

# **Computing and Telematics**

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# Research in Computing Science

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# Computing and Telematics

**Roberto Zagal**  
**Félix Mata**  
**Carlos Hernández (eds.)**



Instituto Politécnico Nacional  
“La Técnica al Servicio de la Patria”



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## Editorial

The purpose of this volume is to present the recent advance in selected areas of Telematics. The papers were carefully chosen by the editorial board on the basis of the at least two reviews by the members of the reviewing committee or additional reviewers. The reviewers took into account the originality, scientific contribution to the field, soundness and technical quality of the papers. This volume contains papers on various topics of computing, telecommunications, image processing and security.

This volume contains 17 papers related to various aspects of the development and applications of Telematics, security, mobile and health computing.

This issue of Research in Computing Science will be useful for research-es and students working in the different areas of Telematics and Computer Science, as well as, for all reader interested you want to enrich your knowledge in this file.

In total, we received 25 paper that were submitted for evaluation; each submitted paper was reviewed by 2 independent members of the editorial board of the volume or additional reviewers. The acceptance rate is 59%. We would like express our gratitude to all people who help to elaborate this volume. Special thanks to UPIIG-IPN for their support. Also we want to give special recognition to the professors Angélica Beatriz Raya Rangel, Alexander Gelbukh, Grigori Sidorov and UPIITA for their support to achieve the success in the publication of this volume. The submission, reviewing, and selection process was supported for free by the EasyChair system, [www.EasyChair.org](http://www.EasyChair.org).

*Félix Mata,  
Carlos Nava  
Roberto Zagal*

Instituto Politécnico Nacional, Mexico  
Guest Editors



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# Development of the Electronic System for Obtaining the I-V and P-V Curves of Photovoltaic Module Using a Personal Computer

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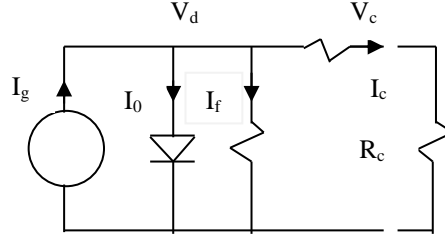
**Abstract.** The test, construction and design of an electronic system in order to measure the electrical characteristic curves of the photovoltaic (PV) module is reported, this electronic system reflects toward the PV module a variable resistance, sampling and capturing the PV module current and voltage, after using software the current and voltage signals are process in order to determinate the power, and also the PV module current- voltage and power voltage curves are gotten, This information is used for engineers who design PV systems to supplies electrical energy from sun energy to whatever equipment, the electronics circuit was made using electrical and electronics devices bought in México. Experimental results were done with 20 W. PV modules manufactured in CINVESTAV Mexico.

**Keywords:** Electronic system, photovoltaic module.

## 1 Introduction

The PV module is an electronic device which transform the visible light into direct current electrical energy, its output power depends of its area, incident light level, efficiency but it is reduced for temperature increase [1]. The PV module can be represented for its equivalent circuit (Fig. 1), considering its electrics parameters of resistance serial ( $R_s$ ), parallel ( $R_f$ ), link current throw ( $I_0$ ) rectifier diode, generated current ( $I_g$ ) output current ( $I_c$ ) and output voltage ( $V_c$ ) all of them are showed in Fig. 1.

From Fig.1 electric circuit, applying the Kirchhoff Laws, the equations of output current and power of the PV module are obtained [2], where T is the temperature and K is Boltzmann constant:

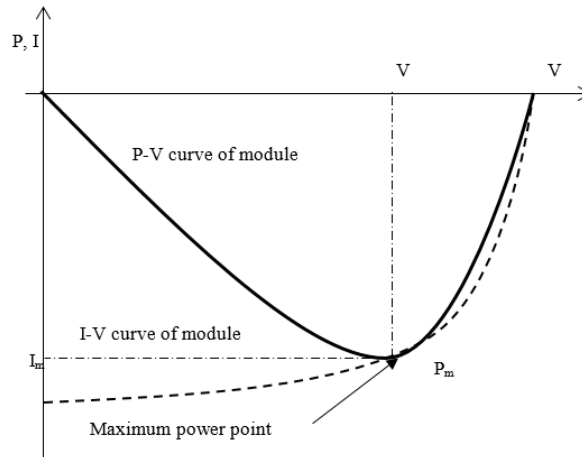


**Fig. 1.** PV module electric diagram.

$$I_c = -I_0 \left[ e^{\frac{q(V_c + I_c R_s)}{KT}} - 1 \right] + \frac{I_c R_s + V_c}{R_f} + I_g, \quad (1)$$

$$P_c = V_c \left[ I_g - I_0 \left( e^{\frac{q(V_c + I_c R_s)}{KT}} - 1 \right) - \frac{I_c R_s + V_c}{R_f} \right]. \quad (2)$$

When equations (1) and (2) are solved changing the values of output voltage  $V_c$  since the open circuit condition to short circuit condition, then all the values of power and voltage are obtained. When the current, voltage and power values are located in Cartesian coordinate system, then the current-voltage (I-V) and power –voltage (P-V) curves of the PV module are gotten (Fig. 2).



**Fig. 2.** I-V and P-V curves of PV module.

From Fig. 2 it is observed that the PV module has only a maximum power point, but in open circuit and short circuit conditions, the output power supplied by PV module is zero.

The most of PV modules are composed by 36 PV cells, they are connected in serial [4], its open circuit voltage is approximately 19 V, It is important to indicate that if the module temperature increases then its output voltage and power decreases [3], reported experimental results indicate the PV module temperature increases around 1.75 times than the local environmental temperature [2]. When PV module working temperature is greater than 25°C, its output power and voltage start decreasing, therefore it is necessary to measure on the installation place its Current- Voltage and Power-Voltage characteristic curve and also to measure its output current and voltage in order to determinate the power, but on remote place there is not electrical energy. Therefore it is necessary to design an interface electronic system to be connected between PV module and a laptop, which collects the data of current-voltage of PV module and then the laptop process the electronic information in order to determinate the PV module output power. In addition, the PV module power – voltage and current voltage are plotted and displayed for the laptop. The technical information gotten of the PV module is useful for the design engineer.

Some researchers have developed electronic systems in order to locate the power of PV modules. Henry Shu-Hung Chung et al. [5], detected the maximum power point of the solar panel connecting a pulse width modulate (PWM) and a converter direct current to direct current (DC/DC) between solar panel and battery. Miguel Goncalves Wanzeller et al. [6] developed a Current control loop for the tracking of maximum power point supplied by photovoltaic array, located the maximum power of the solar array, using a three phase static direct current converter to alternate current (DC/AC), but he did not consider the temperature. Also The PV module maximum power can be located using and capacitive impedance [7].

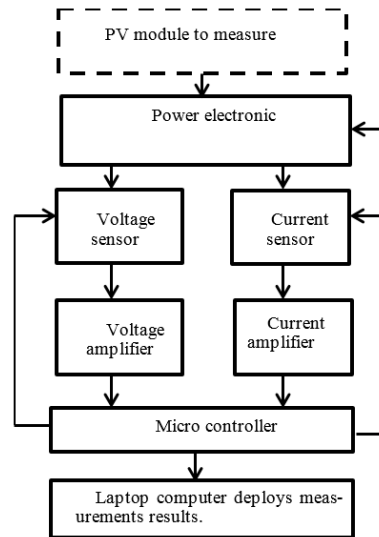
In this work, we developed a theoretical and experimental method to design an analogical and digital electronic system using a micro controller and laptop computer to obtain the current–voltage (I-V) and power – voltage (P-V) curves of the PV module, the equipment can be used to measure PV modules in the installation place.

## **2 Proposal**

The developed electronic system is integrated for: Drive circuit to Power MOSFET transistor, sensed electronic circuit of current (I) and voltage (V), two amplifier stages, microcontroller Arduino, synchrony circuit generator of triangle waveform, and laptop computer (Fig. 3).

The designed electronic system starts when the PV module is in open circuit condition, the laptop send to micro controller 5V pulse, then the Arduino send to analogue voltage starting since 0 V to drive circuit and this activates to MOSFET power transistor, which reflex variable resistance to PV module, then The PV module output current goes into the power transistor, at the same time, the current and voltage are sensed, amplified and sent to laptop PC throw microcontroller, The PC storage 500 samples of current and voltage during the process and detect when the PV module reach the short circuit condition, in this moment send 0V to drive circuit and power MOSFET transistor is turned off, the PV module goes back to open circuit condition. The computer storage all samples of current and voltage, after the laptop process the current and voltage electrical signals and obtain the power. Finally the current - voltage and

power - voltage curves of the PV module are plotted. And we can see all the values of power, voltage and current variables and the characteristic curve of the PV module.



**Fig. 3.** Block diagram of electronic system designed.

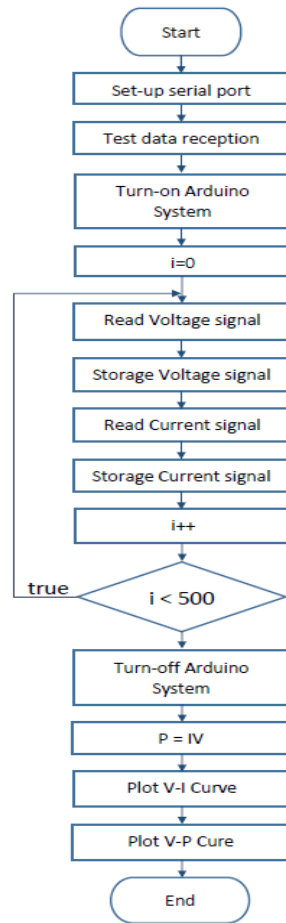
### 3 Software Design

For accessing the voltage and current signals, an Arduino electronic card was used between the developed electronic circuit and the PC, the program was developed using software, with the following logical. The voltage signals were processed using Matlab software with the laptop PC, an Arduino hardware, controlled for the PC, was used in order to capture the electrical signal of current and voltage from PV module and this is transferred to laptop computer, the which process the electrical signals and determinate the characteristic curve of the PV module. The software was designed guessing the following diagram (Fig. 4).

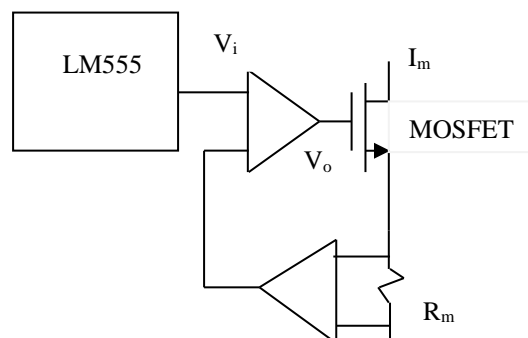
### 4 Electronic Design

The first stage designed was the power driver circuit (Fig. 5), using MOSFET power transistor [8] connected at two operational amplifiers to get output voltage ( $V_o$ ) linearity as function of input voltage ( $V_i$ ) of operational amplifier, the LM308 integrate circuit was used, this circuit is coupled at the PV module to drain its current  $I_m$  since open circuit to short circuit. Also triangle voltage generator was designed using CI555





**Fig. 4** Fluid diagram of the software.



**Fig. 5.** Blok diagram of power driver circuit.

The PV module current ( $I_m$ ) is sensed with  $R_m$  obtaining analogue voltage signal and it is amplified using a difference amplifier [9] whose output voltage  $V_{Im}$  for full scale is 5 V, the PV module voltage ( $V_m$ ) is attenuated with an inverter amplifier. The inverter amplifier adapts the output voltage of PV module from 20 to 5 V and the difference amplifier adapts  $R_m$  voltage as current sample, and its output voltage change from 0 to 5 V. as operational amplifier were used the integrated circuit TL081. The Arduino micro controller card was used to couple the voltage signals from amplifiers with the computer, this controller was selected because has two analogic digital converters, memory unit can be programmed from the computer and is much cheaper (Fig. 6).

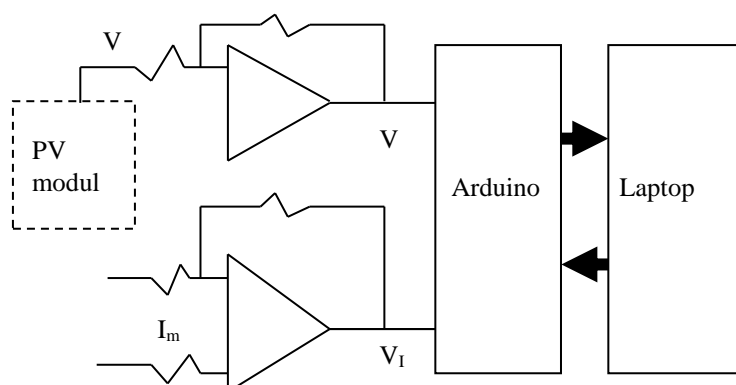


Fig. 6. Sense and amplification stage electronic circuit designed.

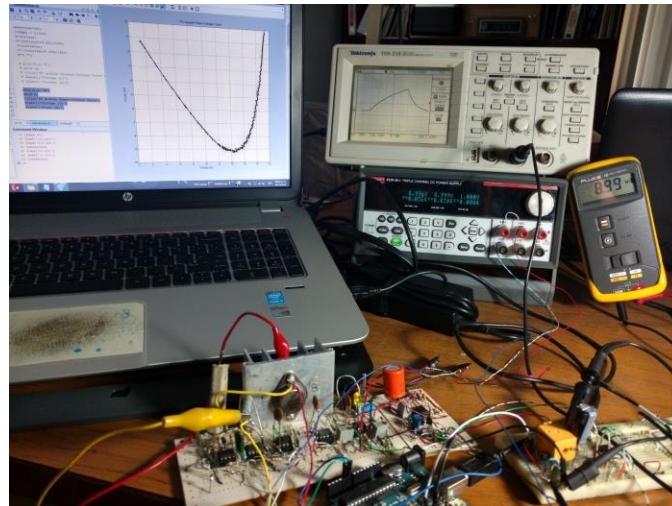
## 5 Implementation

All the electrical and electronic devices used to develop the designed electronic system were located in Mexico, also a printed circuit card was developed where the electronic devices were placed and connected, all resistances were of 0.25 W, BC 557 and CB547 were used for low voltage signal, the MOSFET power transistor N3055V was selected [10] because this drives up 6A and dissipates 90W and also a heat dissipater was used. The electronic system designed and developed (Fig. 7) was used together with an Arduino target UNO it has an ATMEGA328P microcontroller which has a 10 bits A/D converter. And also a laptop PC was used. The laboratory prototype is shown follow (Fig. 7).

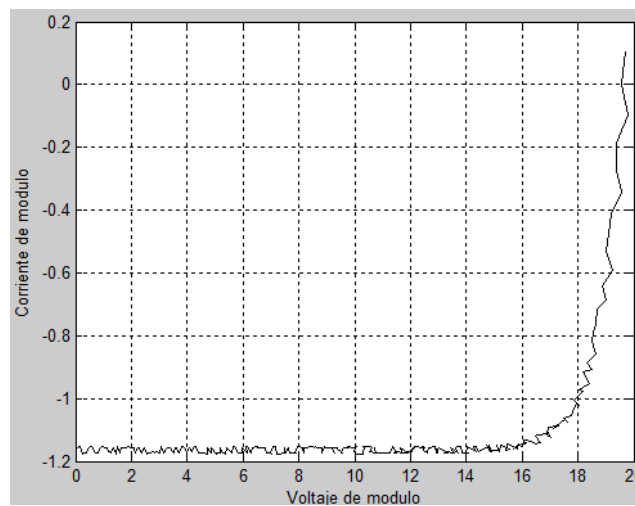
## 6 Previous measurements results

The measurements were done using a 20 W PV module done in CINVESTAV-IPN México. The PV module current-voltage curve was gotten (Fig.8), it was placed at natural solar light, at 13:00 hrs. In a sunny day, also the illumination level was measured and its value was about 820W/m<sup>2</sup>. The electronic system developed was tested

measuring its waveforms to output generator of triangle waveform and current amplifier output (Fig. 7). The PV module current – voltage characteristic curve was measured, the results are in Fig. 8.



**Fig. 7.** Developed Electronic system and waveforms Measurement.



**Fig. 8.** Current-voltage curve of PV module measured with electronic system developed.

Also the PV module power – voltage characteristic curve was gotten, but in this case the measurement was done with  $430\text{W/m}^2$  of illumination level, the result is in Fig. 9.

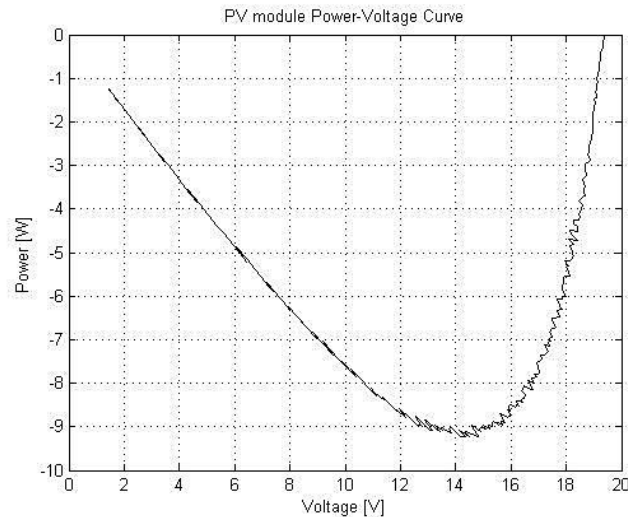


Fig. 9. PV module power–voltage curve gotten from developed prototype.

## 7 Conclusions

Upon experimental results, the electronic system developed and the software designed are working right, because the experimental results showed in Figs. 8 and 9 are agree with theoretical curves of the Fig. 2, all the electronic devices were located in México, the laboratory prototype developed is simple. Although a 20 W PV module was used, the measurement were done with real environmental conditions, then the illumination level was not with ideals conditions, then the power – voltage was measured when the level of illumination incident on the PV module was  $430\text{W/m}^2$ , for this reason the measured power of PV module in this conditions was only a round 9.1 W.

Finally we can said, the developed electronic system to measure the PV module is very simple, easy and cheaper and this can be used in any place where we need to install photovoltaic systems.

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# A Hybrid Approach Based on Cores-Clouds, STAR Methodology and Genetic Algorithms for Rules Extraction

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**Abstract.** The automatic extraction of rules during the search of information in a database (DB) is an important task in the discovery of knowledge, specially, when working with unstructured DB. This hybrid algorithm of unsupervised classification was based on combinatorial logic approach, conceptual clustering and genetic algorithms in order to identify relevant features and find out the semantic of the resulting classes. The algorithm was tested using a benchmark dataset which, with the immersed genetic algorithm gave  $\beta_0$  values from 0.78 to 0.92 for a covering of 100% within 9 rules. The use of CC-STAR-GA algorithm allowed inferring the minimum number of rules with maximum coverage and minimum intersection between classes into the DB. Finally, the algorithm performance was compared with the results of GAJA2 and ROUGH SET and results shows that this hybrid system could be an option for rule extraction.

**Keywords:** Automatic rules extractor, genetic algorithms, fuzzy classification, conceptual clustering, combinatorial logical approach.

## 1 Introduction

Commonly, in the expert systems, the human expert is responsible for deciding which variables are relevant to establish the classification rules. In this situation, the designer of the system requires quantitative information that the expert does not usually have or is not prepared to provide in an understandable way because there are many factors that are not always consciously considered when deciding to which class it belongs. Under

these conditions, the extraction of knowledge is hard to accomplish and time consuming [1].

The alternative to overcome these limitations is to free the expert of this task, through techniques that automatically search the most relevant variables from the evidence stored in databases, formulate rules that express persistent relationships in the data, analyze the information in order to discover semantic structures and, finally, extract knowledge from real and complex domains. Once the information is grouped and its structure is established, new patterns can be classified efficiently [2].

Some automatic classifiers, such as the neural networks or support vector machines, had showed a relevant performance with  $n$  dimensional sets of patterns in generating groups or classes based on the values associated to the variables in the databases, but they are unable to provide an explanation or comprehensible justification for the solutions they reach [3]. Therefore, decision trees are preferred in mining data because, besides the efficient classification, it is also important to discover the structure of the information regardless the type of the study domain. The main goal of these algorithms is to increase the accuracy in the classification of new patterns using previously generated rules. Nowadays, genetic algorithms are combined with basic rule extraction algorithms, such as C4.5 and SPRINT, and they show better accuracy than other decision tree algorithms, but their performance is determined by the database [4].

The aim of this paper is to present a hybrid methodology that combines a Cores-Clouds algorithm with a method based on the STAR methodology as well as the use of a genetic algorithm for optimizing the value of  $\beta_0$  threshold, which is an input parameter for the Cores-Clouds algorithm [5]. These techniques had proved their efficiency separately and with actual speed and memory improvement in hardware could be a viable option.

This paper is organized as follows: In section 2 a summarized description of the algorithms which were selected for this approach of rule generation and its evaluation technique is presented, the Cores-Clouds algorithm, basic STAR methodology, the genetic algorithm application and the validation index. The proposed hybrid algorithm, CC-STAR-GA, is detailed in section 3. The experimental results on a benchmark dataset to investigate the feasibility and validity of our proposed algorithm are shown in section 4 as well as the results of the hybrid algorithm performance and comparison with other algorithms were discussed. Conclusions and future work are presented in Section 5.

## **2 Preliminaries**

### **2.1 Clustering with Cores-Clouds Algorithm**

Clustering is an automatic process that assembles related information together. The grouping could be restricted or free unsupervised. The main difference is that the first considers an initial sample or a proposed number of classes, and the second does not. These types of groupings are called semantic clustering and they can be used to find structures.

The Cores-Clouds algorithm is a combination of clustering by density and hierarchical methods derived from the graphical representation of a covering or grouping patterns. Its main feature is that it considers crisp groupings (cores) and then



a fuzzy analysis in order to generate clusters, called clouds, which establish a membership degree of the different classes. This method is a significant support for generating classes and, consequently, for their interpretation.

The  $\beta_0$  value determines the accuracy for finding classes and rules from a specific database. Once a fixed  $\beta_0$  value is set, the structures (grouping) found for several grouping criteria are related and a hierarchy among the structures or groupings is generated. Then, the structures are organized from general to specific in a descendent order.

There are different types of restricted unsupervised groupings for the Cores-Clouds algorithm and, according to the criteria considered, they are classified as:  $\beta_0$ -connected grouping,  $\beta_0$ -compacted grouping, strictly  $\beta_0$ -compacted grouping and maximally  $\beta_0$ -completed grouping. Each type mentioned is calculated differently. The last two require more computational resources because of the number of combinations that are calculated in the process. The criteria of  $\beta_0$ -connected Cores and Clouds was used in this work because it requires minimum computer resources.

### 2.1.1 $\beta_0$ -Connected Core Section

Let  $\Omega$  be a universe of known objects,  $\Omega = \{O_1, \dots, O_n\}$ , and  $f$  a function of the differences between the patterns associated to each object that belongs to  $\Omega$ .  $\beta_0$  is a difference threshold and it is a real number in the codomain of  $f$ . Therefore, two objects  $O_i$  and  $O_j$  of  $\Omega$  are  $\beta_0$ -similar if and only if  $f(o_i, o_j) \geq \beta_0$ .  $NU$ , a subset of  $\Omega$ , is a  $\beta_0$ -connected core if and only if every pair of objects in the core are  $\beta_0$ -similar through their patterns.

The algorithm for computing cores with  $\beta_0$ -connected items is as follows: (1) the matrix of difference of each pair of patterns is calculated using any known technique, in this case a Euclidian distance [6]; then, it is normalized in a range from 0 to 1. (2) For each pattern, a new matrix is calculated with all new  $\beta_0$ -similar patterns ( $NB_j$ ); and finally, (3) patterns with intersection are joined.

### 2.1.2 Clouds $\beta_0$ -Connected Section

For each  $\beta_0$ -connected core ( $NU_j$ ) obtained with the  $\beta_0$ -connected core algorithm, a  $\beta_0$ -connected cloud ( $NB_j$ ) is computed using function  $\pi(o_i, NB_j)$  as the fuzzy membership function of all objects to each cloud where  $j = 1, \dots, r$  clouds or subsets, and  $i = 1, \dots, n$  patterns considered in the universe (as shown in equation 1).

$$\pi(o_i, NB_j) = \begin{cases} 1, & \text{if } NU_j = \{o_i\}, \\ \max_{\substack{o_p \in NU_j \\ o_p \neq o_i}} \{f(o_i, o_p)\}, & \text{otherwise,} \end{cases} \quad (1)$$

where  $o_p$  are patterns of the elements of the set  $\Omega$  and  $o_i$  is the pattern being evaluated,  $f$  is the difference function applied. In this case, all patterns belong to the cloud but with different degree of membership unless they belong to the core. If any group has only one pattern, then this object has a degree of membership of 1; otherwise, the maximum is considered with the maximal membership defined in the previous equation.

This part of the algorithm has four steps: (1) Compute the cores, (2) Define one cloud for each core; and (3) Generate the membership function and (4) compute the membership degree for each pattern of every defined cloud.

## 2.2 Conceptual Clustering: Star Methodology

The idea of grouping objects into categories described by concept was introduced by Michalski in the late 70s and early 80s [7]. The conceptual clustering proposes a structured space for forming the groups, and gives meaningful information about the relevance of belonging to the same group. This means that the methodology provides the features or concepts, which are defined by the attributes of objects that make up the groups, for these clusters. The aim is to create relations from the database attributes that have a meaning to the expert in the application area [8].

There are four basic concepts in this methodology: Selector, Complex, Coverage, and Seed. Selector allows obtaining information about an object. Its syntax is (Attribute, Operator, Values), where the attribute is a characteristic belonging to the pattern, the operator could be  $\{=, <, >, \geq, \leq\}$  and values are continuous or discrete, depending on the domain of each attribute, for example (Color = Blue). Complex is a combination of selectors. If the object is represented by a pattern, then each attribute could set a relationship, for example:  $l = \{(Color = Blue) \cup (Size = Big)\}$ . If all the elements of a set satisfy the definition of complex, then it is a complex set  $s_1$ , and if  $s_2$  is a set of a more generalized complex, then  $l_1 \subset l_2 \rightarrow s_1 \subset s_2$ . Similarly, a union is defined by  $l_1 \cup l_2 \rightarrow s_1 \cup s_2$  and a junction is  $l_1 \cap l_2 \rightarrow s_1 \cap s_2$ . In contrast, a disjunction is when  $s_1 \cap s_2 = \phi$ . The third concept is coverage of  $s_1$  with respect to  $s_2$ , so coverage is a disjunction of the complex set  $s_1$  and the complex set  $s_2$ . Finally, seed is an initial value of the attribute.

The STAR methodology is an inductive method used to find expressions that distinguish a specific group of data given a set with both, elements that satisfy the complex (positive examples) and elements that do not satisfy the complex (negative examples).  $E$  is a set of expressions that is generated for describing all positive examples but dismisses negative examples [9].

The STAR methodology can be summarized as follows:

1. Let  $E$  be the set of complex to deliver, initially  $E = \{\}$ .
2. Let  $L$  be a list of complex to be selected, initially  $L = \{\}$ .
3. Let  $S$  be the set of the selectors associated to the seed.
4. Do while  $L$  is not empty:
  - a. Create a set  $E'$  of complex created by the junction between the elements of  $L$  and  $S$ .
  - b. Remove from  $E'$  those elements that have been already included in  $E$ .
  - c. If a complex  $E'$  does not cover any negative example, add it to the complex  $E$ .
  - d. Update the  $L$  list with the remaining elements of set  $E'$ .
5. At the end of the algorithm, a set  $E$  is presented using the defined function of the lexicographic evaluation.

The lexicographic evaluation function (LEF) is defined by a sequence of the pairs (evaluation criteria, tolerance threshold). In order to select the best rules, each cluster

is evaluated with defined criteria and only those rules that meet the threshold of tolerance are retained [10]. In this case, the criteria was the maximum coverage with the minimum number of premises, so the number of positive examples covered was evaluated with a set of candidate rules and then the best rule was selected.

## 2.3 Genetic Algorithms

Genetic algorithms are adaptive algorithms intended to find the global optimal solution to a problem based on the emulation of the natural evolution process. The evolutionary techniques are characterized by using three basic operations (1) selection, which is in charge of selecting the individuals that will have an opportunity to reproduce and which ones will not; (2) crossover, which provides a mechanism to inherit characteristics to their offspring; and (3) mutation, which is a random deformation of the gene strings [11]. In genetic algorithms, a right balance between exploration and exploitation has to be obtained. Therefore, mutation operators are used primarily to provide exploration, and crossover operators are used to direct the population to a good solution (exploitation).

So, while the crossing attempts to converge to a specific point, the mutation does everything possible to avoid convergence in order to be able to explore more areas. Then, if the mutation rate is too high, the likelihood of seeking in more areas into the search space increases; however, this prevents population to converge to an optimal solution. On the other hand, if a mutation rate is too small, the resulted value could converge to a local optimum rather than to a global optimum [12]. In this work, the genetic algorithm was used for obtaining the threshold  $\beta_0$  of the difference function in order to have a better clustering. The performance of the selection was evaluated with the fitness function named index I.

### 2.3.1 Fitness Function

Index I is a cluster separation measurement with internal criteria which considered the compactness of the cloud and the maximum distance between clouds. It is used in the genetic algorithm as a fitness function that quantifies how optimal a solution which considered the  $\beta_0$  is. In this case, the result was the selection of an optimal chromosome whose bases will be combined; thus moving towards a new better generation of  $\beta_0$ .

Index I was composed by three factors that looked for a minimum number of classes  $K$  with the maximum coverage and it is defined as follows:

$$I(K) = \left( \frac{1}{K} * \frac{E_1}{E_K} * D_K \right)^p \text{ for } p \in N. \quad (2)$$

In the first factor  $1/K$ ,  $K$  was defined by the Core –Clouds clustering algorithm so if  $K$  increased,  $I(K)$  decreased. The factor Ratio  $E_1/E_k$  was the effect of the function of differences  $f$  for each cluster over the distribution of the entire dataset. So,  $E_1$  was a constant for the entire set and  $E_k$  was the measurement of the distance given by the group to a pattern  $o_i$ . If  $E_k$  decreased, then index I increased.

So  $E_k$  is defined by equation 3:

$$E_k = \sum_{i=1}^n \sum_{j=1}^k [f(o_i, h_j) \pi(o_i, C_j)], \quad (3)$$

where  $f(o_i, h_j)$  is the distance obtained with the difference function from the object  $o_i$  to the centroid  $h_j$  of each cluster and  $\pi(o_i, C_j)$  is the membership value of each object  $o_i$  to the cluster  $C_j$ .

The last factor,  $D_k$  was the maximum distance obtained between two different clusters, over all possible pairs obtained by their objects:

$$D_k = \max_{\substack{p, q=1 \dots k \\ p \neq q}} f(h_p, h_q). \quad (4)$$

The value of  $p$  was used to define the contrast between different clustering configurations. In this application, the  $p$  value was set to 2 because we were considering a Euclidean distance [13].

### 3 Development of the Hybrid Algorithm CC-STAR-GA

This section describes the methodology of the algorithm's design of the hybrid algorithm CC-STAR-GA. It is a combination of core cloud algorithm and STAR methodology used in order to reduce the computational time and work for the resolution of a task. It avoids the generation of the complex list to study on each iteration, and generates all the possible features and its combinations at the beginning. The input variables for this algorithm were the dataset to study, attribute selectors set, maximum number of seeds and type of distance to be computed. The genetic algorithm also requires predefining the number of individuals, chromosome size, maximal number of iterations, and crossover and mutation thresholds. The maximal number of iterations and the variations of the fitness function through each generation worked as stop conditions for the procedure that is detailed below.

1. Creation of an initial population of individuals,  $\beta_0$  value was computed with a random process.
2. Difference matrix was computed and normalized using the data set given.
3. Repeated until the stop condition was obtained:
  - a. Evaluation of each individual of the group using index I.
    - i. For each pattern vector,  $\beta_0$  - similar patterns were generated and concatenated when the patterns were intersected; thus creating cores.
    - ii. A cloud was generated for each computed core and it was considered a class  $C_j$ .
    - iii. Index I was computed as fitness function for the individual.
  - b. Selection of the best individual by means of the genetic operators. This individual was used in the next computation.
  - c. Generation of new individuals using crossover and mutation.
  - d. Replacement of the worst individuals of the population with new individuals.

