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# **Journal of Technological Prototypes**

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## **Presentation of Content**

In the first article we present, *Prototype automation for electrolytic coating*, by GARCIA-RASCÓN, Araly, FRIAS-GUTIERREZ, Edgar José and MUÑOZ-LOPEZ, Luis Enrique, with adscription in the Universidad Tecnológica de Chihuahua, as next article we present, *RLC circuits: Obtaining the current graph using a mobile application*, by MEDINA-HERNÁNDEZ, David, PARADA-PARADA, Luis Roberto and DÍAZ-RIVERA, José Manuel, with adscription in the Instituto Tecnológico Superior de Perote, as next article we present, *Wireless Communication between two robots using a piconet network*, by HERNÁNDEZ-MENDOZA, César Manuel, SERRANO-RUBIO, Juan Pablo and MANJARREZESTRADA, Ernesto, with adscription in the Instituto Tecnológico Superior de Irapuato, as next article we present, *Monitoring system of vital signs at distance and in real time through IoT Technology*, by GONZALEZ-LORENCE, Armida, AYALA-LANDEROS, José G., AMAYA-PÉREZ, Angélica J., and SÁNCHEZ-ORDUÑA, Govani G., with adscription in the Instituto Tecnológico de San Juan del Río.

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## Prototype automation for electrolytic coating

### Automatización de prototipo para recubrimiento electrolítico

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#### Abstract

Corrosion of materials is nowadays one of the problems in the industry. The aim of this article is to integrate an automated prototype electrolytic coating system and implement it in a furniture plant based at Chihuahua, Mexico. It is based on the study and development of the automation process of a manual coating machine with a Chrome bath, in order to reduce production costs, increase quality, and minimize the negative impacts in the workers' safety. The prototype consists of a bank of PVC tubes and a power source; while automation is done through PLCs.

**Electrodeposition, Automation, Programming**

#### Resumen

Hoy en día uno de los problemas en la industria, es la corrosión que sufren los materiales. El objetivo del presente artículo es la integración de un sistema prototipo automatizado de recubrimiento electrolítico, para su posterior implementación en la empresa de cromos y muebles de Chihuahua. Se basa en el estudio y desarrollo del proceso de automatización de una máquina manual de recubrimiento con baño de cromo con el fin de satisfacer la necesidad de reducir costos de producción y minimizar los impactos negativos de los trabajadores en materia de seguridad laboral. El prototipo consiste en un banco de tinas de PVC, una fuente de poder y la automatización se realiza a través de PLC's.

**Electrodeposición, Automatización, Programación**

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## Introduction

Cromos y Muebles de Chihuahua is a company engaged in the electrolytic coating of metal parts and furniture. Currently, the chrome plating process is manually operated, making difficult to control the immersion time, so there is a need to automate the process in order to reduce operating costs, in addition to reducing human error factors and increasing labor safety for workers.

The electrodeposition process is one of the most used techniques in the coating of metals; nowadays, one of the problems in the industry is metal corrosion. Electrodeposition has been widely used in different applications due to good thicknesses achieved in acid electrolytes.

The electrodeposition of metals used in the technological field (circuits, connectors, contactors and electronics in general), is of great importance.

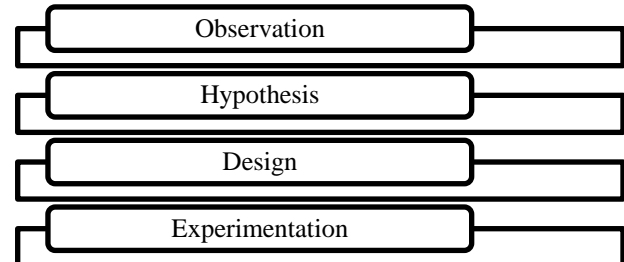
En el mundo actual, esta técnica tiene la capacidad de cambiar las propiedades químicas, físicas o mecánicas de la superficie de las piezas, mejora la resistencia a la abrasión, proporciona propiedades anticorrosivas, mejora su necesidad de lubricación, entre otros beneficios.

The industrial process of electrodeposition in metal parts consists primarily of applying a copper layer, followed by a nickel layer. The copper layer is responsible for offering a surface that facilitates the electrodeposition of nickel, which has a great resistance against corrosion; finally, the chrome layer provides a decorative finish of high hardness and excellent protection against corrosion.

For the Technological Universities of the country, two of its greatest advantages are its academics and its laboratory and workshop infrastructure, since the TU's modality performs at least 70% of the students' activities in a practical way. This type of research allows teachers to update their knowledge and pass it on to students.

## I. Methodology

Firstly, the methodology consists in the investigation design, followed by the construction of the different bathrooms and their automation. The following figure shows the stages of the research methodology:



**Figure 1** Methodology

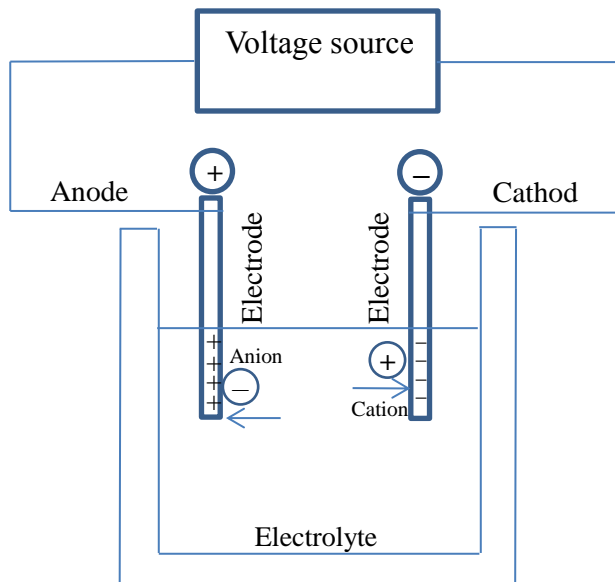
*Source: Prepared by the authors*

1. Investigate, analyze and select the appropriate instrumentation and computation equipment for the operation, measurement, processing and control of the electrodeposition system.
2. Investigate, analyze and select the equipment, tools and chemical substances required for the electrodeposition process.
3. Construction of the electrodeposition process setup.
4. Installation and connection of the equipment.
5. Design and integration of the equipment to a graphical user interface (GUI).
6. Design, development and testing of chemical reagents for electrodeposition.
7. Observation, analysis and data collection.
8. Development of user manual for basic electrodeposition in materials.

## II. Electrolysis process

The electrolytic process consists in passing an electric current through an electrolyte, between two conductive electrodes called anode and cathode, where changes occur in the electrodes.

When we connect the electrodes with a power source (direct current generator), the electrode which joins to the positive pole of the generator is the anode and the electrode which joins to the negative pole of the generator is the cathode. An electrolysis reaction can be considered as the set of two half reactions, an anodic oxidation and a cathodic reduction (Figure 2).



**Figure 2** Elements involved in an electrolytic process

### III. Faraday's Law

Faraday's law constitutes the fundamental principle of electrolysis. With the equation of this law, we can calculate the amount of metal that has been corroded or deposited uniformly over another for a certain time, by an electrochemical process, and it is expressed in the following statement:

“The amount of any element (radical or group of elements) released either at the cathode or at the anode during electrolysis is proportional to the amount of electricity that passes through the solution.”

$$W = \frac{I.T.M}{n.F} \quad (1)$$

Where:

W = amount of metal which has been corroded or deposited [g]

I = current [A]

T = time of the process [s]

M = atomic mass of metal [g/mol]

n = metal valence

F = Faraday's constant = 96500 [A.s/mol]

### IV. Stages for metal coating

The steps comprising the realization of a metallic coating are the following:

1. Pre-degreasing
2. Rinse
3. Electrolytic degreasing
4. Rinse
5. Activation
6. Rinse
7. Nickel plated
8. Rinse
9. Chrome
10. Rinse

**Pre-degreasing.-** In the pre-degreasing stage, an alkaline cleaning solution is used, useful to remove dirt, grease and oils from the pieces.

**Rinse.-** For all rinses the tubs have water, where the pieces are submerged for 1 to 2 minutes to remove waste from the used solutions.

**Electrolytic degreasing.-** It is an alkaline electrolytic degreaser which eliminates impurities and activates the adhesion of the material.

**Activation.-** In this tub, the pieces are submerged for one minute to neutralize the alkaline surface and activate it.

**Nickel plating.-** In this stage, the piece is immersed in nickel at a temperature of 50°C and the current calculated for the desired thickness is applied based on the area of the piece.

**Chromed.-** Finally, it is immersed in the chrome tub at a temperature of 50°C and the calculated current is applied based on the area of the piece and left for a period of 30 seconds.

This is the general sequence applied to a metal piece to achieve a decorative chrome metallic coating. It is very important that the metal piece to be coated reaches a perfectly polished coating process, without scratches and irregularities in its surface.

## V. Process automation

Automation is the application of automatic control of industrial processes.

It arises from the need to minimize human intervention in direct production processes, save labor effort and minimize labor risks.

Automation is the convergence of three technologies: mechanical, electronic and computer science, which have gradually formed an interrelation in the specific universe of mechatronics.

Automation-related industries are basically the manufacturing industry and the process industry, which are the ones making great efforts to optimize their processes in order to improve quality, while others focus on cost reductions.

### Control equipment

The Programmable Logic Controller (PLC) was created as a solution to the control of complex automation circuits.

Therefore, it can be said that a PLC is nothing more than an electronic device which replaces the auxiliary or control circuits of automatic systems. The sensors and actuators are connected to it.

The communication interface is responsible for the transfer of information between man-machine, machine and other elements through ports and buses, thus constituting some type of network. For the development of this prototype, we used PLCs type siemens.

## Results

The construction of the equipment consists of electrolytic tubs or baths, constructed of fiberglass with a plastic coating and an epoxy white paint finish to prevent corrosion caused by the chemicals used for the metal coating. The bank consists of 2 sections, A and B, of 5 tubs each, with a volume of 20 liters each tub.



**Figure 3** Tub Bank Section A  
*Source: Prepared by the authors*

The tubs are marked, have a thermometer, water tap, drain, electrical outlet of 127 VAC, 60 HZ and 4 A, cathode and anodic bars, in addition to having a bar to place the pieces to be coated and a metal folder to place documents or practices to perform.



