can be distinguished into two main parts - one is the comparative constant - it corresponds to the absorption / reflection of light from the soft tissues and the average blood content in the arteries and veins. In addition to this the permanent part changes little in the breathing process. The other part is variable and shows changes in the amount of blood during the time of the systolic and diastolic phases. The base frequency of this ingredient is directly related to heart rate. Like it is as shown by the Figure 1, the variable part is superimposed on the permanent one.



There are two main ways of applying the photoplethysmographic method for measuring the pulse wave frequency:

- Through the passage of light.
- Through the reflection of light.

Figure 2 shows the schematic arrangement of the light source and the photodetector using the first method. In this method, the source of the the light and the photodetector are placed in an easy-to-use location, such as the light source is on one side of the human tissue and photodetector on the other. The most commonly used places on the human body in this method are: finger, ear, nasal barrier, cheek, tongue. In some cases, when the PPG device is placed on the tongue or on the nasal barrier, researches are effective only when the individual is under anesthesia (in a fully static state).

The second way of measuring (by reflecting the light) is shown schematically in Figure 3. The light source and the photodetector are located on the same side of the human tissue. Unlike the previous method, there are more opportunities for where to place the source and the receiver of light on a body. However, the use of the photoplasmographic method has difficulties of a different nature. When the examined individual moves, artifacts are produced on the PPG chart. Changing the pressure between the sensor and the measuring point leads to changing the signal level received by the sensor. There are no standards that to determine what is the most appropriate level of compression. According to Tamura et al (2014) when the pressure increases, the level of the signal increases and after crossing a limit starts decreasing again.

In terms of miniaturization, an important factor in the use of the method is energy consumption. The amount of energy consumed determines the capacity and the size of the power source. According to

Mainsah et al (2007) in the passage method, the energy used is more than an order of magnitude larger than the reflection method.

