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Threads and nanotechnology: monitoring of the vital pulse signal

Hilos y nanotecnología: monitoreo de la señal pulso vital

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ABSTRACT:

This article shows the results obtained in the *Threads and Nanotechnology* research project, in which the monitoring of the *vital pulse signal* was developed. Through the application of concepts such as: the principles of photoplethysmography, piezoelectric sensors, Analog-Digital conversion and digital filters; allowing electronic handling, programming and testing of a microcontroller to send information to the element that processed the sensed signal. An Android and Web application was implemented for its correct visualization. The work finished with the construction of a device to facilitate early alarms of health status in older adults.

RESUMEN

Este artículo muestra los resultados obtenidos en el proyecto de investigación de *Hilos y Nanotecnología*, en el que se desarrolló el monitoreo de la *señal pulso vital.* Mediante la aplicación de conceptos tales como: los principios de fotopletismografía, sensores piezoeléctricos, conversión analógico-digital y filtros digitales, se establece el manejo electrónico, la programación y las pruebas de un microcontrolador para enviar información al elemento que procesó la señal detectada. Se implementó una aplicación Android y Web para su correcta visualización. El trabajo finaliza con la construcción de un dispositivo para facilitar las primeras alarmas del estado de salud en los adultos mayores.

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1. Introduction

From the analysis of the problem arises the question of the development of the project: Is it possible to design a device through bio-nanotechnology in the acquisition of vital signs to monitor, transmit, analyze, diagnose and respond to the needs of the patient?
Older adults require frequent monitoring of their vital signs, however, when they go to the health system, it is possible that the information measured does not reflect everyday life.
The technological proposal began with the Biosensors, which are analytical instruments based on the response of a biological material in contact with a physical / chemical transducer, which converts the response of the transducer into a signal and is recorded in different formats. From this information you can obtain records that are interpreted according to the particular phenomenology that is being studied, these data allowed an approach to the "reality" of the processes that you wish to evaluate, [1]. Biosensors are present in history since 1962 with the creation of the first biosensor for the determination of blood glucose, which was developed at the Children's Hospital of Cincinnati, in the United States, by Clark and Lyons, [2].
On the other hand, the term microcontroller has the function of controlling processes, which are defined by programming; it is constituted in its interior by three functional units as in the robust computational systems, those units are: central processing unit, memory and input and output peripherals, [3].

2. Method

The objective of the project was to measure a vital sign in the daily life of the person, interrupting the minimum development of the same, so we should choose the vital sign that would allow the use of non-invasive methods such as the pulse [4], however it is considered a variable whose behavior cannot be controlled voluntarily by developers, consequently the project was developed under the quasi-experimental methodology.
Three (3) methods were analyzed for pulse measurement, including electrocardiography, phonocardiography and photoplethysmography, [5].
As a first test, electrodes were implemented for the method based on electrocardiography. In the second test, a piezoelectric sensor was used to obtain pressure changes due to the passage of blood through the arteries. The third test was carried out with the application of two sensors based on the theory of photoplethysmography [6], initially the circuit was implemented see figure 1, this consists of a low pass filter after the sensor and a high pass to the output of the circuit , to obtain the signal, whose frequency is in the range of the band of 0,5 Hz - 5 Hz, eliminating the noise due to ambient light, the interference generated by the electrical network, and the effect produced by noise due to movement muscle of the person. Subsequently, a sensor integrating the filtering step described above was used. The experiments were performed on the index finger, where the final device is expected to perform the measurements to monitor the heart rate, [7].

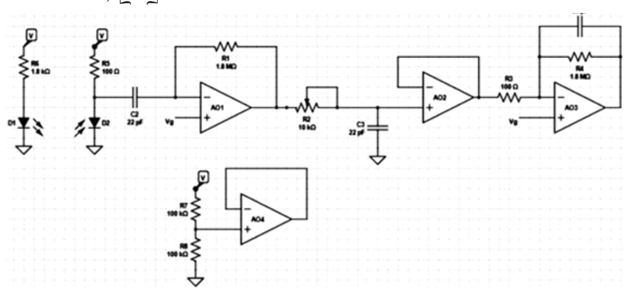

Figure 1. Application circuit of photoplethysmography [6].

Due to this specific application, it was necessary to search for a microcontroller that meets certain special characteristics, such as: ADC module with 10 bits, possibility of USART communication, presentation for a "protoboard" and presentation in PCB for low cost production.
Once the microcontroller was chosen, an in-depth scientific exploration was carried out on its programming, generating ADC conversion and serial communication to facilitate connection via Bluetooth. The design of the Android and Web application was developed, determining the roles, functions and permissions of the different profiles and the manner in which the information will be displayed according to the objective set.

3. Results and Discussion

When carrying out the analysis of different methods for heart rate monitoring, the following results were achieved. In the implementation of electrocardiography (ECG), it was found that it was necessary to have at least three (3) electrodes connected to the patient's extremities, making this method uncomfortable for the patient and impractical if constant monitoring is expected which was not chosen for this project. On the other hand the phonocardiography uses a microphone to perform mechanical measurements of the heart, the same

mechanism used by the acoustic stethoscope; this method requires that the patient is in a resting state, which contradicts the objective of the project.
The tests with the photoplethysmography method [9] were carried out in two phases, the first was to implement the circuit of Figure 1, with which results of Figures 2 and 3 were obtained. Because the different stages conditioning, sensing, "discretize" and emulation were performed independently and then connected to achieve pulse visualization, its measurement was very susceptible to user movements, as well as noise, for the different connections made between the stages, for which were made variants of the sensing phase, testing with different types of emitters and optical receivers, however the results do not differ from the initial measurements.