**Figure 4** Tub 5 section A  
*Source: Prepared by the authors*

The electrodeposition prototype has a cabinet with a DC voltage source with a capacity of 100 Amps, with a data acquisition card, Labview 2018 software.

Inside the control cabin there are 3 selectors to power the tubs 1, 3 and 5 of section A; only these tubs have electrodes to perform the electrodeposition process on the piece to be covered with the desired metal.



**Figure 5** Cabinet with power source  
Source: Prepared by the authors

## Conclusions

The development and linking of projects with the productive sector is of great importance for the Technological University of Chihuahua to contribute to the efficiency of productive processes. The electrodeposition of parts and components can be used to prevent corrosion in metal pieces and give them a decorative finish, contributing to the manufacture of higher quality products.

Applying the knowledge developed in educational institutions to improve production processes within the local industry.

The industry acknowledges the importance and value of linking the educational sector for improving their processes through collaboration, using similar environments to those of the company, thus, placing the students in real-life situations.

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## RLC circuits: Obtaining the current graph using a mobile application

### Circuitos RLC: Obtención de la gráfica de la corriente mediante una aplicación móvil

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#### Abstract

In this document we simulate the response (current value for  $t \geq 0$ ) for a series RLC circuit through the solution of a second order differential equation. A mobile application is developed for the Android Operating System that obtains the graph of this current using the ANDROID STUDIO development environment and the GRAPHVIEW library. With the choice of the mathematical expression that defines the voltage in the circuit and the values of the resistance, the inductance, capacitance, the initial current and the initial voltage in the capacitor or initial charge, this graph is obtained, which when compared with what is obtained using a CAS, no difference is perceived, which shows the validity of the results of the app. This application can help engineering students to understand in an easy and simple way the concepts related to this type of circuits, thus promoting the use of mobile devices in teaching-learning environments.

**Android Operative System, Differential Equation, Mobile application, Response of a circuit, RLC circuit in series**

#### Resumen

En este documento simulamos la respuesta (valor de la corriente para  $t \geq 0$ ) para un circuito RLC en serie a través de la solución de una ecuación diferencial de segundo orden. Se desarrolla una aplicación móvil para el Sistema Operativo Android que obtiene la gráfica de esta corriente utilizando el entorno de desarrollo ANDROID STUDIO y la librería GRAPHVIEW. Con la elección de la expresión matemática que define el voltaje en el circuito y los valores de la resistencia, la inductancia, capacitancia, la corriente inicial el voltaje inicial en el capacitor o la carga inicial, se obtiene esta gráfica, que al compararla con lo que se obtiene empleando un CAS no se percibe diferencia alguna, lo que muestra la validez de los resultados de la app. Esta aplicación puede ayudar a estudiantes de ingeniería a comprender de una manera fácil y sencilla los conceptos relacionados a este tipo de circuitos, fomentando así el uso de dispositivos móviles en entornos de enseñanza-aprendizaje.

**Aplicación móvil, Ecuación Diferencial, Circuito RLC en serie, Respuesta de un circuito, SO Android**

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## Introduction

The use of smartphones with the Android Operating System has increased mainly in aspects such as communications (messaging services) and social networks, which has made them contain increasingly powerful components (processor, memory, capacity, etc.), so they can be considered as small computers capable of performing scientific calculations, analyzing data, graphing results, among others.

The study of electrical circuits is of vital importance for electromechanical engineers, in renewable energies, among others, for which several resources have appeared for their study, among which are the use of simulators such as PSpice, DC / AC lab, edumedia, which also include more electronics elements, or more general simulators such as Matlab Simulink. For the use of these simulators it is necessary to have certain knowledge that goes from the concepts related to the electrical circuits to the approach of a differential equation and its incorporation in a certain language for the simulation by blocks.

The former also require an internet connection to use, while in the latter the license is usually expensive, in addition to requiring desktop computers to run. Other options to consider are the following, WolframAlpha, which can be used on desktop computers or mobile devices, PhotoMath (and similar as MalMath, Mathematical Calculator: do maths per photo). All these apps require an internet connection to operate, which generates costs for the use of data, while WolframAlpha can also generate a cost per download, in addition to the fact that they tend to generate resistance to its use due to the many functions they have incorporated.

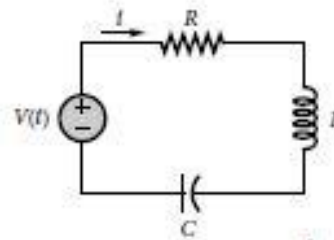
For these reasons, the idea of developing mobile applications for the realization of scientific engineering calculations that do not require the use of the Internet and that are also easy for users to use. In particular, this document presents the development of a mobile application that graphs the response of a series RLC circuit, where the voltage is given by some mathematical expressions that the user must choose, and enter only the resistance values, the inductance, the capacitance, the initial current in the circuit as well as the value of the initial voltage in the capacitance.

The document is structured as follows. The first section establishes the physical and mathematical concepts that determine the differential equation approach for this circuit. In the second section the solution to the problem is determined for some mathematical expressions of the voltage. The document is structured as follows of the app is presented in the third section, so that in the fourth section the result shown by entering a data set in an example is shown. In the conclusions section, areas of opportunity for the improvement of the app presented here are mentioned.

## RLC circuit

We begin by analyzing the differential equation of RLC circuits, also called second order circuits (Alexander y Sadiku, 2006).

A circuit consisting of a resistor  $R$ , an inductor  $L$  and a capacitor  $C$  and a fem (or voltage)  $V(t)$  connected in series, is called the RLC circuit, as shown in Figure 1.



**Figure 1** RLC circuit  
Source: Wei-Chau, 2010

Kirchoff's voltage law (Wei-Chau, 2010) states that the algebraic sum of the voltages in a circuit is equal to zero, so if  $V_R$ ,  $V_L$  and  $V_C$  are the voltages in the resistance, the inductor and the capacitor respectively then,

$$V_R + V_L + V_C = V(t). \quad (1)$$

If  $i(t)$  represents the current in the circuit for  $t \geq 0$ , Ohm's law (Wei-Chau, 2010) states that,

$$V_R = Ri(t). \quad (2)$$

The relationship between inductance, current and voltage in the inductor is (Wei-Chau, 2010),

$$V_L = L \frac{di}{dt}. \quad (3)$$

Finally, the relationship between current and voltage in the capacitor is expressed by (Wei-Chau, 2010),

$$V_C = \frac{1}{C} \int_{-\infty}^t i(\tau) d\tau. \quad (4)$$

From equations (2), (3) and (4) in (1), we get,

$$L \frac{di}{dt} + Ri + \frac{1}{C} \int_{-\infty}^t i(\tau) d\tau = V(t). \quad (5)$$

When obtaining the derivative with respect to time in (5), we find the equation of the RLC circuits in series,

$$L \frac{d^2i}{dt^2} + R \frac{di}{dt} + \frac{1}{C} i = \frac{dV}{dt}, \quad (6)$$

or,

$$\frac{d^2i}{dt^2} + \frac{R}{L} \frac{di}{dt} + \frac{1}{LC} i = \frac{1}{L} \frac{dV}{dt}. \quad (7)$$

Equation (7) must be complemented with the initial values  $i(0)$  and  $i'(0)$  in order to obtain the value of the current (response) for  $t \geq 0$ . In this way the problem to be solved is to obtain the graph of the current from the values R, L, C, of the mathematical expression that defines the voltage and of the values  $i(0)$  and  $i'(0)$ .

In many of the texts of differential equations (Edwards & Penney, 2008, Trench, 2002 and Zill & Warren, 2015) an equation equivalent to (7) is obtained in which the load  $q(t)$  in the circuit is considered with its corresponding initial values  $q(0)$  and  $q'(0)$ .

In the following section we obtain the solution of equation (7) for some expressions of the voltage as well as how to determine the value  $i'(0)$ , which clarifies the approach used instead of the one mentioned in the previous paragraph.

### Solution of the equation

To obtain the solution of (7) some expressions for the voltage are considered. For this, the numbers are defined (Alexander & Sadiku, 2006),

$$\alpha = \frac{R}{2L}, \quad (8)$$

$$\omega_0 = \frac{1}{\sqrt{LC}}. \quad (9)$$

Its importance lies in the fact that the solution depends on an order relationship between them, as will be seen later.

The first situation to analyze is the case of a circuit without a source, that is, when  $V(t) = 0$ , for all  $t \geq 0$ . In this way, (7) becomes,

$$\frac{d^2i}{dt^2} + \frac{R}{L} \frac{di}{dt} + \frac{1}{LC} i = 0. \quad (8)$$

If known  $i(0) = I_0$  and the initial voltage  $V_0$  on the capacitor, (5) concludes that (Alexander & Sadiku, 2006),

$$L \cdot i'(0) + RI_0 + V_0 = 0, \quad (9)$$

or,

$$i'(0) = i_1 = -\frac{1}{L}(RI_0 + V_0). \quad (10)$$

In this way, the solution to the initial value problem (8) given the quantities  $i(0)$  and  $i'(0)$ , where the latter is obtained from (10), it depends on the order relationship between (8) and (9), which is obtained from the solution of the characteristic equation (Trench, 2002) and described below.

If  $\alpha > \omega_0$ , It is said that the answer is overdamped, and is expressed by,

$$i(t) = \frac{m_2 I_0 - i_1}{-2\sqrt{\alpha^2 - \omega_0^2}} \exp(m_1 t) + \frac{i_1 - m_1 I_0}{-2\sqrt{\alpha^2 - \omega_0^2}} \exp(m_2 t), \quad (11)$$

where,  $m_1 = -\alpha + \sqrt{\alpha^2 - \omega_0^2}$ , y  $m_2 = -\alpha - \sqrt{\alpha^2 - \omega_0^2}$ .

If  $\alpha = \omega_0$ , the answer is said to be critically damped, and is given by,

$$i(t) = I_0 \exp(mt) + (i_1 - mI_0)t \exp(mt), \quad (12)$$

where,  $m = -\alpha$ .

