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Theme:

"SISTEMA DE MONITOREO DE RITMO CARDÍACO (S.M.R.C.)

PARA PERSONAS QUE REALIZAN EJERCICIO FÍSICO AERÓBICO"

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"MONITORING SYSTEM HEART RATE (SMRC) for people who exercise AEROBIC "

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Summary - The present work consists in the development of a system for monitoring of heart rhythm for the people who perform aerobic exercise. This project will benefit the population that performs physical exercise, because it is through this system, you can now perform this activity in a controlled way and the most important thing is that it will be very easy to interpret any person, whether or not you have experience with the handling of instruments for the control of your heart rate.

Index Terms - Physical Exercise, Heart Rate, Modules.

I. INTRODUCTION

At present the adequate physical exercise is a key factor to maintain, improve and maintain health, because it helps prevent multiple diseases. The exercise is a basic need. The human body is made to be used, and with the lack of exercise that you surrender the opportunity to improve or maintain health. When the body is not exercised becomes flaccid, slow and, in general, ineffective. However, the physical exercise, most people think that the larger the volume and intensity of work, the better their results; being this wrong concept.

For that reason, it was considered that for the realization of aerobic exercise in any sport, it should be performed in a controlled manner and planned. People who walk, run, trot in the parks, in the city or in their treadmills, do they always wanting to obtain a benefit for their health; but never thinking if they are doing good or evil.

To control this problem, is used instruments of verification of our heart rate as is the pulsómetro, however almost nobody who exercise, except of sportsmen of high performance, use it. The few people who buy a pulsómetro, do so with the desire to see only their keystrokes, but that is not sufficient at the time to control a correct practice of exercise aeróbio.

The system of monitoring of cardiac control for people who perform aerobic exercise, intended to give the user or not, the sportsman ease of obtaining a correct aerobic and anaerobic workout; with reliable data from previous studies carried out by researchers in the physical preparation. For this the system will present ranges of keystrokes reliable, in each area of training intensity, and making it easy to use for any individuals with the experience or without it having used a conventional pulsómetro

II. THEORETICAL FRAMEWORK

A. Arduino technology

Arduino is an electronic platform open source based on the hardware and the software is easy to use. It is aimed at anyone who makes interactive projects. Arduino detects the environment through the receiving inputs from many sensors, and affects your environment by the control lights, motors and other actuators.

Its programming language environment are simple and clear: they are very easy to learn and

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use, at the same time flexible and comprehensive so that advanced users can leverage and squeeze all the possibilities of the hardware. In addition, are well documented, with detailed examples and a large number of projects published in different forms.

The Arduino boards are reusable and versatile. Reusable because you can exploit the same plate for several projects (since it is very easy to disconnect, reconnect it and programd), and versatile because Arduino boards provide several different types of data inputs and outputs, which let you capture information from sensors and send signals to actuators in multiple ways.

B. Arduino Lilypad

The Arduino Lilypad plate is a plate with technology more flexible in terms of use in textiles. You can stitch the clothing that is too easily (see figure 1). The Arduino board is designed to be cooked with textile material. Also allows to connect you (via wires) power supplies, sensors and actuators so that you can "carry over", making possible the creation of dresses and clothes "smart". In addition, it can be washed. This board features the microcontroller ATMEGA328V, which is program to the plate engaging an adapter or USB cable.

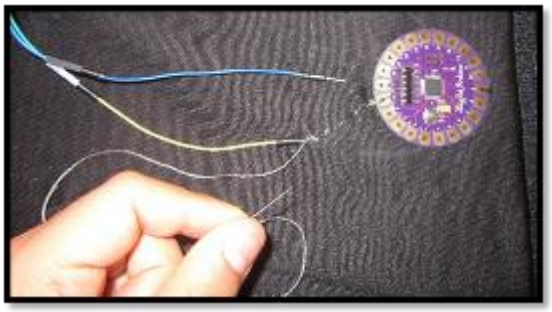

Figure 1. Stitching of the Arduino board Lilypad
Source: Edison Flowers

C. Sports Training

The Sports Training is a process of complex actions whose purpose is to have a planned and objective information on the sports performance

The Sports Training is a planned process and complex that organizes progressively increasing workloads designed to stimulate the physiological processes of supercompensación of the Agency, encouraging the development of the different capacities and physical qualities, with the objective of promoting and consolidating the sports performance.

D. Endurance

The resistance is an important physical capacity in all sports, allowing the individual that trains, withstand resistance to fatigue, in addition to many benefits to the health and physical complement to other capabilities. Some physical trainers the catalogd very important for high performance athletes and amateurs.

The aeróbica resistance not only brings benefits for an athlete of high performance or one that begins to form daily; but for all people, causing on positive aspects in their health, for example, reducing the percentage of the cardiorespiratory diseases. Many people already make this physical capacity a style of life daily.