*Intermediate results:* Cores and Clouds with best value of  $\beta_0$  given by the genetic algorithm that is described in steps 1 – 3.

4. Seed number per class randomly set and restricted by the predefined maximum number.
5. For the selection of the seeds, the objects into the generated cores with higher membership degree were chosen.
6. Complex list  $E$  to be delivered was initialized.
7. Each complex was evaluated in the Cloud and Core considered. Only complexes that accomplished the characterization of the positive examples of each class were maintained in the list.

*Final results:* Rules were listed considering the maximum coverage and the minimum of premises.

The rule evaluation was performed considering the following concepts about association analysis of the rules of each algorithm: Let  $P(X)$  be the probability of appearance of item  $X$  in a set of transactions  $D$  and let  $P(Y|X)$  be the conditional probability of appearance of item  $Y$  given item  $X$  appeared in  $D$ . If  $X, Y \subseteq I$ , which was a set of items, then  $support(X)$  was defined as the fraction of transactions  $T_i \in D$  such that  $X \subseteq T_i$ . If  $P(X) = support(X)$ , the support of a rule  $X \rightarrow Y$  was defined as  $support(X \rightarrow Y) = P(X \cup Y)$ . Then, an association rule  $X \rightarrow Y$  had a measure of reliability called  $confidence(X \rightarrow Y)$  which was defined as  $P(Y|X) = P(X \cup Y)/P(X) = support(X \cup Y)/support(X)$ .

A  $k$ -itemset with support above a minimum threshold was called frequent. We used a third significance metric for association rules called  $lift(X \rightarrow Y) = P(Y|X)/P(Y) = confidence(X \rightarrow Y)/support(Y)$ . Lift quantified the predictive power of  $X \rightarrow Y$  [14].

## 4 Results and Evaluation

The main purpose of the experiments was to gain an insight into the behaviour of CC-STAR-GA. In order to set the condition of this algorithm as rule generator, it was tested with a dataset of acute inflammation information provided by UCI, which is a machine learning repository [15]. This dataset contained 120 records with 6 attributes associated to the following symptoms: body temperature, continuous need to urinate, micturition pain, urethra swelling, lumbar pain, and occurrence of nausea; as well as 2 class attributes: inflammation of urinary bladder and nephritis of renal pelvis origin. This dataset was created for the diagnosis of acute inflammations of the urinary bladder.

First, some parameters were selected by an exploratory analysis going through the possible values in a linearly and bidirectional way in order to find the appropriate rates for this specific dataset, considering the exploration and exploitation observed along the process. Second, the hybrid algorithm proposed here was applied using the entire symptom dataset in order to extract the linguistic rules and to define the range of optimal values of  $\beta_0$ , which were obtained by the genetic algorithm. The analysis of  $\beta_0$  for this specific dataset was performed through index I and its value changes.

Third, the symptom dataset was randomly split into 10 pairs of training and testing sets. Each training set consisted of 63.2% of the dataset and each testing set consisted of the remaining 36.8%. The multiple confusion matrix was used to assess the quality of this structure considering the classes obtained through sensitivity, specificity, positive prediction value (PPV), negative prediction value (NPV), detection rate, detection prevalence, and balance accuracy, using CARET, a package of RStudio [16].

Finally, rules obtained with other algorithms and the same dataset were compared with the rules generated by the CC-STAR-GA algorithm. The concept of association analysis was used to evaluate the results of the comparison.

#### 4.1 Definition of the Optimal Range of $\beta_0$ and Pre-Setting

After the exploratory analysis of the performance of the genetic algorithm for this dataset, proper adjustments of the rate of mutation, crossover, and number of individuals in the initial population were performed. The parameters considered were (1) number of individuals = 6, (2) size of chromosome = 16, (3) maximum number of generations = 20 iterations, (4) mutation threshold = 0.001, and (5) crossing threshold 0.7. Figures 1 and 2 show the performance of the algorithm using the values obtained as explained above. It can be seen that  $\beta_0$  value converged in a range of 0.78 to 0.92 after 20 generations. The procedure was repeated 10 times to confirm the results. The mean  $\beta_0$  value for generation 20th was 0.856 with a SEM of 0.013.

#### 4.2 CC-STAR-GA Application

The evaluation of the fitness function, where the minimum value of index I is associated with experiment 'P2' and 'P4'; then the best grouping for these data had an index I of 0.065. Two tendencies were observed. The first group was around the mean value 0.197, which was associated to a local minimum; and the second, with a mean value 0.066, which was considered the global minimum.

#### 4.3 Generated Rules

Core-Cloud algorithm generated 9 classes and STAR methodology found 16 rules. They are the full set of decisive rules for each class found with the hybrid algorithm without any diagnosis available. After considering the presumptive diagnosis of two diseases of urinary systems: D1, inflammations of urinary bladder, and D2, nephritis of renal pelvis origin, this number of rules was reduced. The hybrid algorithm shows the full set of generated rules with maximum coverage and minimum premises, as an output of the program. But it is possible to further reduce the rules, selecting only one rule per class. So, Table 1 presents the reduced table of rules.

In the study case, the rules selected for this study covered completely all of the items of each class in this database even though only the rules that showed maximum coverage and fewer premises using the lexical function evaluation (LEF) were chosen. And it is possible to interpret the rules or give them a clinical meaning using the results shown in Table 1, for example, rule R5 can be transformed or interpreted as:

if LUMBAR PAIN IS NOT PRESENT and BURNING OF URETHRA is PRESENT then IT IS INFLAMMATION OF URINARY BLADDER and IT IS NOT NEPHRITIS OF RENAL PELVIS ORIGIN

The rules selected for this study covered completely all of the items of each class in this database even though only the rules that showed maximum coverage and fewer premises using the lexical function evaluation (LEF) were chosen (Table 2).

#### 4.4 Evaluation of CC-STAR-GA Algorithm

Overall accuracy rate with a 95% confidence interval was calculated. The total accuracy was 97.53% with a confidence interval from 91.36% to 99.7%. Table 8 lists the parameters that were commonly computed from the confusion matrix. It can be seen that sensitivity remained close to 1.0 for all classes, so almost all positive examples were correctly grouped. Specificity was 1.0, except for class 2, so almost all negative cases were discarded.

If the prevalence of the classes is considered [0.07 to 0.17], then the positive and negative predictive values went from 0.87 to 1.0. On the other hand, the false positive or negative assignment considered in the detection rate had a range of 0.07-0.18. Accuracy or error rate, determined by the effectiveness of the model to cover the data, went from 0.86 to 1 along the classes proposed.

**Table 1.** Rules after pruning per class using CC-STAR-GA algorithm for the Acute Inflammations dataset used.

CLASSES	RULES	
1	RU1	IF ((OCCURRENCE = 0) (LUMBAR = 1) (URINE = 0)) THEN D1=0, D2=0
2	RU2	IF ((LUMBAR = 0) (BURNING = 1)) THEN D1=1, D2=0
3	RU3	IF ((OCCURRENCE = 0) (MICTURITION = 1) (BURNING = 0)) THEN D1=1, D2=0
4	RU4	IF ((LUMBAR = 0) (URINE = 1) (MICTURITION = 0)) THEN D1=1, D2=0
5	RU5	IF ((MICTURITION = 0) (BURNING = 1)) THEN D1=0, D2=1
6	RU6	IF ((OCCURRENCE = 1) (BURNING = 1)) THEN D1=1, D2=1
7	RU7	IF ((OCCURRENCE = 1) (URINE = 1) (BURNING = 0)) THEN D1=1, D2=1
8	RU8	IF ((LUMBAR = 0) (URINE = 0)) THEN D1=0, D2=0
9	RU9	IF ((OCCURRENCE = 1) (URINE = 0)) THEN D1=0, D2=1

**Table 2.** Results of CC-STAR-GA for the acute inflammations dataset.

Classes	Number of items	Coverage	Premises	Number of rules*
1	20	20	3	4
2	20	20	2	1
3	10	10	3	2
4	10	10	3	2
5	21	21	2	1
6	9	9	2	1
7	10	10	3	2
8	10	10	2	1
9	10	10	2	2

**Table 3.** Statistics of the 9 classes obtained with CC-STAR-GA algorithm.

Metric / Class	1	2	3	4	5	6	7	8	9
Sensitivity	1.0	1.0	0.71	1.0	1.0	1.0	1.0	1.0	1.0
Specificity	1.0	0.97	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Positive Prediction Value	1.0	0.87	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Negative prediction Value	1.0	1.0	0.97	1.0	1.0	1.0	1.0	1.0	1.0
Prevalence	0.16	0.16	0.09	0.09	0.17	0.07	0.09	0.09	0.09
Detection Rate	0.16	0.16	0.06	0.09	0.17	0.07	0.09	0.09	0.09
Detection Prevalence	0.16	0.18	0.06	0.09	0.17	0.07	0.09	0.09	0.09
Balanced Accuracy	1.00	0.98	0.86	1.0	1.0	1.0	1.0	1.0	1.0

#### 4.5 Evaluation and Comparison of Generated Rules

The support, confidence, and lift of each rule that belonged to GAJA2, ROUGH SET and CC-STAR-GA were compared and results are presented in Table 4. We were interested in rules such as  $\text{lift}(X \rightarrow Y) > 1$  and  $c(X \rightarrow Y) = 1$ . Table 4 shows the support, confidence, and lift of each rule that belonged to GAJA2, ROUGH SET and CC-STAR-GA. We were interested in rules such as  $\text{lift}(X \rightarrow Y) > 1$  and  $c(X \rightarrow Y) = 1$ .

**Table 4.** Results of the association evaluation of the rules of each algorithm tested.

ALGORITHMS	RULES	$\sigma(X)$	$\sigma(Y)$	$\sigma(X \cup Y)$	$s(X)$	$s(Y)$	$s(X \rightarrow Y)$	$c(X \rightarrow Y)$	LIFT
GAJA2	R1	29	50	29	0.24	0.42	0.24	1.00	2.40
	R2	50	70	50	0.42	0.58	0.42	1.00	1.71
	R3	80	59	59	0.67	0.49	0.49	0.74*	1.50
	R4	40	61	40	0.33	0.51	0.33	1.00	1.97
ROUGH SET	RN1	30	30	30	0.25	0.25	0.25	1.00	4.00
	RN2	11	31	11	0.09	0.26	0.09	1.00	3.87
	RN3	34	31	18	0.28	0.26	0.15	0.53*	2.05
	RN4	30	40	30	0.25	0.33	0.25	1.00	3.00
	RN5	9	40	9	0.08	0.33	0.08	1.00	3.00
	RN6	16	19	16	0.13	0.16	0.13	1.00	6.32
CC-STAR-GA	RU1	20	30	20	0.17	0.25	0.17	1.00	4.00
	RU2	20	40	20	0.17	0.33	0.17	1.00	3.00
	RU3	10	40	10	0.08	0.33	0.08	1.00	3.00
	RU4	10	40	10	0.08	0.33	0.08	1.00	3.00
	RU5	21	31	21	0.18	0.26	0.18	1.00	3.87
	RU6	9	19	9	0.08	0.16	0.08	1.00	6.32
	RU7	10	19	10	0.08	0.16	0.08	1.00	6.32
	RU8	10	30	10	0.08	0.25	0.08	1.00	4.00
	RU9	10	31	10	0.08	0.26	0.08	1.00	3.87

\*Values with confidence less than 1.



The relevance of knowing the optimal value of  $\beta_0$  in order to generate structures for grouping and getting rules with total coverage was shown because otherwise there would have been a risk of finding rules that were unable to classify new patterns within a defined group. The genetic algorithm improved the efficiency for the extraction of the class as well as for the reduction of the number of premises required for a total coverage of the dataset. The results showed that it was possible to obtain a better coverage (up to 97.7%) with the hybrid algorithm.

The results of the CC-STAR-GA algorithm were compared with the results of GAJA2 [17] and ROUGH SET [18] because both algorithms use the same data set and present the rules generated. These results showed that the number of rules obtained with CC-STAR-GA (9 rules) were more than with GAJA2, which found 4 rules, and with ROUGH SET algorithm, which found 6 rules. The rules proposed by the algorithm CC-STAR-GA had an accuracy and coverage from 97% to 100%, while GAJA2 had a coverage from 65.83% to 82.5%, and ROUGH SET had a coverage above 95%. The confidence value was equal to 1 for all the rules generated for CC-STAR-GA, which means that the reliability of the inference made by each rule was higher than the results obtained with the other algorithms. The lift value was more than 3 for each rule of CC-STAR-GA, even though we were just looking for a lift superior to 1. To sum up, all the rules in the algorithm CC-STAR-GA were potentially useful for predicting the consequent in future sets.

## 5 Conclusions

This work presents the performance of the algorithm CC-STAR-GA under an unsupervised search where the main objective is to look for classes that allow inferring new knowledge about the relationship among the attributes in a dataset. Automatic generation of rules as well as optimal definition of the number of premises has been an achieved goal because it was possible to define relations into the structure and type of information of the database. Besides, in a supervised case, the hybrid algorithm managed to find a grouping structure that provided a minimum distance of groups and a maximum distance between groups with the help of the value of the optimized  $\beta_0$  given by the genetic algorithm. Once a range of optimal  $\beta_0$  was defined, the rules obtained showed no intersections on their premises and covered completely each group's pattern.

The evaluation showed a good performance of the algorithm CC-STAR-GA with this case of study. Previously, used techniques had proved their efficiency separately and considering actual speed and memory improvement in hardware, this hybrid system could be a viable option for rule extraction in unstructured databases. CC-STAR-GA algorithm could be a part of a predicting system based on knowledge such as a learning machines or decision support systems contributing with structure information.

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# Hybrid Transmission Scheme for the Cluster Formation in Wireless Sensor Networks with Noisy Channels

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**Abstract.** In this paper, we study the performance of an adaptive and fixed transmission schemes where the transmission probability varies according to the evolution of the cluster formation procedure or is fixed for the entire network lifetime, respectively. Also, we propose a hybrid scheme where the transmission probability can either be fixed or adaptive according to the system's conditions. In order to characterize the performance of the proposed scheme, we present a study under non-ideal conditions where noise, interference and fading are present.

**Keywords:** Hybrid transmission probability, adaptive transmission probability, wireless sensors networks, clustering, channel errors.

## 1 Introduction

Wireless Sensors Networks (WSNs) are composed by nodes distributed over certain region of interest with the objective of collecting information, typically, physical data. Such information is transmitted to, at least, one base station or sink node by mean of wireless links [1,2,4].

The clustering techniques have shown its benefits in many applications like data classification, networks, among others [7,?]. LEACH [5] is a commonly used clustering protocol where a certain number of clusters are formed, each with a node called cluster head (CH) who gathers the information from the cluster members (CMs) and sends it directly to the sink node. This technique reduces high range transmissions which demand a higher energy consumption to reach the sink through enabling the CH nodes as local sinks. Thus the role of nodes acting as either CHs or CMs is rotated throughout the operation of the network in order to avoid a fast energy depletion of nodes acting as CHs by the continuous reception of data.

Cluster-based protocols are composed by two phases: Cluster Formation Phase (CFP) and Steady State Phase (SSP). In the former case, the nodes compete to sharing its own information in order to be discovered in the network and create the clusters. In the last one, the clusters have formed and each node

has assigned to a specific slot to send its collected information periodically to its respective CH in a contending-free scheme based on TDMA. Indeed, since the nodes transmit data continuously, resources are not wasted as each time slot is used by a particular sensor node inside the cluster. Conversely, at the cluster formation procedure, a random access protocol based on the NP/CSMA protocol is used [6,8].

Since transmissions by each node in CFP only occur at certain moments of whole the process, it is not practical to assign fixed resource to specific nodes. Therefore, it is essential to carefully select the parameters of the random access protocol in order to maintain an acceptable operation of the network in terms of energy consumption and reporting latency.

In this work, we study the impact of the transmission probability of nodes focusing on three transmission probability strategies: fixed, adaptive and hybrid that can be used in a noisy channel in order to improve the performance of the system. In this sense the analysis is based on the reduction of the energy consumed and the cluster formation time, comparing each one under the same parameters. Since the analysis presented here focuses on studying the transmission probability in the random access transmissions in noisy channels, the results can be easily extended to any clustering protocol such as HEED [10].

The rest of the paper is organized as follows. In section 2 we present the system model, the clustering scheme, the adaptive transmission scheme, the hybrid scheme and the general assumptions. Then, in Section 3, we describe the parameters used in order to analyze the proposed protocol and in Section 4 we present numerical results that characterize the overall performance of the WSN. Finally, Section 5 presents the conclusions.

## 2 System Model

The cluster formation phase is the crucial state to the correct functioning of the network because it is the first step to organize the network. Base on that, it is important to choose correct parameters to establishing the network.

Independently of what algorithm to build the clusters is chosen, each node have to transmit a *Hello Package* (HP) with its own data in order to be discovered in the network. The main issue is that those transmissions are done inside a contending scheme, therefore a set of collisions and wasted time slots are susceptible to occur because there is no assigned specific resources for nodes. Specifically, all nodes that have not successfully transmitted their HP transmit in each time slot with probability  $\tau$ .

Additionally, the nodes have to deal with the errors that are present in wireless channels like noise, fading or interferences. These errors are the cause of miss detections and overhearing errors [3]. Building from this, the effect of a noisy channel in the packet transmission is modeled as two types of error probabilities: False Positive Probability (Pe+) which means that the sink detected a successful transmission that in fact did not happened, and False Negative Probability (Pe-)

when a successful transmission is not detected by the sink due to fading channels or to obstacles or noise in the transmission trajectory.

Then, the system performance is studied for a wide range of these error probabilities. As its name describes, in Fixed Transmission Scheme (FTS), the value of  $\tau$  is the same for all the nodes along the network lifetime. Under this assumption, each node will transmit all the time with probability  $\tau = 1/N$ , where  $N$  is the initial number of nodes in the network.

In our Adaptive Transmission Scheme (ATS), the value of  $\tau$  is not fixed, but rather it varies according to the number of nodes that have already transmitted their HP successfully. As such, at the beginning of the CFP, nodes transmit with a low value of  $\tau$  in order to reduce collisions, and it is increased at the end of this phase, since at this point, there are only a few nodes attempting to do a transmission. Note that a low value of  $\tau$  at the end of the cluster formation phase entails a longer number of empty time slots and hence unnecessary energy consumption due to long idle listening times. From this, we noticed that an ATS can set the value of  $\tau$  in such a way that it is inversely proportional to the number of nodes attempting to transmit. For each HP successfully received at the sink, the sink sends an ACK packet indicating to all the network that a node has been correctly detected in the cluster formation procedure. Then, all nodes in the system can calculate the current transmission probability  $\tau$  value as  $\tau_A = 1/n'$ , where  $n'$  is the estimation of nodes attempting to transmit. And the initial value is  $\tau_A = 1/N$ .

The main disadvantage of this scheme is that, in a noisy channel, the actual number of nodes may be considerably different than the number of nodes estimated in the system. Consider the case where the sink estimates a valid HP when in fact no node transmitted. This case can occur when a interfering neighbor network performed a transmission, that can happen with non-zero probability since the majority of WSNs are established in unlicensed frequency that are commonly saturated by WiFi, bluetooth users or even other sensor networks. In this case, the transmission probability is increased while the number of nodes remained unchanged, causing a higher collision probability scenario. If this happens many times in a short period of time, the performance of the system can be seriously degraded due to the high number of collisions, as we have witnessed in our experiments.

Note the case where the estimated number of remaining nodes is one. Then, the value of  $\tau_A$  would also be one. In this case, if there are at least two nodes trying to transmit, they will do so with probability one in all subsequent time slots, generating collisions with probability one and hence the clusters would never be formed and these two nodes will run out of energy. A simple solution is to establish a probability transmission threshold  $\tau_{th}$  (in this study it is fixed to 0.45)

In order to mitigate the previously mentioned effect of the channel errors in the adaptive scheme, we propose a Hybrid Transmission Scheme (HTS) that considers explicitly the presence of errors in the following manner: using ATS when the errors are low i.e.  $P_{e-}$  and  $P_{e+}$  are pretty small, and FTS when the

channel presents a burst of errors and both  $Pe^-$  and  $Pe^+$  are high.

The three schemes are studied under a channel that presents burst of errors as an abstraction of environments that does not have a constant behavior like a factory where power on engines causes a noisy channel, but those engines, or even some machines, are not working all the time. These events produce such burst of errors.

These bursts of errors are considered as a period of time in which the channel presents a probability of error relatively high for both false positive and false negative probabilities ( $PePmax$  and  $PeNmax$ ). The time between burst is exponentially distributed with mean  $1/\lambda$  and each burst has a random duration exponentially distributed with mean  $1/\mu$ . Notice that  $\lambda$  in Markovian systems is the arrives rate which indicates the mean speed in that the clients arrive to the system, in this context,  $\lambda$  is the velocity in which the error busts arrive to the channel. It is important to note that the time intervals between two periods of high error is considered as a low-error probability period in which both false positive and false negative error probabilities are small ( $PePmin$  and  $PeNmin$ ).

### 3 System Parameters

In order to study the performance of these schemes, we performed extensive simulations to observe the network behavior. The system is evaluated through the average energy consumption and the cluster formation delay (cluster formation time) as performance metrics. Also, we considered different network conditions in terms of the number of nodes, probabilities of false positive and false negative errors and value of  $\lambda$  and  $\mu$  for error bursts.

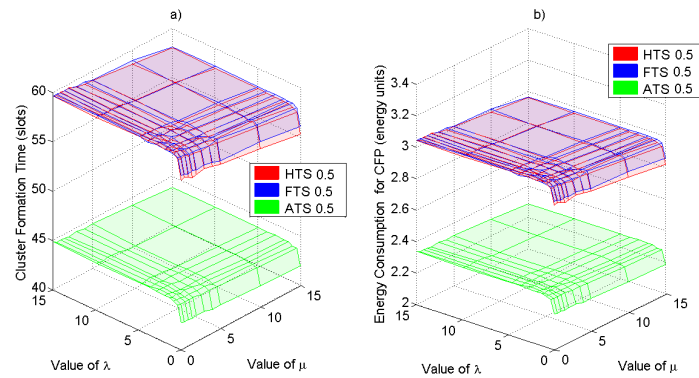
To evaluate the energy consumption we used the following model: Whenever a node performs a transmission it consumes  $E_{tx}$  units of energy, while for any reception each node consumes  $E_{rx}$  units of energy. It is important to emphasize that we assume that the nodes have a single transmission and reception power level. Note that the simplicity of this model allows to describe practical scenarios because the respective values of  $E_{tx}$  and  $E_{rx}$  can be obtained from direct measurements of the energy consumed in commercial devices. In this work is considered the relation of energy consumed by a transceiver MRF24J40MA [9] such that is  $E_{tx} = 1.2E_{rx}$ . Note that this value is used just as reference. The main parameters of the system are given in Table (I).

**Table 1.** System Parameters.

Parameter	Value
Network area	100 square meters
N (Nodes in the network)	5, 20, 50, 100
Value of $PePmax$ and $PeNmax$	0.1, 0.2, 0.5
Value of $PePmin$ and $PeNmin$	0.01
Energy consumption	$E_r = 0.01$ units, $E_t = 0.012$ units
Value of $\lambda$ and $\mu$	.1, .5, 1, 1.5, 2, 3, 4, 5, 10, 15

## 4 Numerical Results

Through the performance of many simulations, we obtained the following results: Fig. 1 shows the system performance with 5 nodes in the network and 0.5 of maximum error probabilities in terms of cluster formation time (a) and the average energy consumption (b). As it shows, the best results, lowest energy consumption and cluster formation times are for the ATS followed by HTS that, in fact, is lightly better than the FTS which had the worse performance. Notice that the system's performance is not affected by the duration of the error bursts.

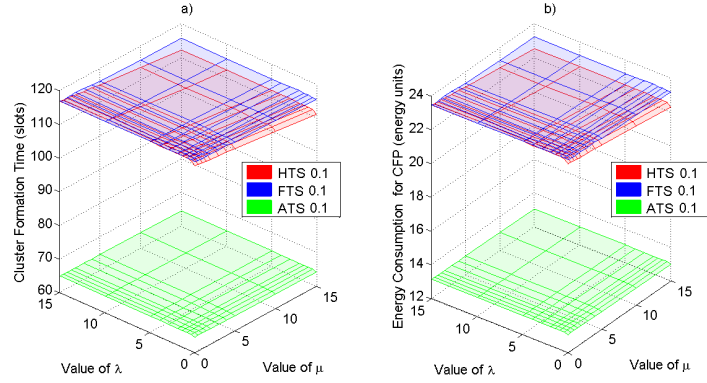


**Fig. 1.** a) Cluster formation time, b) Energy Consumption for 5 nodes network,  $PeP_{max}=PeN_{max}=0.5$ .

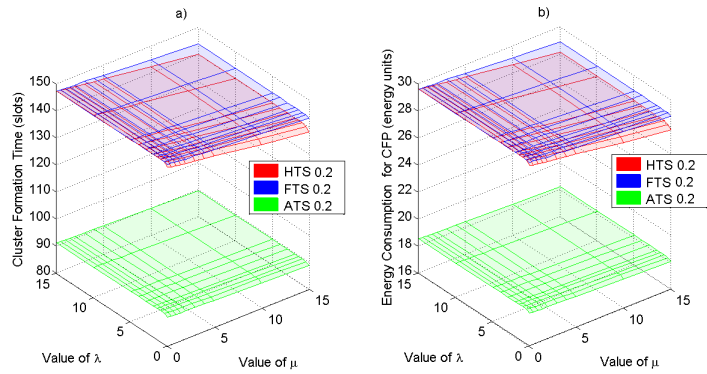
Fig. 2 and Fig. 3 keep the same behavior but with a higher delay and energy consumption levels. Such results were obtained for a 20 nodes network with maximum error probabilities of 0.1 and 0.2 respectively.

Up to this point, it is clear that ATS has better performance compared to FTS and HTS. Specifically, when the error probabilities in the system are relatively low (although a 0.5 value is considerably high), ATS is working in favorable conditions. However, when the error probability increases to 0.5 the same network changes its behavior regarding to each scheme, such that the best performance is obtained when it works under FTS followed closely by HTS, the last place was for ATS which has a worse performance than the two previous schemes and decrease as the length of the bursts increases. This result is shown in Fig. 4.

For more dense networks, the error presence has a higher impact in the system performance specially to whether it works with ATS and HTS. The results of a network with 50 nodes and maximum error probabilities of 0.1 are shown in Fig. 5 which presents a same form of the graph of the smaller networks and offering better results in ATS upon HTS and FTS. Note that it is more notable the improving of HTS for short error bursts.



**Fig. 2.** a) Cluster formation time, b) Energy Consumption for 20 nodes network, PePmax=PeNmax=0.1.

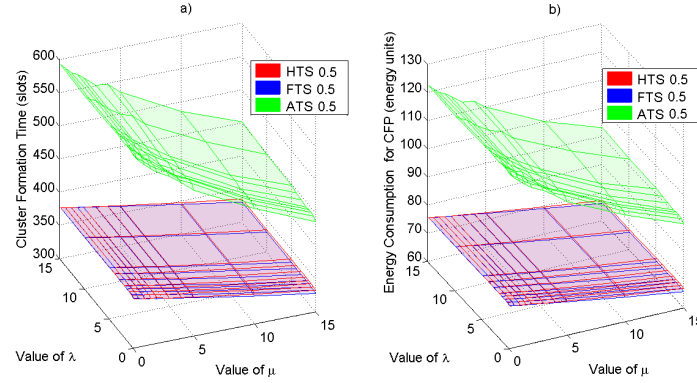


**Fig. 3.** a) Cluster formation time, b) Energy Consumption for 20 nodes network, PePmax=PeNmax=0.2.

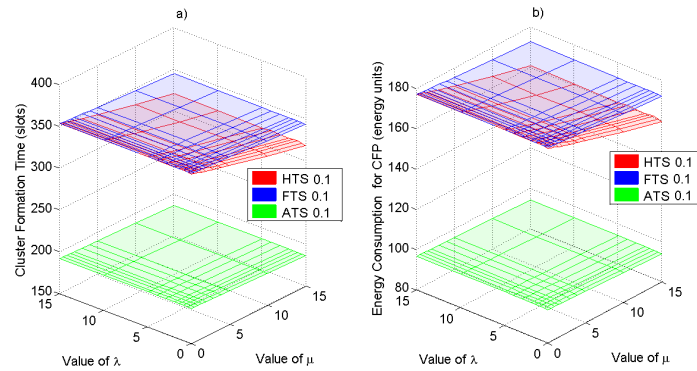
Fig. 6 and Fig. 7 show the results for the same 50 nodes network and maximum error probabilities of 0.2 and 0.5 respectively. The former shows the best performance for FTS followed by the HTS and ATS. It is important to observe that there is a cross point between ATS and HTS, i. e. for length of the error bursts with value of  $\mu \leq 5$  and values of  $\lambda \geq 10$ . HTS has a better performance upon ATS. The last case still shows the best performance to FTS, followed closely by HTS; ATS has the worse performance which decrease as the length of the error burst increase, namely, both energy consumption and cluster formation time increase as the value of  $\mu$  decrease.

The last study was developed for a network with 100 nodes and for maximum error probabilities of 0.1, 0.2 and 0.5. Fig. 8 shows the results for 0.1 of this network, where we observe that the best performance is for ATS and it is followed by the FTS. However HTS increases the energy consumption and the cluster





**Fig. 4.** a) Cluster formation time, b) Energy Consumption for 20 nodes network,  $PeP_{max}=PeN_{max}=0.5$ .



**Fig. 5.** a) Cluster formation time, b) Energy Consumption for 50 nodes network,  $PeP_{max}=PeN_{max}=0.1$ .

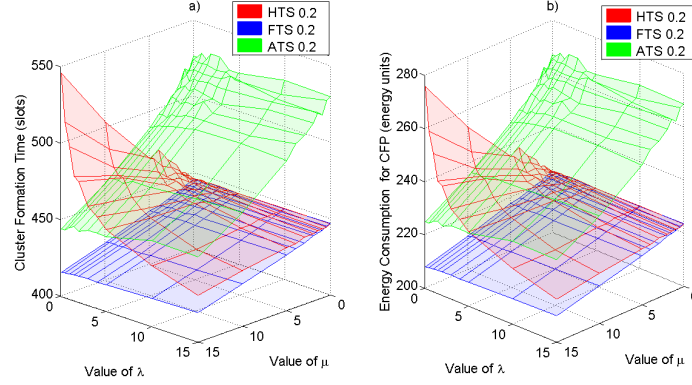
formation time as the bursts are more frequent and shorter, resulting as the worse scheme.

Finally, in Fig. 9, which corresponds to the 0.2 error probability results, clearly is observed that the best performance is for FTS and the worse is for ATS, independently of the value of  $\lambda$  and  $\mu$ .

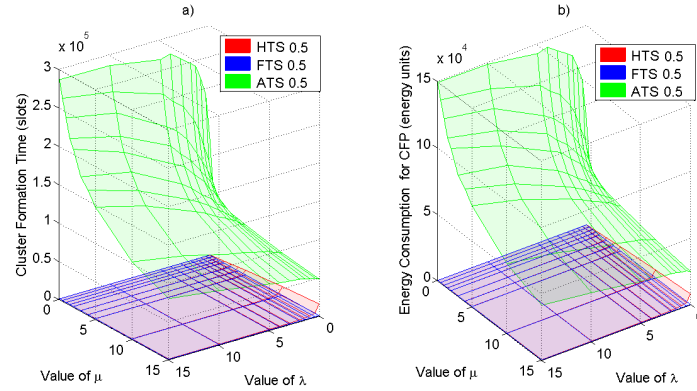
Note that this does not contain results for 0.5 since the performance is not acceptable with very high values of both energy consumption and cluster formation delay.