Finally, if  $\alpha < \omega_0$ , It is said that the answer is undamped, and is given by,

$$i(t) = \exp(\beta_1 t) \cdot \left( \frac{i_1 - \beta_1 I_0}{\beta_2} \sin \beta_2 t + I_0 \cos \beta_2 t \right), \quad (13)$$

where  $\beta_1 = -\alpha$  y  $\beta_2 = \sqrt{\omega_0^2 - \alpha^2}$ .

For the general case, the amount  $i'(0)$  can be determined from the knowledge of the values  $I_0$  and the initial charge on the capacitor  $q_0$  (Borrelli & Coleman, 1998), mediante (5),

$$L \cdot i'(0) + RI_0 + \frac{1}{C} \int_{-\infty}^0 i(\tau) d\tau = V(0). \quad (14)$$

Since,

$$q_0 = \int_{-\infty}^0 i(\tau) d\tau, \quad (15)$$

then, (14) becomes,

$$L \cdot i'(0) + RI_0 + \frac{q_0}{C} = V(0), \quad (16)$$

from where,

$$i'(0) = \frac{V(0) - RI_0 - \frac{q_0}{C}}{L}. \quad (17)$$

With the above, the requirements for the development of the app are determined in the following section.

## App Development

For the development of the app, the cascade model is used (Somerville, 2005), in which the requirements are determined in one of the stages. The first necessary data are obtained from equation (7) in which the resistance (R), the inductance (L), the capacitance (C), the expression that defines the voltage, and the value appear  $i(0) = I_0$ .

The amount  $i'(0)$  is also necessary to obtain the expression of the current  $i(t)$ . However, it can be obtained from the quantities on the right side of equations (10) or (17). Another of the necessary elements is an expression of the voltage, so the following were selected.

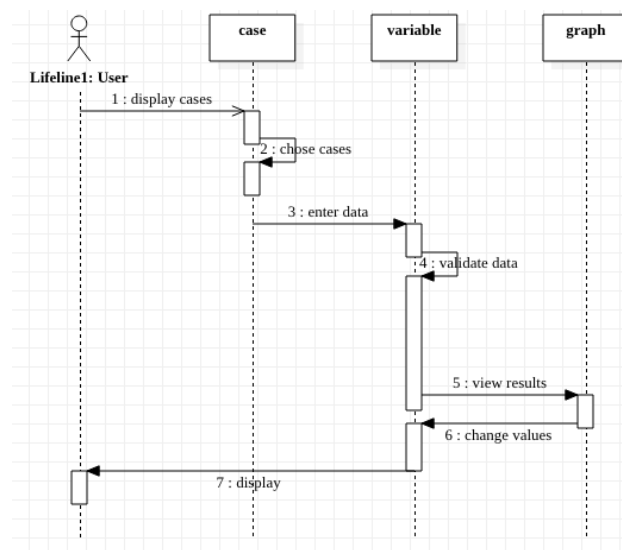
1.  $V(t) = 0$ .
2.  $V(t) = A$ , where A is a nonzero constant.
3.  $V(t) = At$ , where A is a nonzero constant.
4.  $V(t) = A \exp(Bt)$ , where A and B are nonzero constants.

This choice shows that up to two more data that the user will enter are also necessary, whereby the current  $i(t)$  is obtained in each of the aforementioned situations, under the considerations summarized in table 1.

Expression of $V(t)$	Cases to consider to obtain $i(t)$
$V(t) = 0$	a) $\alpha > \omega_0$ . b) $\alpha = \omega_0$ . c) $\alpha < \omega_0$ .
$V(t) = A$	a) $\alpha > \omega_0$ . b) $\alpha = \omega_0$ . c) $\alpha < \omega_0$ .
$V(t) = At$	a) $\alpha > \omega_0$ . b) $\alpha = \omega_0$ . c) $\alpha < \omega_0$ .
$V(t) = A \exp(Bt)$	a) $\alpha > \omega_0$ y $B^2 + 2\alpha B + \omega_0^2 \neq 0$ . b) $\alpha = \omega_0$ y $B^2 + 2\alpha B + \omega_0^2 \neq 0$ . c) $\alpha < \omega_0$ y $B^2 + 2\alpha B + \omega_0^2 \neq 0$ . d) $\alpha > \omega_0$ y $B = m_1$ . e) $\alpha > \omega_0$ y $B = m_2$ . f) $\alpha = \omega_0$ y $B = -\alpha$ .

**Table 1** Cases to consider for obtaining the response of the source RLC circuit: System analysis

With the analysis of the requirements, the following sequence scheme is performed that shows the interaction between the objects of the application, which is shown in Figure 2.



**Figure 2** Sequence diagram of the app  
Source: System analysis

The following section shows the graph generated by the app called RLCGraficador for a specific example.

## Results

The example considered is taken from (Edwards & Penney, 2008). The values are considered  $R = 16$ ,  $L = 2$ ,  $C = 0.02$ ,  $i(0) = 0$ ,  $q_0 = 5$  y  $V(t) = 100$ , which corresponds to the second line of table 1. The result obtained is shown in figure 3.

The comparison was made with that obtained by a CAS, which solves differential equations, finding that there is no difference between the two.



**Figure 3** Graph generated by the app for the mentioned example

Source: System design

### Acknowledgement

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### Conclusions

The development of mobile applications provides a way to streamline many tasks, particularly those involving numerical calculation and / or graphical representations of certain phenomena, since these save a lot of time that students spend to obtain the formal solution to practical problems.

For the design of the RLCGraficador app, it was considered to use a menu for the user to select the voltage expression and thus enter the necessary data. If by mistake any of them is not entered, it has the corresponding validations. With a button the user obtains the corresponding graph. If the user thinks so, he can obtain a screenshot of it, using one of the ways that most devices currently have.

When comparing the results obtained with the app and some CAS, it is noted that there is no difference between the two, which gives validity to the calculations made.

Among the aspects that can be improved are the following. The first of these would be the incorporation of more common expressions that define the voltage, for example trigonometric functions. This would allow the student to have more examples about how a given voltage determines the behavior of the current in an electrical circuit.

Another aspect of improvement would be to incorporate the generation of reports in .PDF format in which the user could visualize the data that was entered and the graph of the current, with which the app in question, it is not considered a pocket calculator.

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## Wireless Communication between two robots using a piconet network

### Comunicación inalámbrica entre dos robots usando una red piconet

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#### Abstract

The objective of this work is to develop an investigation related to the configuration of a piconet network. This piconet network consist of two mobile devices based on an architecture of communication master-slave. One of the devices sends orders via wireless and the other performs the instructions as well as it works with the parameters indicated by the master devices, such as: speed, time and direction. An Arduino nano, an engine controller, an aluminum chassis and caterpillar tires which visually resembles mobile devices to small tanks were employed. The physical structure of our approach can be adapted to various applications in the industry, production lines or in the automation of food services for the transfer of plates from one point to another. Its configuration is implemented based on AT commands and, as a result, we obtained a product that does not depend on the mechanical system, since the technology developed can be implemented in any device or mobile mechanism that can be directed by the motor controller. Finally, we procured a documented investigation related to the configuration and programming of the piconet network, as well as the measurements that indicate a speed-distance-voltage relation.

#### Resumen

El objetivo de este trabajo es desarrollar una investigación relacionada con la configuración de una red de piconet. Esta red de piconet consta de dos dispositivos móviles basados en una arquitectura de comunicación maestro-esclavo. Uno de los dispositivos envía pedidos por vía inalámbrica y el otro realiza las instrucciones y trabaja con los parámetros indicados por los dispositivos maestros, tales como: velocidad, tiempo y dirección. Se empleó un Arduino nano, un controlador de motor, un chasis de aluminio y neumáticos de oruga que visualmente se asemeja a dispositivos móviles a tanques pequeños. La estructura física de nuestro enfoque se puede adaptar a diversas aplicaciones en la industria, líneas de producción o en la automatización de servicios de alimentos para la transferencia de platos de un punto a otro. Su configuración se implementa en base a comandos AT y, como resultado, obtuvimos un producto que no depende del sistema mecánico, ya que la tecnología desarrollada puede implementarse en cualquier dispositivo o mecanismo móvil que pueda ser dirigido por el controlador del motor. Finalmente, obtuvimos una investigación documentada relacionada con la configuración y programación de la red de piconet, así como las mediciones que indican una relación de velocidad-distancia-voltaje.

**Piconet, Prototype, Arduino Nano, HC05**

**Piconet, Prototipo, Arduino Nano, HC05**

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## Introduction

Bluetooth is a short-range wireless communication technology, initially developed to replace cable connections. These connections frequently use point-to-point links between Bluetooth devices; however, the specifications of this protocol offer solutions for the most complex interconnection topologies, called Piconets (Bluetooth, 2004).

To analyze Bluetooth technology, some theoretical concepts are required, such as: analog signal, which is represented by various functions that take an infinite value of values in sinusoidal signals to transmit data; digital signal, that is represented by the coding of electrical pulses to represent ones and zeros according to the increase or decrease of voltage; wireless network, which consists of the connection of two or more nodes connected to each other by means of electromagnetic waves; carrier wave, which is an analog signal in sinusoidal form that contains data and information that travels through a wireless medium; modulation and demodulation, that are techniques in which a series of conversions are processed to generate a digital signal in analog or vice versa. Once synchronized, two devices in the wireless network must operate on the same channel and frequency to transmit the data with a certain amplitude and carrier wave period.

Bluetooth communication uses the Simplex transmission type, which consists of one-way transmission such as the modules available for Arduino technology; a simple example is to be able to control a land drone through the cell phone, in this case, the user through the device orders the drone to move only, also in the synchronization of two phones, or in the pairing of the phone with the car. When talking about a piconet network that uses several bluetooth slaves and a master, the type of Half-Duplex transmission is used, which, unlike Simplex, allows communication in two directions in one direction at a time, that is, it uses an alternate transmission.

Bluetooth is one of the most common wireless transmission means that we can find today, it is efficient, fast and economical; thus, it is an analog medium capable of transmitting data and voice at high frequencies in which the IEEE802.15.1 standard operates.