E. Heart Rate

Heart rate is defined as the times that the heart performs the complete cycle of filling and draining their cameras in a given time. For convenience is always expressed in contractions per minute, because when we take the pulse what we notice is the contraction of the heart (systole), i.e. when ejects the blood to the rest of the body.

F. Training according to the heart rate

The training according to the heart rate, this is performed as an indicator for the realization of a proper training in people who perform physical activity or sports. This type of training refers specifically to the maximum heart rate of each individual; is F.C.M. derive the training area. These areas of training, are ranges of beats where you will need to perform the physical activity; and can be found through specific calculations

G. Training: Karvonen Method using formula of

This method to know our ranges of keystrokes (intensities) is much more feasible and scientific; this method takes into account the physical condition of the individual. You can give to know that the method has its validity in the following relationship: a person of 35 years that has trained his entire life, may not have the same range of intensities, since much will depend its frequency at rest

Some heart rate calculations are based simply multiply the percentage of effort of your maximum heart rate. This does not take into account the fact that each one has different resting heart rate. The Karvonen physiologist, who noticed this, affirms that our heart rate of reserve is equal to the maximum heart rate, less our resting heart rate.

To calculate the area of work would be sufficient to multiply the cardiac frequency of reservation by the percentage strength and to add our resting heart rate to this figure.

F. .C.Ent = (F.C.Max - F.C.Rep) x intensity of exercise) + F.C.Rep

F. .C.Ent = (R.F.C. x intensity of exercise) + F.C.Rep

F.C.Ent: cardiac frequency of training.
F.C.MAX: Maximum heart rate.
F.C.Rep: resting heart rate.
R.F.C: functional reserve of the heart.

III. DEVELOPMENT OF THE SYSTEM OF MONITORING OF HEART RHYTHM

The project is in the design an electronic system of monitoring of heart rhythm for persons who perform aerobic exercise using free software and hardware.

For the project will use an electronic system, which will consist of a plate with microcontroller with characteristic that is adaptable for smart textiles and will be used for those who do aerobic exercise. To this plate will be connected to a sensor of Vitals and the power is used type of battery lipo. The system will use a Bluetooth communication, between a module connected to the plate and the Smartphone user.

A. System Hardware

For the implementation of the hardware will be used such essential elements as the Arduino Lilypad, the sensor, the Bluetooth module cardiac HC-05 and the Smartphone. These items will be located in a wrist strap, type material licra and the Smartphone in the arm.

Once chosen the items to use, in addition to the different devices will be the design of blocks and cardiac system flow. In a general way, Figure 2 shows the devices and components that are involved in the system and its location.

Figure 2. Design of the system
Source: Edison Flowers

B. *Characterization of the system*

It was assigned a letter, such as data communication, for each training area, for the normal heart Pulse, Pulse of reserve, age, gender, among others. These data will serve to the application made on Android recognize the limits of the areas and process the information as appropriate. Then it will show in the table 1 with the characters of communication that contains the Lilypad Arduino board.

Character		**Meaning**
Sends	Receives	
	"A"	Training in Zone 1
	"B"	Training in Zone 2
	"C"	Training in Zone 3
	"D"	Training in Zone 4
	"E"	Training in Zone 5
	"F"	Age of the athlete
	"K"	Stop the training
	"H"	Normal pulse
	"I"	Booking Pulse
	"M"	Gender: Male
	"L"	Gender: Female
"or"		Low pulsation in Zone 1
"P"		Beats High in Zone 1
"Q"		Low pulsation in Zone 2
"R"		Beats High in Zone 2
"S"		Low keystrokes in Zone 3
"T"		Beats High in Zone 3
"U"		Beats low in Zone 4
"V"		Beats High in Zone 4
"X"		Beats low in Zone 5
"AND"		Beats High in Zone 6

Table 1. General layout of the Cardiac System
Source: Edison Flowers

C. *Arduino Lilypad Firmware*

T othe system of monitoring of heart rhythm is used the Arduino environment, with their respective blocks of instructions, was used variables, events serial, switch, among others. Is detailed below the programming of system configuration in a very general way.

1. *Description of the main program*

For the calculation of the maximum heart rate, there are several formulas as mentioned in the theoretical foundation, the traditional way, which is the most commonly used but less accurate by all heart rate. This brings the ranges of pulsations of the training areas on the basis of the maximum heart rate (220 - age). This formula does not take into account the way the individual current sporting, which make it unstable.

For the system of cardiac monitoring will be used the Karvonen Formula. In this formula unlike the traditional, adds the use of the normal pulse (option to view the current sporting form of the individual), a pulse of reservation and the specification of the genre.

For the description of the main program, what we will structure by the order of each specific requirement for find our maximum heart rate, our normal pulse and reserve, among others.

D. *Android Firmware*

The application was made in MIT App Inventor2, is designed for any smartphone with Android operating system from version 4.1.2 (this is one of the older versions, so there will be no problem in any current smartphone). The application that can

be seen in figure 3, was carried out with a schedule by blocks.