## 5 Conclusions

Through the results we observe that the number of nodes affects directly the system performance independently of errors in the channel and the scheme of



**Fig. 6.** a) Cluster formation time, b) Energy Consumption for 50 nodes network,  $PeP_{max}=PeN_{max}=0.2$ .

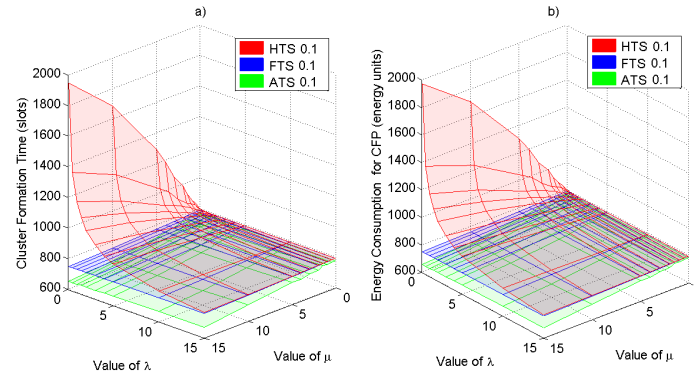


**Fig. 7.** a) Cluster formation time, b) Energy Consumption for 50 nodes network,  $PeP_{max}=PeN_{max}=0.5$ .

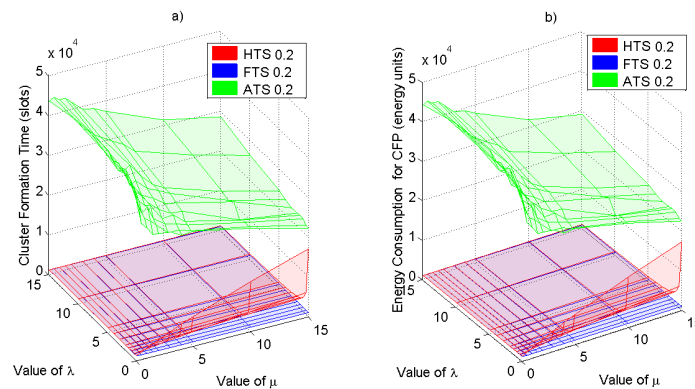
contending that is adopted, this is quite intuitively because as we have more nodes, we need more transmissions and consequently more energy consumption.

Observing the impact of errors, we note that the three schemes have a different behavior respectively to the error probabilities and the number of nodes. As we see, the adaptive scheme has the best performance as long as the probability  $PeP_{max}$  and  $PeN_{max} \leq 0.1$ , independently of the number of nodes. On the other hand, ATS is the best proposal for small networks less than 20 nodes and error probability of 0.5. This is because ATS estimates the current value of  $\tau_A$  based on the successful transmission, as the channel presents more error, the estimation will no longer be the adequate.

FTS has a better performance in networks larger than 20 nodes and error probabilities higher than 0.1. Comparing to the ATS, FTS is better under hostile channels with error probabilities higher than 0.1 because FTS does not change



**Fig. 8.** a) Cluster formation time, b) Energy Consumption for 100 nodes network,  $PeP_{max}=PeN_{max}=0.1$ .



**Fig. 9.** a) Cluster formation time, b) Energy Consumption for 100 nodes network,  $PeP_{max}=PeN_{max}=0.2$ .

the value of  $\tau$  and it is not affected by the error presences, in this way, it is no feasible that nodes transmit with a higher probability than the optimal which causes collisions and, consequently, wasted time slots.

Finally, HTS, has a behavior similar to FTS. Although in small networks and with less error probabilities HTS is lightly better than FTS, in large networks and bad transmission conditions is closely similar to FTS.

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## Experimental Information Management System with Creation of Questionnaire Using NoSQL Databases

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**Abstract.** This article presents the development of a computer system that through a Web application allows to manage information generated in a laboratory of signal acquisition and processing, where research studies were carried out monitoring electrical measurements. The on line management of the information allows users to share and access from different places. One of the most critical points in the management of this information is that the experimental protocols must be stored in a single way, thus a relational data base was proposed. On the other hand, the generation of different questionnaires associated to a protocol implies that database structure should consider different form and sizes so the use of a NoSQL database is proposed thus ensuring the system to upgrade and be adaptable to several kind of studies.

**Keywords:** NoSQL data base, structured data bases, clinical studies, dynamic questionnaires.

### 1 Introduction

The increase of information available from clinical studies, biomedical systems and evaluations, offers the opportunity to the clinical area personnel, to the investigators and to the students to carry out integral and complex studies in search of information that allows to prevent, treat and monitor diseases in a more efficient way. The obtained data from experimental protocols, where the data in question is generated by different people in different places, like hospitals, experimental laboratories, etcetera, requires of tools that can help in the study and processing of biological signals in an ubiquitous way.

This project is intended to provide an accessible solution through a system that manage information such as, the conditions before and during registry as well as

signal conditioning characteristics that determine the interpretation of those signals. This system is a tool that gives freedom to the specialist to create questionnaires for his/her specific area of research, creating his/her own questions and storing the answers associated to the patient for future analysis, once or several times.

## 2 Background

The great volumes of *Big Data* represent a challenge and an opportunity for the innovators and all those that worry about the information management. In the area of the health, the adequate management of *Big Data*, substantially increases the possibility of obtaining more effective knowledge on the sufferings and related symptoms on a great scale. Modelling and inferring on them are conditioned by the integrity and completeness of the information [2]. As an answer to the need of managing huge volumes of information appears the NoSQL Database System, term coined at the end of the 90s and which includes all the structured storage technologies which do not fulfil relational schema [4]. The term NoSQL has evolved not to stop using the SQL language, but to refer to systems which are no traditional SGBD (Data Bases Management Systems), and those which do not impose a data structure in the form of tables and the relationship among them, if not to provide a much more flexible scheme [6].

## 3 Description of the System

The present article shows the design and implementation of a biological signal storage system and the dynamic creation of questionnaires, the Protocol Management System (SAP) allows the management of clinical studies through a Web application. The solution was to integrate different technologies that allowed to obtain a system for storing the clinical studies and their protocols. The first part contemplates the gathering of the required general information from the person in charge of the study and the information about signal conditioning for its interpretation such as sampling frequency, type, number and duration of the records of the study, and solve it with a relational database. The second part, where the subject or patient will be interrogated one or several times about parameters related to his/her health condition. All of them have to be specific to the study. For example: duration of fasting, if he is taking drugs that could affect the signal response, etc.

Each question is defined by the author of the study and the software let him to choose the type of answer. This entails a problem in the design with relational databases. Reason why it was proposed to generate dynamically questionnaires which are store in a NoSQL Database. The person in charge, “responsible”, of the study will be able to generate and to select questions according to his/her knowledge and/or to the needs of the new study and then he creates the questionnaire. It was considered that the information should be analyzed by the experts in the area of study so the system considers the role named “physician”, who can consult and download the information of the studies through remote access and in order to safeguard the integrity of the system and to give maintenance to the same, the “administrator”

figure was created. The general structure appears in Figure 1 and in the following sections their elements will be discussed.

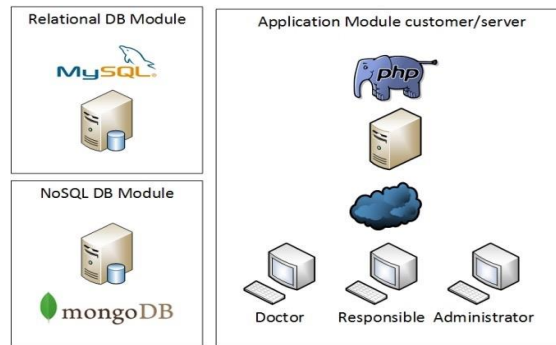


Fig. 1. Architecture of the SAP system.

### 3.1 Module 1: Relational Database

This model must guarantee that the data are represented in a unique and structured way, conformed by rows and columns [9], fulfilling the characteristics of atomicity and integrity of the data of the clinical protocols and of measurements, information of the patient, the responsible of the study and of the archives containing the signal records, because the information contained in the system must have a defined structure for example: archives txt and data files, that contain the relevant clinical information to the study, technical conditions of registration, etc., the administration was proposed through an URL storage and it was also implemented in the SGBD MySQL. The relational diagram of the database show in Figure. 2.

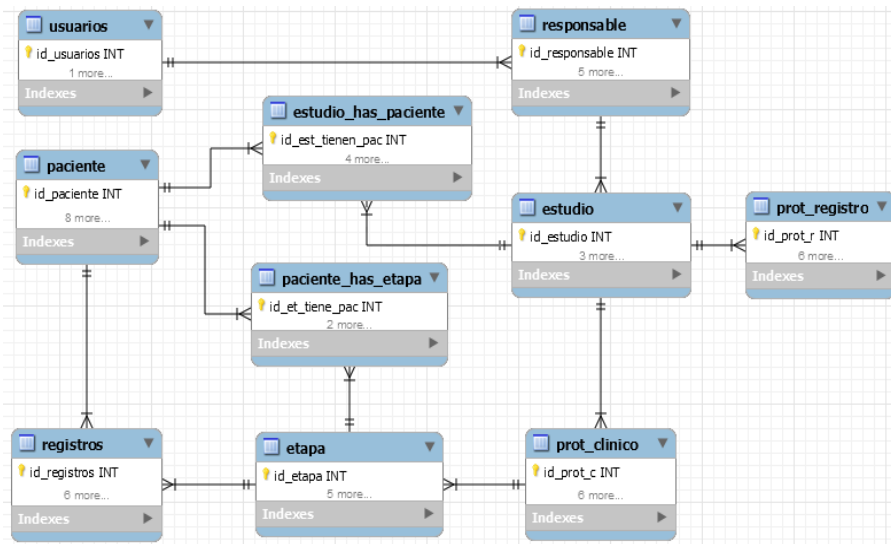
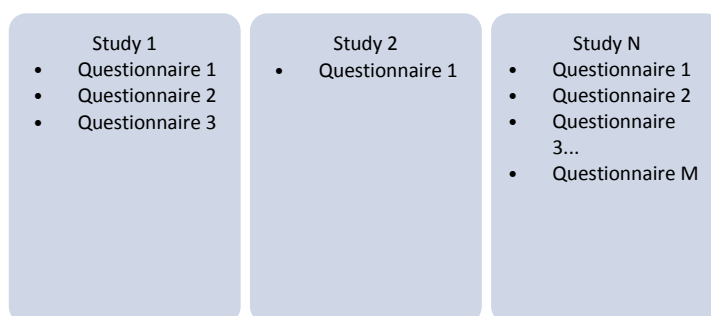


Fig. 2. Relational model database (diagram in Spanish).

### 3.2 Module 2: NoSQL Database (Not only SQL)

The application of the NoSQL Databases has experienced an important growth lately. The great flexibility which they offer and the possibilities of the optimisation in their designs according to the problem to be solve turn them into an attractive variant to consider to the management of information application developers at large scale [4]. For this system it was necessary to count on a tool that allows generating questionnaires for patients according to the clinical study and the specific protocol that is being carried out on him/her. This technical requirement conditioned the design and development of the system, so it required the creation of questionnaires with dynamic storage.



**Fig. 3.** Design of dynamic questionnaires for M patient in N where each questionnaire can have R questions.

As it is observed in Figure. 3, the questionnaires have different contents since each study can have N questionnaires, each questionnaire R questions that can be answered with an open answer as well as selected into multiple option, and these as well can be answered by M participants in the study. This technical requirement conditioned the design and development of the system, so it required the creation of questionnaires with dynamic storage. It was decided to use the NoSQL Databases oriented to documents, specifically MongoDB, using the category of key – value storage, in them a unique key is assigned (primary key) to a value that is typically an arbitrary chain. The operation of finding the associated value to a key is called “lookup” (indexing), and the relationship between a key and its value is called correlation (binding) [3].

### 3.3 Module 3: Web Interface

For this last module, the “backend” of the system was implemented in language PHP, whereas for “frontend” the HTML5, CSS3, Javascript and the jQuery bookstore languages were used. It was implemented in a HTTP web server of Apache open code installed on the operating system Ubuntu 14.04. Integration in this way allows to have a Web surrounding with the purpose of facilitating access to the information from the user’s place just with an Internet line and a navigating Web.

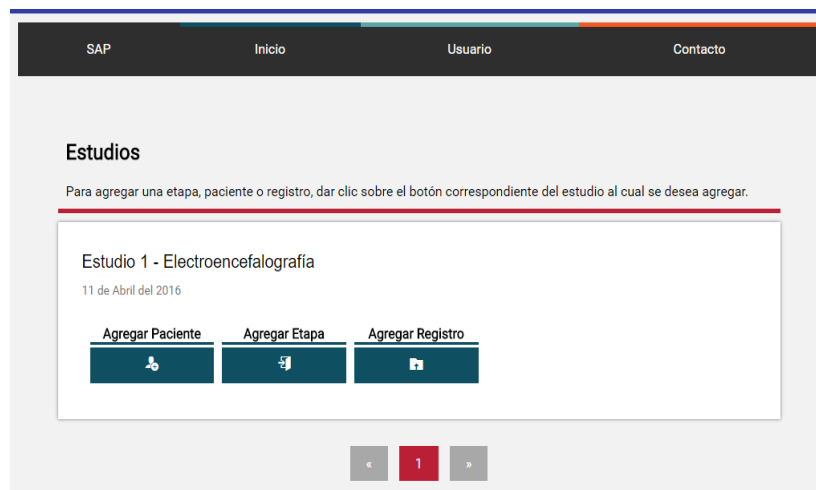
As the system will be used in a ubiquitous way by users with different types of needs, three types of roles were generated: administrator, responsible and physician.



In Table 1, the permissions for each one are described according to their needs. An example of the Web application interfaces is presented in Figure. 4. In this view, the user can edit the already registered studies, such as the stages, patient information and then he/she can add the records associated to that patient. All this information is stored in the SQL database.

**Table 1.** Users and permissions in the system.

Permission	Administrator	Responsible	Physician
To register new users	X		
To create studies		X	
To eliminate studies		X	
To see the existing studies		X	X
To unload archives of the study		X	X
To add registry archives		X	
To unload registry archives		X	X
To create questionnaire		X	
To respond questionnaire		X	



**Fig. 4.** Study editing interface (screenshot in Spanish).

In Figure. 5, it is shown the interface that displays all relevant information previously included as well as the dynamic questionnaires management module, which performs the administration of them consulting the NoSQL database.

## 4 Dynamic Questionnaires

Once the person in charge defines the characteristics of the study, he or she generates the recording procedure named recording protocol, the clinical protocol and the questionnaire(s) to be applied. This questionnaire can be answered whenever it is required meanwhile a recording session exists, so the design of the database must consider the answers associated to multiple applications of the questionnaires according to the number of proposed records.

The dynamism in the definition of the structure for each responsible user is obtained because this NoSQL Database is oriented to documents that are located with a particular key/value, each value can be a whole number, a chain of characters, an adjustment of values or even another document, these characteristics allowed to obtain the required dynamics in questionnaires in a simple and agile way [4].

**Información del estudio**

Estudio 1 - Electroencefalografia  
11 de Abril del 2016

Información del protocolo de registro

Línea de grabación:	Número de segmentos:	Frecuencia de muestreo:	Número de muestras:	Tiempo base:
22	7	5000 Hz	12	segundos

Información del protocolo clínico

Número de etapas:

2

Etapas

Pacientes

Pacientes

Cuestionarios

Haga clic en el nombre de algun cuestionario para editarlo

Nombre	Responder	Ver respuestas	Eliminar
Cuestionario 3	<input checked="" type="checkbox"/>	<a href="#">Ver</a>	<input checked="" type="checkbox"/>
Cuestionario1	<input checked="" type="checkbox"/>	<a href="#">Ver</a>	<input checked="" type="checkbox"/>

[Agregar Cuestionario](#)

**Fig. 5.** Study information view (screenshot in Spanish).

For the implementation MongoDB was used, [8] its name comes from “*humongous*”, gigantic and is a data base of open code based on JSON documents [5]. These documents have dynamic schemes, instead of the static tables of the SQL language, it has a format for data interchange similar to XML but with a simpler structure [1]. The document is the unit of storage of a JSON object.

In MongoDB, documents JSON are grouped in a collection. A collection is the equivalent to a DBMS relation. The JSON documents from same collection not necessarily become attached to the same scheme or configuration [1].

<p>Name: <i>Questionnaire 1</i></p> <p>Study: <i>1</i></p> <p>Question 1: <i>What is your occupation?</i></p> <p>Answer: _____</p> <p>Question 2: <i>How many hours does you use the computer continuously?</i></p> <p>a) <i>Less than a</i> b) <i>One</i> c) <i>More than two</i> d) <i>Three or more</i></p>
--

**Fig. 6.** Example of a questionnaire contained in the document type JSON.

The advantage obtained by choosing a NoSQL Database oriented to documents like MongoDB is that each questionnaire can be developed freely, without depending on the format of questionnaires that already exist within the collection of the database. In Figure. 6, a proposed questionnaire is exemplified and in Figure. 7, the modified structure for the JSON files that conform the data in MongoDB is presented.

Questionario 1	Questionario 2
<pre>"id_cuestionario" : 1, "pregunta1" : { "oracion" : "...?", "tipo" : "abierta" }, "pregunta2" : { "oracion" : "...?", "tipo" : "opcion_multiple" } }</pre>	<pre>"id_cuestionario" : 2, "pregunta1" : { "oracion" : "...?", "tipo" : "abierta" }, "pregunta2" : { "oracion" : "...?", "tipo" : "opcion_multiple" } }</pre>

**Fig. 7.** Json files belonging to a collection in the used NoSQL database (questionnaire in Spanish).

The number and type of questions could be different for each study but all of them will be grouped in a collection of files easily accessed.

## 5 Combination of Relational Database and NoSQL

The general architecture of the system is hybrid because it shows two databases with different structures, the relational and the oriented to NoSQL documents. When managing these two types of data bases in the same system, it was necessary to make a link between the identifiers of each study in the relational database with the respective questionnaires in the NoSQL Database. This was achieved using specific PHP sentences in the “*backend*” of the system.

The methodology used to link the identifiers between the two data bases is summarized in the following steps:

1) **Add a study**, implies to add all the information necessary to be kept in the relational database, thus obtaining this way a sole identifier (ID) or primary key for each stored study.

2) **Create a questionnaire**, through the Web application, the person in charge can generate questionnaires with the required characteristics, then they are stored in the NoSQL Database.

3) **Request of the identifier of the study**, subsequent to the creation of the questionnaire, it is required to assign it to a pre-existing clinical study in the system. For that an identifier of the said study is requested through consulting the SQL relational data system.

4) **Carry out a connection between the identifiers**, the system sends the identifier of the clinical study along with the rest of the other necessary data for the creation of a questionnaire to the NoSQL Database, then storing the identifier in a field of the questionnaire.

With the previous methodology it is achieved that the system is coherent and maintains the consistencies that the system demands between the clinical studies and their questionnaires.

## 4 Evaluation and Results

The application was lodged in the Web server and it can be consulted using any Web Navigator in the [www.lpssepi.upiita.ipn.mx](http://www.lpssepi.upiita.ipn.mx) page which it is administrated by the laboratory of instrumentation and processing of signal (LISP). The evaluations were made with a sample of: 1 user as administrator, 5 users as responsible role and 5 users as the physician role. All of them used SAP indistinctly in or outside the Institute during a week for generating and manage their studies. The participants recorded physiological signals logs and associated them to their clinical studies for further analysis. They used to generate non structured databases with general programming software such as Matlab®, Labview®, Excel® and they themselves are not Telematics professionals or similar, within an age range between 20 to 46, being the average age 39.

The procedure for the evaluation of the software entailed 1) A talk explaining the purpose and operation of the software, 2) Delivery of the User's Manual, 3) Delivery of instructions and questionnaire evaluation form, 4) Allocation of tasks according to Table 2.

**Table 2.** Activities made for the evaluation of software.

Administrator	<ol style="list-style-type: none"><li>1. You will have to register to 5 users in the system.</li><li>2. To consult the information of one of them.</li><li>3. It eliminates a user.</li></ol>
Person in charge	<ol style="list-style-type: none"><li>1. It generates a study</li><li>2. To create questionnaire</li><li>3. To add registry archives</li></ol>
Physician	<ol style="list-style-type: none"><li>1. To consult a clinical study with its registries</li></ol>

The criteria considered for the evaluation of software were: functionality and easy to use, technical support, performance, safety, integrity, availability, all of which were evaluated in a rank from 1 to 4, where the headings valued less than 3 should be

improved and all the headings with a value greater than 3, the user considered them as acceptable. 6 out of 10 users evaluated the performance of the program above 3. The results by characteristics are presented in Table 3.

**Table 3.** Results of the feedback of the evaluated characteristics of SAP.

Characteristics	To improve [Evaluation < 3]	Good performance [Evaluation >= 3]
Functionality and ease of use	2.66	
Support	2.35	
Performance		3.42
Safety		3.25
Availability		3.1

## 7 Discussion

Although specialized programs in generating software for an application of recording and generation of signals data bases already exist, like LABVIEW® or MATLAB® and it is a common practice that each person in charge of a study of signals, makes his/her own system of registry and saves it with the computing programs available to them and they do it using their own personal computers, it is unlikely that the information can be shared because they do not follow a saving standard. On the other hand, centers such as Physionet that manage a large number of recordings have public web services in order to share this information but it is necessary to cover certain specific requirements.

The proposed system used the two types of data bases in a transparent way to the end user through a Web application and in 100% of the cases where it was used, it achieved to generate the storage of clinical studies according to the set out requirements, the management of the data bases and it maintained its integrity. On the other hand in the results of the evaluation of the SAP system web application, it was observed that it fulfilled the expectations of 66% of the users, and further improvements were proposed. It is necessary that: 1) the administrator have access to all the information of the stored studies, 2) to extend the permissions in the information for the physicians, 3) due to the diversity in the user profiles, the documentary technical support of the system should be improved and reorganized, as well as to provide user's quick guide according to the role.

## 8 Conclusions

This proposal of application allowed to unify and standardize the type of relevant information in a follow up of the information management in an experimental laboratory where it is known that the size of the database will increase with time. The results demonstrated that the group, which evaluated the system, considered that SAP fulfils the expectations of managing the information on line and by different type of

users, not having to worry about the size and content of the archive generated by the study and about some particular characteristics such as the generation and management of the questions required by each one. In the technological development, it can be said that the use of NoSQL Databases to create health management systems is a good alternative, if the need is to cover the dynamic growth of the information without a defined structure of the data. Further work in web functionality and support is required but this type of hybrid systems has allowed to solve some of the dilemmas in managing databases in Big Data Systems.

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# Collaborative Multi-Source Scheme for Multimedia Content Distribution

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**Abstract.** Demand for multimedia contents has increased in recent years, and several distribution services have emerged. Many of these multimedia distribution services are based on central servers, which introduce several limitations related with costs, dependence, performance or scalability. This paper presents a collaborative scheme for multimedia content distribution. Collaborative infrastructures for multimedia services are critical because multimedia contents have an import consume of resources in the communication networks. P2P networks have emerged as promising solution to implement collaborative infrastructures. Multi-source schemes are a practical solution when different parts of multimedia content is generated or stored in two or more sites. We have used a P2P network to implement a practical distribution prototype of our collaborative multi-source scheme. Our evaluation shows as peers share storage capacity, contents and bandwidth capacity, while server is released from this workload.

**Keywords:** P2P networks, content distribution, distributed systems.

## 1 Introduction

During recent years, several content distribution infrastructures have emerged in response to high demand for multimedia contents. Most of these infrastructures have based on central servers, which present several limitations and present a reduced collaboration between requesting nodes. Because the multimedia content consumes a large amount of resources in a communication system, collaboration between requesting nodes play an important role. In this context, peer-to-peer (P2P) networks have emerged as practical solution for constructing collaborative infrastructures. P2P systems have generated great interest in the research community who find in these systems a fast and efficient way to deliver movies, music or software files [1, 14, 15]. In a P2P system, the users interact directly as a way to exchange their resources and services through the Internet. Multimedia content requires large storage spaces, and large multimedia contents (e.g. movies) often exceed the storage capacity of a personal device. Multi-source schemes are used in order to solve these requirements. Multi-source schemes are also required when content is generated from multiples sites. For

example, in soccer match. This paper reviews different content distribution schemes, and introduces a collaborative distribution scheme based on P2P networks. In a P2P network, a node can take the role of both a server and of a client at the same time. Thus, when a new peer arrives to the system, the demand in the system is increased, but the system's overall capacity is increased too. A P2P system distributes its load and duties between all participating peers, which is not possible in a system based on central servers.

P2P networks are becoming more and more popular today (they already generate most of the traffic in the Internet). For instance, P2P systems are very used for file sharing and distribution; some examples are Bittorrent [2], Tribbler [3], eMule [4], GridCast [11], etc. Main technical problem is that peers connect and disconnect with high frequencies, in an autonomous and completely asynchronous way. This means that the resources of the network as a whole are also highly variable, and thus, that the network must be robust face to these fluctuations. In order to face the high dynamicity of such a system, we explore a multi-path approach where (i) the stream is decomposed in some way into several flows; (ii) each client receives those flows following different paths and sent from different other clients.

On the other hand, in a multi-source scheme, each source can distribute different video sequences to all requesting peers. How much the source can redistribute depends on the available upload capacity. At the same time, each requesting peer forwards the video directly received from a source to the rest of the peers. Again, the amount of redistributed content depends on the peers upload capacity. The upload capacities of the sources are divided equally among the different video streams. In this paper, we present a collaborative multisource scheme based on P2P networks. In this paper is proposed a multi-source scheme to disseminate multimedia content from multiple source to multiple requesting peers. Initially, sources distribute the original content to each requesting peer. After the requesting peers receive the content, they can redistribute this content to other peers in a collaborative way.

The rest of this paper has the following organization. In Section 2, we present information about different multi-source schemes based on P2P networks. Section 3 presents our proposed model. A practical implementation of our multi-source scheme is described in Section 4. Our paper concludes in Section 5.

## **2 Related Work**

Dissemination information to a large group of nodes from many sources is fundamental in many systems and applications. Multi-source P2P multicast applications recently have been used for collaborative environments such as conferencing or multi-player games. A P2P network is an overlay network formed by a group of nodes. P2P systems maintain their independence of the underlying physical network by using this overlay topology. In a P2P network, a company can disseminate information. Thus, content can be distributed to an audience without the need for any special support from the network (Jannotti et al 2000), and where the upload capacity of the participating peers is only considered to forward the content. We can create a collective organizational knowledge within the organization, or share data and application files between computers without a dedicated server. However, P2P overlays known as unstructured

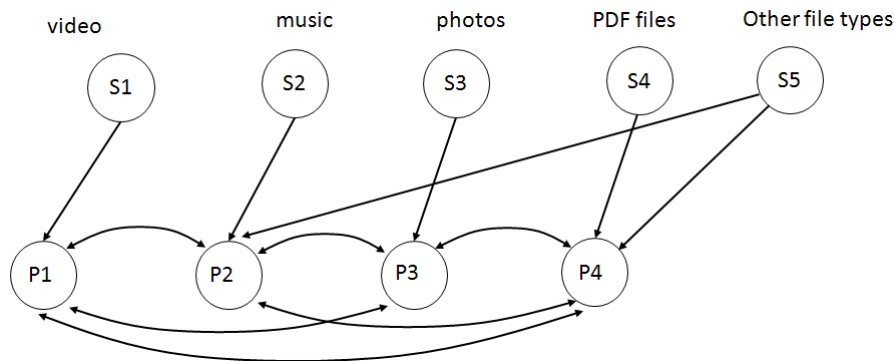


and structured overlay show limitations for multi-source multicast such as scalability [6], large overhead [7] or complex protocols [8].

Several approaches for content distribution from multiple sources to a single receiver can be found in the literature. Authors in [9] exploit the similar source concept to significantly improve the download time of a file from multiple sources to one receiver. Push is proposed in [10] as an efficient generic push-pull dissemination protocol. Pulp exploits the efficiency of push and pull approaches, such that it presents achieve reasonable latency and presents a low overhead by limiting redundant messages. In a multi-source environment, sources can provide conflicting values (false or true information). To deal with this problem, authors in [12] propose Datafusion, a novel solution to find true values from conflicting information when in the system there are a large number of information sources. In [13] is proposed a framework for video delivery from multiple sources to multiple receivers using P2P networks. In this work, authors consider that sources are requesting peers too. This work introduces a concept called helper peer, which is not interested in receiving the content and just contribute their resources during distribution.

### 3 Proposed Model

Our proposed model with multiple sources is shown in Figure 1. Each source distributes its initial content to different requesting peers. Our solution assumes that sources are independent of each other. Different type of files are distributed from each source. Source S1 distributes video files, while S2 distributes music files, S3 distributes photos files and S4 distributes PDF files. S5 is used to distribute other type of files.



**Fig. 1.** Proposed model.

Initially, each server sends its content to requesting peer. After a peer receives a type of file, it can be distributed to rest of requesting peers. Thus, each source distributes only its files in the first stage. In the second stage, files are redistributed among all requesting peers. Each server has two functions. First function is to distribute the original content, and second function is to maintain information about peers with distributed files. This information is stored in a database in each server, which is periodically updated. In this way, a server reduces its workload. When new peers arrive

to system, information about IP address of each peer and its shared content can be obtained from any server.

In a multi-thread application, different processes can be executed at the same time concurrently. The number of processes is variable and depends on the amount of connections that are established. In this work, we have used multi-thread to improve the performance of our system. Figure 2 shows threads active in each peer. Coordinator peer is the main thread in each peer, and it is responsible for synchronization and control of the others threads. Client\_thread\_1 is responsible for connecting with the main servers. Thus, this thread requests a content and receive it from the source. Client\_thread\_1 also receives from the source the table with information of IP address and name (ID) of all requesting peer in the system. In this way, if a requested content is available in a requesting peer, then the content is downloaded from this peer. Client\_thread\_2 is responsible for receiving content from one or more peers in the system. To request contents from other peers, each peer uses the database with IP address and name of peers. A peer can receive multimedia contents from the main sources and from other requesting peers. These contents are stored in a database. Using this information each peer can work as server and redistribute information to other peers. Server\_thread is responsible of this task in each peer.