Like any transmission medium, it requires a transmitter and receiver in most equipment and devices such as phones, tablets, cameras or laptops. There are 3 classes of Bluetooth, which can be differentiated due to the scope they have: Class 1: 100 meters approximately, Class 2: 10 meters and Class 3: 1 meter. The hardware it requires consists of the radio it modulates to transmit the signal and a digital controller that processes the signals.

To begin with the development of a piconet network it is necessary to know some basic aspects of electronics, telecommunications and programming, which are the scientific areas involved in the project. The topology of a piconet network is a star configuration: slave devices will connect to a master, who will regulate traffic on the channel. By definition, the unit that establishes the piconet assumes this role and all others will be slaves (Moraleda, Gonzalez, Almendra, Jimenez-Leube, & Sanz Maudes, 2014).

In the electronic part, it is necessary to know the terms that are used for the connection pins of the bluetooth modules, Arduino nano, and the motor controller, the latter being the most complex due to the various configurations available for motor control, since they must be adapted and synchronized based on programming.

Arduino Nano, as the name implies, is an abbreviated version of a common Arduino, for the creation of smaller electronic objects (Caicedo Pedrera, 2017). The voltage flow and resistance are other parameters that must be well mastered in order to adapt the voltage supply to the various modules with which they work, since we used 5-volt components, while the motor controller has an input from 9 to 32, and this in turn can have an output of five, as well as digital and analog inputs.

A particular case of digital signal is the binary signal, where the number of possible values is only 2. Knowing this type of signals is important because in electronics, it is very common to work with voltages (or intensities) with only two values (Torrente Artero, 2016). Likewise, an analog electrical signal the values of the voltage vary constantly and can take any value (Crespo, 2017).

To program and configure the piconet network, it is necessary to establish a digital and direct communication with the hardware based on the factory settings of the bluetooth modules using AT commands (Attention Command). The AT commands were developed by Dennis Hayes in 1977, and they are a set of universal open standard commands that were created in order to control and configure modems from a PC or terminal (Aranda, 2014). These are coded instructions that make up a communication language between man and a terminal, whose main purpose is communication with modems; however, GSM mobile telephony has also adapted this language as a standard to be able to communicate with its terminals (Bluehack the Spanish Bluetooth Security Group, 2005).

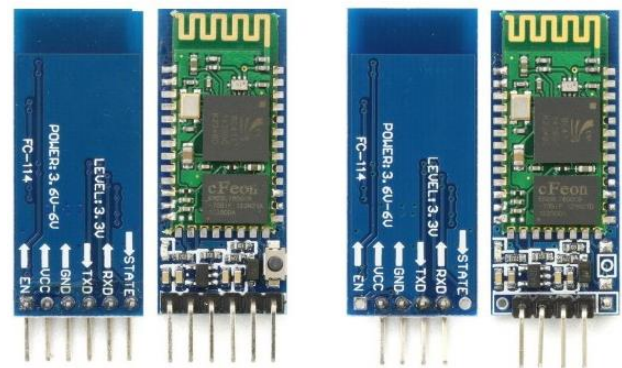
One of the best-known parameters for identifying devices within a network is the IP address of the device, but this IP address can change dynamically, so it is not an accurate value. Therefore, there is the MAC address (acronym for Media Access Control), a unique and irreplaceable identifier for any network device. In this way, it is much more precise to identify a specific computer, a printer or a smartphone by its MAC address (Barbero, 2018). Some of the parameters that are configured are: baud rate, password, master/slave and the MAC address of the slave device in the master, among others. This ensures efficient and secure communication between the two mobile prototypes as there is communication, if and only if, one has the MAC address and password set.

In terms of telecommunications, it is necessary to know the characteristics of bluetooth technology, such as modulation and multiplexing techniques, to understand the transmission by channels, along with characteristics of the wireless medium like amplitude, period and frequency of a carrier wave, since this allows to determine the proper transmission speed between one device and another. Bluetooth technology was designed from the outset to support data and multiple voice channels with a range of approximately ten to one hundred meters, without requiring a direct line of sight between the devices (Bellido O., De la Cruz F., Torres R., & Gistas P., 2004). As for the transmission speed, the 2.4 GHz band is the one that is physically responsible for sending and transmitting the information.

It emits and receives the electrical signals to the other bluetooth devices of the piconet (Varela & Domínguez, 2002). Finally, the main advantage of Bluetooth is the ability to handle voice and data transmission simultaneously, with the ability to support an asynchronous data channel and up to three synchronous voice channels (Torres Hurtado & Álvaro Bernal, 2006).

## Development

The configuration begins by identifying the conventional and easily accessible bluetooth modules, since it is common to find two types of them, the HC05 and the HC06, which have some characteristics and differences. The HC06 module, a component with only four pins, is quickly identified, this indicates that they can only act as a slave and have the pins: Vcc (voltage), Gnd (ground), Txd (transmission) and Rxd (reception), at the same time, it has a lower cost and for its implementation it is only required to have the login password, which is usually 1234.



**Figure 1** Bluetooth Modules

Fuente:

<https://aprendiendoarduino.wordpress.com/tag/hc-05/>

In contrast, the HC05 module is relatively more expensive than the HC06 and can be visually identified by having six pins, Vcc (voltage), GND (ground), Rxd (reception), Txd (transmission), State (state), En (enable key) and, depending on the manufacturer, it can have or not a reset button, which is indispensable for the configuration of the Master mode. Both modules work specifically at 3.3v; however, the pins and connectors can support up to 5v. Initially, when the HC05 module is new, it is preconfigured in slave mode and ready to use. Figure 1 shows both modules, on the left the HC05, on the right the HC06.

The devices send and receive data through a channel and are continuously jumping in a pseudorandom way from one channel to another; for the communication to be correct, sender and receiver must know that sequence of jumps (Pascual, 2012). Then we proceed to configure two HC05 modules, one as a slave and one as a master.

### Slave configuration

Starting the configuration, a communication code between the Arduino IDE and the Bluetooth must be uploaded, in Figure 2, the example code to enter the AT commands in the HC05 module is shown. Once the Arduino has the program, it is required to press and hold the "reset" button of the HC06 module for about 3 seconds while the voltage pin is connected. To verify that it was successful, the module LED stops blinking continuously and must make longer pauses between one ignition and another, in this way, the module enters configuration mode.

```

comunicacion_bluet1 $
#include <SoftwareSerial.h>
SoftwareSerial bluet(10,11); //RX,TX
void setup() {
  Serial.begin(9600);
  bluet.begin(38400);
  Serial.println("configuracion!");
}
void loop() {
  if(bluet.available())
  Serial.write(bluet.read());
  if(Serial.available())
  bluet.write(Serial.read());
}

```

**Figure 2** Configuration of AT commands  
Source: Prepared by the authors in Arduino-IDE

A terminal is required to access the configuration of AT commands, in this case Arduino IDE, it has this option when choosing the menu: "Tools," submenu "Serial Monitor."

Subsequently, the AT commands must be entered, the most important ones are listed and exemplified in Table 1. It should be emphasized that it is important to know the MAC address of the slave module (last command in the table), since it will be required at the time of configuring the Master, to indicate the module to which it will be connected.

Commands	Description	Example	Answer
AT	Check communication	AT	Ok
AT+NAME	Assign a name to the module	AT + NAME= ESCLAVO	Ok
AT + PSWD	Assign Password	AT + PSW= 5678	Ok
AT + BAUD	Change transmission speed	AT + BAUD = 9600	Ok
AT + ROLE	Assign Slave Mode	AT + ROLE = 0	Ok
AT + BIND	Check MAC Address	AT + BIND?	XXXX, XX, XXXXXX

**Table 1** Commands to configure slave  
Source: Prepared by the authors

### Master Configuration

In the case of the Master, the code in Figure 1, the Arduino loaded with the same program and most of the commands in Table 1 can be used again, with some changes in their parameters. Likewise, it must be kept pressing the "reset" button of the module for a few seconds, while the voltage pin is connected. The main commands to configure the Master mode are shown in table 2.

Commands	Description	Example	Answer
AT	Check communication	AT	Ok
AT+NAME	Assign a name to the module	AT + NAME= MAESTRO	ok
AT + PSWD	Assign Password	AT + PSW= 5678	ok
AT + BAUD	Change transmission speed	AT + BAUD = 9600	ok
AT + ROLE	Assign Master Mode	AT + ROLE = 1	ok
AT + CMODE	Connect Master with a particular device (slave).	AT+CMODE=1	ok
AT + BIND	Check MAC Address	AT + BIND =	Ok XXXX, XX, XXXXXX

**Table 2** Commands to configure the master  
Source: Prepared by the authors

Once the Master and Slave devices have been configured, an examination is conducted. Simply supplying both devices with voltage, once they synchronize, they must stop blinking continuously. It is important to mention that during the automatic pairing process, in the first seconds both modules should flash every second, then the pauses will be longer (about 3 seconds), and their LED lights will be longer, if this action happens, the configuration is successful.

## Programming and configuration of other components

Specifically, for the project developed, the configuration and programming of the following components was necessary:

- H bridge controller L298, capacity from 5 to 32v
- 12v motor, 21000rpm
- Arduino nano

The codes that are used as the basis of experimentation and tests to move forward or backward the mobile prototypes as indicated by the Master, are shown in Figure 3, in which the coding of the Master device is shown on the left side and on the right side is the coding of the slave device. It should be noted that this code is enough to make the prototypes move according to programmed instructions and based on the analysis or algorithm of the programmer, the necessary lines can be added so that the operations or actions to be performed are executed. Therefore, for demonstrative purposes this information is shared.

```

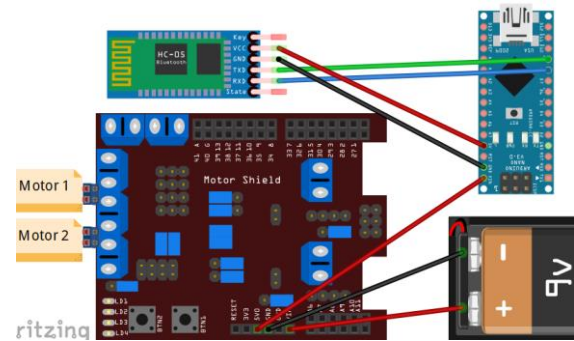
bluet_Maestro$
#include <SoftwareSerial.h>
SoftwareSerial bluet(10,11); //RX,TX
void setup() {
  Serial.begin(9600);
  bluet.begin(9600);
  Serial.println("comienza el bluetooth");
}
void loop() {
  Serial.println("AQUI COMIENZA");
  bluet.write('0');
  Serial.println(bluet.read());
  delay(5000);
  bluet.write('1');
  Serial.println(Serial.read());
  delay(2000);
}

```

**Figure 3** Experimentation Code

Source: Prepared by the authors in Arduino-IDE

The electronic scheme was generated in the free software "Fritzing," since it allows to visualize the connections and pins used.