Figure 3. General layout of the Cardiac System
Source: Edison Flowers

E. The process of implementation of the system for the monitoring of heart rhythm - Prototype #1

Once you made the block diagram, flowcharts, and firmware in both Arduino, as in Android; undertook the first prototype for the implementation of the system of heart rhythm. This was only a way to test, to check the programming previously established.

We proceeded to implement a prototype that allows me to check the set schedule, therefore was conducted tests in a "ARDUINO MEGA 2560". In this first prototype was not made use of the guiding thread, here is only made the connections with the normal cables of connection that is used in a protoboard as shown in figure 450

For the implementation of Android, similarly, you must use the same set schedule. Although for initial tests for the Prototype #1 was structured basic parts of the complete application, such as age, F.C.M., the pulse and the training areas.

With this basic application shown in figure 4, derived from the App completes are proceeded to carry out the tests and Tomas pulse in the people. It is mentioned that this application in regard to programming structure was completely equal to the full version

Figure 3. The main menu of the application (Demo Version)
Source: Edison Flowers

1. Description of the main program

For connections is proceeded to connect as follows:

- Connecting the press sensor to Arduino Mega 2560
- Connecting the Bluetooth module HC-05 to the Arduino Mega 2560
- electrical power connection from a laptop to the Arduino module Mega 2560 via USB.

Was connected directly the pins in the "Press sensor" to the Arduino module. As has been mentioned, the sensor only needs a minimum of 3 volts for operation and current 4 mA. In the Arduino module mega 2560, is built in sources of voltage connection for these cases, 3.3 volts and 5 volts; that is why connects directly without any problem. Also in each pin delivery a current of 40 mA, which is more than enough for your use.

The Bluetooth module is connected a protoboard, for easier handling in their connections to the Arduino Mega. Similarly the electrical connections were taken of the pins of the Arduino board.

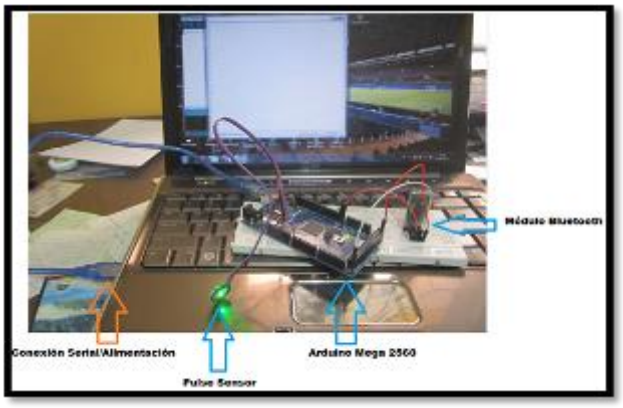

Figure 4. Connections of the prototype#1
Source: Edison Flowers

2. *Tests and Results of the Prototype #1*

In the Prototype #1 tests were conducted to check that the programming of the Arduino and Android is correctly. We proceeded to check the correct operation of sensor pulses socket. It is mentioned that was positively the recognition of pulses, noted normal ranges in sleep state, that is to say between the 60 and 75 ppm.

These pulses are able to check in three ways. One of them was in the Arduino serial monitor, i.e. we note the pulses that are issued, on the computer screen as shown in figure 5

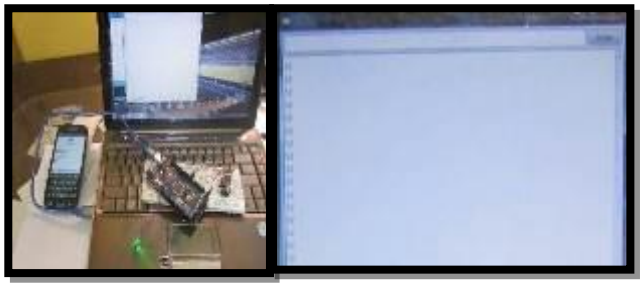

Figure 5. Verification of pulses in Arduino serial monitor
Source: Edison Flowers

IV. Conclusions

The other way was by observing through a program installed on your Smartphone, called "Blue Term+". This program using Bluetooth communication, was connected between the module HC-05 and this application. In this way we could see the cardiac pulses that were broadcast.

The third way to observe the pulses in the heart is in the application installed on your smartphone. Here similarly communicates via Bluetooth. The pulses are observed in a text box in the application.

This Prototype #1 is designed it specifically only for check the programming of both Android and Arduino, i.e. for testing of the programming. In this design, the user did not have the flexibility to use, to be connected to the computer, you could only perform the tests in the same place on the PC. It is so that the user was dependent on the place where you find the system of monitoring of heart rhythm.

A. The process of implementation of the system for the monitoring of heart rhythm - Prototype #2

In the second prototype, are proposed to incorporate the electronic elements to a wrist strap, so that the use is more flexible for the user (mobility of uses). This wristband has to adapt to the mobility of the person who performs physical exercise, as well as to the electronics that Iran within it. It was proposed to convert a wrist strap in a smart textiles.