## 4 Implementation

We put in practice our scheme by using different entities and servers, these entities are peers and servers. The servers store information about the connected peers and the file shared in each peer. There are different dedicated servers and each of them gives out and stores information about different types of files, which means there is a server for video another one for images another for music, another for pdf, and another one for any other kind of file so that we can do it multi-source. In this work, two main

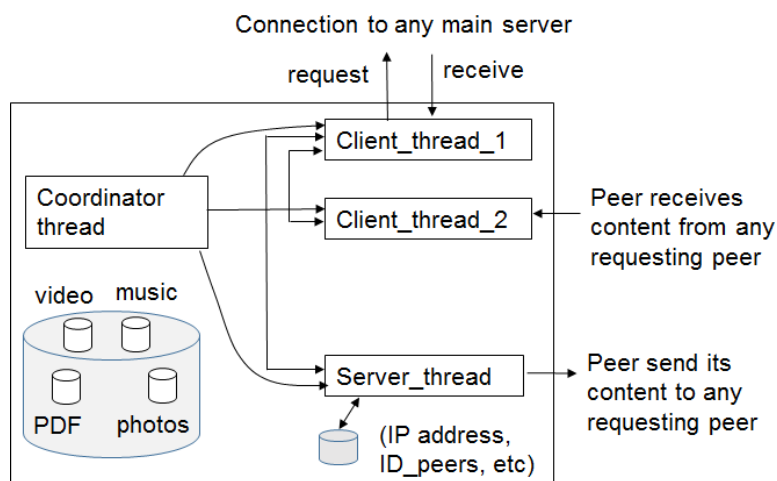
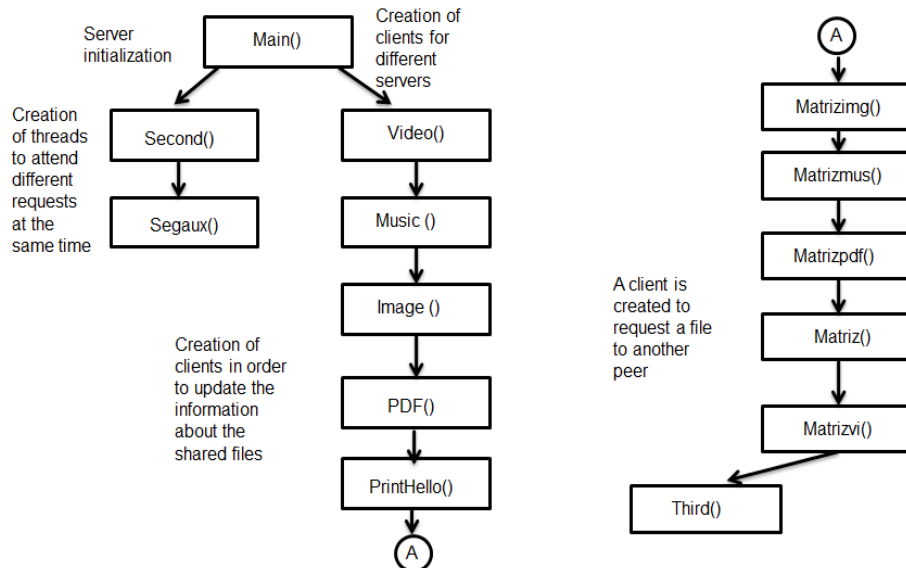


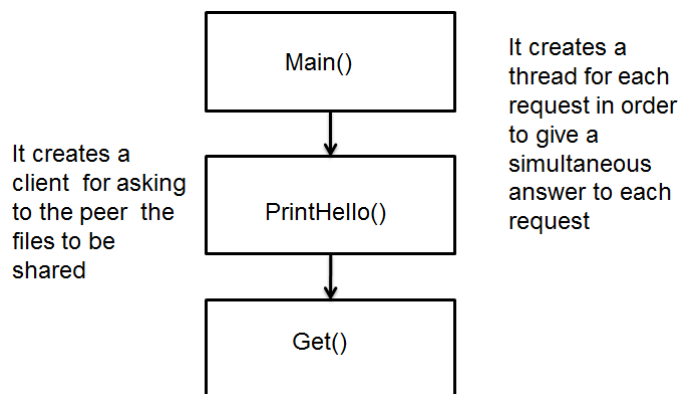
Fig. 2. Peer model.



**Fig. 3.** Flow diagram for peer application.

applications called peer and server has been implemented. Each node in the P2P network runs a peer application, such that each node must receive and send files at the same time. To reach time goal, peer application performs both tasks simultaneously. Peer application is formed by two parts: a server and a client. Server part always is listening in order to attend to other peers, while client part makes different functions such as uploading files, display files and exit. Peer application is placed in each node of the P2P network (in each individual computer). A peer is an entity that sends and receives files at the same time. Peer application creates different threads when is running. First thread is to manipulate the server, and then other threads are created to connect them to the different servers. Each peer inserts its IP address, the amount of shared files with their names. Each server sends to all peers the information about the different connected peers. Each server sends updated information about the connected peer to all peers in the system. Figure 3 shows the flow diagram for peer application. Here, we can see the different steps developed by this application.

Our second application is the server. This application is responsible to give information about the peers in the system and store all files to be shared. A server is receiving requesting from peers while is sending files to them. While a server application is running, a socket is listening and waiting for new requests. When a new request from a peer is received in the server, a new thread is created to attend this request. Each server has a global matrix where IP address and the files names that peers want to share are registered. For each file to be shared by a server is created a thread toward that peer in order to store that file. Peer receives the matrix with information of connected peers and the shared files by these peers. An experimental prototype is implemented using five different servers. Each server offers a dedicated service, such that each server manages a specific type of file: video, music, images, PDF and one for other kind of files. Main steps for server application is shown in Figure 4. A matrix is



**Fig. 4.** Flow diagram for server application.

used to store the name of the shared files and the IP address of the peers in order to request files to different peers.

We have evaluated the operation of our prototype in a local red of our campus. Both servers and peers work correctly. Files are sent from each dedicated server and each requesting peer correctly, and after this, each peer can forward the received files to rest of peers. To compare performance of our collaborative P2P scheme against a distribution scheme based on client-server, we have measured the distribution time to requesting peers. Our work is in progress, and preliminary tests have been done. First, we distribute four files of 28MB to two clients from a server at same time. Client 1 receives the four files from the source in 7.56 minutes, while client 2 receives the four files from the source in 8.08 minutes. On the other hand, using P2P architecture, peer 1 receives the four requested files in 2.25 minutes, while peer 2 receives the four files in 2.16 minutes. Preliminary results show that P2P architecture presents a best performance than architecture based on client-server because. This is because the server is congested to send all files, while in the P2P scheme all nodes collaborate to distribute content faster. However, obtained measurements may change depending on the variation of the network. We can continue testing our collaborative transmission scheme in order to make more efficient our proposal.

## 5 Conclusions

There is currently a high demand for multimedia content, and collaboration among requesting nodes play an important role. In this paper has been proposed a collaborative multi-source scheme to distribute multimedia content to many requesting peers. Collaboration between peers is implemented by using a peer-to-peer network. Our framework is suited for collaborative environments, where the system inherently has multiple senders. Using this proposed approach, the sources can distribute their workload between all requesting peers, and the system can improve its performance. Our collaborative scheme uses threads to establish collaboration connections with other peers. The number of threads is variables and depends on the amount of established

connections. In each peer, a coordinator thread deals with the incoming requests and creates the rest of threads that handle the requests. Our current effort is focused to complete the implementation of our proposed framework for video streaming sessions.

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# How to Improve the Reach and Impact of Social Media Content

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**Abstract.** The growing relevance of social media for the communication strategies of public entities – like governmental, political, commercial and NGOs, and public personalities – has been widely accepted in recent years. It is plausible that the lack of a method for delivering content to the general public diminishes the reach and impact of the communication strategies of any such entities. It is commonly accepted that the general public decides which contents to interact with, mostly on an emotional basis. Thus, such a method should be more effective if common psychological factors are taken into account. The method proposed in this paper has been developed and tested empirically working with nineteen public entities. The method has been applied on different entities achieving improvements in content reach on every case, this suggests that the application of a method that guides the entity through this process is effective in improving the reach and engagement of the public with the content. Because of the empirical methodology used to develop and test this method, it is in a very precarious and early state. Still, having shown promise, plans to increase its robustness include research in the areas of AI automation, neuromarketing and systems analysis, as well as the development of falsifiable tests for application.

**Keywords:** Content creation, content reach, neuromarketing, social media, social networks.

## 1 Introduction

Social networks have been a subject of great interest for well over a century now. Sociology, mathematics, computer science, ethnography and other disciplines have been applied to understand and develop advanced theories on the subject. In the information age social networks have evolved from the physical realm to the virtual; social networking platforms emerged and now span a major share of the Internet's usage [1,2].

Social networking platforms running on the Internet such as websites and apps (software applications) are commonly referred as social networks. Since this term might cause confusion with the homonymous networks this paper favors the

widely accepted term social media when referring to the aforementioned social networking platforms [3].

Governmental, political, commercial and non-profit organizations, as well as personalities -which as a group will be referred as entities in this paper- are adopting social media at an accelerating rate [4], yet the lack of a method for creating content that has reach and impact is notorious and widespread. For the purposes of this document the general population with access to social media will be regarded as public or general public. Also the terms reach and impact can be used as similar, likewise relevance and engagement even when their meanings have semantic differences, because of their relation in the context they will be used.

It can be frequently observed that said entities' social media content is: disperse, self-promoting and posted without a sense of timing. It is also common to observe such a content to raise poor reactions from the public [5].

## 2 Methodology

This method was developed by the author of this paper empirically, through trial and error, and incorporating previous and on-the-go acquired knowledge in the fields of social networks, viral vectors, motivators, dynamics of power, psychology, neuromarketing and journalism. The subjects of such trial have been over twenty entities which include politically active personalities, political parties local wings, NGOs, small companies, PR consultancies, and local governments from the central region of Mexico, better known as "Valle de Mexico" (Valley of Mexico) between of the years 2009 and 2015.

Different techniques were used in an iterative process, starting with a few entities and moving progressively to the addition of techniques from different areas, as well as the incremental addition of subjects to study. As the method gained robustness and complexity, ideas or techniques that didn't provide improvements within certain time were deprecated. Additionally when new knowledge was acquired recommendations regarding it were added to the method and applied accordingly. Every new recommendation was tested for improvements and subject to permanence according to the results obtained.

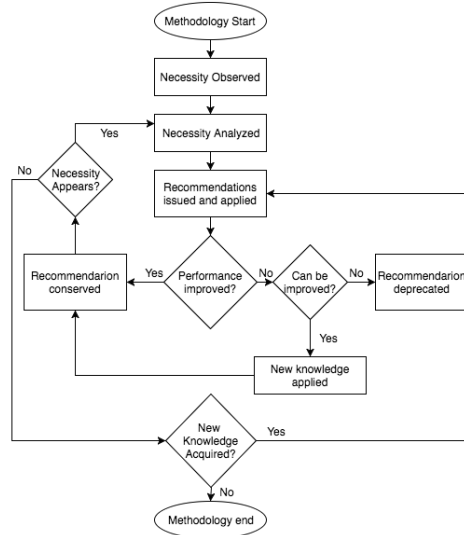
The process is not finished at the moment of the writing of this article since new knowledge is continuously acquired and tested, and plans to move the methodology from the purely empirical towards more robust methodologies are described in the future developments section.

The diagram in Fig. 1 represents the proposed methodology.

## 3 Context

The context for the development of this method can be traced to the remarkable success of the POTUS Barack Obama in 2008, both in the primaries of his party and in the general elections, mostly attributed to his tactical use of grassroots movement and social media for fundraising and support.





**Fig. 1.** Diagram of methodology.

Regional and national levels of the political parties in Mexico started hiring renowned public relations (PR) agencies, which started migrating their regular campaigns to the social media. Discussion on their methods and success rate is beyond the scope of this paper, but the fact that the parties at national level started paying attention to social media prompted local parties and politically active personalities seeking election posts known to the author to take action in the same direction.

Similarly other entities such as NGOs and small businesses that had previously worked with the author started noticing declines in the traffic and contacts received through their traditional websites. Having worked with those entities previously in journalistic and web projects the author was hired to either set up, manage or consult on social media, and eventually to train personnel on social media usage and to develop strategies to improve their statistics on this media, poorly known by most of them at the time.

Starting in 2009 with the regular campaigns already going on development of a solution was rushed with only user level knowledge on social media but with professional experience in web design and web newscasting – dating back to 1999 – first approaches were commonsense; improving the organization, graphic design and quality of the texts and videos shared through the social media. This increased the interaction of the public with the contents slightly and helped attract likes and views, but was clearly not a strong enough improvement.

Methods and strategies for ecommerce and social media marketing have been developed by authors like Fazlollahi [6] and Evans [7] their contributions are exhaustive and technical in the descriptions of the social media platforms, but elusive in the details of how to create engaging content. This could alienate the

less technical people or have them go through an extensive and steep learning curve just to find themselves without practical knowledge that can be applied,

Attempting to address these issues the method proposed incorporates basic knowledge from several areas and is aimed to be usable almost immediately, produce improvements within a few days of implementation, and improve over time.

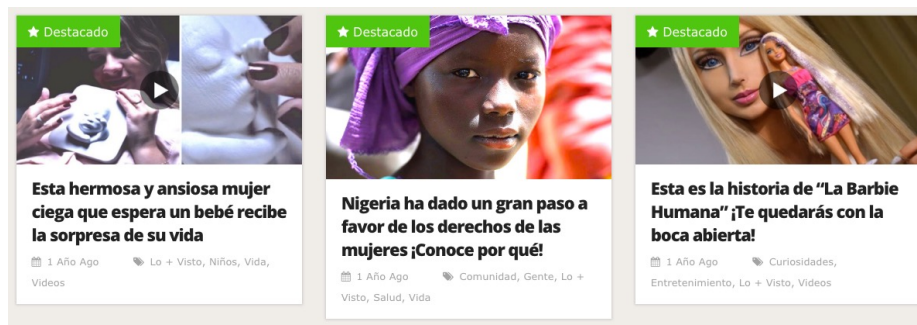
## 4 Development

The method started developing formally for the pre-campaigns of 2012 where increased social media awareness prompted even more local entities to look for the author's services, on this occasion there was enough time before the campaigns. On the first version of the method the following recommendations were included.

The first step was to define upgrades to regular websites from the entities towards social friendly versions, with linkable contents and social media widgets. Graphic aspects should also be taken into account by preferring images and styles consistent with the ones to be used in the social media accounts.

Instructions were included for standardizing social media pages and accounts by using visually consistent styles in the headers and account pictures, links back to the regular website and sharing contents that were updated there.

It had also been observed that the contents that engaged the public better had the characteristic of attractive and superlative titles and included images that were colorful and, in the case of videos, the thumbnails had those characteristics. So an initial suggestion was made to create titles with those attributes. As suggested by neuromarketing principles. An example of these can be seen in Fig. 2.



**Fig. 2.** Example of contents with high impact (screenshot in Spanish). Source: <http://viralistas.com>.

Observing that within the most used social media platforms response rate was mentioned or measured, the initial version of the method also included the

instruction to answer each comment, reply, repost, sharing and message received from the public.

These four areas – website improvement, social media standardization, content creation, and response management – conform the core of the method, and simple as they are they proved to be effective in improving the reach of the contents; views and click through in social media contents surged with increases in the order of 20 percent from the traffic previous to the application of the method, with a side-effect increase in traffic to the regular websites. Interactions with the social media content (including likes, shares, reposts, retweets and similar actions) showed slight improvements, from near-zero to around four interactions per item on average.

Improvement was noticeable but still not enough, statistics showed that people bounced -clicking a link but staying for less than 20 seconds- in the traditional websites. Looking for possible causes, but finding difficult to know third parties content bounce rate, social media contents with high numbers of interactions were sought for and analyzed.

Around 100 items with over one thousand (1000+) interactions each from Facebook, Twitter and Youtube presented by the social media platforms in the main pages of brand-new accounts were observed, looking for similarities. It was inferred from the contents analyzed that most of them did not come from an entity but from single users. Thus, it was decided to look for content items with around one hundred (90-110) interactions to find a more realistic model to analyze taken that the entities that were applying the method were much more local.

Similarly about 100 items were examined and it was noticed that within this range of interactions, still about three quarters of the items were produced by regular users, but more entities produced content started showing success at this level. Within this set it was observed that the titles of the items fell within five categories: surprising, salacious, funny, gossipy and useful. Also the posts did not attempt to sell products or services, but were mostly informative. Over 70 percent had too the qualitative characteristics of being colloquial and informal in nature.

This was taken into account for improvements to the core of the method in the content area. With the previous editorial knowledge a model of four paragraphs for the written content was devised to prevent the content from being stiff, aloof, technical or appearing institutional and promotional. This four paragraph model will also be described in the next section. From the few conversations with the general public that started to arise, it was observed that the public contacted the entities for three main purposes: support/congratulate, complain/criticize and to ask for information/help. Of the three groups the most numerous by far was the one that asked for information/help -grossly two thirds- of the total messages.

It was also observed that the teams tasked with managing responses, did so inconsistently and confusing in terms of style and frequency -they answered everything as instructed but sometimes took too long- and also tended to engage

in arguments with the public of the group that complained/criticized, that their responses often lacked clarity and were not always useful or didn't provide the requested information.

Also, noticing the majority of requests wanted information, help or complained about something it was inferred that the public perceives the entities as capable of providing solutions, therefore, as wielders of power lacked by themselves. Thus, it was derived that answers and contents that offered power or the illusion of power to the public would have more chances to engage the public. The concepts of Kenneth Galbraith regarding the types of power were included and paired to the types of entities that could offer them to the public: compensatory for commercial, condign for governmental, and conditioned for political and NGO [8].

During the years the development took place, some of the teams that managed the social media started to incur into practices that ended up in sanctions or closing of the social media accounts these included spamming, indiscriminate tagging, usage of services with fake accounts to bulk massive interactions (bots), and creating multiple accounts to add positive comments and likes to their own social media. These problems were addressed too.

Finally starting 2015, experiments to apply this method to small-business start-ups in the context of an e-commerce university course proved useful, this led to the inclusion of steps going back to the creation and setup of the entity, selection of the model -such as B2B, B2C, C2C, etc- that applies better, selection of requirements and setup of the website. The latest additions come in the form of optimizations in the creation of a single content -text (with images) or video- that can be automatically replicated in the different social media platforms from the entity.

## **5 Overview of the method**

An overview of the method will be described general terms using mainly an infographic (Fig. 1) specially developed for the purpose and going into more depth in some aspects. In-detail instructions are out of the scope of this paper and are planned for future articles.

The method starts with the Setup in which the first step is to define if the entity is already operating or has yet to be created and if so which stages need to be executed: Brick and mortar creation, if needed, -which is mentioned but doesn't prompt any action because is outside the scope of the method. Also if the online resources are already up, they might need adaptations which can reduce time by skipping steps. Finally if the online resources are not setup yet they will need to be developed from scratch. The online resources needed include a traditional website which can be commercial or informative in nature. This type of website serves as a support for the social media accounts and to host information in formats social media may not fully support, as well as institutional information that doesn't change over time (Fig. 3).

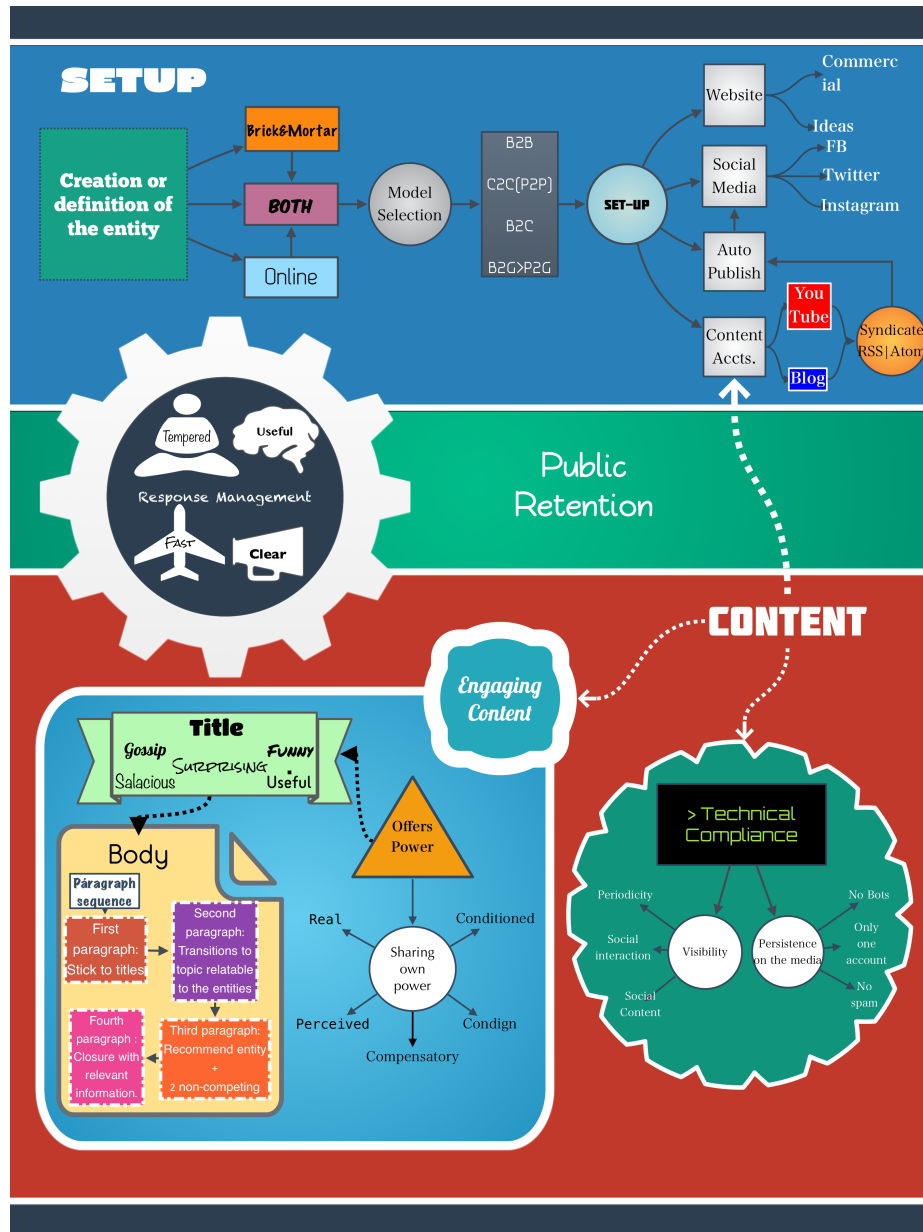


Fig. 3. Infographic of the method.

Social Media Accounts are also needed for the entity and the key players -noticeable leaders, PR deputies, and others- within the entity's structure. The method so far includes detailed instructions for Facebook, Twitter, and recently

Instagram.

Content Accounts for text and/or video which already have syndication services or feeds. Youtube is recommended for the video, although alternatives can be selected if Youtube is not viable for any cause. For the text content no specific service is required, as long as it has a feed service. Auto Publishing services, free or paid, use feeds from the text and video contents as input and automatically publish them in the social media accounts. The second and main area is about content with two sub-areas first technical compliance, which are basic general rules to both promote content visibility in social media and prevent the social media accounts from being blocked for policy violation.

The most detailed area of the project has been named “Engaging Content” in this area we have the overview of the process of content creation that applies for both text and video, detailed application is out of the scope of this paper, but it is important to notice that the content will derive its engaging appeal from the offer of power or the illusion of it. Also of high importance is the creation of the title which should fall within one of the following categories: Gossip, Funny, Salacious, Useful or Surprising. Possible examples of these are in Table 1.

**Table 1.** Examples of titles method by category.

Category	Example
Gossip	It is incredible how Serena Williams failed to see this!
Funny	5 things that happen when you mix tequila and girls!
Salacious	These irish girls will take your breath away...
Useful	You would have never imagined this simple trick can get you a flat stomach
Surprising	Is this the UGLIEST hairdo ever seen?

Finishing the content creation area we find the Paragraph sequence model for the body of the text or video which seeks to provide with a colloquial text that won’t be rejected immediately and can capture the attention of the reader while hinting towards the social media of the entity. it is explained in Table 2.

**Table 2.** Structure of the paragraphs.

Category	Example
First	Completely consistent with the title, provides the information promised in it.
Second	Smoothly shifts the topic towards a setting more related to the entity.
Third	Recommend and link social media accounts of 3 entities that fall within the scope.
Fourth	Give more relevant information related to the main topic and thank the public.

The final area corresponds to the Response management this area outlines four principles to have in mind when answering comments and messages from the public. The responses should be clear and useful. Special care should be given to give the public tempered positive answers even -and specially- when the message is offensive or rude. The responses should be as immediate as resources allow and coherent in style. Also when not possible to solve the problem of the person, a route of possible solution should be presented.

## **6 Results**

The application of the method in different types of entities showed noticeable improvements in every case. In terms of reach -views, clicks and traffic-, relative to figures before the application of the method, surges in the order of 20 to 50 percent were the norm, in two cases with increments of over 100 percent.

In terms of impact and engagement, most entities went from near zero interactions -likes, shares, replies, reposts- in the social media contents to 20-50 interactions and for two entities -one local political party and local political personality- achieving 60 to 200 interactions for most of the content. Likewise bounce rates diminished noticeably.

For the small companies created during the e-commerce course six out of six students successfully created small businesses from scratch which managed to generate contents that had modest reach and impact. Two of the businesses managed to sell products both through their traditional website and social media accounts and pages within the four months of the course and continue to operate and sell online and offline unassisted at the time of the writing of this paper. These results suggest that the method is effective for the purposes of improving reach and impact of social media contents and show promise as the startpoint for the further development of a more robust method with strict testing and research methodologies.

## **7 Future Developments**

Using the current version of the method as a startpoint various areas of opportunity are perceived. First and foremost falsifiable tests need to be developed to make a robust assessment of the effectiveness of the method in controlled environments and to detect the influence of the different instructions and recommendations in place to robustify the more effective and avoid diluting resources in developing areas with little or no influence on an eventually positive outcome.

Future articles with specific details for different elements of the method and a systems Analysis on the entity-public communication issue are currently undergoing, it is expected that this will provide valuable insights for the design and development of the aforementioned tests. In order to improve the response rate, time and relevance, AI response automation using Google APIs for natural language recognition and processing is currently being examined in terms of feasibility.

Finally, neuromarketing is being assessed as perhaps the most promising area in terms of exponential improvement to the content impact, reach and engagement. Advances in neuromarketing in other areas and in similar applications have shown remarkable results and it is, thus, an exciting idea to improve the method using this knowledge area [9].

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# Humanoid Robot Programming for the Assistance of an Artistic Performance

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**Abstract.** In this paper the methodology of programming a Darwin-Op® humanoid robot for the assistance of an artistic performance is shown. A performance is composed of elements that express emotions and feelings in people, fulfilling a series of movements defined by sequentially angles, lengths of the limbs and joints of the body. A biomechanical analysis was done for a dimensional relationship between humans and humanoid robot movements and allow a choreographic environment, which are sequences of basic movements accompanied by music in sync. The vision system Motive Tracker OptiTrack® and costume with markers to analyze the graphs, positions and trajectories of a skeleton in a three dimensional space generated for each routine, to obtain the angular information required was used. The extracted angles represent a sequence of movement and are placed on a table that is used to program the DarwinOp® humanoid robot with Roboplus®, this program to take care of mimicking the sequence performed by humans. The positions of the servo motors in each static pose was plotted and compared to those generated with the test subject. The degree of error is at its peak 5%, demonstrating that the humanoid robot has a mimicry of human movements. The interaction with the user is carried out by processing voice commands to call specific routines programmed into the humanoid robot.

**Keywords:** Humanoid robot, Darwin-Op®, performance, biomechanical analysis.

## 1 Introduction

Man has sought to develop robots to increase its data processing capacity to interact with the environment and especially trying to mimic human anatomy [1], from which arise the so-called humanoid robots that have bipedal walking [2]. Nowadays, the advancement of robotics has become a contribution to the development of society in

different fields such as medicine, industry, entertainment, among others. In the near future, the use of humanoid robots will increase in modern societies and will have applications in areas of entertainment with social interaction and education.

In the field of this work are among others the project called "Guided gestural of a humanoid robot using a Kinect sensor", where a biomechanical model is developed by software Skeleton tracking of Kinect, which allows tracking of the body of a user in real time and applies the model in a humanoid robot Bioloid with implementing firmware control of the actuators of the robot and the inverse kinematics of the arms [3]. "Environment to choreograph movements on a Humanoid Robot" It's application presents an environment for modeling choreographies of movement for humanoid robot Robonova. This environment allows users to graphically model in the robotic platform and formally validate the sequences of movements of the robot (choreography) and automatically generate the implementation associated with each choreography in robot programming language, called roboBASIC [4]. The project "Humanizing Robot Dance Movements" captured the human movement to dance samba and programmed into the humanoid robot NAO with the robotic simulator SimSpark [5].

The above projects use programs and platforms that give the programmer the movement data the human being, emphasizing the use of the Software Model-Driven (DSDM). In our case all the analysis and modeling was developed with a view to the DarwinOp® robot is part of an artistic performance that has an interaction with humans through voice commands for each routine and thereby give more work guideline for social interaction and teaching dance steps for children

## **2 Materials and Methods**

For the development of this project 34 infrared decoys were made, the Motive Tracker® program for recording movement, Camtasia® and Kinovea® was used to analyze video pictures, RoboPlus® and VNC Viewer® to program routines in the robot, Audacity to synchronize music tracks and DarwinOp® platform to run the preprocessed models.

The first step consists in selecting a genre of music, in order to observe the movement capability of the DarwinOp® humanoid robot and its direct relationship with humans. Every musical genre was obtained basic information such as speed of movement, characteristic steps of the musical genre and the bit (musical time) style itself, which allows the synchronization of steps to music. Subsequently, a static set of movements, which together correspond to a choreographed routine identified and parameterized angles that can perform DarwinOp® robot with angles that are required to execute the routine choreography generated; audio tracks together with the corresponding Audacity program performance and execution times of the robot were made. To do this the following methodology was applied:

### **2.1 Registration of Movement in the Vision System Motive Tracker®**

34 infrared decoys of fluorescent markers were constructed to create a skeleton movement called Baseline (34) for recording and analysis of the lower body and upper

body in the vision Motive Tracker® system as shown in Figure 1. Once placed markers in the body as indicated in the program the choreography for the performance was executed and stored in the sessions generated by the vision system.

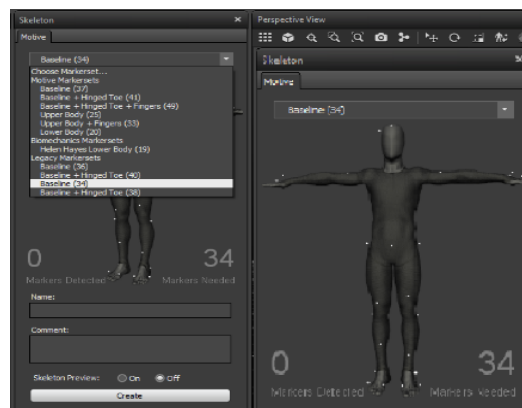


Fig. 1. Motive Tracker baseline 34.

## 2.2 Extraction of Graphics and Videos Generated in the Vision System

The Motive Tracker® vision system works in three dimensional space, so there are 34 graphs to the axis "x", 34 for the "y" axis and 34 to the axis "z", which indicate the path traveled by each marker on each axis in the performance. Thus, keep sessions in which through its data makes a reconstruction of 3D motion (Figure 2). but it cannot export the video to a processable format by this reason Camtasia program was used, because it allow us record the pc screen and in this manner create a video with the routine performance previously captured.

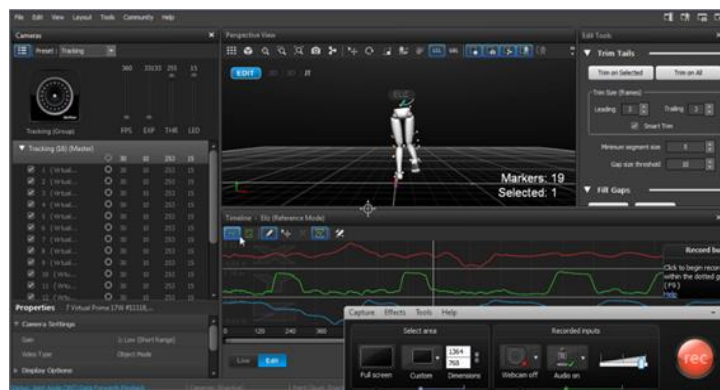
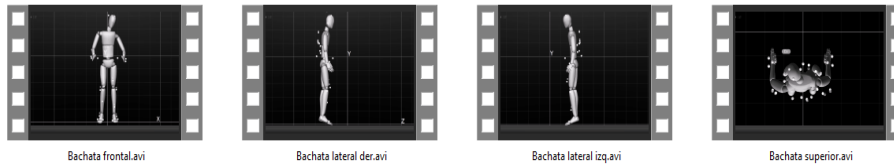


Fig. 2. Video and graphics extraction with Camtasia.

The vision system Motive Tracker® requires controlled lighting conditions, as well as reflective decoys placed in the suit that includes this system to generate the skeleton.

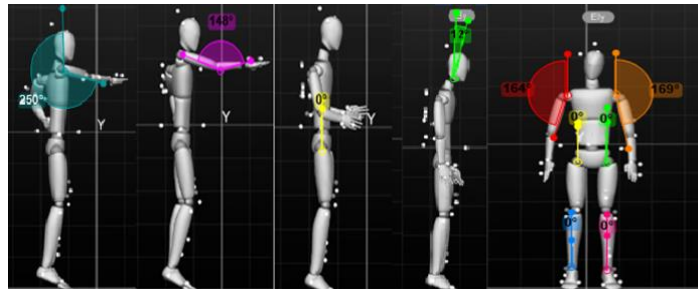
Subsequently graphics and video extraction for each marker for each movement routine are made with Camtasia®. Three angular analyzes were performed corresponding to the lateral, superior and frontal sides of view, thus for obtain the articular movements of each 20 degrees of freedom (DOF) for the robot Figure 3



**Fig. 3.** Sides of view extracted from the vision system. (screenshot in Spanish).

### 2.3 Angular Movement Analysis with Kinovea®

Every video of lateral, frontal and superior sides of view of each movement routines obtained with Camtasia® and Motive Tracker® are analyzed with Kinovea® to obtain the angular position of the 20 angles corresponding to the 20 DOF of the actuators DarwinOp® robot, see Figure 4.