**Figure 4** Schematic design of the prototype

Source: Prepared by the authors in Fritzing

It is important to emphasize that Figure 4 is only a representative image and only similar to the real model, since the diversity and electronic components are in permanent development, the "H-bridge L298" module used is not available in Fritzing, so we used a Motor Shield for representation.

## Algorithm used

The algorithm that was implemented considers the measurement and control of some important parameters, such as the response time of the slave, the established speed of the motors, the travel time in variance with the distance that it should travel, as well as the adaptation of the time of the slave according to the pattern to follow. One of the objectives of the mobile prototype was to go through different patterns, as rails in a production line, like a prototype capable of being implemented in the manufacturing industry.

Motor control pins:

- D1 advance motor 1
- D2 reverse engine 1
- D3 advance motor 2
- D4 reverse motor 2

Instruction sent from the Master to the Slave:

A = Advance

R = Go back

S = Stop

Terms:

**Si Maestro avanza then Esclavo avanza**

(Maestro= ON 5 segundos, D1=ON, D3=ON, velocidad=200, SEND= A, , Esclavo= 5 segundos, D1=ON, D3=ON, velocidad= 200)

**Si Maestro para then Esclavo avanza**

(Maestro= OFF 5 segundos, D1=OFF, D3= OFF, velocidad=0, SEND= A , Esclavo= 5 segundos, D1=ON, D3= ON, velocidad= 200)

**Si Maestro para then Esclavo retrocede**

(Maestro= OFF 5 segundos, D1=OFF, D3= OFF, velocidad=0, SEND= R, , Esclavo= 5 segundos, D2= ON, D4= ON, velocidad= 200)

**Si Maestro retrocede then Esclavo retrocede**

(Maestro= ON 5 segundos, D2=ON, D4= ON, velocidad=200, SEND= R, , Esclavo= 5 segundos, D2=ON, D4= ON, velocidad= 200)

**Si Maestro retrocede Esclavo para**

(Maestro= ON 5 segundos, D2=OFF, velocidad=200, SEND= S, , Esclavo= 5 segundos, velocidad= 0)

**Si Maestro retrocede Esclavo avanza**

(Maestro= ON 5 segundos, D2= ON, D4= ON, velocidad=200, SEND= A, , Esclavo= 5 segundos, D1= ON, D3= ON, velocidad= 200)

Some parameters always maintain the same value; however, they can be adapted according to the needs (routes or inclinations), in this case, the time and speed of the motors, since there is a distance-time relationship.

**Results**

To generate the results, some necessary tests were carried out to determine the efficiency of the prototypes by measuring the path of the Master in relation to the distance and time traveled in comparison to the Slave. One of the doubts to be resolved was the relatively short time it takes for the Master to send the instruction wirelessly and that the Slave can also process it. Specifically, this sending/receiving period was minimal, almost imperceptible, but it exists.

In Table 3, experimental results are shown with which a latency in the travel time that affects the Slave prototype is verified.

The values of the motors in Arduino are from 0 to 250, there is a voltage ratio, in which, if the motor speed is 0 then the assigned voltage is 0v, if the motor speed is 250, the assigned voltage is a voltage higher than it is working, in this case it is 9v. For which the route of both (Master and Slave) is programmed at a speed of 200 units. It should be noted that the minimum speed is 180 and maximum 250, since, if programmed to less than 180, the motors do not generate enough force to rotate, so the prototype does not move. Also, in Table 3, it is observed that the Time columns (sec.) are very even and imperceptible to the eye, but it is determined that the greater the distance traveled, the time needed by the Slave must be greater than that of the Master, in an approximate proportion of two hundredths of a second.

Master		
Speed	Distance	Time(sec.)
200	1.27 m	2.24
200	5 m	8.81
200	10 m	17.63
200	15m	26.4
Slave		
Speed	Distance	Time(sec.)
200	1.27 m	2.26
200	5 m	8.84
200	10 m	17.72
200	15 m	26.8

**Table 3** Results of experimental tests  
Source: Prepared by the authors

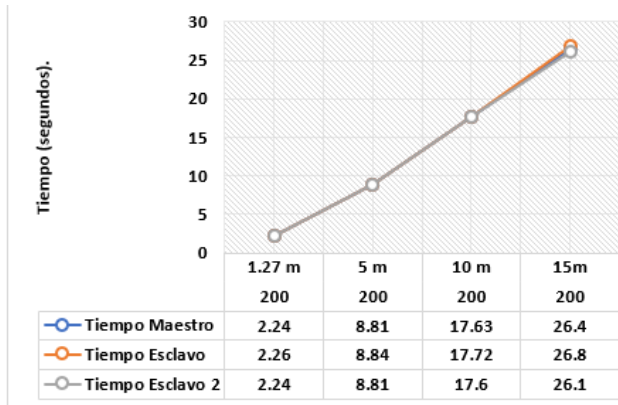
To improve these and obtain more equitable and precise comparative results, it was necessary, during the experimentation stage, to modify the parameter of the speed in the Slave, in order to match the values thrown by the Master. In Table 4, it is observed that the Slave speed is 220.

Master		
Speed	Distance	Time(sec.)
200	1.27 m	2.24
200	5 m	8.81
200	10 m	17.63
200	15 m	26.4
Slave		
Speed	Distance	Time(sec.)
225	1.27 m	2.24
225	5 m	8.81
225	10 m	17.60
225	15 m	26.1

**Table 4** Results of experimental tests  
Source: Prepared by the authors

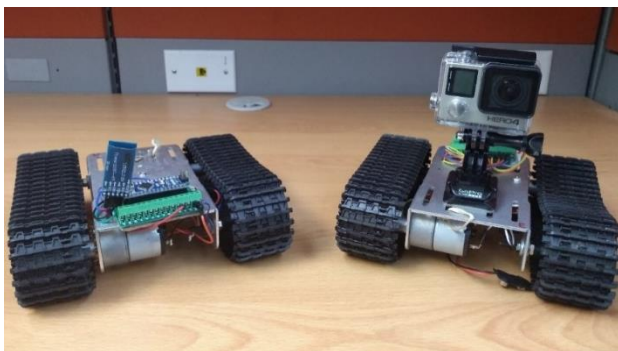
Finally, Figure 6 shows a graph in which Tables 3 and 4 are presented, in which the path of:

- Master Time: 200 speed, blue line
- Slave Time: speed of 200, orange line
- Slave Time 2: 220 speed, gray line



**Figure 5** Graph with the obtained results  
 Source: Prepared by the authors

It is important to mention that the blue line can not be perceived because the times obtained once the speed in the Slave is modified to 220 equals the values obtained by the Master with a speed of 200, so both lines are overlapped, which is evidence of accurate results.



**Figure 7** Piconet network prototypes  
 Source: Prepared by the authors

In figure 7, the two mobile prototypes are shown with the chassis, the tracks, engines, Arduino nano, controller, bluetooth modules, in addition to the finished project, a GoPro camera was added, capable of sending the live transmission of the route to the phone or laptop via Bluetooth added to the piconet network.

**Discussion**

The implementation of a Piconet network applied to mobile robots can improve production processes in manufacturing industries, so this project is feasible to apply with a chassis and professional mechanical system that allows the transfer of material between a workstation and another, since the brain of the project lies in the implementation of wireless technology and programming developed based on actuators, in addition to being able to add sensors that match the needs of the operator or the company.

In industrial environments, it is common to monitor parameters where Bluetooth can form a network of sensors and measuring instruments that removes the connections, which would allow the connection, monitoring and programming of PLCs and RTUs programmable logic controllers, and field points installed in production lines or plants (Linares Ruiz, Quijano Vásquez, & Holguin Londoño, 2004). This feature is one of the qualities of the proposed system.

Some of the benefits found include the following:

1. It is an automated but intelligent system to make decisions, according to the conditions or states of the master device.
2. It is a secure wireless system that pairs only with the selected equipment, avoiding interference.
3. It is adaptable to the needs and conditions of the company's production line.
4. It provides a work area free of operators or work to maintain its integrity.
5. Increased production within the production line.
6. It reduces the amount of time on production lines at the time of failures or stoppages.
7. Increased personnel safety in the area where this system will be placed.
8. It avoids deception or anomalies in production information.

9. It allows the transfer on flat and steep surfaces.

### Conclusion

The contribution of the project with the Piconet network lies in the freedom that the mechanical system possesses for making programmed decisions, such as the route it takes in measuring time, distance, speed, as well as stopping or continue its way.

The project had a positive impact for the work group, since a tangible product was obtained that requires the skills of a Computer Systems Engineer, as well as the generation of new prototypes capable of being optimized and improved in order to participate in events and academic competitions. Likewise, the use of the Piconet network implemented in this prototype can be applied as pilot tests in production lines of the industries, which will allow to determine what are the specific requirements and benefits that we must have in order to use them professionally.

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**Monitoring system of vital signs at distance and in real time through IoT Technology****Sistema de monitoreo de signos vitales a distancia y en tiempo real mediante Tecnología IoT**

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**Abstract**

This article presents the architecture, design and development of an Internet of Things (IoT) tool that performs remote and real-time monitoring of immunosuppressed terminally ill patients, who have been sent home by their doctors to wait the time of death, however, these patients usually are cared by the useful but unexperienced hands of their relatives. This tool aims to facilitate communication between the attending medic and the relative who takes care of the patient, it promotes the patient's comfort and accurate care using sensors, devices and mobile applications linked to each other. The methodology includes: the patient's characterization, in order to identify their requirements and characteristics that distinguish them; existing medical sensor's study and selection of the necessary ones. Subsequently, signals acquisition and compatibility effected for the selected sensors, and finally, the tool's design includes: Selected sensors, controllers, server, translator, databases and web application.