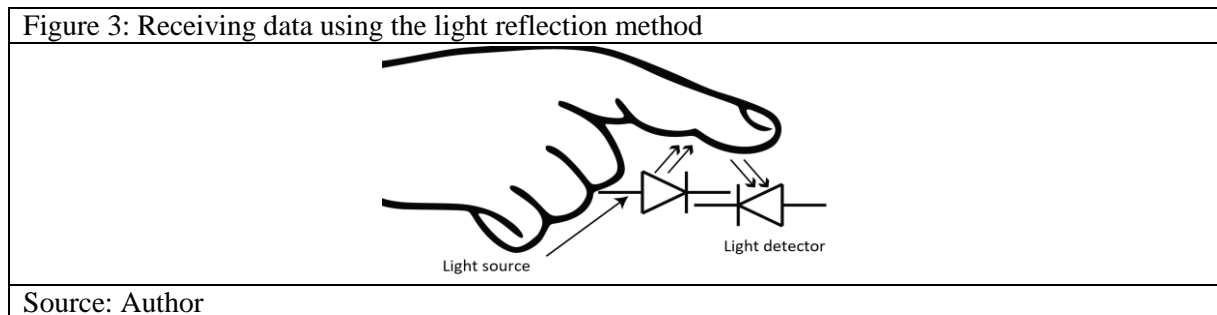
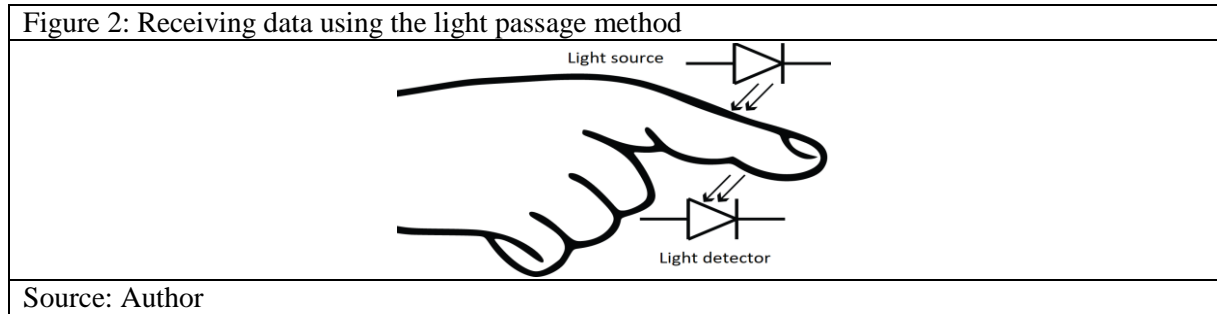
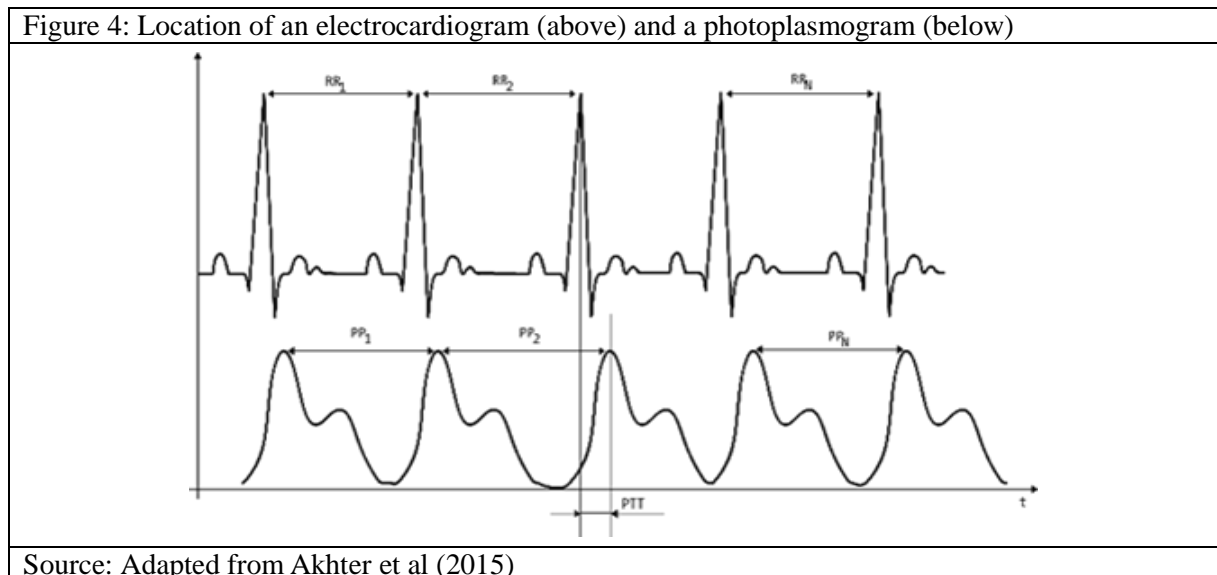