**Fig. 4.** Angular Analysis with Kinovea®.

### 2.4 Analog to Digital Angular Conversions to Drive Darwinop® Servo Motors

The motors 20 DarwinOP robot are digital servomotors Dynamixel MX28 which are configured to generate movements between 0° and 360° with numbers between 0 and 4095 respectively.

Each servomotor due to its location in the robot has different minimum and maximum limits to generate joint movements. These limits are programmed in a card called internal Control CMX730.

Because of this, it is necessary to convert all angular movements tables routines to digital values required by servomotors. Each frame of the video obtained with Kinovea® was processed in an Excel® program to convert all angles to digital values that the robot can obey as particular position. The equation is shown below.

$$\begin{aligned} &\text{Ángulo}_{\#} \\ &= \text{INDICE}(\text{Servo}_{\#}(A_c:A_f), \text{COINCIDIR}(\text{Celda}_{comp}, \text{Servo}_{\#}(A_c:A_f), -1), 2) \dots (1) \end{aligned}$$

$$RES1 = Coincidir(Celda_{comp}, Servo_{\#}(A_c: A_f), -1) \quad \dots (2)$$

$$POS_{\#} = IF \left( \left( \frac{4096 * \text{Ángulo}_{\#}}{360} \right) \leq ServoMin_{\#} \right), ServoMin_{\#}, IF \left( \left( \frac{4096 * \text{Ángulo}_{\#}}{360} \right) \geq ServoMax_{\#} \right), ServoMax_{\#}, \left( \frac{4096 * \text{Ángulo}_{\#}}{360} \right) \dots (3)$$

Subsequently a data base with the digital values that needs the robot of each movement are generated.

## 2.5 Humanoid Robot Programming and Synchronization to a Music Track

To load the robot movements the network cable connected from the computer terminal to terminal DarwinOP® and Ultra VNC Viewer® program was implemented to allow us RoboPlus® run from the command console and the robot from the computer. This is necessary to change the servo motors digital values Figure 5.

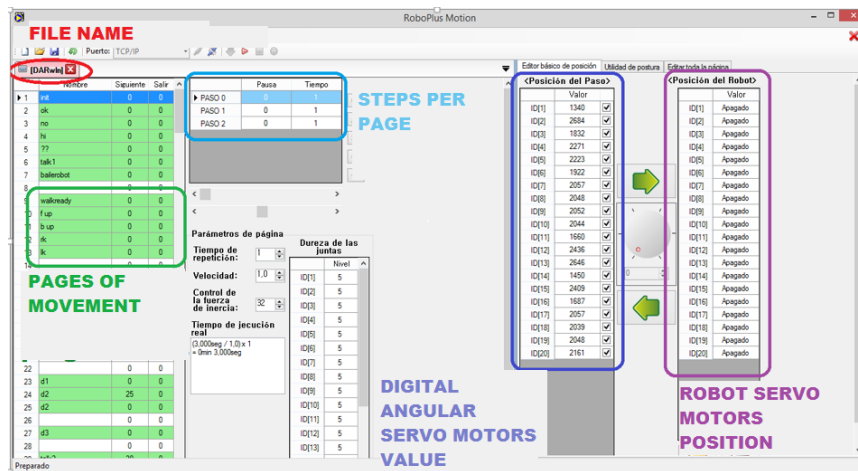


Fig. 5. RoboPlus® screen to program humanoid robot.

Once in the program, pages are created to send for movements, each page can have 7 steps and each step biomechanical models are programmed [6] obtained from the analysis of data in Kinovea® and the database generated with the values digital for every servo motor.

From the database in Excel can be copied directly to the digital values of the 20 servomotors and then press the right arrow to allow engines put the desired position, thus can verify the performance to be programming step by step.

It is important to note that not only is mark positions in sequence on the robot, you should use the established parameters and correct the balance of the robot, using information known as well as the information obtained by the human who performs the same sequence of movements.

After the programming of a complete routine, the movements generated to the corresponding track are synchronized. The process of this stage starts running track and the sequence of movements created at the same time, it should be noted that movements go with the music time, if at any point the movements are faster or slower than the music must be corrected speed steps, also, if by changing the amount of movement speed is less than the length of the track, should add new pages, new steps for the missing track time.

## **2.6 Wireless Communication, Voice Processing and Commands**

Voice processing was performed on another computer with Linux operating system Ubuntu 12.04, as other versions are not compatible or generate errors with libraries for speech processing and computer robot uses Linux 9.04 or 10.1.

The voice processing program loads the necessary libraries containing phonemes and parcels to initialize the voice recognition feature, check that the audio system work properly and requirements for the microphone are made. Because the total of routines scheduled for this performance are three the number of commands corresponding to these routines, identified by orders "one, two, three".

In order to make a WiFi wireless communication and TCP / IP protocol module is used because this channel ensures that all data to be transmitted arrive in order, complete and unabridged. It requires therefore a program for server and for client one. The voice processing program is the server where the routine is executed in the robot, it is the customer. So the program on the server data acquisition (phonemes) compared with phonemes is established, identifies the order of appearance and the probability of occurrence and finally the program sends the robot routine to be executed.

## **3 Results**

The performance consists of three scheduled routines, gender chosen for the routine one was pop music, with the song "La Macarena" by Los del Rio, this song consists of predefined steps that were used as a basis for the performance of the robot, this routine lasts one minute with thirty four seconds, this was scheduled starting on page number 98 and ending on page number 117, which gives us a total of 20 pages programmed, each of these pages contains a number of steps between one and seven, which modify the 20 servomotors, moving from one position to another, with the programmed sequence and the required speed.

For routine two, music genre was "bachata" with a remix of songs titled "Obra Maestra" and "Amigo" from Romeo Santos; this genre takes steps base with hip movements, arm movements are titled with cadences and steps bases of this dance, like the so called "arrastra" which is to drag a foot, this routine has a duration of one minute thirty six seconds is scheduled starting at the page number 136 and ending at the page number 162, which gives us a total of 27 pages programmed.

In the routine three, the chosen genre was disco music in English with the song "YMCA" by the Village People, 1978. This song was chosen because it is preset to dance steps, lasts one minute and seventeen seconds, it was scheduled starting on page number 190 and ending at the page number 214, which gives us a total of 25 pages programmed. Evidence of this can be seen in Figure 6.

	Nombre	Siguiente	Salir		Pausa	Tiempo	
189		0	0	▶ PASO 0	0	0.8	+
▶ 190	YMCA	191	0	PASO 1	0	0.4	↩
191	YMCA	192	0				✗
192	YMCA	193	0				⬆
193	YMCA	194	0				⬇
194	YMCA	195	0				
195	YMCA	196	0				
196	YMCA	197	0				
197	YMCA	198	0				
198	YMCA	199	0				
199	YMCA	200	0				
200	YMVA	201	0				
201	YMCA	202	0				
202	YMCA	203	0				
203	YMCA	204	0				
204	YMCA	205	0				
205	YMCA	206	0				
206	YMVA	207	0				
207	YMCA	208	0				
208	YMCA	209	0				
209	YMCA	210	0				
210	YMVA	211	0				
211	YMCA	212	0				
212	YMCA	213	0				
213	YMCA	214	0				
214	YMCA	0	0				
215		0	0				
216		0	0				

Parámetros de página		Dureza de las	
Tiempo de	1	ID[1]	Nivel
Velocidad:	1.0	ID[2]	5
Control de la fuerza	32	ID[3]	5
Tiempo de ejecución		ID[4]	5
(1,200seg / 1,0) x 1		ID[5]	5
= 0min 1,200seg		ID[6]	5
		ID[7]	5
		ID[8]	5
		ID[9]	5
		ID[10]	5
		ID[11]	5
		ID[12]	5
		ID[13]	5

Fig. 6. Pages programmed in routine 3. (Screenshot in Spanish).

For the three established routines have 72 pages of programmed movement, all with about 7 steps per page and 20 digital values for each servomotor, which gives us a total of 504 steps per program and a total of 10,080 angles.

The 10,080 angles are in a database generated in the Excel program, each step has angular positions and the digital values of every movement for each of the 20 servomotors of the robot. Thus for routine 1 we have 20 pages with 7 steps per page giving a total of 140 steps. See Figure 7.

	Valor de rutina P0	Angulo	Datos	Valor de rutina P1	Angulo	Datos	Valor de rutina P2	Angulo	Datos	Valor de rutina P3	Angulo	Datos	Valor de rutina P4	Angulo	Datos
1	1500	225	1538	1500	225	1538	1500	225	1538	1500	225	1538	1500	225	1538
2	2517	220	2501	2517	220	2501	2517	220	2501	2517	220	2501	2517	220	2501
3	1834	150	1850	1834	150	1850	1834	150	1850	1834	150	1850	1834	150	1850
4	2283	155	2276	2283	155	2276	2283	155	2276	2283	155	2276	2283	155	2276
5	2380	115	2324	2380	115	2324	2380	115	2324	2380	115	2324	2380	115	2324
6	1710	115	1751	1710	115	1751	1710	115	1751	1710	115	1751	1710	115	1751
7	2043	-5	2005	2043	-5	2005	2043	-5	2005	2043	-5	2005	2043	-5	2005
8	2033	-5	2005	2033	-5	2005	2033	-5	2005	2033	-5	2005	2033	-5	2005
9	2057	0	2000	2057	0	2000	2057	0	2000	2057	0	2000	2057	0	2000
10	2043	0	2000	2043	0	2000	2043	0	2000	2043	0	2000	2043	0	2000
11	1277	65	1238	1277	65	1238	1277	65	1238	1277	65	1238	1277	65	1238
12	2797	-30	2080	2797	-30	2080	2797	-30	2080	2797	-30	2080	2797	-30	2080
13	3513	145	3513	3513	145	3513	3513	145	3513	3513	145	3513	3513	145	3513
14	571	140	621	571	140	621	571	140	621	571	140	621	571	140	621
15	2843	80	2843	2843	80	2843	2843	80	2843	2843	80	2843	2843	80	2843
16	1240	80	1240	1240	80	1240	1240	80	1240	1240	80	1240	1240	80	1240
17	2077	35	2086	2077	35	2086	2077	35	2086	2077	35	2086	2077	35	2086
18	2037	0	2050	2037	0	2050	2037	0	2050	2037	0	2050	2037	0	2050
19	2050	0	2050	2050	0	2050	2050	0	2050	2050	0	2050	2050	0	2050
20	1809	-55	1790	1809	-55	1790	1809	-55	1790	1809	-55	1790	1809	-55	1790

Fig. 7. Excel book with angular values (screenshot in Spanish).

Each step has an image and a table for angles of 20 servomotors, obtained from 3D videos of the lateral, frontal and top views. Of the 504 steps were chosen at random 51 angles and 1020 steps were chosen and read with RoboPlus program and compared with the value angle of the table in the database, as shown in Figure 8.

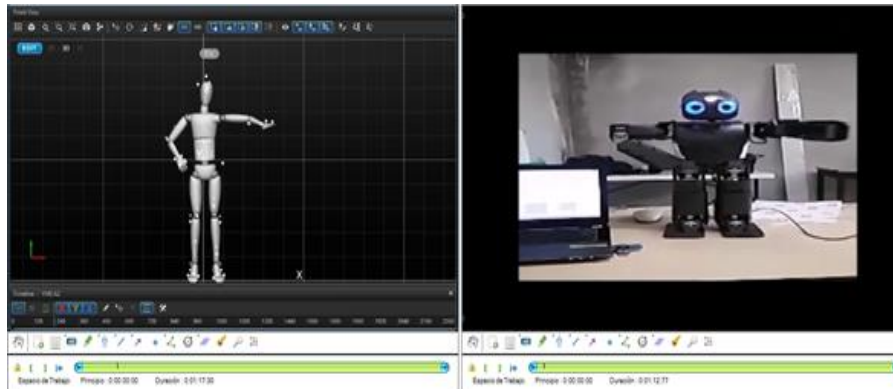


Fig. 8. Angles comparison.

Each motor in the robot has an ARM 32bit microcontroller, which contains settings in PID control to reach the position (Figure 9), so when converting the digital value read from the robot to the angle and compare it with the data table gave us a 5% error in 100 angles off 1020; i.e., 9.8% of the total sample has a maximum error of 5% and only in the extremities were the robot makes mayor effort.

For each routine robot video recordings were made and analyzed in the Kinovea® program, which allows us to track a specific point; in this case, a point is placed in a similar position, where the test subject have a marker, the trajectory generated in the



software is similar to the graph given by the Motive Tracker, as shown in Figure 10 which guarantees that the error rate is 5%.

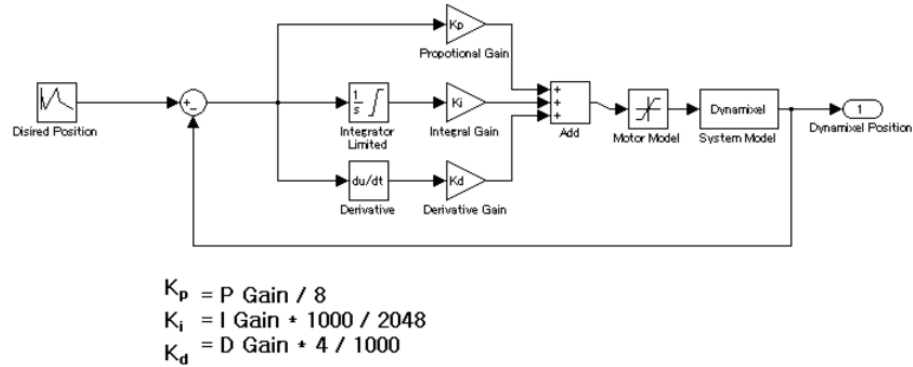


Fig. 9. PID Dynamixel motor control model.

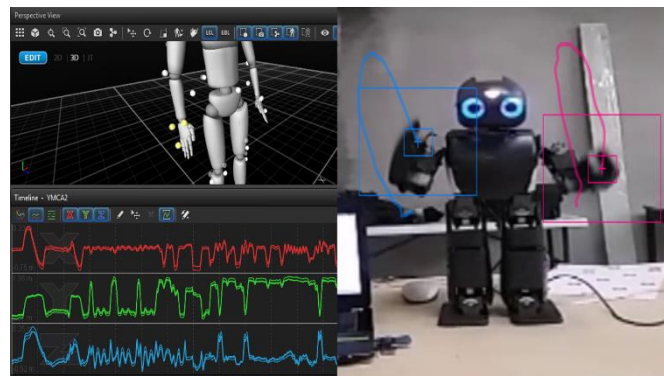


Fig. 10. Graphic comparison.

At this stage it can be seen the visual comparison of some positions, a specific routine that checks to similarity between the performance played by the DrawinOp® humanoid robot and human.

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# Embedded Prototype System for Monitoring Heart Rate

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**Abstract.** The vital signs monitoring is very important for patients that suffers some chronic disease because they reflect basic and essential functions in the body. In Mexico, in the last few years, we have noticed that the mortality rate in patients with heart disease has increased significantly due to late diagnosis and lack medical care to patients who have been diagnosed. This work presents a proposal embedded system, that allows continuous monitoring of heart rate with an optical sensor and a Microblaze soft-core embedded in a Spartan-6 FPGA of Xilinx. The Microblaze processor works whit the local processor bus for managing peripherals. Core SPI is used to interface with the sensor. The system detects the heartbeat through the sensor which is placed on the index finger of the patient, the signal is acquired by the soft-core, where the heart rate is obtained through the autocorrelation function. Finally, UART core is used to send data to a computer where is implemented a server application that enables remote monitoring of sensor information.

**Keywords:** Embedded system, FPGA, heart rate.

## 1 Introduction

Vital signs are clinical parameters that reflect the physiological state of the human organism, and essentially provide the data which will establish the guidelines for evaluating the homeostatic condition of the patient. Vital signs indicate the present health status of the patient, as well as changes or evolution, either positively or negatively. Vital signs include: temperature, respiratory rate, heart rate and blood pressure, among others.

Monitoring of vital signs and biomedical covers a wide spectrum in different contexts today, so, it has been a concurrent research topic in the last decade [1-5]. Currently, there are systems designed to monitoring vital signs through different technologies.

In [2, 3, 5], the use of technology based on a microcontroller, has been proposed in order to monitoring many different vital signs like heart rate, breathing and others. In

[4] is used an embedded system with an ARM processor and a Linux OS for the motoring of an electrocardiographic signal (ECG) of the patient.

This paper presents an embedded system that is developed in a Field Programmable Gate Array (FPGA) in order to monitoring de heart rate (Fc). The use of a FPGA is convenient because allows the use of a soft-core. A soft-core processor is a hardware description language (HDL) model of a specific processor (CPU) that can be customized for a given application and synthesized for an ASIC or FPGA target [7].

Heart rate is the rate at which the heart beats to pump blood throughout the body. In other words, is the number of times the heart beats per unit time, commonly measured in a minute.

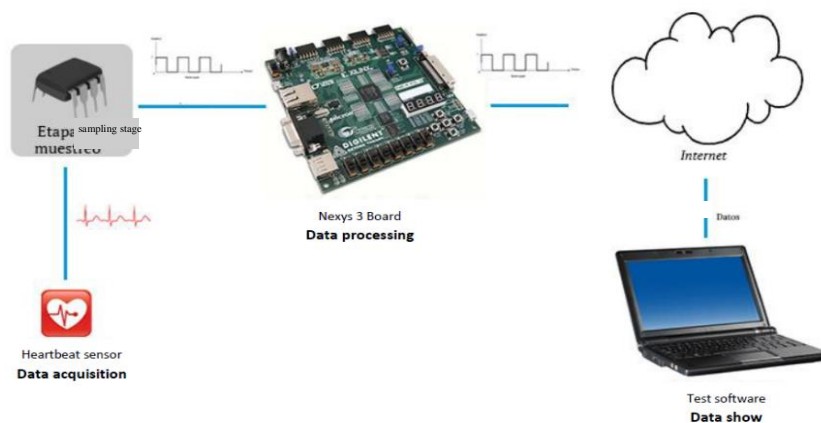
When the heart pumps blood through the arteries these expand and contract with the blood flow. By taking the pulse, not only the heart rate is measured, it can also indicate the strength of the heartbeat.

The normal rate for healthy adults ranges from 60 to 100 beats per minute. The rate may fluctuate and increase with exercise, illness and injuries. Girls from age 12, and women in general, tend to have faster than boys and men heartbeat. Athletes, such as runners, who do a lot of cardiovascular conditioning may have heart rates of 40 beats per minute without any complications [6].

The commonly way used to measure the heart rate is counting the beats during a minute placing the index and medium fingers on the wrist, with a distance of 1.5cm of the joint. The proposed system uses the calculation of the heart rate by obtaining the fundamental frequency of the signal. The embedded system obtains a set of samples of the heartbeat, which are taken through an optical sensor, and then apply the technique of autocorrelation in order to calculate the heart rate.

## 2 Architectural Design Proposal

The proposed architecture of the embedded system is shown in the Figure 1, the architecture consists of three main parts.



**Fig. 1.** Proposed architecture of the embedded system.

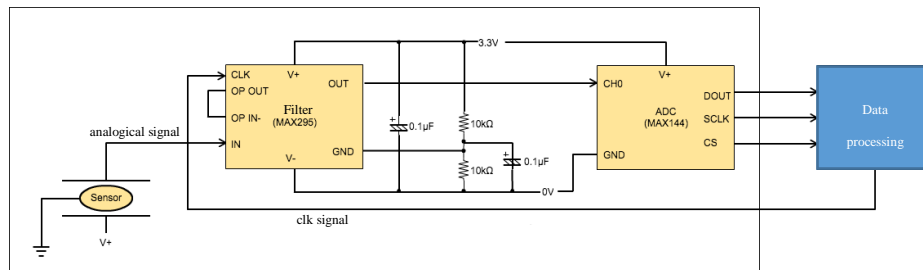
- **Data acquisition stage.** This stage allows detecting the heartbeat of the patient using an optical sensor with analogical interface. For the correct use of the system, the patient must be relaxed, under normal resting conditions. The obtained signal is sent to a filter circuit and then, it can be converted in a digital signal using the MAX144 ADC.
- **Data processing stage.** Once the data was converted in a digital signal, this signal is sent to the Nexys3 board, which has an embedded soft-core where the heart rate is estimated using the autocorrelation technique. Finally, the result is sent to the software application.
- **Software application.** A web application that can display the acquired patient information was developed. This software allows to storage a patient's clinical history too, where a doctor can check it.

### 3 Implementation of the Proposed Architecture

The proposed architecture was implemented in stages like the design, in this section, each stage is described.

#### 3.1 Data Acquisition Stage

The Figure 2 shows the circuit that is used for the data acquisition of the sensor.



**Fig. 2.** Schematic circuit diagram for the data acquisition.

For detecting the heartbeat, the sensor that is shown in Figure 3 is used. This is placed and secured in the user's index finger is used. The sensor is a free hardware design and has 3 connector pins, two for supply voltage (5V) and one for signal output, this sensor has an analog output.

Once you have the output signal of the sensor, this is filtered using the MAX295 circuit, this is a filter circuit of eighth order which can be set to a cutoff frequency in a range that goes from 0.1Hz to 50KHz. To set the cutoff frequency of this filter, it was considered that this circuit has a ratio of 50:1, i.e.:

$$F_s = 50F, \quad (1)$$

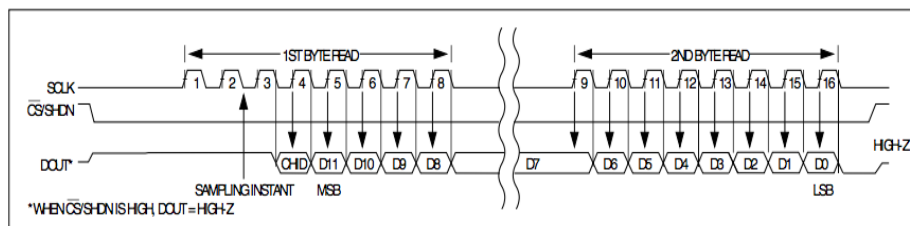
where  $F_s$  is the clock frequency and  $F$  is the filter frequency of the signal to be filtered. The clock signal  $F_s$  that was used to set the filter was generated using a Core-Timer in the FPGA, which is controlled by the soft-core.

Heartbeat signal can vary within a range of frequencies ranging from .81Hz to 3.66Hz approximately. Taking the maximum frequency of heartbeat and fulfilling the relationship indicated for the sensor, the filter was set with  $F_s = 200\text{Hz}$ .



**Fig. 3.** Pulse amped sensor.

To complete the data acquisition stage, the MAX144 circuit, that is a 12-bit ADC with an operating voltage of 2.7V to 5.2V and handle the SPI protocol, was used. According to the specifications, to be configured for operation by an external clock signal, this generates a 16-bit frame with the format showed in Figure 4.

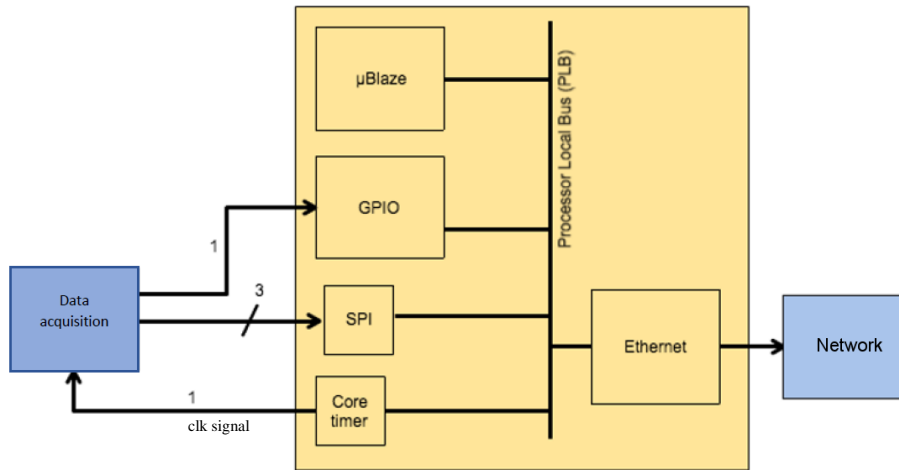


**Fig. 4.** MAX 144 ADC output frame.

The first three bits remain at high level, the fourth bit (CHD) allows to set the channel and the last 12 bits (D) containing the data resulting from the analog-digital conversion. Once the sensor signal has been digitized, this is sent to the FPGA.

### 3.2 Data Processing Stage

Once the signal has been digitized, this is sent to a Spartan 6 - FPGA Spartan 6 where the architecture shown in Figure 5 was configured.



**Fig. 4.** Embedded system configured in Spartan 6 FPGA.

The architecture consists of a XPS General Purpose Input / Output driver that sends the voltage supply for the heartbeat sensor.

The LogiCORE IP XPS Timer / Counter can generate a clock signal that is sent to the stage of data acquisition, this clock signal has a frequency of 200Hz and is what allows to set the low pass filter for a cutoff frequency 4Hz approximately.

Dedicated Core XPS SPI Interface, which allows the reception of data from the ADC, was used. It allows the data reception from ADC circuit through two frames of 8 bits length to complete a unique frame of 16-bits due to this is the work protocol.

Finally the soft-core MicroBlaze embedded in the FPGA, which allows you to calculate heart rate and control peripherals through a general purpose bus PLB was configured.

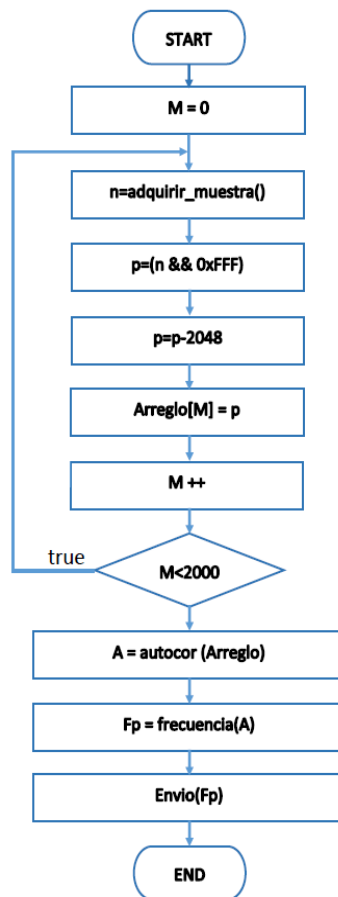
The diagram of Figure 6 describes the flow of operations performed to obtain the heart rate from a set of samples acquired. In the process, can be noticed that a set of samples is acquired using the *adquirir\_muestra()* function, this function gets a 16-bits frame from two frames of 8 bits from the data acquisition module. Once one has the entire frame, the mask 0xFFF is applied and subtracted 2048 to remove the DC component, finally the last 12 bits have the value of the sample that is stored in an array, the process is repeated until to get 2000 samples, when the array is complete, the *autocor()* function, defined by Eq. (2), is executed to obtain the autocorrelation of the samples:

$$r_{xx}(l) = \sum_{n=0}^{N-l-1} x(n)x(n+l); l = 0, 1, 2, \dots, n. \quad (2)$$

The code of the function is shown below.

```
For(m=0; m<1; m++){
    rxx=0
    for(n=0;n<N-m;n++){
        rxx = rxx+(muestra[n]*muestra[n+m])
    }
    Res[m]=rxx;
}
```

To calculate the heart rate is necessary obtain the fundamental frequency of the signal, this can be done by many techniques, for example, Fast Fourier Transform, Discrete Fourier Transform or Autocorrelation. In this case, autocorrelation technique was chosen for its low computational complexity. Table 1 shows the comparison of the computational complexity between these techniques.



**Fig. 5.** Flowchart of calculation of the heart rate.



**Table 1.** Comparison of the computational complexity.

Algorithm	Computational complexity
Fast Fourier Transform	$n \log_2 n$
Discrete Fourier Transform	$n^2$
Autocorrelation	$n$

Once you have the resultant vector of the autocorrelation, the function *frecuencia()* is executed to estimate the heart rate. This function looks for the second highest peak, which represents the fundamental frequency of the signal.

In order to calculate the period of the occurrence of a heartbeat, the next relation is necessary:

$$t_s = \frac{X}{300}, \quad (3)$$

where  $X$  is the value of the second highest peak of the autocorrelation result and the constant of 300 it is the working frequency of architecture. Once obtained  $t_s$ , the  $F_c$  is calculated such that:

$$F_c = \frac{60}{t_s}. \quad (4)$$

The  $F_c$  value obtained is sent by the Core UART to the computer in order to be stored in the application server.

### 3.3 Web Application

A web application was designed and implemented, in order to test the system. The web application allows register a patient and do the monitoring of  $F_c$ , and generate a record of the measurements performed for the patient. Medical personal has the option to check these and do new measurements, in the Figure 7, the main screen is shown and in Figure 8 an example of the medical history is shown.



**Fig. 6.** Web application main screen (screenshot in Spanish).



Fig. 7. Medical history example (screenshot in Spanish).

## 4 Test and Results

The hardware configuration of the embedded system was done using Xilinx Platform Studio (XPS), where the necessary drivers to Nexys 3 FPGA must be chosen, also the processors, the Microblaze soft-core and the GPIO, UART, Timer/Counter and SPI Cores, as well as, make the assignation of the memory space. Then, the in-out signals must be configured with the FPGA pins.

In the Figure 9, the sensor test with the filter circuit is shown. The X axis represents time while the Y axis represents voltage. It can be noticed the reduction of noise between the original sensor signal output (top graph) and the signal resultant of the filter (bottom graph).

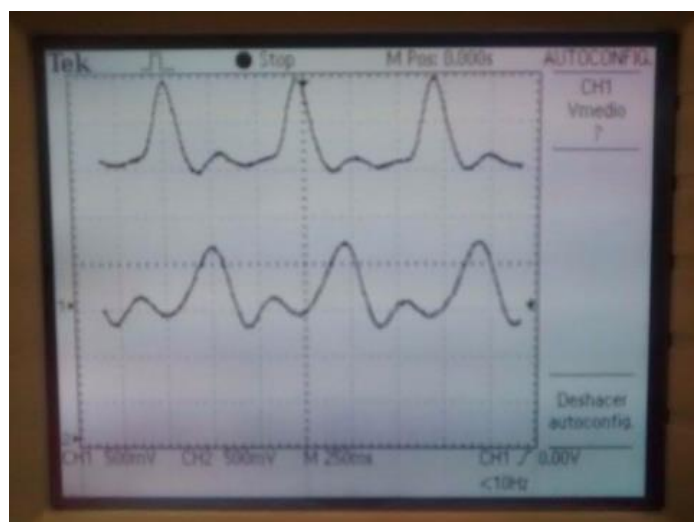
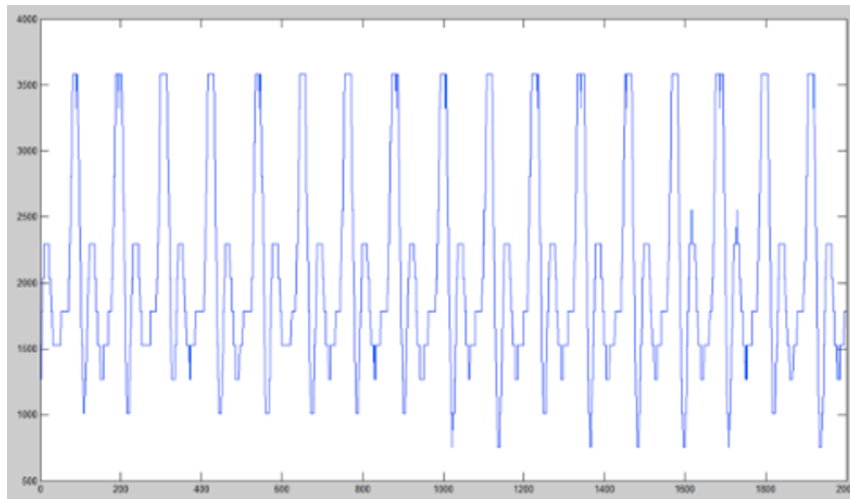


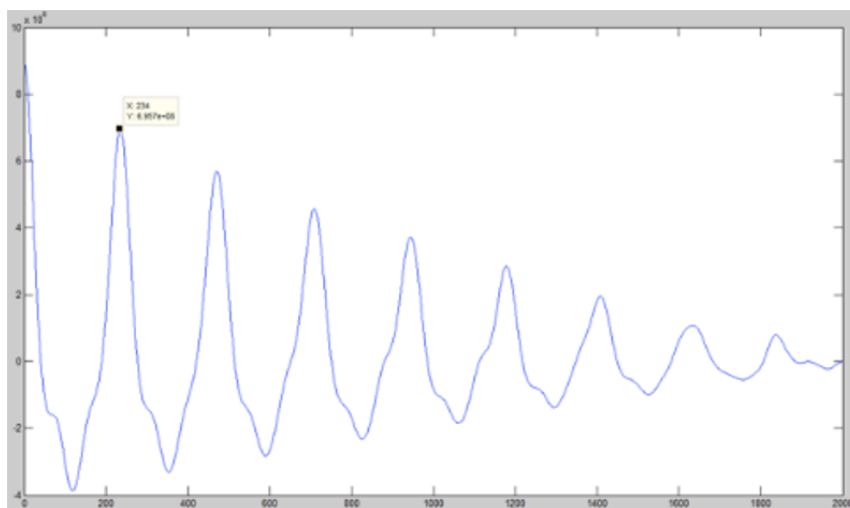
Fig. 9. Test of the sensor and the filter circuit (screenshot in Spanish).