**Internet of things, Monitoring, Health**

**Resumen**

Este artículo presenta la arquitectura, diseño y desarrollo de una herramienta de Internet de las Cosas (IoT) que realiza el monitoreo a distancia y en tiempo real de un paciente inmunodeprimido en etapa terminal, que ha sido enviado a su casa por los médicos tratantes para sólo esperar el momento del fallecimiento, sin embargo, dichos pacientes quedan al cuidado de las manos útiles pero inexpertas de sus familiares. Esta herramienta pretende facilitar la comunicación entre el médico tratante y el familiar que esté al cuidado del paciente, promueve la comodidad y atención adecuada del mismo, utilizando sensores, dispositivos y aplicaciones móviles relacionados todos entre sí. La metodología incluye: Caracterización de pacientes de interés, para identificar sus requerimientos y características que los distinguen, estudio de sensores médicos existentes y de éstos selección de los necesarios. Posteriormente, se efectúa la adquisición y compatibilidad de señales de los sensores, se diseña la herramienta incluyendo: Sensores elegidos, controladores, servidor, traductor, bases de datos y aplicación web. Finalmente, se realizan pruebas para comprobar ejecución, desempeño y confiabilidad del nuevo sistema de IoT desarrollado.

**Internet de las Cosas, Monitoreo, Salud**

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## Introduction

The concept: "Internet of Things" (IoT) was coined in the early 21st century by MIT's Auto-ID Center by Kevin Ashton (Ashton 2009). The IoT integrates everything: Detection, identification, communication, networks, devices and computer systems; it interconnects people with things in real time anywhere, through any device and means of communication.

The IoT promises numerous social and economic benefits not only to emerging economies but also to developing economies. The IoT promises an "intelligent" world, fully interconnected, constantly advancing, efficient and with great opportunities which will result in billions for industry and the global economy (Thierer, 2018).

It is expected that by 2020 more than 65% of companies (up to 30% today) will adopt IoT products (Gartner, 2017). Gartner predicts that by 2021, less than 1% of motorway transport will be made up of autonomous trucks, but if we consider that there are 3.6 million vehicles, then that means that within five years there could be up to 36,000 autonomous trucks traveling on the roads.

In addition, Huawei asserts that in 2025 there will be 100 billion connections to IoT (Huawei, 2018) and the McKinsey Global Institute believes that the financial impact of IoT on the global economy could be 3.9 to 11.1 billion dollars in 2025 (Manyika, 2015), which shows a significant influence and growth for the IoT.

In this sense, the IoT offers promising solutions for health care, since it is possible to consider the care and maintenance of medical equipment, the registration and control of medical assets in hospitals, as well as the care, control and supervision of patients.

Thus, the Internet-of-Things (IoT) based home health care services, which is the ultimate goal of this research, have great potential in the health care field.

## Background

The IoT delivers a data source which provides embedded sensors and actuators (Arriarán Rooms, 2015) that allow the capture, storage and management of information emitted by these objects in order to automate daily life activities and processes. Today, the IoT encompasses virtually everything, such as: security and autonomous control systems for homes (post-scapes, 2018), control and monitoring systems for shops, banks, restaurants (Meola, 2018), energy management and security systems in office buildings (Wesson, 2018), production environments (Abdulla, 2017), systems for monitoring and control of mining, oil and gas, construction (Meola, 2018), moving vehicles such as automobiles, trucks, ships, airplanes and trains (Meola, 2018), adaptive traffic control systems, intelligent meters and environmental monitoring (Fischione, 2016). There are even IoT devices attached to the human body to monitor and maintain people's health, fitness and well-being (Farooq, Waseem, Mazhar, Anjum, & Kamal, 2015).

## The IoT and health

Improving human health and well-being is anyone's primary purpose, so health care systems around the world are vitally important.

For a decade, hospitals have endeavored to be equipped with RFID tagging technology, tagging patients so that doctors and nurses can monitor their heart rate, blood pressure, temperature and other conditions (Fuhrer, 2006). The internet-of-Things (IoT) offers promising health care solutions focusing on the care and maintenance of medical equipment, the recording and control of medical assets, and most importantly, the care, control and supervision of patients.

These are some of the most important works that have been developed previously: The patent WO2009/022320A2 (Colombia Patent No. WO2009022320A2, 2009), it is a system that integrates the functions of basic equipment for monitoring patients in intensive care or critical condition, in which the monitoring and transfer of patients should be performed only by highly trained personnel due to the complexity of the technology that can be understood only by medical specialists.

Patent WO2014/163475A1 (Mexico Patent No. WO 2014/163475 A1, 2014), it is a telemedicine operating system with various devices that connect to the patient and generate medical information transmitted to the specialist, who can make a diagnosis and propose a medical treatment for the patient who is in a remote location. However, it does not work in real time. It is necessary to emphasize that the intention of the work proposed here is the monitoring of vital signs and resolution of problems in real time of a patient who is being treated at home, with the help of relatives without medical knowledge, providing comfort to such relatives, since they have a fast, timely and effective monitoring system to care for their patient.

### Justification

At present there are situations concerning health care which are impossible to develop in a traditional way, due to the natural growth of population and the evolution of humanity. Therefore, the technological possibilities of the IoT can be exploited.

Through the development of this research, it has been possible to distinguish and solve a series of problems on device architectures, sensors and system integration, which necessarily appear in the initial stage of development of any technology, because the applications of IoT are not fully implemented as of today.

It must be considered that currently there are too many medical treatments that for most patients are unreachable, either because of difficult access to hospitals, excessive hospitalization costs, or because they require long and expensive transfers. Research like this, focusing on the use of IoT technologies in the area of health, will bring these treatments to anyone regardless of their geographical and economic situation.

For this reason, an application of the IoT has been developed to treat terminally ill patients cared at home, to help the patient's well-being, as well as appropriate and real time care, and to provide comfort and adequate information to the family members assigned to their care; consequently, it will favor the family economy by avoiding hospitalization expenses and payment of specialists.

### Hypothesis

By using a monitoring system based on IoT technology, real-time care and control of immunocompromised patients whose health is characterized as delicate but stable and who are in a terminal stage will be facilitated.

### Objective

To design and develop an IoT tool, through the integration of various sensors and devices, to monitor, control and provide treatment in real time; to improve the medical care offered by doctors, family and staff assigned to the care of an immunocompromised patient, delicate but stable, in terminal stage staying at home (see figure 1).

### Procedure and description of the activities

The activities carried out during the development of this research are described below:



**Figure 1** IoT tool, monitoring from home (*Prepared by the authors*)

### Patient Characterization

The patients for whom this IoT system has been designed are in terminal stage conditions, so their doctors have sent them to their homes to be cared for, so that they may have the opportunity, in this final stage, to be close to all their loved ones; they are patients who mainly come from long processes of suffering and lack of control with a high mortality rate.

Patients suffering from Diabetes Mellitus, a disease that can give rise to many illnesses which at times dehydration should be strictly monitored and keep the patient asymptomatic and controlled while blood glucose numbers remain between 150 and 250 mg/dl (Cortés Bejar, 2016).

Terminal AIDS patients who require constant control of pain, hydration, nutrition, skin care, recurrent infections and agitation. Patients with Arterial Hypertension, in the advanced stages of the disease patients are placed in terminal stage situations where monitoring of blood pressure and heart rate is indispensable.

Heart failure is a progressive, lethal disease, with many symptoms, which affects a large part of the population, although some patients may suffer sudden death due to cardiac arrhythmia, most die from progressive failure. The economic impact of heart failure is high and almost all resources are spent in the last six months of a patient's life. For patients with these diseases, blood pressure, heart rate, respiratory rate, pulse, and temperature should be monitored.

Cancer can affect people of all ages, causing about 13% of all deaths according to the American Cancer Society (Society, 2019). Cancer is very serious due to its ability to spread throughout the body, producing metastatic cancer, with treatments for its side effects, mainly consisting of pain control (symptom that can be identified through body sweating), and also, depending on the type of cancer the patient presents, they will also require assistance in breathing, body position, temperature control and heart rate.

The IoT monitoring system developed in this research can be used to send and receive reliable data in real time between doctors and caregivers of the patient, thus facilitating comfort and timely care for the patient.

### Selection of sensors for measuring vital signs

The sensors were specifically selected for the monitoring of the essential vital signs which must be tracked during terminal stage situations, assigning priority according to the advice provided by the doctor Enrique Araujo Vargas (professional card: 5102204), which are listed in order of importance below:

- Body temperature sensor
- Blood Glucose Sensor
- Electrocardiogram sensor
- Cardiac pulse sensor

Initially, we identified and researched the vital sign sensors existing in the market and from there, we selected the most suitable for the project.

### DS18B20 Temperature Sensor

The DS18B20 temperature sensor (figure 2) accurately measures the temperature and provides an output of alarm/interruption/stop of temperature, it can measure temperatures between  $-55^{\circ}\text{C}$  and  $125^{\circ}\text{C}$ . (Maxim Integrated, 2018).



**Figure 2** DS18B20 Sensor  
(Maxim Integrated, 2018)

This sensor allows its integration with most existing controllers, its accuracy, low power consumption and operating range are in line with the needs of a project dedicated to the health field (Maxim Integrated, 2018).

### MAX30100 Pulse and Oxygen Sensor

The MAX30100 (figure 3), contains an oximetry pulse and a heart rate integrated in the same sensor (Maxim Integrated, 2018).



**Figure 3.** MAX30100 Sensor  
(Maxim Integrated, 2018)

It has been chosen for its small size of only 5.6mm x 2.8mm x 1.2mm, 14 pins, low power consumption, programmable sample rate and energy-saving LED current.

Its advanced functionality improves the measurement procedure, has high resistance to robust motion, and fast data output capability.

### Heart Rate Sensor

The AD8232 sensor (figure 4) is a block of integrated signals necessary for ECG (Electro cardiogram), useful for measuring the electrical activity of the heart and other applications of electrical measurements of the human body (bio-potentials).