1. *Design for the implementation of the Prototype #2*

For the implementation was a previous design for a chart, this to distribute where you were going to locate the electronic elements, in the person who carries out physical exercise.

In the design of implementation in the Prototype #2 considered the following:

- In the electronics segment, the Arduino board Lilypad, sought to be sewn directly to a wristband (inside). The Bluetooth module does not require be sewn, but I needed to go on the inside of the wristband, like the lipo batteries.

- For sensor heart, was needed that the connecting pins are on the inside of the wristband, and the part of census of pulses is located in one of the fingers of the user.
- For this system was used a battery Lipo for all electronic components.
- The armband was ranked among the forearm and the hand, and the Android device, if placed in the arm, with a band of arm to Cellular. (See Figure 6)

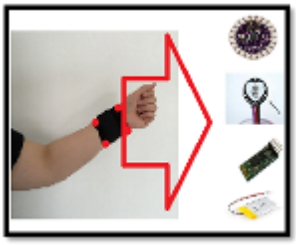

Figure 6.- Design for deployment of the Prototype #2
Source: Edison Flowers

2. Arduino Lilypad sewn to the wrist strap

The Arduino board Lilypad is sewed in the inner part of the wristband, to grasp, was used pins that are not being used, i.e. with normal thread, you could hold the plate. The plate is set further to sew the pin used for the connections of the elements, because he had to pass the conductor, at least three times for the pins (holes where it passes the thread). This ensured that the thread will achieve a correct electrical connection with the elements.

Figure 7.- Arduino Lilypad sewn completely to the wristband (Prototype#2)
Source: Edison Flowers

3. Connect the Bluetooth Module

The Bluetooth module was located in within the wristband., fixed with normal thread so that it will not move. In this prototype #2 The connection was made between the Arduino board and the module using the conductor, i.e. from had direct connection through the thread. This hampered the connection in the pins of the module, as if there was a thread striking lightly with the other, could produce a short circuit. Therefore, in the Bluetooth module, was isolated in each pin not to join with the thread. This is what he could do with pieces of chopsticks, to separate the pins and the twine.

This electronic element had to connect to two elements, one was the Arduino board and the other was to the battery for your power supply

4. Sensor connection

The cardiac sensor, has three terminals, one of them that is purple, is the one that sends the signal to find the pulses in the heart, this is sewed to "pin 0 of the Lilypad and the other two, the black (ground) and red (Vdc) will have connection to the Lipo Battery. The specific part of the sensor has to be outside of the wristband, because it will be to place it on the finger of the user where you will capture the heart pulse.

5. Electrical power to the system

To power the system, connected the positives and negatives of the Arduino board Lilypad, the Bluetooth module and cardiac sensor to terminals of positive and negative battery lipo. The lipo battery that was used was of 3.7 volts to 200 mA.

6. Tests and results of the Prototype #2

Unlike the Prototype #1, this is carried out tests in several aspects, cardiac sensor tests, tests of sending characters, tests of electrical power supply and also evidence of comfort using the wrist strap.

As a result of the Prototype #2 is obtained the following wristband which is shown in figure 8, converted into smart textiles. In appearance is note

a wrist strap more the cardiac sensor by outside it.

Figure 8 .- Wristband (Prototype#2)
Source: Edison Flowers

7. *Evidence of comfort of the Wristband*

In this prototype the user is placed the wristband, entering the opening of this, in front of the fingers of the hand, ending up in the wristand the sensor you will be positioned on any finger. With the design of this wristband in the Prototype #2 is able to observe and appreciate that so little that it was, although very elastic; was very uncomfortable when entered by hand until you reach Place it between the forearm and the hand. The electronic elements could be felt clearly its relief doing bothersome for the user who puts it, and not having a lot of space for connections with the thread; at several points that joined or topaba, was due to tape in certain sections of wire to not cause short circuit.

8. *Cardiac sensor tests*

For the verification that the sensor programming cardiac and not be affected by the connections with the main thread is proceeded to show whether the pulses emitted were correct, as shown in Figure 9; where you first found these pulses in the application "BlueTerm+".

Figure 9. Verification of cardiac pulses in prototype#2
Source: Edison Flowers

9. *Proof of sending characters*

Testing the functioning was conducted to check the configurations of age, training areas, lower and upper limits of the areas. This was done to analyze the wireless communication and sending characters between the application in Android and the Lilypad Arduino board.

In the Android application, the user enters with first parameter their age. This is very important because with this age the calculation will be made of the Maximum Heart Rate. This data is sent from the application to the Lilypad Plate. This check is carried out using the program "BlueTerm+" (see figure 10, 11 and 12).