In the Figure 10 is shown a plot of the set of 2000 samples in the X axis and his magnitude in the Y axis, that were got by the sensor and then were digitized, this graph was plotted using Matlab software.



**Fig. 10.** Graph of the set of Samples of the original signal.

In the Figure 11, the result of the autocorrelation of the samples is shown. In this case, the second highest peak is corresponding to  $X=234$ , solving the Eq. (3) and (4) with this value,  $F_c=76$  heartbeats per minute is obtained. Finally, this result can be stored and monitored in the trail software as is shown in the Figure 12.



**Fig. 11.** Graph of the autocorrelation result.

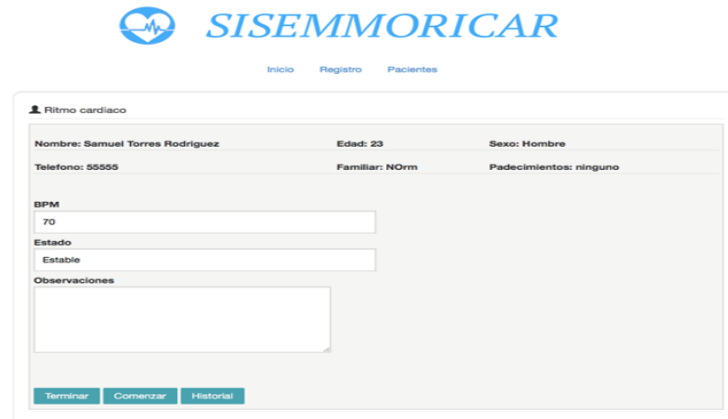


Fig. 12. Example of the web application (screenshot in Spanish).

## 5 Conclusions

In this work, a proposal for an embedded system to monitoring heart rate using a Nexys 3 FPGA and a softcore Microblaze is presented. An analogical sensor is configured and conditioned, and the output signal is filtered using the Maxim Integrated MAX295 that allows an output response without noise, then and Maxim Integrated MAX144 ADC is used in order to get a digital signal with a resolution of 12 bits.

The embedded system architecture was designed using the Microblaze soft-core which is used to the reception and the processing of the data obtained through the sensor in order to get the heart rate, this tool also allows the use of personalized cores, in this case, the GPIO, UART, Timer/Counter and SPI Cores were configured

A web application was designed and developed using web technologies like PHP, HTML, JavaScript and the data base handler MySQL. The web application shows the information obtained from the embedded system and it can store the clinical history of the patient.

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# Applications on Mobile Devices for Solving Derivative Problems

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**Abstract.** This paper presents a set of 3 mobile applications where derivative concept is analyzed through everyday life examples of rate of change and optimization. Augmented reality and GeoGebra were used as computational tools. In the applications test, a sample of 30 students formed the control group (GC) and 30 student formed the study group (GE). Both have been applied the same initial and final questionnaire. The GE used the applications on their mobile devices, while the GC worked the same subject without them during 1 hour and a half in 5 sessions. Results for both groups in initial and final evaluation mean results on 2.08 to 3.30 and 2.58 to 7.47 for GC and GE respectively. Applying F test, a statistically significant difference in increase was found ( $p < 0.002$ ). This results showed that GE identified the concept of derivative and correctly applied that concept to real problems solving correctly 74% of the final questionnaire, so it is concluded that these activities supported mobile devices open a new way in educational research.

**Keywords:** Classroom learning, mobile computing, educational research, augmented reality.

## 1 Introduction

Currently there are software programs that are directed to help understanding of mathematics, however, it was found that most of them help to develop algebraic and memorizing skills but visualization, understanding and reasoning mathematics are lacking [1]. These programs are generally designed to be used on a desktop computer by limiting the scope and availability of the software. Although there is a tendency to include this software in classrooms to integrate their capabilities to the tools for

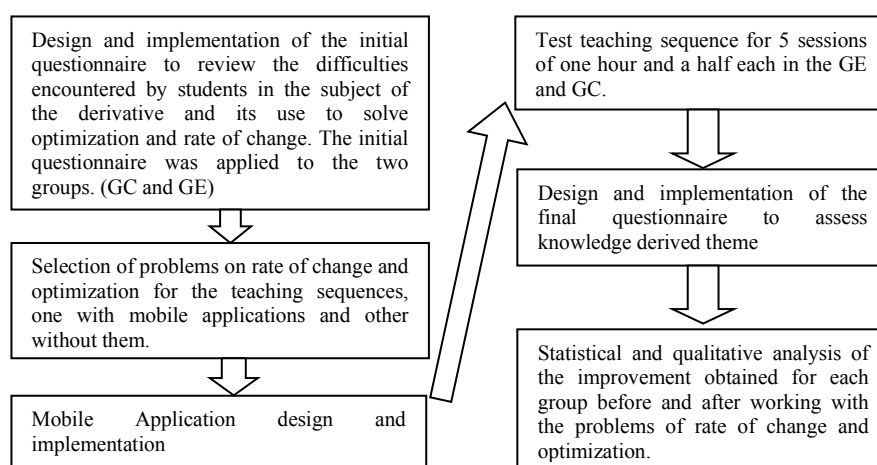
teachers in Mexico, it has been limited its introduction because classrooms don't have infrastructure and associated maintenance is required.

On the other hand, it is known that the population between 15 and 35 years old have a mobile phone and the trend of acquiring mobile devices is increasing [2, 3] as well as their processing capabilities, visualization and internet availability so this situation makes mobile a viable tool to be include in the education process named *m-learning* [4].

In this paper, three mobile applications that are intended to help in different cognitive skills development during its use in classroom teaching. These applications were based on problems taken from textbooks [5, 6, 7], with some changes and programmed as interactive environments in a mobile software. The topic was the derivative and its use in situations where a rate of change and optimization is required [8, 9].

The first application, "Android balloon" used augmented reality concept, allowing to analyze a real situation, take measurements and use them to solve problems associated with what happens to an object when it undergoes a change in any of the variables that define (volume and radius of the sphere). The "building a box" and "clockwise" application used GeoGebra, a dynamic program that offers various representations of objects from each of its possible perspectives: graphical views, algebraic topics, and information organization in charts and spreadsheets, together with data sheets dynamically linked [10]. The application, called "trickle", uses the GPS positioning system with other sensors that owns the device to catch elements that could be analyzed by the student.

## 2 Methodology



**Fig. 1.** Steps followed in the study.



The application was tested in two groups, one called control group (GC) and the other study group (GE). Each group consisted of 30 students who were taking their first semester of studies in one of the units of the Instituto Politécnico Nacional. In order to evaluate if the mobile applications improved the learning of students after being working on the derivate topic and solving problems of rate of change and optimization, it was applied two questionnaires: one before the topic was studied named initial questionnaire, and a final questionnaire after finished the topic learning then it was compared the mean results obtained in both questionnaires. Two sequences were designed, one to be worked with the control group (GC) and the other for the study group (GE).

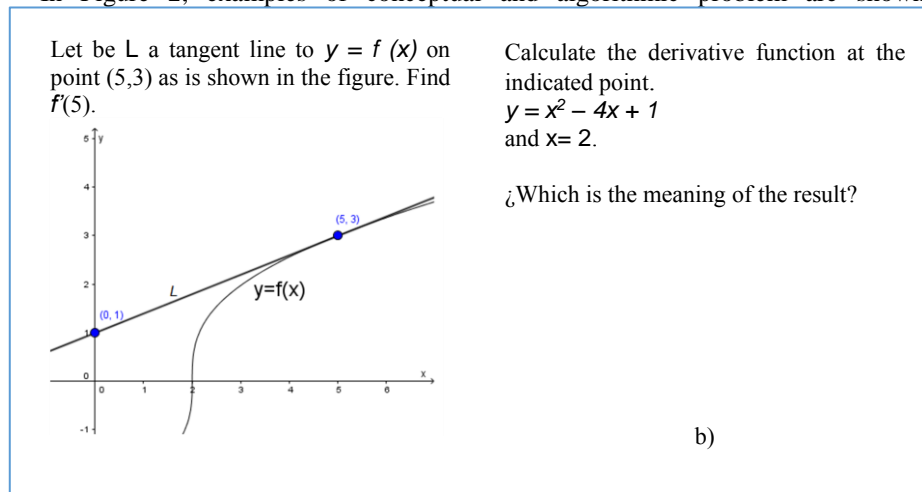
The teaching sequence worked with GC, was integrated with problems taken from textbooks for engineers [5], [6], [7], and were worked traditionally in the classroom. That is, the teacher wrote down information on the board, explained, solved it and the students copied in his notebook what has been done by the teacher.

The GE teaching sequence consisted of the same problems, included the mobile applications and teacher allowed students to interact with them and respond to the questions asked. The steps followed in this work are shown in the diagram of Figure 1.

## 2.1 Design and Implementation of the Initial Questionnaire

The diagnostic or initial questionnaire has 8 questions related to the learning Unit named Calculus and specifically to the issues of the derivative and their uses as the rate of change and optimization. Three of the 8 questions had incised so the total number of question to answer was 12.

In Figure 2, examples of conceptual and algorithmic problem are shown.



**Fig. 2.** Examples of the types of questions. On the left side: a conceptual problem and on the right side: an example of an algorithmic problem.

Questions were classified into two types: algorithmic and conceptual type. Algorithmic questions [8, 9], are those in which the student must know the method or

steps to solve the exercise and will only be asked to calculate or find a result. (Questions 2b, 3a, 5a, 5b and 5c). On the other hand, concept questions imply that the student has understood the concept involved (1, 2a, 3b, 4, 6, 7, y8) and applies it to find the answer to the situation proposed in question.

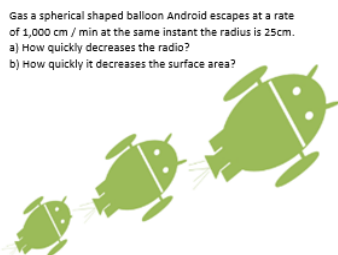
## 2.2 Selection of Problems

Three problems were chosen from the textbook [6], [7], and then they were converted into interactive applications for students in the study group (GE). Those mobile applications are explained in order to show how they were generated. They were named: “Android balloon”, “Building a box” and “Clockwise”.

About the control group (GC) they worked the same problems, but without using the applications, instead of, the teacher explained using the blackboard and the students solved them using for this a calculator, and wrote the answers in their notebooks.

### 2.2.1 Android Balloon

This mobile application was intended to support the student understanding of the rate of change. “Android balloon” shows this phenomenon, using an example where a balloon with shape of android, it lost gas and how, as time goes by, the radio and surface changes.



**Fig. 3.** Examples of the application where the object undergoes a change and can apply the concept of rate of change.

In this application, the student could see, in real time and in the classroom, what happens to an object when it undergoes to a change in an instant. This phenomenon is called rate of change and it can be quantified using the derivative concept. This activity used the camera of mobile device and a marker of augmented reality. The first one, for obtaining the scenario and the second one, to take the decision of where to display the globe. In order to keep the application as simple as possible and reduce the mobile requirements, the use of the location sensors of the device were avoided, even though it is common to use it in augmented reality applications. Instead of this, the markers or labels helped to place where the Globe should be and where, part of image was overlapped when an increase of Globe size have to be displayed.

Although it is easy to create own marks, in this application we use the official one in order to allow students to reproduce this exercise by themselves. It was selected an easily identifiable image such as a black question mark on a white background so a quickly recognition of the marker allowed to determine the orientation and scale of the object to draw. The AndAR library was used with this purpose (Figure 3).

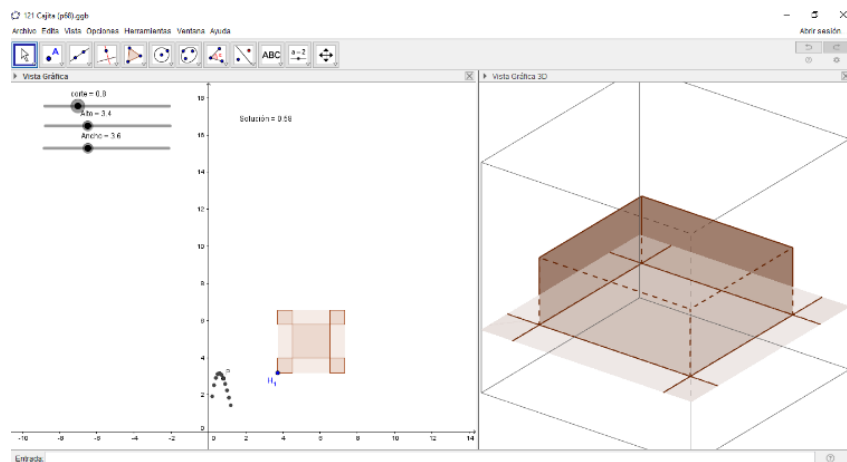
The student can stop the animation at different times, measure on the figure and then respond to questions with the obtained data.

### 2.2.2 Construction of a Box with Maximum Volume

The purpose of this application is to obtain the maximum volume of a box without a lid if a specific area was given. It was intended that the student visualizes the change in the volume of a box through different registers of representation of the volume function (algebraic, tabular and graphic register). In the algebraic register, the change in volume was observed by replacing the values of the independent variable "x" in the analytical expression of the volume:

$$V(x) = x * (high - x)(width - x). \quad (1)$$

In the tabular register, a volume change was observed when the x value in the table is changed then a change of the value of the variable V is observed. In the graphic register, if the curve changes then a modifying volume is presented.



**Fig. 4.** Application for analyzing volume optimization of a box based on a sheet and a side cut x. It contains: sliders on the left side, in the middle area, the volume (y-axis) with respect to the cut (x axis) and the sheet in which is presented the cut to be made. Finally, a 3D view of the box in the right side.

For the construction of this mobile application, the free GeoGebra software was used [10]. As is shown in Figure 4, to build the simulation of this problem, slide bars controls were created for the height and width variable of the sheet that are shown in the center as a polygon. Four boxes are used to show the cuts that have to be

performed. It has a point  $H_1$  from which both the whole picture and the boxes generated by the cut. In the first case the image is generated by adding the coordinates of this point to the width and length of the sheet, which also can be modified using the sliders on the left side and in the second case, represents the independent variable.

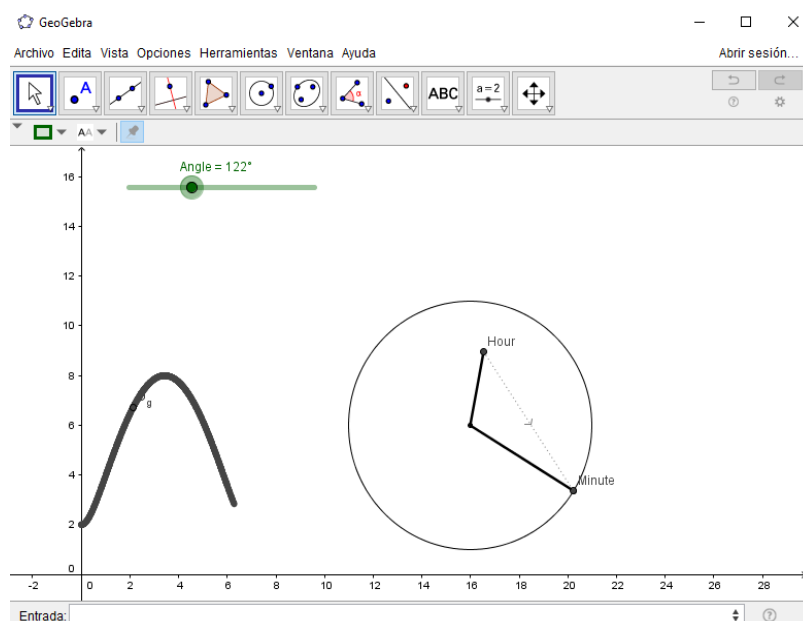
In the 3D graph, the sheet is located in the  $z = 0$  plane and the cut sheet has been folded up to conform the complete box. When the sliders are moved, the changes are reflected in the other zones of the window. It can also be observed the point  $P$  whose coordinates are  $x$ , the cut dimension and the volume of the box  $V(x)$  computed.

Student can change the scales, see the generated data in a spreadsheet and images so he can explore different representations that could help to understand the concepts and solve the problems.

### 2.2.3 Clockwise

In this application, the student is asked to find the speed of changes in the distance between the tips of the hands of a clock after a lapse of time and find some of the extreme values such as maximum and minimum.

He solves this problem using GeoGebra again, a response windows is shown in Figure 5. The hands of the clock were made with two line segments, one of greater length such as in a clock. One segment is entirely free, representing the minute hand and the other hand position is calculated as a fraction of the angle and the minute rate with the vertical position as reference.



**Fig. 5.** Clockwise. The circle on the right represents the clock and the two line segments, the hands. The graph on the left shows how the distance between the handles changes the angle that makes the minute hand with the vertical.

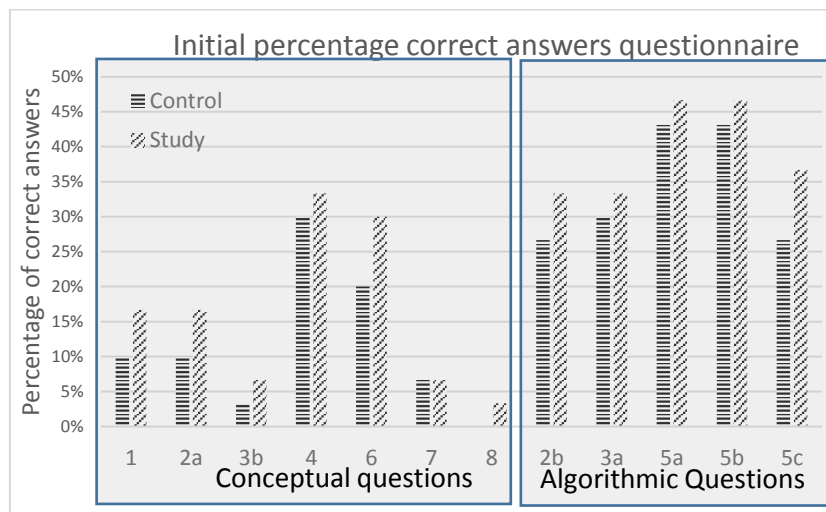
The obtained data is presented in animation and the average rate of change and approaching the instantaneous rate of change is requested. So the user could observe and find the need data just checking the animation and thinking about the meaning of the function graph and the derivative.

### 3 Results

The initial questionnaire was a diagnostic and was graded using right or wrong (in the case of not answering the question was taken as incorrect). The questions were focused on reviewing both conceptual and algorithmic abilities of the students and found that most of them showed gaps related to the derivative concept.

There were 12 questions in total, 5 evaluated the algorithmic problems and 6 the conceptual problems. The graph in Figure 6 shows the percentage of correct answers for each question, the questions do not appear in the order in which students answered, but have been divided into conceptual and algorithmic type.

It can be seen that both the control group (GC) and the study group (GE) have the same performance in the initial questionnaire, which is low. It was demonstrated by grouping together the results of the 60 students of the initial questionnaire and calculating the student's t-test, along with the Mann-Whitney test showing that they are not different with  $p < 0.05$ . GC averaged was 2.02 in the initial questionnaire and GE obtained an average of 2.58.



**Fig. 6.** Results of both groups, showed how algorithmic questions are answered correctly more often than the others in initial questionnaire.

Considering only the average of algorithmic questions and comparing to the average of conceptual questions is observed that in the case of algorithmic questions, the control group obtained 3.40 and 3.93 mean grade. But in conceptual questions

averages was 1.14 for the GC and 1.96 for GE. So both groups showed deficiencies, especially about the application of the concept of derivative.

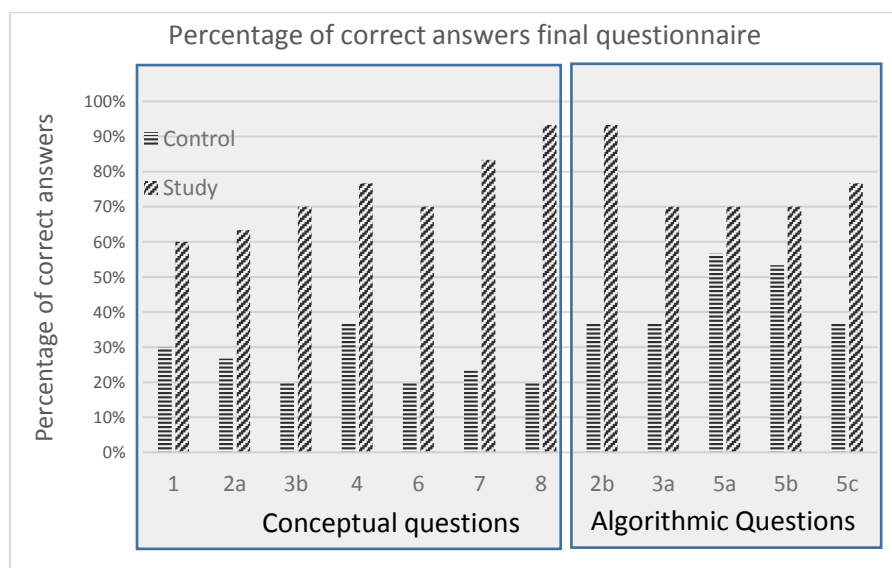
The more frequently error detected is that students replaced the given values in the mathematics formula without noticed what the exercise was asked to respond. The second most common mistake was to confuse the concepts they were asked.

After working with the traditionally teaching sequences in GC and in the GE using the mobile applications, a final questionnaire was conducted in order to evaluate if there is a different performance between students of GC and GE.

Both groups improve their performance. In the GC, the average grade increment was from 2.08, which was obtained in the questionnaire diagnosis, to 3.30 in the final questionnaire. In the case of GE, the average number of correct answers changed from 2.58, which was obtained in the diagnostic questionnaire to 7.47 that was obtained in the final questionnaire. When comparing the two groups with the F test, it was observed that the increases are different with  $p < 0.002$ .

On the other hand, the results of analyzing each of the questions grouped by the concept and algorithmic type are shown in Figure 7.

In both groups, the percentage of correct answers is higher for the questions algorithmic regarding conceptual type, indicating that students are better following a steps set or memorizing the derivation rules than in the construction of the concept of the derivative.



**Fig. 7.** Questions by type answered correctly in control and study group in final questionnaire.

Whereas in the control group, the teacher drew static graphs on the board, in the study group, the student used dynamic graphics through the mobile applications and it was noted that the interactions with cellphone mainly, zooms, interaction with the mathematical model and visualization of the effects, positively contributed to student performance.

## 4 Conclusions and Future Work

It was observed that the students of the control group still required to know the algebraic expression of the function derivative in order to substitute the data on it. On the other hand, students in the study group were able to recognize that the function derivative value is the slope of the tangent at the given point, and thus remembered the definition of a line by two points so they could answer correctly.

It was observed that most of the student had cellphones, then these applications are feasible and could be integrate in the education system because this concept strengthen the learning skills promoted in the IPN. In reviewing applications and activities developed in this research, it was observed that with a mobile device with current performance, ubiquity is achieved and m-learning could be used in education.

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# Optimization through Automation of Malware Update Process, Capable of Evading Anti-Malware Systems

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**Abstract.** Implementation and maintenance of malware protection measures imply high resources usage. Such is the case of Information Security Management Systems (ISMS), whose suggested structure is described by ISO Standard 27.001:2013. In this standard, work with malware is contemplated for penetration testing (pentesting) purposes, allowing to evaluate the response of computer systems against this kind of events. The present document approaches one of the existing malware usage methods for this purpose: encrypted malware obfuscation, through dead code insertion. This method is evaluated in terms of monetary cost and required time, through simulation, to later evaluate those metrics against an automated model, tested through a prototype software. The optimization of this process through the proposed automation, yielded a significant reduction of the monetary cost and time needed.

**Keywords:** Malware, obfuscation, automatization.

## 1 Introduction

Achieving a precise estimation of the actual economic cost caused by malware is an expensive and very complex task, which has been discussed by many authors and institutions [1, 2, 3, 4, 5, 6, 21], but that has not resulted in the development of a tool nor system solid enough to be accepted worldwide, although there is a consensus that such costs are high and are increasing [7].

In 2010, economic losses related to cyber crime were estimated at USD \$70 millions (at consumer-level), amount that reaches USD \$30 millions at business-level. In 2014, annual losses at a global scale went up to USD \$400 billions [1], evidencing the explosive impact of these kind of crimes in the world.

Bernik states that a large portion of the costs that malware causes to organizations, are not related to the crimes per se, but to the implementation and maintenance of protection systems [1], making it harder for organizations with less resources to get access to such protection measures.

Latin America has not been oblivious to this situation, although the countries in this region acknowledge the importance of approaching this issue, current knowledge about cyber threats in this region is reduced [9]. With these limitations in mind, it has been estimated that for 2013, economic costs related to cyber crimes went up to USD \$113 millions [10].

In Chile, this situation is present too: there is awareness at a government-level of the problem, but authorities themselves stated in 2013, that they did not have enough information to provide numbers about increases or decreases of the occurrence of those events in the country.

## **2 Malware, ISMS and ISO Standards**

For crimes happening in the cyber space, malware is a leading component [20], which has transformed these activities into actual business models, developing a market on its own for development, purchases and sales, including whole kits with user-friendly interfaces [11].

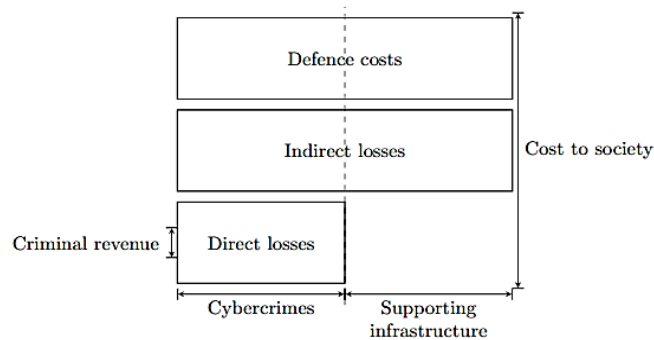
For this research, we consider malware as any software that deliberately achieves the goals of an attacker, in order to cause some sort of loss to a target [12].

In order to face this threat, it is crucial to have specialized systems for the protection of the different elements of the computer systems in an organization. A suggested structure for such systems, called Information Security Management Systems (ISMS), is described by ISO Standard 27,001:2013 which, among many other aspects, includes security self-analysis, through penetration tests (pentesting). Those tests can make authorized use of malware, under monitored conditions in order to accurately measure the response capabilities the target system [13].

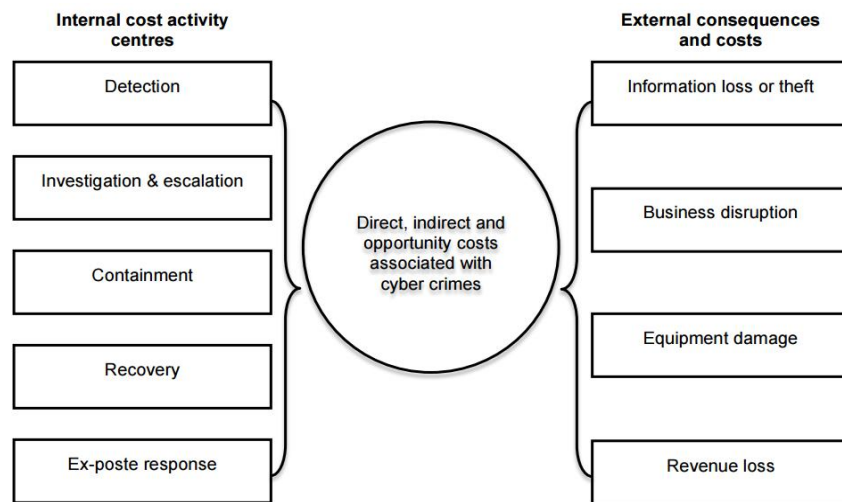
## **3 Related Work**

As mentioned before, there are different opinions about how to quantitatively estimate worldwide economic impact of malware. In 2012, Anderson et al. conducted one of the first systematic studies about this subject, where they propose a multi-level structure, categorizing the economic impact of malware as follows [8]:

- **Direct Losses:** The economic equivalent of all losses, damages or other suffering perceived by a victim, as a consequence of a cyber crime.
- **Indirect Losses:** The losses and opportunity costs imposed to society by the fact that a certain attack is carried out.
- **Defense Costs:** The economic equivalent of prevention efforts conducted to avoid new losses.



**Fig. 1.** Costs measure scheme (Source: Adapted from the work of Anderson et al. 2012).



**Fig. 2.** Cyber crime costs scheme (Source: Ponemon 2015).

Another classification model, proposed by Ponemon Institute (2015) [14], considers two main and separated costs streams: Internal Costs Activity Centers, and External Consequences and Costs. The internal stream is divided into five points:

- Detection,
- research and escalation,
- Containment,
- Recovery,
- Ex-post Response.

On the other hand, the external stream is divided into four main points:

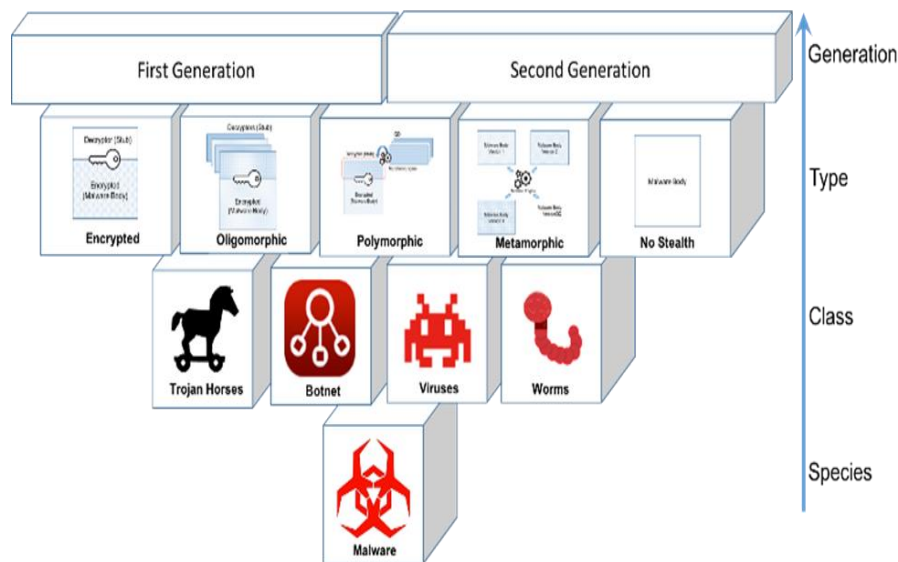
- Costs due to information loss or theft,

- Costs due to business disruption,
- Costs due to Equipment Damages,
- Revenue losses.

