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Design and implementation of a simple portable biomedical electronic device to diagnose cardiac arrhythmias

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ABSTRACT

This paper presents the development of a simple portable biomedical electronic device to detect cardiac arrhythmias in humans. It identifies three main parts: an electrocardiograph, a device for data communication and a personal computer with software for diagnosis. The system performs automatic diagnosis of cardiac arrhythmias by comparing the patient's electrocardiogram with those contained in a database stored in a personal computer. The biomedical device performance is satisfactory and it demonstrated its usefulness even in the absence of medical specialist in cardiology.

1. Introduction

The human circulatory system consists of the heart and the blood vessels, which together maintain a continuous blood flow throughout the body. The heart is a hollow muscle that can pump blood throughout the body, in normal state it beats about 60–80 times per minute, but during exercise, excitement or anxiety situations, heart rate can be increased to 200 beats per minute. The heart beats about 100,000 times a day and with each heartbeat, sends blood around the body carrying oxygen and nutrients to the cells. Heart diseases are one of the major health problems today. It is estimated that heart diseases are among the three leading causes of death, consequently a large effort in their study, prevention and treatment are designated [1]. The human heart is a complex tissue consisting of muscle fibers, called myocardium, which is responsible for its contractions using bioelectrical activity. This bioelectrical activity is detected as changes in an electrical potential, generated by the whole cardiac cells, which are received in the body surface. These bioelectrical signals whose frequency ranges are from 0.01 Hz to 150 Hz with 1 mV amplitude [2], spread throughout the body and can be detected by special surface electrodes placed in different sites of the body surface. The simplest configuration uses three surface electrodes that are placed in the order given by the *Einthoven's* triangle [3], so named to remember the pioneer of electrocardiography Willem Einthoven, whose connections are called bipolar derivations and can be of type I, II or III as illustrated in Fig. 1. The information obtained from these surface electrodes can be sent to a recording instrument, called electrocardiograph for plotting the characteristic PQRST complex wave [3], see Fig. 2.

Some of the most dangerous forms of heart failure are not due to heart muscle disease, but rhythm disorders of the heart beat [1]. When a change in the heart rate contractions is detected in the rate of heart contractions, significantly different from the normal rhythm of the heartbeat, there is a dysfunction called arrhythmia. Among the defects which can be diagnosed by the electrocardiograph include arrhythmias that are classified according to the heart rate of pathological rhythm in bradarrhythmias and tachyarrhythmias. In general, if the heart rate is below 60 beats per minute provides a bradycardia, and if the heart rate is above 90 beats per minute is diagnosed a tachycardia [4]. The electrocardiograph is the fundamental tool used in cardiology for the diagnosis, prevention and treatment of this condition [3].

This paper presents the development of a simple portable electronic biomedical device to detect, monitor and diagnose cardiac arrhythmias in humans. Its purpose is to assist and monitor the health status of patients with these conditions. Because of its autonomy and portability characteristics, it can be used as a valuable aid in public health services, in both densely populated areas and in remote regions, even in those places where there is a lack of commercial supply of electrical energy. It is designed to be operated by personnel with basic training, as it includes a database that

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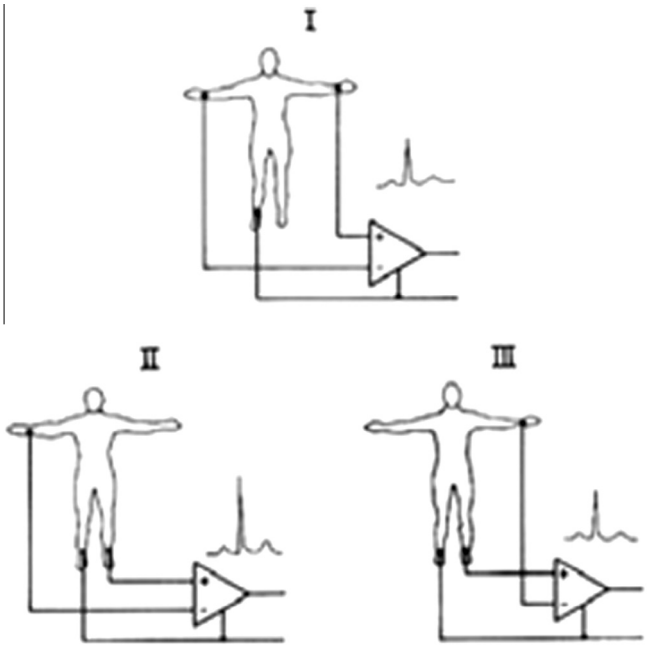