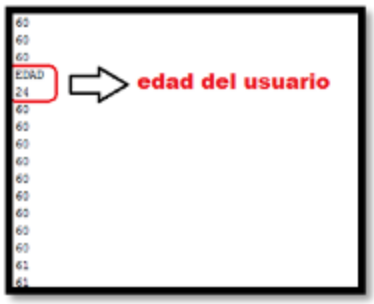

Figure 10. Verification of income of age
Source: Edison Flowers

Another parameter to check is when the user choose the training area from the application, the Lilypad plate will recognize the area, printing "Zone#"

Figure 11. Verification of choice of training area 1
Source: Edison Flowers

Figure 12.Box of choice of training area 2
Source: Edison Flowers

Within each training area, there are lower and upper limits of heart beats. Each limit in every area, has a character associated with it. This character emits the Arduino board toward the implementation, to issue the corresponding alarm as shown in figure 13.

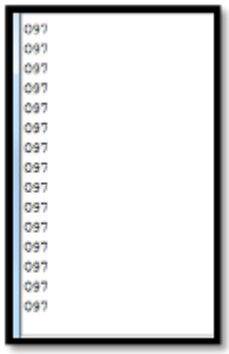

Figure 13. Sending character of lower limit in zone 1
Source: Edison Flowers

10. Evidence of power supply

For the testing of electrical power in this prototype was conducted in two ways. One of them was with a battery type Lipo of 3.7 volts to 200 mA., and the other way was through a 5 volt source to 1 Ampere (transformer from 110V to 5V).

With the use of the battery type Lipo, the elements of the system, the sensor correctly lit heart, the Arduino board and the Bluetooth module. Verified the transmission of data issued, pulses, characters sent between plate and the application; everything is presented in a correct manner until 30 seconds after ignition.

After this time, all items remained lit without any problem, but the problem with a single battery and current too low, was that in the Bluetooth module, no longer sent the frames with the corresponding data. It was observed in the application that after the time mentioned was left to receive the cardiac pulses and therefore the alarms in each zone, age and other data. This affected the functionality of the system, since they could not be set in a defined way wireless communication between Arduino board and application.

With the use of a transformer from 110V to 5V and 1 amp as a source of electrical power to the system, the operation of this was correct all the time, i.e. increased the current for the system of 200 mA. to 1A. and also the voltage of 3.7V to 5V. It was noted in the application that the data were sent correctly and constantly all the time. But with this source you removed the flexibility of use to the user because the system was dependent on the place where you find the source.

11. Analysis of the results of the Prototype #2

Carried out the various tests in the prototype#2, it could be observed that the system of cardiac monitoring was totally successful in terms of programming carried out both in Arduino, as in Android.

With regard to the portion of power supply there were problems with the battery type lipo of 3.7V 200mA. Since lasted a very short time of

wireless communication between the Arduino board and the application. It will have to take this parameter into account for the following design.

As regards the design of the wristband is noticed that there was discomfort at the time of entering it by hand, since that was palpable elements and was very small, despite its elasticity. It was noted that problems can occur as shorts, if the thread runs between yes, and by the small size of the wristband the circuit pipe is very united. It can be taken into account in order to improve this problem in a new prototype.

Opens the gap to be able to make any changes to improve the design of the armband and for the power supply in the system. The tests were carried out trying to simulate the reality with daily conditions of use, in addition to observing the priority needs to guide the good use of the system.

B. Process of Implementation of the cardiac system - Prototype #3

On the basis of experiences of design and configurations of the Prototype #1 and #2 in both software and hardware, they proceeded to the design and implementation of a new prototype#3, which aims to improve the features and give a better flexibility and convenience in regard to its use.

For this prototype was not performed any changed in programming in Arduino and Android. Will be used the same electronic elements of the Prototype #2 and the same connections; it is only to make a design change to the wristband, i.e. this prototype will be made to improve the design of the smart textiles.

1. Application on your smartphone

The application that was used for this prototype was the same one used in the Prototype #1 and #2; is served to monitor the pulses and choose the desired training. Was not performed changes already that contained the necessary elements for proper operation.

2. Arduino lilypad Configurations

The software developed above, will be used in a similar manner in this new design. The programming will be the same to run the cardiac monitoring system

3. Design of the muñuquera in the Prototype #3

In this design was used a new Wristband made in its own way, the material that the lining was of cloth type towel and by within normal cloth was used so that you can sew the elements. This was not from any manufacturer in particular and the design features to present greater comfort for the user. This wristband has a wide sector where could distribute the elements and perform the stew of the same without any problem as can be seen in figure 14.

Figure 14. Wristband design to prototyp
Source: Edison Flores

This velcro strap are located (see Figure 15) for a better grip on the forearm of the individual. It will also help to make electronic devices and cardiac sensor can be fixed without much movement and contact between them. The pin connections cardiac sensor, will be more fixed than the prototype # 2, this will help aq pulses altered values will not occur.

Figure 15. Velcro straps on the wrist strap of the Prototype #3
Source: Edison Flowers

The wristband had two voiceovers (see figure 16), the first will serve to cover the electronic elements, to protect elements of impurities that may affect its operation, the possible sweat produced in the area, as well as also has the advantage that when the user you want, you can check whether the items are turned on or not, and if there is a problem visible in the elements.