These streams converge in the affected organization, in the form of costs and losses, both direct and indirect.

#### 4 Malware Taxonomy and Strategies to Avoid Detection

It is convenient to understand the characteristics of malware in order to understand the strategies applied on it when evading anti-malware systems. Although it is common to wrongly refer to malware as “viruses”, it is important to note that a virus is a type of malware. In general terms, there are four main malware classifications [15]: 1) viruses, 2) worms, 3) botnets y 4) trojan horses.



**Fig. 3.** Inverted pyramid model for malware classification (Source: Barría et al., 2016).

There are other criteria to classify malware, organized by Barría et al. into one big classification structure, in the form of an inverted pyramid model [16]:

The different characteristics of each malware type determine the strategy used to avoid anti-malware systems (commonly known as anti-virus systems). However, in order to understand the reasoning behind each strategy, it is necessary to understand how anti-malware systems works to achieve their goal of successfully detect malware.

Those systems mainly work based on two different approaches: Signature-based Detection, and Heuristic Detection. In the Signature-based Detection, the anti-malware engine looks for known data patterns, inside the executable code of each file. On the

other hand, Heuristic Detection involves behavior analysis, structure analysis and other attributes, which is more efficient for mutated malware detection, but also usually more time needed to perform the analysis [17].

For malware to successfully evade signature-based detection, there are different strategies [18], among which we can mention:

- Encryption: It aims to change the malware appearance, consisting of two basic sections: a “stub” (encryption algorithm) and a “body” (encrypted malware code).
- Oligomorphism: Like encryption, this strategy has two basic sections, including a body, but it has a set of different stubs, randomly executed on each iteration.
- Polymorphism: This strategy can be understood as a improved version of Oligomorphism, by adding a third section, called mutation engine, which generates a new stub version on each iteration.
- Metamorphism: Unlike the previous strategies, metamorphism does not use a stub, because it directly uses a mutation engine on the malware body, making it very hard for signature-based anti-malware systems to detect this kind of malicious code.

All these strategies can be complemented with other techniques to make the malware code harder to analyze and, as consequence, harder to identify as a threat. Among the main techniques to achieve this goal, we can find the code obfuscation, which is basically the application of code transformations (over the source code or the binary), whose change the malware appearance through a set of steps, keeping its functionality intact. At the same time, there are different techniques for obfuscating code [18], among which we can mention:

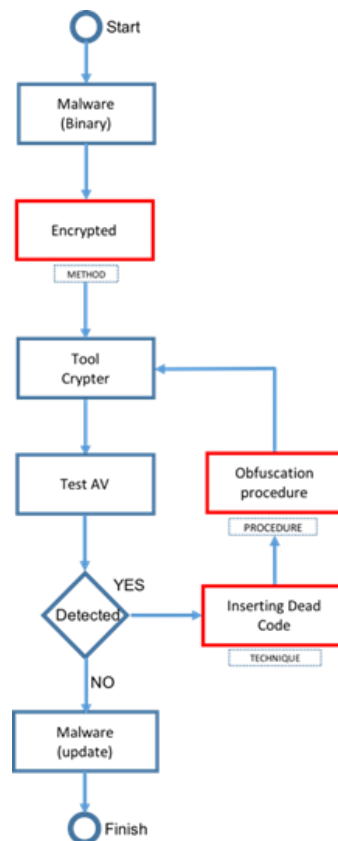
- Dead code insertion: Is the addition of code aiming to modify the binary sequence of a program, without affecting its functionality.
- Code transformation: Is the reordering of the original code sequence, without impacting its behavior.
- Sub-routine reordering: Random changes in the order of the sub-routines of a given code.
- Instruction substitution: A library of equivalent instructions is set, allowing instruction substitution in the code, without affecting its functionality.
- Code integration: It is the generation of new structures of the malware body on each iteration.
- Encryption/Decryption: Systematic encapsulation of the information, through a two-parts structure: a) Encrypted body, and b) Decrypted code.

To implement these techniques, a set of instructions and tasks, called procedures, are used. Among the most common procedures we can find: AvFucker, DSplit, RIT, Hexing y XoR, and others.

For this study, we have chosen the strategy of encryption, using the AvFucker procedure to update a test malware, based on the dead code insertion technique.

## 5 Current Malware Update Process

The process of taking a program whose signature is already recognized by anti-malware systems as a threat, and transforming it in such a way that is no longer detected, without losing functionality, is described by Barría et al. as an iterative process of malware “update” [19].



**Fig. 4.** Malware update scheme (Source: Barría et al. 2016).

This process involves a procedure cycle, where malware is encrypted thanks to a Crypter, to then be analyzed by one or more anti-malware systems. In the case of being detected, the malware is inserted with dead code, supported by some obfuscation process, and then encrypt the resulting code again with a Crypter.

Finally another test is conducted against the anti-malware system and the cycle is repeated until a program which signature is no longer detected, is obtained. A graphical explanation of the previously mentioned process, is provided below:

Nowadays, iteration of this model is executed with the help of different tools, including crypters, hexadecimal editors, anti-malware systems engines, among others. It is also common to use a tool which allows to generate “n” number of copies of the

original file, modifying each copy in a different offset range, replacing those locations with dead code. Although the usage of that kind of tools means an important reduction of the time required for this process, compared to the “manual” way to do that process (for example, editing the offset range by using an editor), this part of the process still is the one that adds the most amount of time to the whole process, thus increasing its final cost.

Having identified this difficulty, the possibility of automating this iteration arises as a natural option when it comes to reduce the costs in terms of money and time.

## 6 Testing through Prototype Software

A Python version 2 was coded, with the addition of the PyWinAuto library, in order to automate the process in study.

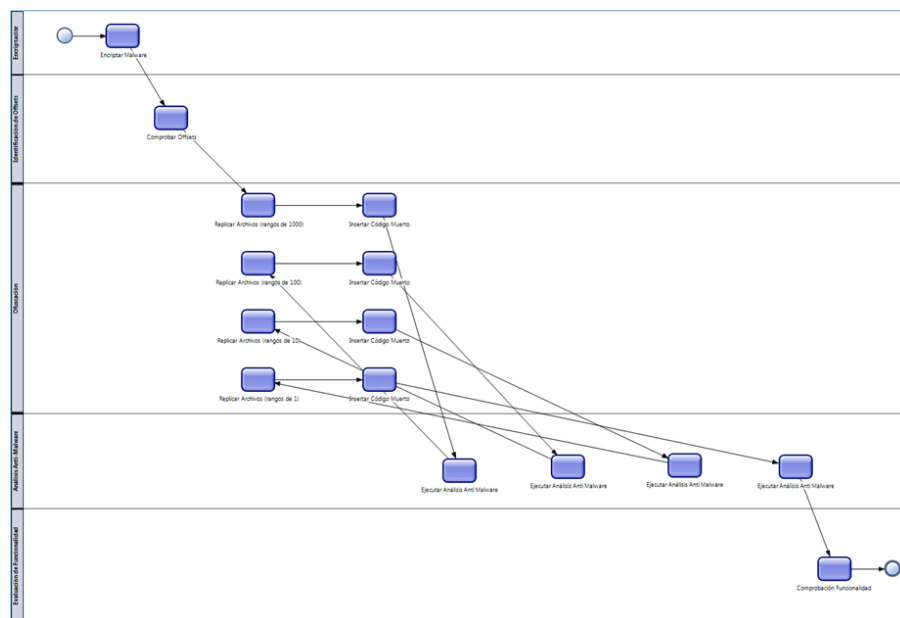


Fig. 5. Automated process scheme (prepared).

## 7 Metrics Comparison

Having the prototype ready, we proceeded to compare the time required to finish a whole instance of the process, from beginning to end, both in the case of the automated process and the original one (manual process), and then use a simulation software which allowed us to evaluate the required time for 50 instances.

In order to homologate the experimental conditions for both cases, the same tools and the same base file with the malware signature were used, as described below:

- Base file,
- Crypter tool,
- Hexadecimal edition and file replication tool “Offset Locator”,
- Anti-malware engine “Eset Nod32”.

Both processes were executed in the same computer, under the same operative system (Windows 7).

Finally, to evaluate the economic dimension of each process, it was given to each working hour the value of CLP \$1100 each one.

### 7.1 Experimental Evaluation

The execution of the manual process lasted 420 minutes (7 hours), while the prototype software took 5 minutes to finish the whole instance. In both cases we obtained a set of files whose successfully evaded the anti-malware engine.

Considering the value assigned to each working hour, we obtained the following results presented in Table 1.

**Table 1.** Comparison chart for time and cost between both processes, experimentally evaluated (prepared).

	Manual Process	Automated Process
Time (hours)	7	0,083
Cost (\$ CLP)	7700	1100

### 7.2 Simulated Evaluation

The execution of 50 whole instances generated the following results presented in Table 2.

**Table 2.** Comparison chart for time and cost between both processes, evaluated through simulation (prepared).

	Manual Process	Automated Process
Time (hours)	350	4,2
Cost (\$ CLP)	385000	5500

## 8 Conclusions

The observed time reduction in the automated process has an evident impact in the final cost of it. The fact that the tests were performed with ligh files (5KB) allows us to deduce that, if applied to larger files, the benefits of this process will be even more significant.

The possibility of reducing the cost for this kind of processes is, undoubtedly, a great chance to bring this kind of tools closer to smaller organizations, thus helping them to



gain access to security evaluations for their computer systems, contributing to create a safer environment for all kind of organizations.

Being possible to approach this kind of process from a modular perspective, the doors for future software versions are left open, potentially including other tools, allowing for future experimental comparisons of performance, efficiency, to name a few. This could lead to potential improvements for each module, in terms of the process itself, or execution times, among other points.

Furthermore, the path is open for approaching other techniques and strategies, expanding the range of tools whose time and money costs can be reduced.

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## Virtual Environment of Learning to Support the Topic of Proportionality at Elementary Levels

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**Abstract.** This article describes the technological and educational factors involved in the development of the educational software proposal named Dwarfs and Giants, which is expressed as a Virtual Environment of Learning developed under the standard Sharable Content Object Reference Model in its version 1.2. This tool lends a helping hand to the teacher in the classroom. It has activities, according to the studying plan of the Secretaría de Educación Pública in Mexico. To strengthen the topics of ratio and proportion in students of the sixth grade of elementary school. The VLE was tested and used by a group of 28 students in the sixth grade of elementary school during 8 sessions, once every week. As field research these students answered some initial questions before using the software and answered some more questions at the end. Meaningful attainments were obtained and these are shown in the information given by the teacher in charge of the group and related to the raising of the grade in the mathematics exams from various students. There was an increase in the final evaluation compared to the initial one (43.2% to 73.2%). When applying the test t-student, a statistically meaningful difference was observed ( $p < 0.005$ ), that is why the VLE is considered to have had profound positive impact on the students' learning.

**Keywords:** Virtual learning environments, agile methodologies to develop software, object-oriented programming, SCORM.

### 1 Introduction

The use of the Information and Communication Technologies (ICT) in the teaching-learning process has been increased in recent years and it has had a powerful impact due to the fact that more people can access knowledge without being present in a classroom, as well as the outstanding decrease of time to make educational material to convey topics. In this regard, Mendoza [1] comments that the challenge of bringing ICT into the classroom is not only what can be related to the infrastructure or the acquisition of technological resources, but also the way how the teacher works with them, when you use them, for what and what hopes to achieve learning in students.

The elementary education is the basement of people's professional development. According to the results of the Census of Population and Housing conducted by the National Statistics Institute and Geography [2], Mexico has a population of 119,530,753 people, of which 35.2 million are enrolled as students in basic school education, accounting 73.4% of enrollment in the education system [3]. On the other hand, according to the Organization for Economic Cooperation and Development Economic (OECD) about 55% of students did not achieve the level of basic skills in math test [4]. [5]. Although this problem is multifactorial, one of the causes is due to the poor development of the concepts and skills that children have in the elementary school, one of the concept is ratio and proportion, because that permit to the student development his/her the *proportional thinking*, which is a cognitive characteristic of people [6]. A human being has the proportional thinking totally developed when he/she can explain this relation of relations not only qualitatively, by using intuition, but also quantitatively. So, there are two aspects of the proportional thinking: the qualitative proportional thinking and the quantitative proportional one.

There are educational models that support the development of the qualitative and quantitative proportional thinking in children according to what is shown by Piaget in [7]. Such educational models were developed by Ruiz [6]. For so doing, Ruiz used drawings, physical objects, classical literature tales, puppets and some other educational materials. This article shows part of the investigation, and emphasizes the use of technology to implement as a Virtual Learning Environment (VLE) the work done by Ruiz. Some of the models created by Ruiz are known as "The development of a party room", and "The house furniture". In the last one the student uses graphic elements to hold relations among the furniture of a house by using verbal categories (bigger than, smaller than, etc.). Through the use of the proposed VLE the proportional thinking of the students was benefited.

The rest of the paper is organized as follows: section 2 describes the role of the technology in education. Section 3 depicts the VLE developed. Section 4 shows the implementation. Section 5 describes the preliminary results. Section 6 presents the conclusion. Finally, the references are depicted.

## 2 Technology in Education

Nowadays, the use of technology is everywhere in our lives and education is not an exception. Education is benefited from educational software and from the Internet, among others, the first one employs, computationally speaking, pedagogical activities that support the understanding of concepts [8], the second one, Internet; lets the knowledge be gotten by more people without needing to be present in a classroom. When combining these technologies a more robust software which is known as Virtual Environment of Learning (VLE). A VLE is a computational system designed to facilitate the management of resources of learning [9].

Something important when developing VLEs is the use of standards to guarantee quality tools that fulfill the desired needs and goals. The Sharable Content Object Reference Model (SCORM) was created to establish principles and guides to work which are needed to develop and implement efficiently, effectively and on a broad scale, education about new web technologies [10]. Such standard is adapted to the

definition of Learning Object (LO), a digital or not digital entity which can be used in learning, education or training [9]. The LO is more philosophy than technology itself which is based on the stream of the sciences of computing known as object-oriented programming. By now the LO's lack of a universally accepted definition and they are polemical too [11], [12].

SCORM divides the world of technology in functional components which are:

- Sharable Content Object (SCO): content that can be supported by a Web browser and it can send information to the system. It is divided into: simple SCO and data management SCO. The minimum unit of the SCOs is the Assets.
- Learning Management System (LMS) is software for Internet-Intranet servers and also manages the learning resources. It manages users, learning resources and communication services, and sends learning resource videos to the student.
- The bidirectional communication through an API among the SCOs and the LMS which uses 15 defined variables by the standard used to exchange data.

Mixing technology and education is a good choice to modernize the teaching - learning process; however, developing the right tools is something really challenging in different ways. First, it must be considered what to teach and how to do it, it means: 1) identifying the course or topic to be taught as there are lots of topics, and the ones to be chosen are the ones to which we need to pay more attention, and it depends on their difficulty or on their importance related to the following subjects, and 2) developing activities that support the topic to be taught, and their benefits. Second, the available technological tools must be analyzed so as to implement the activities of the first step to set up functional systems. And, finally, it is compulsory to evaluate the use of colors, shapes, visual designs, uses, contents, skills, etc. of the concerning group of study. In this sense, the Latin American Institute for Educational Communication (ILCE), in coordination with the Secretaría de Educación Pública (SEP) [13]. In Mexico, in 1997 created a school network taking into account students, teachers, parents and principals of public primary schools. Such network is aimed at bringing to the schools, through the use of Internet, educational opportunities and materials of great relevance based on the existing SEP's study plans and programs to help to improve the quality of teaching. Educational authorities began to direct their efforts towards the establishment of Information and Communication Technologies (ICT) in basic education. In 2003 "Enciclomedia" made its appearance in the educational scenario. The main idea which gives rise to it is the digitalization of free textbooks, supplemented with audiovisual and interactive resources. The primary objective of this educational supplement is that students in public elementary schools in Mexico, with a more significant learning, encouraging interaction, teamwork in the classroom and cooperation of society to improve overall quality education. But these objectives were not achieved for various reasons, focusing on public policy [14], [15]. Nowadays, members of the Educational Computer Network as part of Network Computing IPN develop projects aimed at incorporate technology into education through the construction of a laboratory for the development of computer-educational resources for different educational levels [16]. One of these resources is shown in this article, and has been developed for primary education on the topic of ratio and proportion this is related to the proportional thinking which lets someone, after a certain mental process; establish the relation of equivalence between quotients of lengths [6].

### 3 Dwarfs and Giants

Dwarfs and Giants is educational software, created as a VLE, which is an aiding tool to the teacher in the classroom to teach the topic of the proportional thinking. It has the crucial features of an VLE which are: management of information, definition of the user roles (manager, professor, and student), authentication of the users in the system, implementation of activities structured as courses, standardization of the tools for activities containing SCORM, text and image questioning that can be auto evaluated as well as certain personalizing of the graphic interface.

#### 3.1 Types of Users

Table I shows specific actions each kind of user can do according to their role.

**Table 1.** Users' functionality.

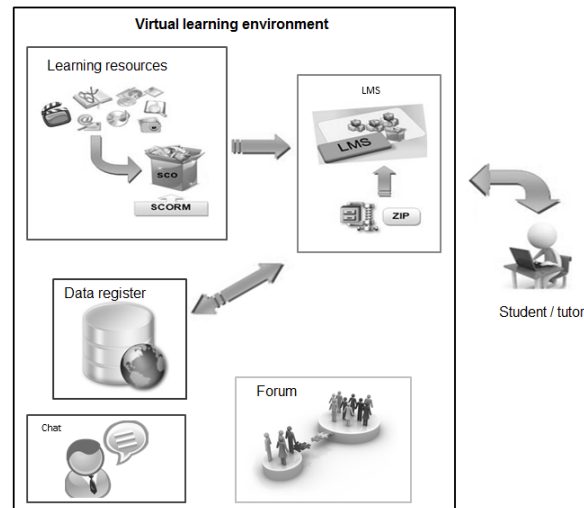
Role	Funcionalidad
Administrator	<ul style="list-style-type: none"> <li>- Administration of students, professors, groups.</li> <li>- Changing of the user's password.</li> <li>- Restoration of the professors &amp; students' password.</li> <li>- Enrollment and change of group of students</li> </ul>
Profesor	<ul style="list-style-type: none"> <li>- Administration of question papers, learning resources.</li> <li>- Monitoring the student's academic record.</li> <li>- Group statistics, reporting the academic information generated of the group students.</li> <li>- Internet forum, chatting, changing of password.</li> </ul>
Student	<ul style="list-style-type: none"> <li>- Use of the learning resources (activities &amp; courses), forum y chat.</li> </ul>

#### 3.2 Architecture

Dwarfs and Giants takes the architecture IEEE 1484 Learning Technology Systems Architecture (LTSA) [24], established by the Institute of Electrical and Electronics Engineers Learning Technology Standards Committee (IEEE LTSC), as a reference to identify the components. The IEEE 1484 LTSA architecture adapts to each critical part of a VLE: students, repository of the learning resources, tutors (professors), storage the student's personal information and academic record, as well as iteration among its components. The IEEE 1484 LTSA architecture adapts perfectly to the Client - Server model [17]. One of the advantages of this architecture is portability as the resources are stored in the server and the client just needs to access to Internet from an intranet or on the Web.

Dwarfs and Giants uses the version 1.2 of SCORM. In fact, SCORM does not validate the contents of the learning resources that integrate the SCOs, as it just maps the learning integrating resources according to the rules established to be transparent in

the systems using the standard. Besides the components used by the architecture IEEE 1484, Dwarfs and Giants uses tools that promote the collaborative learning as those ones of a forum of discussion or a chat. Figure 1 shows the general architecture of Dwarfs and Giants based on the IEEE 1484 LTSA architecture and the Client - Server model.



**Fig. 1.** General architecture of Dwarfs and Giants.

### 3.3 Technologies Used

It was decided to use 1) MySQL as Database, 2) PHP as the programming language, of the server to obtain information of the database and to launch the content of learning resources, 3) HTML in combination of JavaScript and CSS to show the multimedia content on the side of the client, and 4) AJAX to send and receive data asynchronously to update specific components on the page, taking into account the standards of the World Wide Web Consortium (W3C) [18], [19], to execute on the commonly used browsers: Internet Explorer 8, Google Chrome, Mozilla Firefox, Safari and Opera.

## 4 Implementation

Using the learning model by Ruiz [6], activities were selected to help the student to acquire the concept of proportional thinking in its two parts. Dwarfs and Giants takes the structure of an LO based on a course: diagnostic questionnaire, introduction to the topic, activities for the qualitative a quantitative proportional thinking and the final evaluation. The initial screen of Dwarfs and Giants (see Figure 2) has a menu having the initial options: start session, colors and contacts. In the menu colors a list of colors is displayed on the left so as to personalize the interface. Each user must enter the user's name and the password in order to access the system, depending on their privileges, as mentioned, feasible actions are shown.



Fig. 2. Main screen (screenshot in Spanish).

The following figures show the screen for the teacher.



Fig. 3 Teacher's interface (screenshot in Spanish).

## 5 Preliminary Results

In collaboration with the elementary school “Jaime Torres Bodet”, working with the A and the B sixth grade groups, 58 students. There was technological and pedagogic validation of Dwarfs and Giants. Technologically speaking some aspects were verified: information distribution, content of the visual interface, colors, size and typography according to the students' opinion, this is done by asking for the colors, shapes and use of computer they prefer.



On the pedagogic side, students use Dwarfs and Giants first to answer the diagnostic questionnaire and then the activities of proportional thinking and finally they answer an evaluation to compare the initial and final knowledge after using this tool.

According to the technological verification, the results are the following ones:

- 90 % of our sample think that the distribution of graphic interface is a proper one to their age, which means they get familiar with the images shown and they are well distributed with no too much information.
- 52 % point out the typography is the right one which is the Comics Sans MS, having a 14 and 16-pixel letter size, Dwarfs and Giants uses a similar source with sizes 12 and 24 pixels which adapts to the students' preference
- The students' favorite colors are: Violet, Red, Green, Turquoise and blue, all of them but violet are considered in Dwarfs and Giants when choosing from the list of colors to personalize the interface.

Qualitative analysis: Schooling teaching has not made good use of the students' qualitative thinking around proportionality, this was observed when focusing on the average correct answers which were in one of the dimensions of the figures they were asked to either reduce or maximize. Visualizing a complete drawing without focusing on its single parts so that we can choose the reduction of the original one that suggests that we need to work more on the qualitative aspect of the proportionality, so it was considered as an aspect that must be done by using the VLE Packages and big.

In some cases, for some students the qualitative aspect is poorly set out as the previous step of the quantitative aspect since the linguistic categories detected in them are the following ones: "it is bigger than...", "it is smaller than..." which reflects certain rudimentary understanding of the proportion, there were no other categories through which they would show a better understanding of the idea about proportion.

There was confusion for them when establishing relation between lengths so it was necessary to emphasize it to get the notion of ratio through the VLE. The familiarity that both students have with the drawing done to scale was recognized when part of the drawing was already done, that is why the predominance over law of closing prevailing in them was pointed out.

The difficulty detected is not recognizing the scaling factor ( $x^3$ ) in this kind of task. It was observed that children can easily fill out a table by adding certain times the same number or by multiplying, once the corresponding scaling operator is found. The problem detected employing the table was that the students did not extract the data from it when responding to the situation caused.

There was no comment by the students taking into account the different ways of representation: that of the table, that of the drawing, and the numerical one; when solving the classified problems "as the ones having a lose value", question tasks are in this category, thought the situations were different, but one which was solved by most students in the group.

Some other aspect considered to be a students' frequent answer was using the strategy of the unit value when solving some homework which matches what some researchers have found including the theoretical framework of this document, interested in recognizing strategies while solving ratio and proportion problems. After having

worked on Dwarfs and Giants, students answered final questions and they got a significant improvement talking about the concepts ratio and proportion.

Almost totally, students expressed a development of their proportional thinking either qualitatively or quantitatively speaking. Most of them recognize reduction and widening as a specific way of proportion. They used mathematical concepts as they are understood, as ratio and proportion, recognizing the first one as relations between lengths and the second one as a relation of equivalence between reasons

Many ways of representing were employed: that of the drawing, on the table, and the numerical one, which was observed when doing some tasks of the final questions.

Despite what has been pointed out, there are topics that were slightly set out therefore it is necessary to do some more research on them, as the case of employing two symbolic systems of representation, the use of reverses, relying on the operators to establish ratios.

Statistical Analysis: The percentage of correct answers obtained by the group on the initial questionnaire was 47.2 % and after employing the Virtual Environment of Learning, Dwarfs and Giants, the percentage of the correct answers on the final questionnaire was 73.2 %. Considering a paired-sets the results before and after the use of the application as a paired-sets and that different subject had specific initial knowledge of the topic, then the mean was computed for each condition. Then, the difference from each student was obtained and finally the average of differences was tested in order to check if it was significantly different. The results of the t-student showed a meaningful difference ( $p < 0.005$ ).

## **6 Conclusions**

It has been seen that the use of technology in the teaching-learning process has had great advantages in recent years, but it is not only important to use technology but also three important aspects must be taken into account while developing educational software: what and how to teach and the tools (methodology, standards, technologies) the developing ones.

The first aspect is crucial, knowing why we choose such topic, as for us and as mentioned there are deficiencies in mathematics in the elementary schools in Mexico, in the case of the topics of ratio and proportion which are attached to the proportional thinking, these are the bases of mathematical branches which are Algebra, Trigonometry, calculus, etc. and other sciences: Physics, Chemistry, etc.

The second step once the topic or course has been defined, we must look for pedagogic fundamentals that use educational techniques to lecture the topic, Dwarfs and Giants is based on the teaching models developed by Ruiz [10], they got good results proven in black and white.

In the final step, it is important to define the process of development software which best adapts to the client's needs, besides using the adequate tools to guarantee success of such development.

Using standards in educational software has great advantages which are reusability, portability, scalability of activities and courses; portability due to having an established model, lets us integrate easily some more content in either the courses or the activities. Something else is taking into account the target population, in this case Dwarfs and

Giants has got a young population, 8 to 10 years old children, so this makes developers take the visual issue as something really important, design and distribution of the page in order to get children's interest, so as not to bore them and resulting in a lower performance, pedagogically speaking.

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# Design and Implementation of a Medium Access Protocol for a Heterogeneous Wireless Sensor Network

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**Abstract.** The present work is focused on the development and implementation of a low energy consuming medium access protocol, based on the characteristics of the S-MAC (Sensor Medium Access Control) [7] protocol, with a test scenario of a homogeneous network that uses heterogeneous information. Several other protocols are being implemented under similar conditions but this has been proven to be far from optimal [4]. It is proposed the design of a protocol that allows, through a sleep-active time schedule, energy savings, synchronization and correct management of heterogeneous information. The approach to managing heterogeneous information is made by assigning different medium access priority to each kind of information. On the test scenario it's used "continuous monitoring" mode, where nodes use a CSMA/RTS medium access protocol, and "priority mode", where nodes that need to transmit information that has higher information get to do so immediately while the rest of the nodes enter sleep mode. In this way we can guarantee there are energy savings and at the same time different kinds of information are being transmitted.

**Keywords:** Medium access protocol, wireless sensor network, software defined radio, S-MAC protocol, continuous monitoring and event detection.

## 1 Introduction

The MAC layer, which belongs to the Data Link Layer, is in charge of defining the protocols that dictate who gets to use the link and how he's supposed to do so. Some medium access protocols used in wireless sensor networks assume that every node and the kinds of information managed inside the network are

all homogeneous. These kind of implementations don't guarantee stable communication amongst nodes due to different kinds of possible interference, limited frequency ranges or geographic related losses.

Medium access protocols designed for homogeneous networks tend to be centered around channel usage optimization, throughput efficiency and less energy conservation, however, when it comes to wireless sensor networks its actually the opposite [1]. These protocols are gaining importance because future development of wireless communications involve Wireless Sensor Networks [5].

The protocol proposed in this work was mostly based on the idea of combining the energy saving characteristics from S-MAC and an information classification system. The information classification system was implemented in a way that nodes would work under different roles depending on the kind of information that they need to deal with.

Another important part of this work is the development of a testbed that guarantees the communication between heterogeneous nodes and information. This approach has been chosen since heterogeneous sensor networks works have been analysed from the energy efficiency approach and not from the heterogeneous information approach [2].

## **2 Protocol Overview**

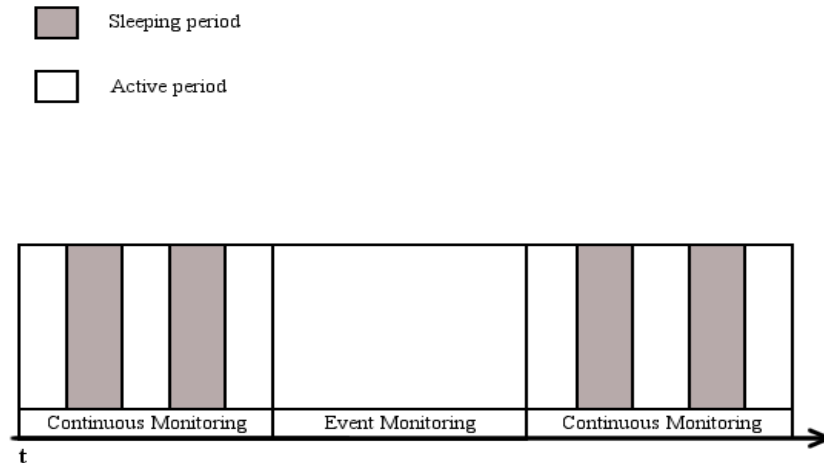
In order to manage different kinds of information, in this case two, it is proposed to implement different kinds of active times based on their needs to access the channel. The proposed kinds are: continuous monitoring and event detection.

These active times must be preceded by a sleeping time in order to save energy through the most characteristic attribute of S-MAC, active and sleeping time regular intervals. In order to do so in a way that all kinds of information can access to the medium, it is proposed that each active time implements a different Medium Access mode.

In continuous mode all nodes transmit and compete for the medium under a CSMA/CA protocol. This was chosen because continuous monitoring requires nodes to constantly transmit information that has low priority. If a transmission is under way and the continuous monitoring phase suddenly ends the whole transmission is discarded and the nodes enter sleep mode.

When event detection phase starts all nodes also compete for access to the medium through CSMA/CA since it's highly likely that several event detection nodes try to communicate the same event. If this phase ends when a transmission is under way the phase gets extended until the transmission ends successfully. If no events are detected during event detection or if no information needs to be transmitted during continuous monitoring phase the phase ending time doesn't change since this could lead to desynchronization among many nodes. It could also interrupt transmissions that occur during the last milliseconds of the phase. As we can see from figure 1 if the continuous phase is larger than the event detection phase, critical events may not be detected but if event detection phase

is larger than continuous monitoring phase, drastic changes in continuous data could be detected with a certain delay.