Fig. 1. Diagrams showing the connection of the surface electrodes on the patient using *Einthoven's* Triangle bipolar derivations I, II and III.

allows determining in many cases the appropriate treatment to prevent or correct a possible cardiac arrhythmia. However, the apparatus described in this paper is also useful for medical professionals with a high level of expertise in the field of cardiology.

The following sections describe the three main parts of the biomedical instrument developed in this work: an electrocardiograph, a device for data communication and a computer with the appropriate software for the diagnosis, as shown in the block diagram of the Fig. 3. Both parts, the electrocardiograph and the device for data communication, are housed in a plastic box of size 19 cm × 11 cm × 7.5 cm. The cabinet includes the appropriate inputs for the connection of the three cables that are attached to the surface electrodes and to the USB communication cable to the computer. The cabinet also contains the regulated power supply and the batteries. This biomedical device, including batteries, does not exceed 950 g. Fig. 4 shows the component parts of the equipment: electrocardiograph and USB data communication device inside the cabinet, USB cable, three-wire bipolar derivations for three surface electrodes and three bands of adjustment. The diagnostic software was developed in *Language G* for *Labview*, which can be executed by an inexpensive portable computer with conventional features and allows you to monitor, analyze and diagnose information from the electrocardiograph. Under a friendly graphical user environment, the system interacts with a database, which increases according to the amount of time the system has been used, to make a diagnosis.

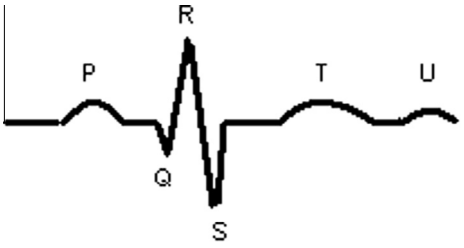

Fig. 2. Diagram of a heart pulse and the *PQRST* complex.

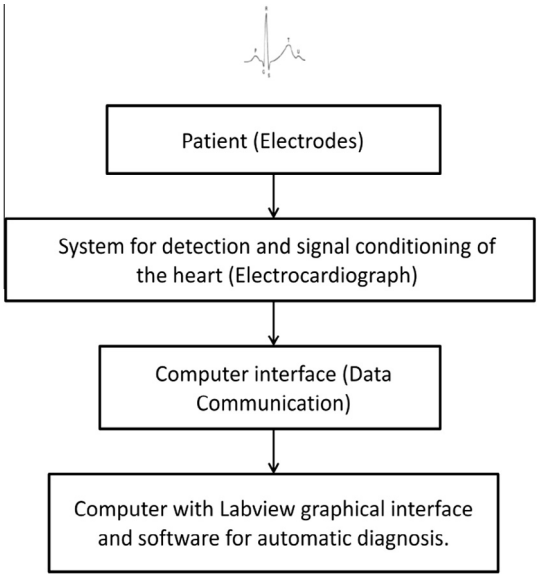

Fig. 3. Electronic system block diagram to diagnose cardiac arrhythmias.

Fig. 4. Cabinet containing the electrocardiograph and the USB communication device and its accessories: USB cable, three-wire bipolar derivations for three surface electrodes and three bands of adjustment.

The paper is structured, firstly, through this introduction that describes the general aspects of the work and provides an overview of it. Secondly, a section on design and construction of the electrocardiograph, its hardware and its characteristics and their principles of operation are included. The third section deals with the data communication between the electrocardiograph and the computer system, discussed both hardware and software necessary to fulfill this function. The fourth section describes the diagnostic software, their properties and the format used for outputting the results obtained from the database. The paragraphs of the fifth section are intended to describe and analyze the results found and cite the benefits of this research. The conclusions are in the sixth section, where the virtues of the device developed in this study when compared with other commercial biomedical equipment are highlighted. Finally bibliographical references used for this research are listed.

2. Electrocardiograph

The electrocardiograph is an electronic device that captures and adjusts the heart's electrical signals for their analysis and study.