Figure 16. First dubbing of the wristband in the Prototype #3
Source: Edison Flowers

The second dubbing served to give Accuracy of adjustment to the wrist strap on the forearm of each person (see figure 16, 17, 18). Helped the wrist strap will not move and locks in the forearm of persons, when performing physical exercise. Presents a velcro tape for adjustment.

Figure 17. Second dubbing of the wristband in the Prototype #3
Source: Edison Flowers

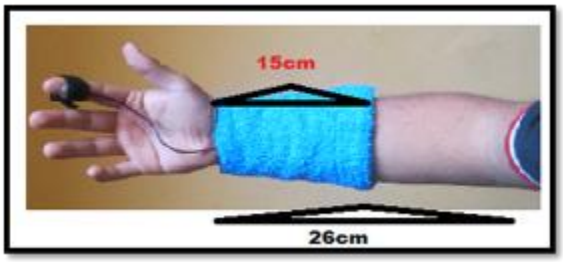

Figure18. . Dimensions of the armband and the forearm (prototype#3)
Source: Edison Flowers

4. *Connections of components*

As mentioned previously, the connections in this prototype will be equal to those of the prototype#2, i.e. it shall perform similarly stitching of the Arduino board Lilypad, there will be the connections of the Bluetooth module, cardiac sensor and battery

5. *Stitching and connection of the electronic elements*

The stitching is I do this with the same thread, began sewing the Arduino board Lilypad, subsequently the Bluetooth module and finally the heart and the battery sensor. In this Wristband took the ease of having more space (see figure 19) where you can organize the twine routing driver. This helped in large part to prevent a possible short circuit.

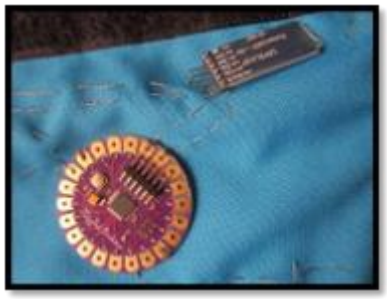

Figure 19. Stitching and connection of elements in the wristband (prototype#3)
Source: Edison Flowers

6. Tests and results of the Prototype #3

The Configurations in the Arduino board and in the implementation remain the same; that is why the heart sensor tests and sending characters produced the same results of the Prototype #2. These results were correct in this prototype.

7. Evidence of comfort of the Wristband

In this prototype the important thing was to conduct the tests of comfort in the use of the wristband, here you could observe and feel clearly its flexibility and comfort of use, the user will feel more comfortable with this new design of wrist strap, will be much easier to reach, drawn and use it at the time of physical exercise.

It was concluded clearly that this prototype was better than the previous one, not in terms of their software configurations because it does not change, but in terms of a better ease of use, is what made it much more feasible.

8. Analysis of the results of the Prototype #3

The tests carried out in the prototype#3, were carried out in a positive way, introducing success in each one of them. In regard to the configurations are not obtained no problem, it is worth mentioning that these configurations are the same of the Prototype #1 and #2 and earlier there were no problems with it. The results were the same positive.

With regard to the electrical supply is wine by dragging the same drawback that the Prototype #2 as it used the same battery, it happened the same thing, that this prototype, wireless communication is established for a short time. But if you changed the font with higher voltage and current, was a success the system, but with the disadvantage of mobility.

The wristband to be larger, presented advantages when sewing with the conductor, is now had more space for channelling the conductor, without having problems of possible shorts. In addition, with respect to the prototype#2, this new, introduced greater ease to get and pulled out. In the Prototype #2 the wristband was very adjusted for any user and the electronic elements could be palpation, and could possibly hinder to some users.

Now in the new prototype account with velcro tape that helps the perfect fit of the wristband, as well as by having two voiceovers, makes it more resistant, more robust and not to feel the spongy electronic elements in the skin of the user.

As a parameter to improve in this design was that the velcro used were very thick and widths and the cloth the covered that was type also, when towel made the voiceovers these occupied a lot of space and it was very thick the wristband.

C. Process of Implementation of the cardiac system - final design

For this final design, departed from configurations and designs made in previous prototypes. In this design took the following considerations:

- The use of a switch to turn the system on and off.
- was used two batteries to power the system.
- was loaded into the Smartphone the complete application with all the parameters for the training of the user to be customized.
- improved the design of the wristband.