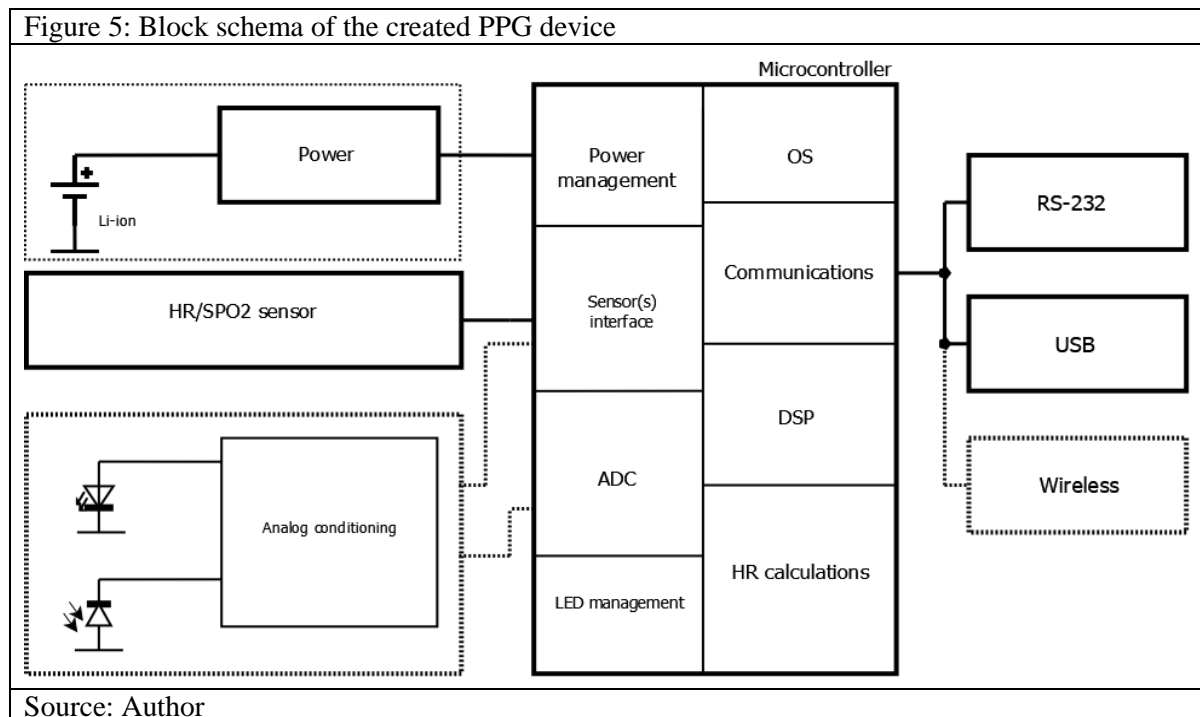
Figure 4 shows the location in electrocardiogram time (above) and phototypesmogram (below) and from the presented graph, it can be seen that the distances between the vertices of the electrocardiogram, named RR intervals, coincide with the distance between the phototypesmogram peaks (PP intervals). According to the authors of Kim et al (2010) and Yoon et al (2009) it is possible to determine the blood pressure by the simultaneous use of an electrocardiogram and a phototypesmogram. For this purpose a method is used based on pulse wave delay, as measured by a photoplethysmograph, against the QRS complex of electrocardiogram. That delay is time between peaks of both charts is indicated by PTT (pulse transit time) in Figure 4.



Description of a created photoplattismograph signal recording device

Figure 5 shows a block diagram of the created device for heart rate measurement and the oxygen content reporting in the blood, through the photoplattismographic method. Several aspects were taken into account when creating the device: minimum sizes; sufficient computational power; the possibility to use different types of sensors - both integrated and discrete. The created device prototype is portable

with approximate dimensions of 85x55x10mm. The device has several basic blocks, presented in Figure 5.



Power Supply - Powered by a dedicated integrated circuit for charging Li-ion batteries, with the power supply being controlled by the microcontroller.

Pulse sensor - an integrated Maxim MAX100100 sensor from Maxim Integrated (SAM4S ARM Cortex-M4 Microcontrollers) is used. It contains the following most important components: infrared LED pulse counting a red LED for detecting the oxygen level in the blood; current control system via LEDs; photoreceptor; a system for filtering the surrounding light; analog-to-digital converter; interface bus for connection to a microcontroller; temperature sensor.

Another possibility is the use of standard sensors for multiple use with a DB-9 connector. As an example Nellcor DS-100A.

For the basic computing component of the created device an Atmel microcomputer SAM4S was selected which performs the main tasks related to communication, reading, sensor management, etc.

The interface for communication with external devices. The device has been tested with 3 types of interfaces:

- standard serial RS-232;
- USB – the device is recognized as standard serial port and installing drivers are not required;
- Wireless - WiFi and 3G.

Depending on the specific conditions, the appropriate interface can be used for the connection of the device to the environment.

Digital Signal Processing - thanks to the use of the microcontroller's basic functions, the primary digital signal processing from the sensor, such as averaging, filtering, remove artifacts, etc., can be programmed to be performed by the device itself.

To managing the various functions of the device and the connections between the separate subsystems is used an open source real-time operating system (NuttX Real-Time Operating System). A software program for PC is created, which visualizes the received data, converts it into a format suitable for digital processing and saves the data into a custom database.