**Figure 4.** Heart Rate Sensor  
(Maxim Integrated, 2018)

### Blood oxygenation and pulse sensor

This sensor (Figure 5) is used to measure pulse oximetry which is a non-invasive method of indicating arterial oxygen saturation of functional haemoglobin. Oxygenated and deoxygenated hemoglobin absorb different wavelengths.



**Figure 5.** Blood oxygenation and pulse sensor  
(Libelium Sistemas Distribuidos, 2018)

Normal acceptable ranges for patients are 95-99%, ranges with hypoxia conduction problems 88-94%, values of 100% **may** indicate carbon monoxide poisoning.

### EMG electromyography sensor

This sensor (figure 6) detects the electrical potential generated by muscle cells when these are activated electrically or neurologically. The signals can be analyzed to detect medical abnormalities in the biomechanics of human or animal movement. (Libelium Distributed Systems, 2018)



**Figure 6** Electromyography sensor  
(Libelium Sistemas Distribuidos, 2018)

This sensor measures the filtered and rectified electrical activity of a muscle, depending on the amount of activity in the selected muscle.

### Blood Glucose Sensor

The glucose sensor (Figure 7) is used to determine the concentration of glucose in the blood. For the type of patients characterized in this research, continuous monitoring of their glucose readings is of paramount importance.



**Figure 7.** Glucose Sensor  
(Libelium Sistemas Distribuidos, 2018)

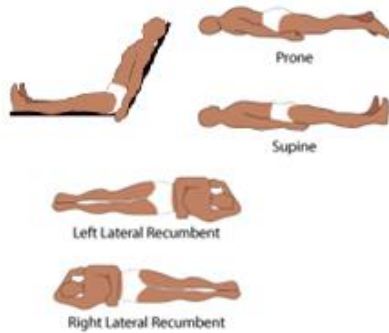
The meter displays the level in mg/dL or mmol/L.

### Body Position Sensor

This sensor controls five different patient positions (standing/sitting, supine, face down, right and left; see figure 8 and figure 9). (Libelium Distributed Systems, 2018).



**Figure 8.** Body Position Sensor  
(Maxim Integrated, 2018)



**Figure 9** Positions detectable by the sensor  
(Maxim Integrated, 2018)

It uses a triple-axis accelerometer to obtain the patient's position. It is an ultra-small low-gravity device, which allows the measurement of accelerations in 3 perpendicular axes to identify the sensations of inclination, movement, shock and vibration.

### ECG electrocardiogram sensor

The electrocardiogram (ECG, Figure 10) is a diagnostic tool used to evaluate the heart's muscle functions. It uses "continuous telemetry electrocardiogram" over a long period of time.



**Figure 10** ECG Sensor  
(Libelium Sistemas Distribuidos, 2018)

This sensor uses high quality disposable pre-gelified electrodes to measure EEG, ECG and EMG.

### Galvanic Skin Response Sensor

The galvanic skin response sensor (Figure 11) measures the electrical conductance of the skin, which varies with its moisture level. This is of interest because the sweat glands are controlled by the sympathetic nervous system. Drier skin registers a much higher resistance (Libelium Distributed Systems, 2018).



**Figure 11** Galvanic Skin Sensor  
(Libelium Sistemas Distribuidos, 2018).

Emotions such as pain, excitement, stress, shock, etc. can cause the skin's conductivity to fluctuate.

### Airflow Breathing Sensor

Abnormal respiratory rates and changes in respiratory rate are a broad indicator of greater physiological instability, with this sensor (Figure 12) it is possible to monitor respiratory rate as an indicator of patient status.



**Figure 12** Air Flow Sensor  
(Maxim Integrated, 2018)

The AirFlow sensor can provide early warning of hypoxemia and apnea, it is used to measure the respiratory rate in a patient needing respiratory assistance.

### Body temperature sensor

By means of the D-S18JK sensor (figure 13) the indispensable body temperature is monitored, because several illnesses are accompanied by characteristic changes in the corporal temperature, in fact, the course of certain diseases is made by measuring the aforementioned temperature.



**Figure 13** Body Temperature Sensor  
(Maxim Integrated, 2018)

### Connection between the different IoT sensors and devices

The devices and sensors are connected under the MQTT protocol (MQTT, 2018), which offers advantages over other protocols, we also used the standard 802.11 (WiFi) for communication between the controller and the server.

### Priority and importance of vital signs to be measured in patients

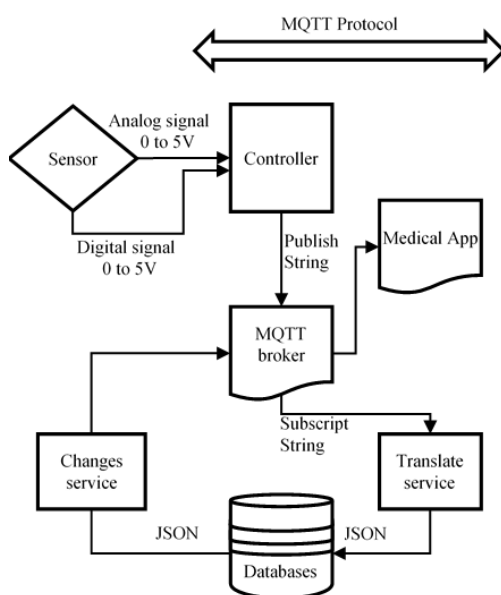
According to the importance given to vital signs for the monitoring of the diseases mentioned, we chose to start with the following sensors:

- Body temperature
- Heart rate
- Oximetry MAX30100

### Design of the IoT tool for patient monitoring

Figure 14 shows the design of the IoT tool, which consists of the following elements:

- Body temperature sensor
- Heart Rate Sensor
- Oximetry Sensor
- Controller (myRIO-1900).
- MQTT Server (Mosquitto)
- Translator and change service (background programs, programmed in Ruby).
- Database (ArangoDB).
- Mobile application (programmed with Android Studio)



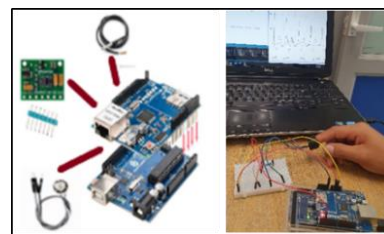
**Figure 14** General system diagram  
(Prepared by the authors)

The operation consists of sending a pulse from the sensor to the controller, which interprets the signal and sends it through the network to the MQTT server, which retransmits the message to subscribers. The translator program is in charge of giving it the JSON format so that it can be interpreted correctly by the database.

There is another service running continuously that immediately identifies any alteration in the database, and reports in real time via MQTT to the application of the patient and the doctor. In the same way, this last service allows the pertinent queries to be made to the database.

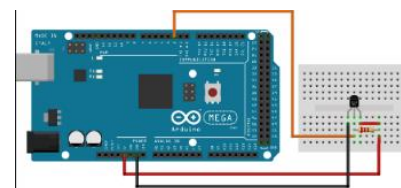
### Configuration and integration of selected IoT devices and sensors

Initially, the readings of the chosen sensors are acquired and the configuration of the prototype is carried out. The DS18B20 temperature sensor, the MAX30100 oximetry sensor and the GY-61 cardiac pulse sensor are connected with the Arduino MEGA 2560 ATMEGA components, Shield Ethernet for Arduino, Router with LAN ports (figure 15).



**Figure 15.** Integration of Devices and Sensors  
(Prepared by the authors)

The corresponding connection diagram for the temperature sensor is shown in figure 16.



**Figure 16** DS18B20 Temperature Sensor  
(Prepared by the authors)

Taking as reference the flat part of the DS18B20 temperature sensor, on the left is the GND ground output, on the center is the data output that can go to a digital or analog pin and the right should go to 5v current.

3 male/female wires are inserted into the sensor terminals, the central pin is located on digital pin 2 of the board (or it could also be tapped directly to the proto as shown in the diagram). The resistance greater than or equal to 4.7KOhms is placed between the current pin and the digital pin (pullup), in order to protect the sensor from a high voltage.

The corresponding wiring diagram for the oximetry sensor can be seen in Figure 17.

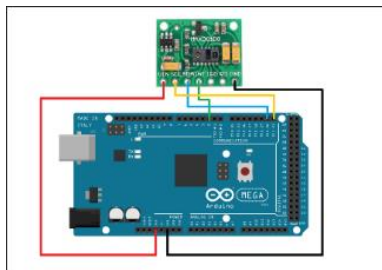


Figure 17 Oximetry Sensor  
(Prepared by the authors)

The sensor has the name of each terminal printed on the front: VIN, SCL, SDA, INT, IRD, RD and GND. A male/female cable is placed on each of its outputs and associated with the arduino according to table 1:

AD8232 Sensor	Arduino MEGA
VIN	3.3v/5v
SCL	SCL/21
SDA	SDA/20
INT	Digital pin 2
IRD	-----
RD	-----
GND	GND

Table 1 Oximeter Terminals  
(Prepared by the authors)

Regarding the electrocardiogram sensor, the corresponding wiring diagram is presented in (figure 18).

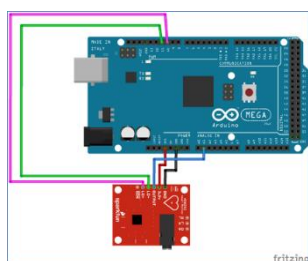


Figure 18 Electrocardiogram sensor  
(Prepared by the authors)

The sensor has printed on the front the name of each of the terminals: GND, 3.3v, OUTPUT, LO-, LO+ and SDN, a male/female cable is placed in each of its outputs as shown in table 2:

AD8232 Sensor	Arduino MEGA
GND	GND
3.3v	3.3v
OUTPUT	Analog Pin 1 (A1)
LO-	Digital pin 11
LO+	Digital pin 10
SDN	-----

Table 2 Electrocardiogram terminals.  
(Prepared by the authors)

The connection of the AD8232 cables is indicated on the plastic end (depending on the manufacturer colors may vary), the RA (Right Arm) cable should be placed on the right chest, the LA (Left Arm) cable under the heart area and the RL (Right Leg) cable on the right side (Figure 19).

The sensor has a 3.5 mm input to connect the cable that combines each of the 3 inputs where the electrodes are placed on the patient's body.