2. *Design for the implementation*

In this final design added more elements, as is the use of two batteries and the switch, the objective was to give an on and off the system. The design was presented below in Figure 20:

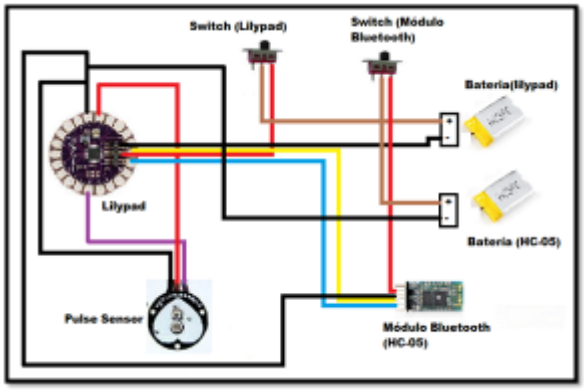

Figure 20. Schema prior to the deployment of the system
Source: Edison Flowers

3. *Design of the Wristband*

For the design of the wristband complied with the following requirements:

- The color used was black.
- confecciono with fabric type spandex.
- was used velcro thinner (0,5cm).
- thin pads was used to make it more robust and comfortable.
- Added small strips within the wrist strap to secure the elements.
- was used strips of fabrics on the stitching of the conductor, to prevent short circuits
- it made a small opening in the wrist strap to move the sensor wires from the heart.
- Has two voiceovers, as the prototype #3.

Improved design, taking account of the results presented in previous designs, with this Wristband, the user could obtain more comfort and flexibility of use (see figure 21,22).

Figure 21. Velcro areas in the wristband (final design)
Source: Edison Flowers

Figure 22. Location of the wristband (final design)
Source: Edison Flowers

4. *Stew of arduino lilypad wrist*

Set the lilypad Arduino board to the fabric type licra, this cloth was very thin, so that there was no inconveniences when cooking with the conductor. It was baking each pin, for each item.

In the holes of the electronic board i.e. pins, it is suggested that at the time, the thread sewing pass three times by the hole, this is so that there is continuity of voltage and current. Once this is done, will take the twine to a specific point to unite the flexible cables of protoboard. (See Figure 23).

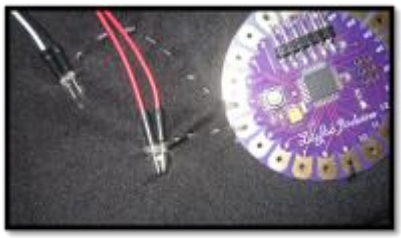

Figure 23. Intersection of cables with thread (final design)
Source: Edison Flowers

5. *Connect the Bluetooth Module*

For connections to the Bluetooth module, was held the following

- For pins "tx" and "Rx" module that are of type male female type cable was connected- female. This was done to get an extension of connection of these pins to then connect to the thread.
- For pins "VDC" and "GND" was connected directly to a battery lipo, this I do not need of thread, only used the protoboard flexible cable.

6. Electrical power to the system

For the power supply in this final design, was used two lipo batteries, each of 3.7 volts to 680 mA. The fact of using two batteries was because in previous designs was tested with a single and had problems of data transmission with the Bluetooth module.
Now with two batteries, one for the Lilypad Arduino board and the heart sensor, and the other for the Bluetooth module; there was no inconvenience in any aspect. To view the connections of the batteries with the elements, can be seen in figure 24.

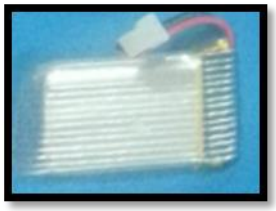

Figure 24. Lipo Battery for monitoring system
Source: Edison Flowers

Checked the voltage from the battery lipo, although the battery was theoretically of 3.7 volts, at the time of measure its voltage by means of a multimeter, this was 4.09 volts. This voltage does not affect any item already that the range The range of operation of all was between 3.3 to 5 volts.

To feed the Arduino board connects in the sprat that stand out in the top of the plate. Connects to the first pin to "gnd" and the third pin to "VDC". Then this board has pins for sewing to feed other devices, in our case the sensor heart.

7. Sent test correct characters

Test was carried out sending characters, in two ways, one was through a serial communication, where they could observe in the serial monitor Arduino IDE data sent.

Was the verification of the different variables of the monitoring system, through the serial communication. As a result, it was observed that all the data were transmitted correctly. To use the same In addition to the electrical part in this final design using two switches, one for each battery to better use the system on and off it is included. The implementation of the switch was first tested on a breadboard for later attachment to the wrist. The user knows that the system is on, when the switch lever, this blue dot next to that is in it

8. Evidence of comfort of the Wristband

In this final design, introducing improvements in its design, testing of comfort were very positive for the use of the person who do physical exercise. The Cloth Wristband type licra, smooth texture to the skin, along with a few thin pads (sponges), made that is present much comfort for your use. (See Figure 25).

Figure 25. Side view of the wristband (final design)
Source: Edison Flowers

In addition was also tested the system in conjunction with the band in the arm, this served to give comfort to the user when you take the cell phone, because this is the one that sounds alarms,

and there needs to be close to our hatred; an alarm was by means of vibration and the other by sound. (See Figure 26).