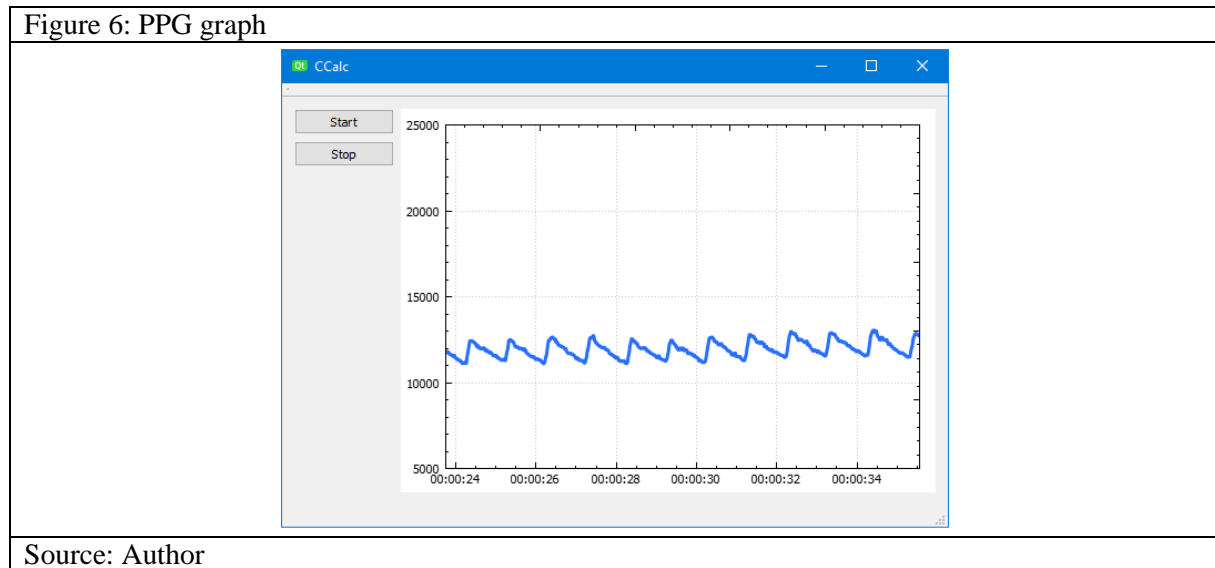
Test of the Device and Results

The created device based on the photoplasimographic method has been tested on volunteers at different places of the human body: finger, wrist, ear, etc. The choice of the used interface depends of

the optimum ratios between: the speed of data exchange, choice of the type of communication (one-way / two-way); the losses, determined by the number of incorrectly transmitted packets on the unit of time; consumption requirements of electricity; device size requirements; price etc. The Wireless interface is a reasonable choice to observe the above requirements. The received data from the device via the selected interface are transmitted to a PC for visualization and post-processing. To illustrate the output results of the pulse curve measurement in a graphical form and the subsequent storage of the received data, a Visual C++ software program running under on a Windows operating system was created.

Figure 6 shows the graph of the resulting PPG signal at the location of the ring finger of a volunteer and the use of the method by reflection of light. The data shown on the chart had not been processed - no filtration, averaging, removal, etc.

Figure 6: PPG graph



Source: Author

Advantages of the device based of the photoplethysmograph method:

- High sensitivity;
- Portable dimensions and low weight;
- Easy to use;
- Low price;
- Ability to position the device on different parts of the human body;
- The operation of the sensor is not influenced significantly by the specific positioning of the device.

Observed negative impacts on the accuracy of the research:

- Accuracy of the device is dependant on the temperature of the patient and ambient temperature;
- Influence of external light;
- Influence of various artifacts as a result of movement of the investigated patient and the condition of the surface of the biological tissue.

Conclusion

This report describes the principles of the PPG method and presents the model and the way of functioning of a device for extracting real cardiac data for cardiac function measurements. The Physiological data obtained from the device can be used for further processing and analysis. The research described in the article is a result of the authors' work on a project funded by the National Science Fund of Bulgaria. By monitoring the function of the heart in a convenient and unobstrusive way, the photoplethysmographic method is suitable for the long-term study of patients and has the advantage of providing better comfort of the observed individual compared to conventional methods. The pulse wave detection device described in the report allows for the remote monitoring of the heartbeat and can be used in telemetric monitoring systems for risk patients with cardiovascular problems. Using the device will improve the capabilities for tracking and controlling risk groups

patients suffering from cardiovascular disease. The device can also be used in the learning process of universities in Bulgaria as a means of extracting real Physiological data.

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