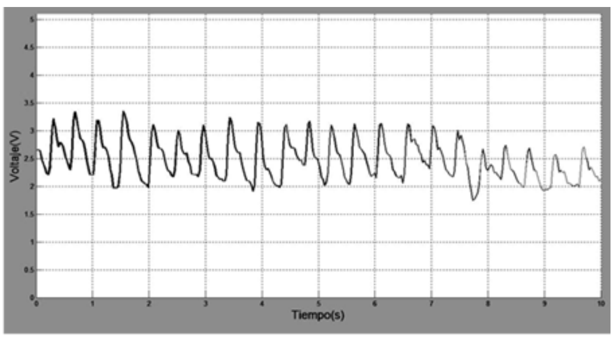

Figure 2. Result with time measurement. Source: own.

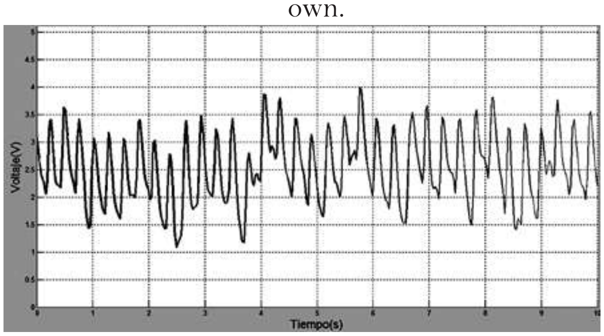

Figure 3. Result with expanded time measurement. Source: own.

Figure 4. Result with integrated filter. Source: own.

The last phase of this method consisted in the detection and correction of errors, with the different tests carried out it was possible to appreciate that the conditioning phase was very susceptible to noise by the filters implemented, consequently it was inquired about an integrated one that had embedded this stage, after the acquisition of the device, the same tests of the previous phase were performed as shown in Figure 4, and we noticed a lower noise interference, as well as a lower sensitivity to the movements of the user, so that it was decided to continue with this methodology, for the development of the entire project.
We searched the different microcontrollers available in the market. For the choice, a comparative table (Table 1) was made between the options found in the ATMEL and PIC brands [10].

Functional characteristics	PIC 16F688	ATMEL
ADC module with 10 bits	X	X
Possibility of UART communication	X	
Presentation protoboard for tests	X	X
PCB presentation for production	X	X
Low cost	X	X

Table 1. Comparative property of microcontrollers. Source: own

As it could be seen in the previous table, the two references have similar characteristics; however, the communication with the visualization device was carried out by means of the UART protocol, for which the reference of the PIC brand was chosen.

The same search was made for the Bluetooth module finding the following:

Functional characteristics	HC – 05 Card	HC – 06 Card
Vcc	3.3 – 6.0 V	3.3 – 6.0 V
Tx	X	X
Rx	X	X
Pin to enter setup mode	X	
Status Pin (output)	X	

Table 2. Comparative property of bluetooth. Source: own.

The HC-05 card was implemented because it allows the master-slave configuration, in addition to presenting the status pin, the configured speed was 9600 Baud, this being the standard measurement and self-connection of the device with the latest default configuration. After the configuration of the microcontroller was verified with the Putty tool, this computational tool allows verifying what enters the serial port.
The next step corresponded to the development of an Android application to receive information via

stored information; as can be seen in figures 5 and 6. Then an identification stage was carried out since three roles are proposed: one as patient, tutor and doctor, after the measurement the results could be visualized to be analyzed by the professionals of health as shown in figure 6.

Figure 5. Screen Identification. Source: own.

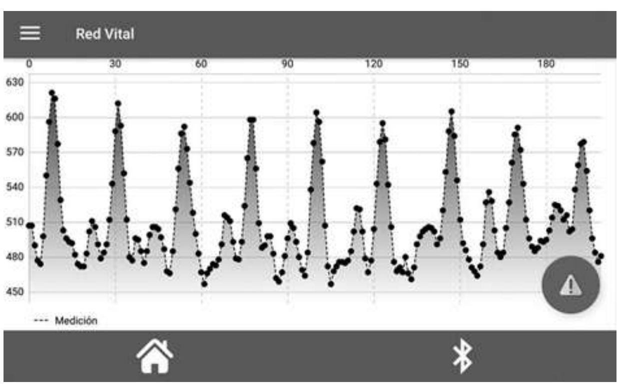

Figure 6. Data visualization. Source: own.

A Web application was also developed to store the information. Figure 7 shows the identification stage. Figure 8 shows the graph that contains all the data stored by a patient, at different times.

Figure 7. Start session. Source: own.

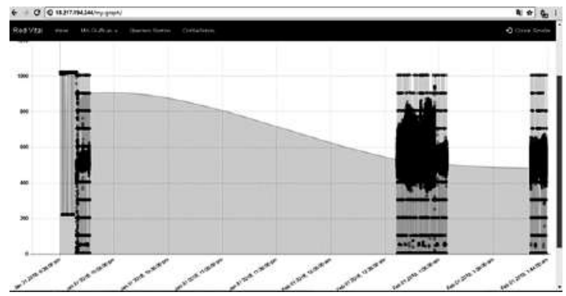

Figure 8. Data. Source: own.

3. Conclusions

After developing the project for the monitoring of cardiac activity, pulse, in people of the third age it is concluded that: photoplethysmography, turned out to be a more effective method in the conditioning of the patient since it does not require the patient's immobility and is only considered a point of access to the measure. The method with the piezoelectric sensor, still requires a more detailed study since the noise due to the movement of the muscles, turns out to be a critical factor that alters the measurement in a significant way.
The microcontroller was selected for the task of converting and sending data of the signal emitted by the sensor to the device that processes it, as was observed in the results, however, it is necessary to perform a digital filter to reduce the noise that may occur. The development of Android and Web applications were satisfactory for the correct visualization of the information obtained.

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