Figure 26. Wrist strap more arm band
Source: Edison Flowers

9. Analysis of the results of the Final Design

Carried out the various tests in the final design, it could be observed that the system of cardiac monitoring was totally successful in terms of programming carried out both in Arduino, as in Android. As programming was not changed, and when used in previous prototypes, it is clear that in the final design would not be presented no problem.

With regard to the portion of the electrical power supply, with the use of two batteries 3.7 volt 680mA, it was verified that the system functioned properly and so perfect in the final design. In addition was also tested together with the connection of the switch. This parameter was corrected, since in previous prototypes had problems.

As relevant to the design of the wristband, advantages were presented at the time of the seam with the thread, had enough space for channelling the twine. In addition to the coatings on the same were an essential part for which the user this quiet that there will be a short by the union of this thread. It is mentioned that with regard to previous designs, in this final design, the wristband has two adjustment measures, is robust and comfortable; what makes it very versatile for use

III. COST-BENEFIT ANALYSIS

In this analysis are detailed all costs used in the final design of the monitoring system of heart rhythm, taking into account that the costs should be tangible, that is to say that can be measured in any economic unit, which in this case are US dollars; while the benefits are determined in a personal manner as these will get health benefits and good living of the person who performed or not physical exercise (see tabala 2).

Description	**value**
costs of wrist strap system of monitoring of heart rhythm	$ 24.70
costs of electronic elements	$ 98.50
Cost of smart mobile device	$ 285.00
software Cost	$ 0
TOTAL COSTS	**$ 408,2**

Table 2 . Project Costs
Source.- Edison Flowers

The benefits that are obtained at the end of the implementation of the system of monitoring of heart rhythm, is the enable all people to perform physical activity in a planned and controlled, thus helping them to the fulfilment of a sports activity that will favor their health, injury prevention, possible taquicardias, among others. Will help people, are professional sportsmen or not, to adapt the exercise to the objectives that have been proposed, controlling the intensity of the exercise and to report on the improvements of the physical condition, through the resting heart rate

Will fulfill one of the objectives of the "National Plan of Good Living" which is to improve

the quality of life of the population, guaranteeing the health from the generation of healthy practices; in addition to motivate the permanent or eventual sports practice and healthy way.

It also mentions that the sport is one of the best methods to unite different people and thus enhance the capacity of socialization of each person.

IV. CONCLUSIONS

With the development of the monitoring system of Rhythm (S.M.R.C.) allows to all persons, whether amateurs or professionals in the practice of sports, physical exercise in a planned and controlled; being the key to obtain benefits such as the strengthening of the heart, activate inactive areas of the brain, maintain strong bones and muscles, as well as will also be the correct way to lead a healthy life with the prevention of muscle injuries.

The training according to the heart rate, through the application of the formula of Karvonen, is the most widely used method in the present by the coaches, to perform properly the practice of aerobic exercise. The ranges of keystrokes that you set in this procedure, depend on physiological characteristics and cardiovascular own of each person, having as a result the compliance with the principle of the individualization in sports training.

The system of monitoring of heart rhythm will help people who are unaware of the use of a Pulsómetro, is an application system will provide intuitive graphical for anyone, as well as people will have the confidence that when performing the exercise, the system will alert the exact limits in which he should train, important aspect that only the high-end Pulsómetro do.

It was investigated the characteristics of each electronic element that was implemented in the system, where the cardiac sensor is adapted from the best way at the same, for the consensus of the pulse in the people was also used the electronic board Lilypad Arduino ATmega128 and their advantages of use together with the thread complied with the requirements of both subject to the wrist strap as the use of pins required for the respective connections; in addition to the use of a Bluetooth module HC-05 that allowed to establish and maintain a short-range wireless communications.

The realization of the application called Pulsómetro, with programming development in blocks in the App program Inventor under operating system Android, which together with a Smartphone, fulfilled the function of informing the user alarms issued by switching out of a range of keystrokes, a vibrate and established the other sonically. In addition by means of this device served to wireless communication via Bluetooth technology.

V. RECOMMENDATIONS

The present draft gives an initial regimen for the development of future electronic systems that are related to the benefit of the health and sports training in their different areas.

Use the data sheets (data sheets) of the electronic elements, these allow a proper configuration and connection of the same.

At the time of use the conductor, i.e. at the time of sewing, care must be taken in the path of the same, because if the thread runs between yes, will cause a short circuit and may burn and alter the performance of all the electronic components connected. This is why it is advisable that before you must have a sewing schematic guide of sewn to organize the paths of the thread.

It is recommended the use of free software, as is the App program for the development of inventor a mobile application and Arduino environment, as these allow to reduce costs in the development of

projects.

It is recommended the implementation of the accompanying user manual in the project, before use, in order to see the correct operation and avoid possible damage to the system.

It is recommended for future projects to develop a monitoring system for heart rate, to the field of medicine, related to pathologies of arrhythmias; to permit verification of real-time alerts and cardiac pulses on a platform on the internet.

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