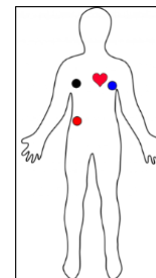
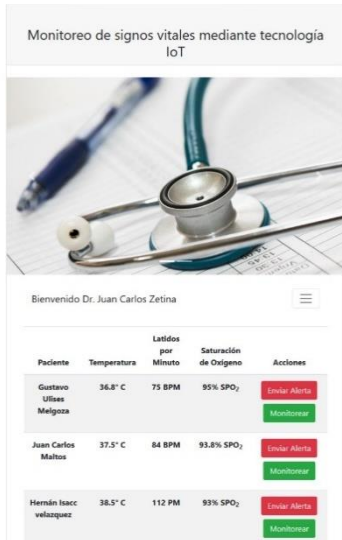


Figure 19 Position of electrocardiogram connections  
(Prepared by the authors)

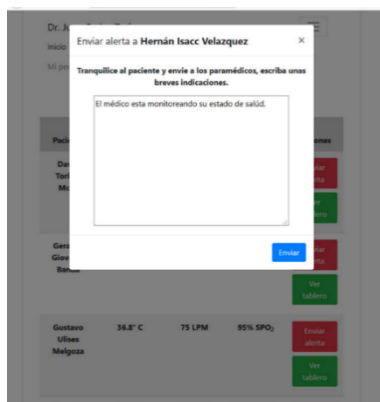
**Application of the System and its functions**

The software system developed consists of a web application that performs the control, acquisition and processing of data, and updates the system in real time, allowing the doctor to immediately have the current information of the patients. In figure 20, the medical screen is presented, where the doctor can immediately see the situation of the patients, facilitating instant attention to the patient who requires it. It is possible to view and search information in alphabetical order and visualize the name of the patient, along with the reading of each of their vital signs.



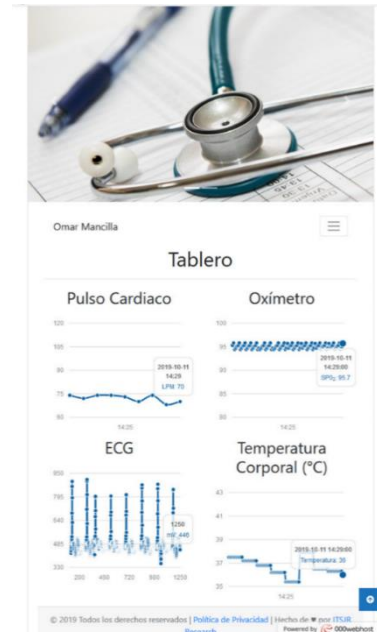
**Figure 20** Medical Screen  
*Prepared by the authors*

Also, a red action option (red button) was implemented to send the patient's relative an immediate indication regarded as necessary at that time, figure 21.



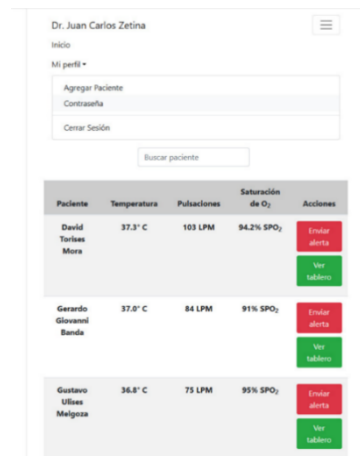
**Figure 21** Sending a message to the patient's caregiver  
*Prepared by the authors*

Likewise, a green action (green button) appears to access the historical situation of each patient (figure 22).



**Figure 22** Patient History  
*Prepared by the authors*

The medical screen (figure 20) has a drop-down menu as shown in figure 23, for changing passwords, logging out or adding patients.

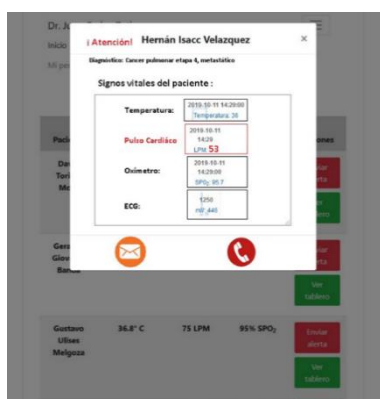


**Figure 23** Medical-screen drop-down menu  
*Prepared by the authors*

On the other hand, on the patient's screen it is possible to see the personal data and graphs of the behaviour of the readings of the sensors connected to them, as it is seen from the doctor's application, (figure 24).

**Figure 24** Patient Information  
Prepared by the authors

The important part of the patient is that when any sensor detects an abnormal reading, it sends an immediate alert (in real time) to the doctor, requesting instant attention, (figure 25).



**Figure 25** Alert the doctor, requesting immediate attention to the patient  
Prepared by the authors

By means of the previous request, the doctor can send indications to the patient's family member, thus making them know that if the doctor does not observe any extra indications, it means that the patient is as well attended and comfortable as possible.

## Results

Table 3 shows the values received from each patient in real time, the latency time is not significant, the continuous readings of the sensors are presented to the doctor in maximum three minutes; it has been observed that the transmission of the reading of each vital sign is immediate.

Patient ID	Date	Hour	Arduino	MongoDB	Web
10025	11/10/19	14:21	14:21:05	14:21:05	14:21:08
10045	11/10/19	14:21	14:21:05	14:21:05	14:21:08
10063	11/10/19	14:21	14:21:05	14:21:05	14:21:08
11247	11/10/19	14:21	14:21:05	14:21:05	14:21:08
11533	11/10/19	14:21	14:21:05	14:21:05	14:21:08
157	11/10/19	14:21	14:21:05	14:21:05	14:21:08
2154	11/10/19	14:21	14:21:05	14:21:05	14:21:08
68	11/10/19	14:21	14:21:05	14:21:05	14:21:08
5473	11/10/19	14:21	14:21:05	14:21:05	14:21:08
7001	11/10/19	14:21	14:21:05	14:21:05	14:21:08
821	11/10/19	14:21	14:21:05	14:21:05	14:21:08
10025	11/10/19	14:22	14:22:05	14:22:05	14:22:08
10045	11/10/19	14:22	14:22:05	14:22:05	14:22:08
10063	11/10/19	14:22	14:22:05	14:22:05	14:22:08
11247	11/10/19	14:22	14:22:05	14:22:05	14:22:08
11533	11/10/19	14:22	14:22:05	14:22:05	14:22:08
157	11/10/19	14:22	14:22:05	14:22:05	14:22:08
2154	11/10/19	14:22	14:22:05	14:22:05	14:22:08
68	11/10/19	14:22	14:22:05	14:22:05	14:22:08
5473	11/10/19	14:22	14:22:05	14:22:05	14:22:08
7001	11/10/19	14:22	14:22:05	14:22:05	14:22:08
821	11/10/19	14:22	14:22:05	14:22:05	14:22:08
10025	11/10/19	14:23	14:23:05	14:23:05	14:23:08
10045	11/10/19	14:23	14:23:05	14:23:05	14:23:08
10063	11/10/19	14:23	14:23:05	14:23:05	14:23:08
11247	11/10/19	14:23	14:23:05	14:23:05	14:23:08
11533	11/10/19	14:23	14:23:05	14:23:05	14:23:08
157	11/10/19	14:23	14:23:05	14:23:05	14:23:08
2154	11/10/19	14:23	14:23:05	14:23:05	14:23:08
68	11/10/19	14:23	14:23:05	14:23:05	14:23:08
5473	11/10/19	14:23	14:23:05	14:23:05	14:23:08
7001	11/10/19	14:23	14:23:05	14:23:05	14:23:08
821	11/10/19	14:23	14:23:05	14:23:05	14:23:08

**Table 3** Real-time value figures  
Prepared by the authors

It is evident that the execution of this system is done in real time, the reception of alerts and data could only be affected by the behavior of communication networks, and not by the system developed in this investigation.

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## Conclusions

The care required for the patients characterized in this research is decisive and must be immediate, to ensure the best possible quality of life. Patients and their families often have uncertainty about whether they are being cared for in a timely and appropriate manner at this late stage of life.

Having full confidence that patients are receiving the best physical care can help them live more fully, and thus better manage the emotional side of their situation.

Through the use of this tool for monitoring patients in real time with the immediate attention of the treating physician, family members assigned to the patient's care can be sure that the best medical attention is received, freeing them from stress about any unexpected situation they might face derived from the patient's illness, and allowing them to have timely information in real time about what measures to take when the patient requires some type of assistance.

The development of this work certainly includes only a few sensors for monitoring the patient, however, we considered all sensors suitable for reading the vital signs of patients and in a later work, we propose to incorporate them and thus complement the prototype, seeking to detect any present situation for real time assistance for the patient in terminal phase.

According to medical comments, this tool will diminish the tension of the doctor when trying to offer care and attention to this type of patients. Family members gain the advantage that the physician is continuously monitoring their patient's health parameters.

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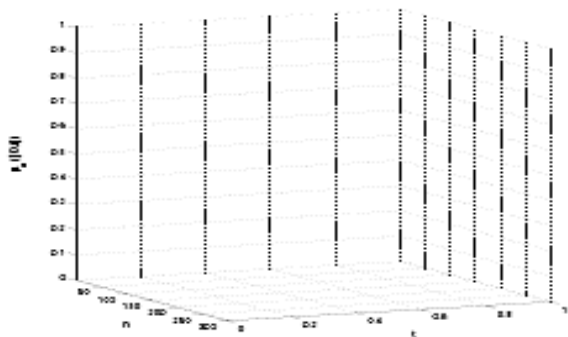
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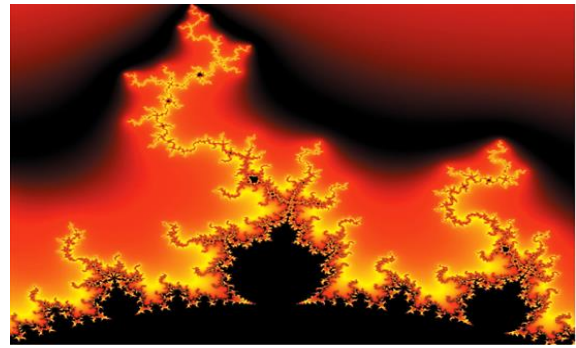
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