**Fig. 1.** Time relation between phases.

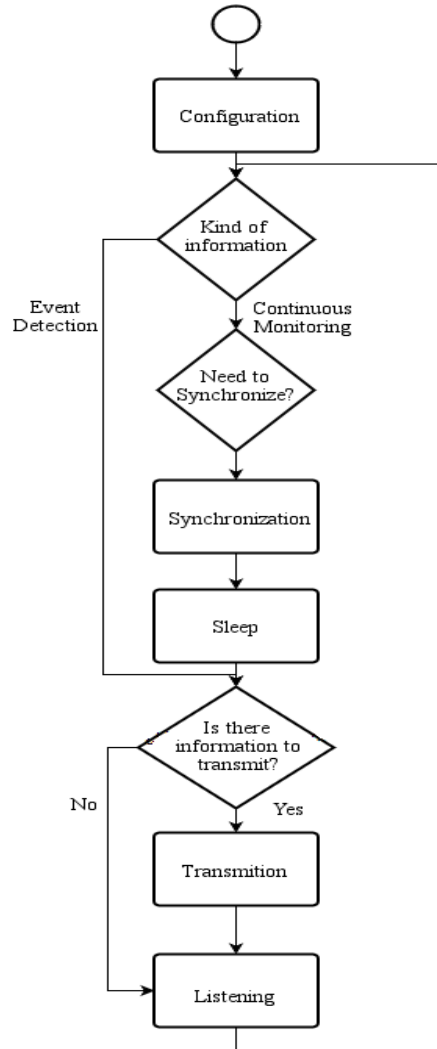
Another very important factor to keep in mind is the synchronization of neighbour nodes. This has been solved by proposing a synchronization role scheme where a node can be a master, which helps other nodes to synchronize, or a slave, which synchronizes its actions through the use of SYNC packets over the network. This is similar to the scheme proposed in [8]. Simply put, if a slave node doesn't get a SYNC packet after a few cycles assumes the master node has run out of battery or has unexpectedly left the network, in that case he assumes master mode and continues operating normally. So, in general the proposed protocol needs to implement the next characteristics:

- Implementation of an energy saving scheme through sleep and active phases.
- Synchronization through messages.
- Priority access for critical or important information.

It should also be noted that the next capabilities are desired, needed or innate in the final implementation:

- Implementation algorithm must be cyclic.
- Implementation code must use as little resources as possible.
- Packet fragmentation must be present.
- IEEE 802.11 compatibility because of its general acceptance.

The figure 2 illustrates the proposed workflow for the protocols implementation.



**Fig. 2.** Proposed workflow for the implementation of the protocol,

### 3 Testbed

The implementation of the protocol was made on nodes composed by a micro controller mounted on a prototyping platform, a software defined radio and a power module. Node control is achieved through the prototyping platform ChipKIT Uno32. ChipKIT platform was chosen over other more popular options, such as Arduino, because of its lower cost and higher performance [9].

The chosen software defined radio was the CC1101 radiofrequency transceiver due to its low cost, 10 USD approximately, and its highly customizable capabilities



such as base frequency, modulation, number of transmission channels, etc. This module is specially useful for low power applications since its specially designed for the ISM (Industrial, Scientific and Medical) / SRD (Short Range Devices) band [3].

Transmitted information was simulated, but it can be easily generated since the ChipKIT platform has many input methods available. The final implementation of a node can be appreciated on figure 3.

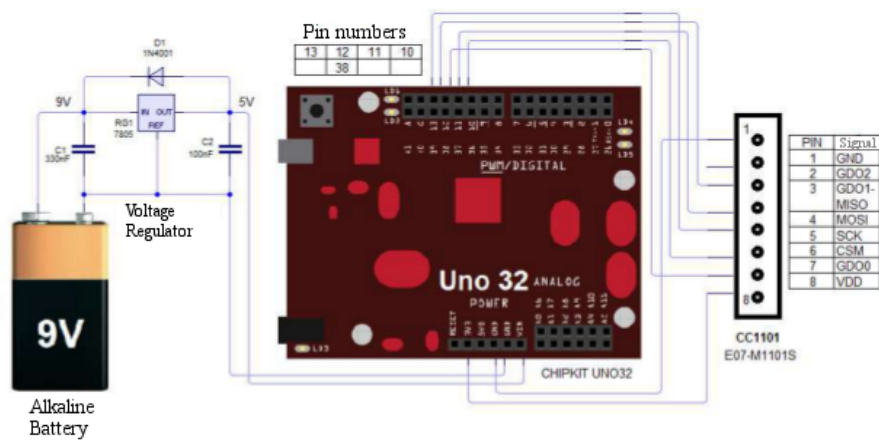


Fig. 3. Physical implementation of a node.

## 4 Tests

Four different tests were run and all information was logged through serial port to PC to validate the correctness of the test.

### 4.1 First Test: Hidden Terminal

In the first test three nodes were used in such a manner that the hidden terminal problem was present. In this case scenario three nodes, A,B and C, are connected in an unstructured network. Node A is in range of node B, Node C is in range of node B but Node C and A are out of range. Node A transmits regularly continuous monitoring information to node B while node C transmits event detection information to node B as well. Normally nodes C and A would cause a collision on node B since both of them try to communicate with it, but the implemented protocol uses CSMA/CA and timed phases so node A and C won't

cause a collision since their transmissions occur during different phases and even if they occurred in the same phase CSMA/CA would prevent them from colliding.

#### **4.2 Second Test: Time Synchronization**

In this test four nodes are turned on at random times. The first node that was turned on assumed master role and started transmitting SYNC packets periodically. When continuous monitoring phase is active a led is supposed to turn on on every single node and when event detection phase is active said led is supposed to flicker. By sending each phase initial time through the serial port we were able to make sure that all nodes were synchronized.

#### **4.3 Third Test: Medium Access and throughput**

Again, in this test case four nodes were used. The first two would generate and transmit data to the fourth node. The third node would be used as a "data bridge" between the first, the second and the fourth node of the network. Data was generated in such a manner that it would cause collisions, however thanks to CSMA/CA the delay caused by simultaneous transmissions is very small.

#### **4.4 Fourth Test: Lifetime Test**

In this test three nodes are used, one of the three nodes is connected to a PC, works as a master synchronizer and logs every single package that is transmitted. The other two send continuous information from both kinds and after a fixed time consumed energy was measured. Because of time restraints more accurate tests couldn't be run, however it was shown that after 20 minutes the variance in energy was of only about ten millivolts.

### **5 Conclusion and Future Works**

The main focus of this work was to develop a medium access protocol that provided many features needed in very specific areas. This protocol was developed alongside a testbed that simulated a wireless sensor network, said testbed proved to be highly customizable and powerful, however if this protocol gets to be implemented a dedicated hardware platform would be much more suitable when it comes to performance.

The measurements made when the tests were run weren't more accurate than values of the  $1 \times 10^{-3}$  order due to the tools available at the time. It's proposed that further and more exact measurements are done in order to be able to make a more complete analysis.

A big part of this protocol is the use of synchronizing nodes. This goes along well with the concept of clustering, so a clustering method focused on making the network scalable would be a great addition to this protocol, that as of the writing of this paper, lacks a complex routing method. Many clustering methods have been proposed specially for Wireless Sensor Networks so no further research might be needed [5].

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# Diet Generator Based on World Health Organization Recommendations

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**Abstract.** Scientific advances in the last years have helped to clarify the role of diet in the prevention of premature mortality resulting from non-communicable diseases. In particular chronic diseases, thus like obesity, diabetes mellitus, hypertension between others have become a significant cause of premature death. The World Health Organization (WHO), have analyzed this problem and elaborated some dietary guidelines to follow, specifically, in WHO technical report #916, establish some ranges for population nutrient intake goals. That consider fats, carbohydrates and proteins as main parameters, but also specify limits for Cholesterol, sodium, fruits and vegetables, and fibre. This paper focuses in automatic diet generation following the rules established in this report, in order to do this a genetic algorithm is developed.

**Keywords:** Genetic algorithm, machine learning, nutrition systems.

## 1 Introduction

In the last years, scientific advances and in particular the amount of population-based epidemiological evidence has helped to clarify the role of diet in preventing and controlling morbidity and premature mortality resulting from non communicable diseases (NCDs) [6]. The NCDs includes obesity, diabetes mellitus, cardiovascular disease, hypertension, stroke, and some types of cancer.

Nutrition is coming to the fore as major modifiable determinant of chronic disease, with scientific evidence increasingly supporting the view that alterations in diet have strong effects, both positive and negative, on health throughout life, dietary adjustments may not only influence present health, but may determine whether or not an individual will develop such NCDs [6,18].

Diet and nutrition are important factors in the promotion and maintenance of good health throughout the entire life course. Their role as determinants of

chronic NCDs is well established and they therefore occupy a prominent position in prevention activities [17].

But NCDs not is the only one problem derived from a bad diet, hunger and malnutrition remain among the most devastating problems facing the majority of the world's poorest nations. Nearly 30% of humanity are currently suffering from one or more of the multiple forms of malnutrition [16]. This forms of malnutrition includes, but not are limited to, Iodine deficiency, Vitamin A deficiency and iron deficiency anemia.

Food strategies must not merely be directed at ensuring food for all, but must also achieve the consumption adequate quantities of safe and good quality foods that together make up a healthy diet [6].

Population nutrient intake goals represent the population average intake that is judged to be consistent with the maintenance of health in a population [6]. Health, in this context, is marked by a low prevalence of diet-related diseases in the population. consistent with the concept of a safe range of nutrient intakes for individuals, there is often a range of population averages that would be consistent with the maintenance of health [6].

The population nutrient intake goals for consideration by national and regional bodies establishing dietary recommendations for the prevention of diet-related chronic diseases are presented in table 1 [6]. These recommendations are expressed in numerical terms, rather than as increases or decreases in intakes of specific nutrients, because the desirable change will depend upon existing intakes in the particular population, and could be in either direction. This table complements another reports on energy and nutrient requirements issued by FAO and WHO [5,3,4]. In order to translate this goals into a dietary guidelines, due consideration should be given to the process for setting unp national dietary guidelines [15].

The recommendations for total fat are formulated to include countries where the usual fat intake is typically above 30% as well as those where the usual intake may be very low, for example less than 15%. Total fat energy of at least 20% is consistent with good health. Highly active groups with diets rich in vegetables, legumes fruits and wholegrain cereals may, however, sustain a total fat intake of up to 35% without the risk of unhealthy weight gain [6].

It is recognized that higher intakes of free sugars threaten the nutrient quality of diets by providing significant energy without specific nutrients. It is necessary to consider that:

1. Free sugars contribute to the overall energy density of diets.
2. Free sugars promote a positive energy balance. Acute and short-term studies in human volunteers have demonstrated increased total energy intake when the energy density of the diet is increased wheater by free sugars or fat [14,13,12]. Diets that are limited in free sugars have been shown to reduce total energy intake and induce weight loss [10].
3. Drinks that are rich in free sugars increase overall energy intake by reducing appetite control. There is thus a less of a compensatory reduction of food intake after the consumption of high sugars drinks than when additional

**Table 1.** Ranges of population nutrient intake goals.

Dietary Factor	Goal (% of total energy unless otherwise stated)
1. Total fat	15-30 %
1.1 Saturated fatty acids	< 10%
1.2 Polyunsaturated fatty acids (PUFAs)	6-10%
1.2.1 n-6 Polyunsaturated fatty acids (PUFAs)	5-8%
1.2.2 n-3 Polyunsaturated fatty acids (PUFAs)	1-2%
1.3 Trans fatty acids	< 1%
1.4 Monounsaturated fatty acids (MUFAs)	By difference
2. Total carbohydrate	55-75%
2.1 Free sugars	< 10%
3. Protein	10-15%
4. Cholesterol	< 300mg per day
5. Sodium Chloride (Sodium)	< 5g per day (< 2g per day)
6. Fruits and vegetables	≥400g per day
7. Total dietary fibre	from foods
8. Non- starch polysaccharides (NSP)	from foods

foods of equivalent energy content are provided [12,8,2,9]. Children with a high consumption of soft drinks rich in free sugars are more likely to be overweight and to gain excess weight [9].

The benefit of fruits and vegetables cannot be ascribed to a single or mix of nutrients and bioactive substances. Therefore, this food category was included rather than the nutrients themselves. Wholegrain cereals, fruits and vegetables are the preferred sources of non-starch polysaccharides (NSP). The best definition of dietary fiber remains to be established, given the potential health benefits of resistant starch. The recommended intake of fruits and vegetables and consumption of wholegrain foods is likely to provide > 20 g per day of NSP (> 25 g per day of total dietary fiber) [6].

The basis of this problem is to establish a diet that fulfill the previous requisites, thus is find a set of appropriate combination of aliments. The aliment database should contain one hundred or one million of aliments, but is necessary to consider most of them when the diet is generated to add versatility.

Genetic algorithms already has been utilized in order to generate diets, for example, Catalan et al. developed one, which generates a diet considering the lipid, carbohydrate and lipid distribution [1].

In similar way in this paper we show a way to generate the diet using genetic algorithms, not for complexity nor the existence of high search space, simple for the ability of find different possible solution in any part of the search space, that is traduced in find different available diets.

Anyway the diet generated must be approved by one specialist, this algorithm does not replace them, is only a tool to help them.

## 2 Materials and Methods

A genetic algorithm emulates the biological evolutionary process in intelligent search, operates through a cycle of the following stages [7,11]:

1. Creation of a population of strings, representing possible solutions.
2. Evaluation of each string.
3. Selection of best strings.
4. Genetic manipulation to create a new population of strings.

We consider as an aliment as any food stored in the aliment database, for which one we have the measure of kilocalorie, carbohydrate, protein and lipid for each 100gr.

In our database all kind of fats are referred as lipids, for this reason we only use the total fat income range specified in table 1. Also the value specified is Sodium in place of Sodium Chloride. The NSP and free sugar values also are not specified and not would be considered. First of all is necessary to make the following definitions:

$r$  is the goal of total energy intake per day,

$a$  is an aliment stored in a database for which one we have the data of lipids, carbohydrate, protein, cholesterol, sodium, aliment type (from which one we can know if it is a fruit or vegetable), and fiber amount,

$d$  is a diet defined as a vector of  $n$  aliments  $a$

$$d = [a_1, \dots, a_n],$$

$k(d)$  is a function that returns the total energy intake of the aliments  $a$  that compound diet  $d$

$$k(d) = \sum_{i=1}^n k(a_i).$$

Following the same notation for others dietary factors and considering their constrains, we can establish the set of functions and constraints that we use in this paper as shown in table 2.

### 2.1 Chromosome Representation

As we already said, a diet  $d$  is a collection of  $n$  aliments  $a$  per day, so our chromosome representation is a vector as follows:

$$d = [a_1, \dots, a_i, \dots, a_{15}],$$

where:

$a_1 \dots a_3$  are drinks to be consumed,

$a_4 \dots a_{15}$  are aliments to be consumed, is necessary to say that we use a zero value to indicate the ausence of an aliment in that position.

The order and time in which the aliments are consumed are delegated to the user.



**Table 2.** Dietaries factors, symbology and constraints.

Dietary Factor	Function	Constraints
1. Total fat	$l(d)$	$.15r \leq l(d) \leq .30r$
2. Total carbohydrate	$c(d)$	$.55r \leq c(d) \leq .75r$
2.1 Free sugars	$s(d)$	$s(d) < .10r$
3. Protein	$p(d)$	$.10r \leq p(d) \leq .15r$
4. Cholesterol	$h(d)$	$h(d) < 300\text{mg per day}$
5. Sodium	$m(d)$	$m(d) < 2g \text{ per day}$
6. Fruits and vegetables	$v(d)$	$v(d) \geq 400g \text{ per day}$
7. Total dietary fibre	$f(d)$	$f(d) > 25g$

## 2.2 Fitness Evaluation

In order to get the fitness evaluation  $e$ , we consider that for each constraint accomplished we add a point and for each not accomplished we subtract point

$$e(d) = \begin{cases} +1 & \text{for each constraint accomplished,} \\ -1 & \text{for each constraint not accomplished,} \\ +2 & \text{in case that } 0.15r \leq l(d) \leq 0.35r \text{ and } v(d) \geq 400g, \\ -1 & \text{per each drink rich in free sugar,} \\ +1 & \text{per each drink rich in free sugar.} \end{cases}$$

## 2.3 Selection

According with the evaluation we order the population from best fitness (higher evaluation) to lower fitness, we select half of the population that corresponds to the best evaluated chromosomes in order to survive and be reproduced.

## 2.4 Crossover

Being  $C^1$  and  $C^2$  two chromosomes of the same dimension as follows:

$$C^1 = [a_1, \dots, a_n],$$

$$C^2 = [b_1, \dots, b_n].$$

A single point crossover between this two chromosomes is used in order to generate another two chromosomes, being  $p$  the cross point position we have:

$$C = [a_1, \dots, a_p, \dots, b_{p+1}, b_n],$$

$$C = [b_1, \dots, b_p, \dots, a_{p+1}, a_n].$$

In order to avoid premature convergence and add diversity to population, the parents chosen for reproduction are selected aleatory, and we repeat this process half of the population size, due that is amount needed to be replaced.

## 2.5 Mutation

Mutation only select one child chromosome and one position randomly and change its value, in meaningful terms it is equivalent to exchange one aliment for another.

## 3 Results and Discussion

We test our algorithm using the following parameters:

- Population size: 20,
- Generations: 100,
- Crossover position: Random per child created,
- Mutation frequency: each 3 generations each child created is mutated.

We run several test in order to find a diet for a 800 KCal, 1,000 KCal, 1,200 KCal, and 1,500 Kcal. In all of this experiments, the algorithm converges around the 60 generation, arriving to a good solution. We have detected that between bigger is energy intake more difficulties have the algorithm to find an acceptable solution, as it was expected from the nature of the problem.

## 4 Conclusions

In this paper we introduce an automatic diet generation using genetic algorithm, which satisfies the dietary guidelines established in WHO technical report #916 for population nutrient intake goals.

We take advantage of the combinatorial nature of the genetic algorithm in order to generate diets. Generally, due to that it generate a set of aliments and drinks to be consumed in a day it is possible to find an adequate way to do it, thus is, which ones in each meal time. However some of the aliments are not considered in their cooked forms, and some ways of cooking them and the additives used can vary their properties. So the inclusion of these cooked aliments in the database is desired and proposed as future work.

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## Forearm and Hand Vein Detection System for an Infrared Image Database

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**Abstract.** This paper presents a system that allows defining the vein patterns of a person's forearm and hand. In order to accomplish this, infrared (IR) images of the region of interest were registered. The main goal is to help in vein detection, to aid in procedures like intravenous catheter or venipuncture, in a non-invasive way. In the image acquisition protocol, the anterior and posterior compartments of the left and right forearms of each subject were considered to create an image database each one containing the anthropometric data of the subject. A GUI was developed to allow recording an image by gender, age, weight, high and blood group and to allow two filtering options; the standard histogram equalization or fuzzy equalization. Finally, the user is able to choose and apply one of the two classification methods: one using the Fuzzy C-means algorithm, and the other using a Bayesian probabilistic model.

**Keywords:** Infrared images, vein patterns, GUI, image database, histogram equalization, fuzzy C-means, Bayesian model.

### 1 Introduction

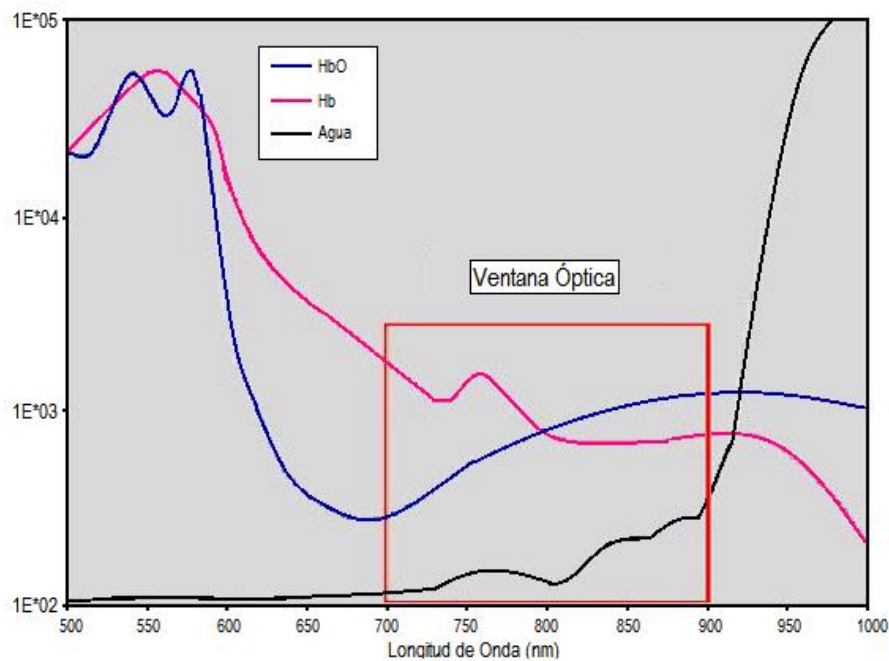
The deoxygenated hemoglobin, which flows within the veins, has the property to absorb the infrared radiation (IR). Crisan & Tarnovan [1] have measured the absorption pattern, in Figure 1 the obtained data is shown; from this data it is established that maximum absorption range is found in the near infrared spectrum (700-900 nm). This property is exploited by different systems for the vascular detection, either by the transillumination or by reflectometry techniques. The first one consists to expose the forearm to an infrared light source to measure its transparency, however it has the inconvenience that the regions to process need to have the enough thickness to be traversed by the light, restricting its use to the hands and fingers [2-3]. For the reflectometry technique the infrared light is impinged to the exploring surface, which allows to be used regardless of the forearm complexion [4-5]. In both techniques a digital camera is used, which captures the different infrared light intensities and represents them as an image. The main feature of this camera is that it has a filter to allow only the pass of light in the near-infrared range.

The vascular detection systems have different means to represent and/or display the acquired information. They can be from a simple monitor, where the captured image is displayed, to a graphic user interface (GUI) that allows the user to capture, process and storage images for the creation of a database.

Contrast improvement filters are a topic in the image processing, they are developed to emphasize certain characteristics or accent gray levels off interest. In the last years, studies based in fuzzy logic of this kind of filters had been made. Tizhooch, in [6] has proposed the contrast improvement based in the concept of fuzzy histogram hyperbolization, adding to the classic methods like the adaptive histogram equalization [7].

To improve furthermore the contrast of the acquired images and their later classification, different techniques in the artificial intelligence area, which develops this task, had been proposed (Fuzzy C-Means, FCM and Expectation Maximization, EM). An ulterior phase in the image processing is the segmentation. The image segmentation is a technique that decomposes the images in regions of interest; the pixels, that integrate a region, are classified based on a common feature, like the position hold in the image or its value in gray scale.

In this work, it is presented the development of a GUI for an infrared reflectometry system, which incorporates the processing and classification of objects of interest (the veins) to ease the medical personnel's job to locate the veins in the venipuncture and intravenous catheter procedures. In the next section is detailed the methodology used in this paper.



**Fig. 1.** Optical Window for the IR image acquisition.

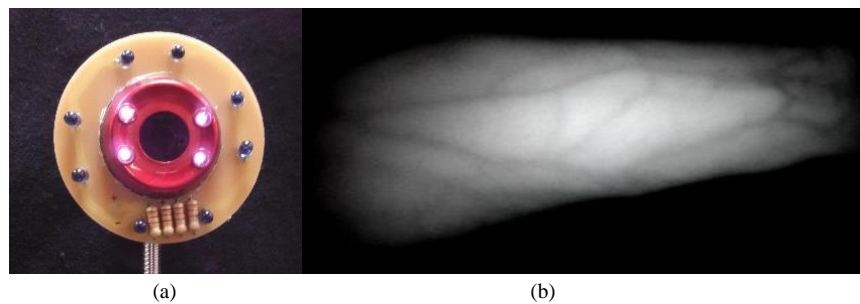
## 2 Methodology

### 2.1 IR Image Acquisition System

The IR image acquisition system is based on a commercial digital camera, “Green Leaf 18-9805”, which has an image resolution of 640x480 pixels and that is able to capture images at 30 frames per second, also it has a light filter that only allows the pass of wave lengths for the visible range.

It is used photographic film that has been thought the photographic process, allowing to be applied as a band pass filter in the wavelength range between 700 & 1200 nm, which appertains to the infrared [8].

The type illumination employed in the vein detection system is reflective. Infrared light is impinged to the exploring surface, capturing the reflected light with the modified camera. The incident light is generated by an array of light emitting diodes (LEDs) that supply wavelength of 80 nm. This array was designed in a circular shape seeking for a uniform illumination upon the exploring region, helping to spotlight the vein distribution. The circular design allows the array to be attached to the camera. In Figure 2a, is shown the modified camera with the LED array.



**Fig. 2.** (a) Modified camera attached with the IR LED array (b) Image obtained from the reflective illumination acquisition system.

Figure 2b features the resulting image of the acquisition system. It can be noticed that the gray tones that appertain to the veins are obscure. Looking forward to obtain the veins region segmentation, it is applied an ulterior digital processing that allows to enhance the image's contrast.

### 2.2 Digital Image Processing

In image processing, the image's contrast improvement emphasizes certain characteristics, like specific gray scale levels. In this case, the pixels with low numeric values depicts the vein distribution.

This work proposes the utilization of two different methodologies to perform the task of contrast enhancement: the adaptive histogram equalization and the fuzzy hyperbolization. Both methods divide the image in subsections and locally modify the

pixel values. This local modification has displayed better performance improving the contrast of images with uniform histograms[9].

The adaptive histogram equalization maxes out the image information using the entropy as data scattering metric. This method modifies the gray scale pixel's tonalities, and achieves a redistribution of the histogram [10]. This is made by a function obtained by the pixel's numeric value scattering applied upon a section of the image. Eq. (1) gives the mathematical definition:

$$s' = (1 - y)((1 - x)g_A(s) + xg_B(s)) + y((1 - x)g_C(s) + xg_D(s)), \quad (1)$$

where  $s$  is the current pixel grayscale level and  $s'$  is the modified value,  $g_A$ ,  $g_B$ ,  $g_C$ ,  $g_D$  are the histogram mapped value of the restrained pixels in the subsections appartained to each region center A, B, C & D, at the same time  $x$  and  $y$  are the normalized distances regarding to the point A.

The second regarded method is the fuzzy histogram hyperbolization which comes from the fact that the human perception of the illumination is not linear [11]. According to that is why the histogram is modified with a logarithmic pattern.

The fuzzy histogram hyperbolization's algorithm is shown in Eq. (2):

$$g' = c \left( \exp \left( \log \left( 1 + \frac{1}{c} \right) \int_0^g p(g) dg \right) - 1 \right), \quad (2)$$

with  $p(g) = \frac{h(g)}{MN}$ . Where M & N are the image dimensions and  $h(g)$  is the histogram. To explain furthermore the idea of fuzzy histogram hiperbolization it is necessary to define the membership value of each gray level in respect whit its histogram instead of using its probability. That results in the use of equation (3):

$$g' = (L - 1) \left( \exp^{-\mu(g)^\beta} - 1 \right) / e^{-1} - 1. \quad (3)$$

For a membership value  $\mu(g) = g - gmin / gmax - gmin$ . Where gmax & gmin are the maximum and minimum, gray intensities in the image.

The next step in the image processing is the segmentation. The image segmentation is the process of pixel grouping based in a common characteristic. To achieve this process as a common characteristic the gray scale intensity levels it is considered. This work uses two different methods to make this grouping, the first one is the so-called Fuzzy C-Means (FCM) and the second one is a Bayesian type classifier, the Expectation Maximization algorithm EM.

The FCM algorithm uses fuzzy set memberships to associate every pixel with at least one cluster. Given an image  $X = \{x_i \in R^p, i = 1 \dots n\}$ , where  $n > 0$  is the number of pixels and  $p > 0$  is the dimension of the data space of X let  $c \in N, 2 \leq c \leq n$ , be the number of clusters in X [12].

Denote  $V = \{V_k \in R^p, k = 1 \dots c\}$ , as the set of center points of  $c$  clusters in the fuzzy partition;  $U = \{u_{ki} \in [0,1], i = 1 \dots n, k = 1 \dots c\}$  as the partition matrix, where  $u_{ki}$  is the fuzzy membership degree of the data point  $x_i$  to the  $k^{th}$  cluster, and



$$\sum_{k=1}^c U_{ki} = 1, \quad i = 1 \dots n. \quad (4)$$

The clustering problem is to determine the values of  $c$  and  $V$  such that:

$$(X|U, V) = \sum_{i=1}^n \sum_{k=1}^c u_{ki} \|x_i - v_k\| \rightarrow \min, \quad (5)$$

where  $\|x - y\|$  is the distance between the data points  $x$  and  $y$  in  $R^p$ , defined using Euclidean distance as:

$$\|x - y\|^2 = \sum_{i=1}^p (x^i - y^i)^2. \quad (6)$$

By using fuzzy sets to assign pixels to clusters, FCM allows adjacent clusters to overlap, and therefore provides more information on the relationships among the pixels. In addition, by using a fuzzifier factor,  $m$ , in its objective function (7), the clustering model from FCM is more flexible in changing the overlap regions among clusters:

$$J(X|U, V) = \sum_{i=1}^n \sum_{k=1}^c u_{ki}^m \|x_i - v_k\| \rightarrow \min, \quad (7)$$

where  $m$ ,  $1 \leq m \leq \infty$  is the fuzzifier factor.

Equation (7) can be solved using Lagrange multipliers with respect to (4):

$$V_k = \sum_{i=1}^n u_{ki}^m x_i / \sum_{i=1}^n u_{ki}^m, \quad (8)$$

$$u_{ki} = \left( \frac{1}{\|x_i - v_k\|^2} \right)^{\frac{1}{1-m}} / \sum_{j=1}^c \left( \frac{1}{\|x_i - v_j\|^2} \right)^{\frac{1}{1-m}}. \quad (9)$$

To estimate the solution of the system of equations (8) and (9), FCM uses an iteration process. The values of  $U$  are initialized randomly. The values of  $V$  are estimated using (8).

The values of  $U$  are then re-estimated using (9) with the new values of  $V$ . This process is iterated until convergent where  $\exists \varepsilon_u > 0, T > 0; \forall t > T$ :

$$\|U_{t+1} - U_t\| = \max_{k,i} \{|u_{ki}(t+1) - u_{ki}(t)|\} < \varepsilon_u, \quad (10)$$

$$0, \exists \varepsilon_v > 0, T > 0; \forall t > T,$$

$$\|V_{t+1} - V_t\| = \max_k \{|v_{ki}(t+1) - v_{ki}(t)|\} < \varepsilon_v. \quad (11)$$

The second implemented method comes from a Bayesian classification, based on Expectation Maximization algorithm (EM); it consists in building a model of the distribution of the gray scale levels  $Y$ , from an image  $A$ , as a mixture of simpler distributions. In this work, it will be made the assumption that each class in the image has a Gaussian distribution, and so the distribution of  $Y$  will be a weighted sum of Gaussian functions [13]. The probability to observe value  $y_i$  at pixel  $i$ , knowing that this pixel belongs to class  $k$ , is:

$$p(y_i|z_i = c_k, \mu_k, \sigma_k) = \frac{1}{\sqrt{2\pi}\sigma_k} \exp\left(-\frac{1}{2}\left(\frac{y_i - \mu_k}{\sigma_k}\right)^2\right). \quad (12)$$

In equation (12),  $z_i$  is the class of pixel  $i$ , and  $Z$  is the class distribution in the image. Bayes' formula uses this probability in order to find out the probability of pixel  $i$  to belong to class  $k$ , knowing that value  $y_i$  is observed:

$$p(z_i = c_k|y_i, \mu_k, \sigma_k) = \frac{p(y_i|z_i = c_k, \mu_k, \sigma_k)p(z_i = c_k)}{\sum_{k'} p(y_i|z_i = c_{k'}, \mu_{k'}, \sigma_{k'})p(z_i = c_{k'})}. \quad (13)$$

In equation (13),  $p(z_i = c_k)$  is the a priori probability of the  $i$ -th pixel to belong to class  $k$ . In order to find out the most likely class for each pixel, we often use a ML (maximum likelihood) approach. Here, it means searching estimates of the Gaussian distribution parameters  $\mu_k$  and  $\sigma_k$ , denoted by  $\hat{\mu}_k$  and  $\hat{\sigma}_k$ . These parameters are intended to maximize a likelihood function:

$$\hat{\theta} = \arg \max_{\theta} \ell(\theta; y; z), \quad (14)$$

where  $\theta = [\mu_k, \sigma_k]k$ ,  $y = [y_i]i$ ,  $z = [z_i]i$ , and

$$\ell(\theta; y; z) = \log p(y, z|\theta) = \log \prod_i p(y_i, z_i|\mu_k, \sigma_k). \quad (15)$$

Since variable  $Z$  is hidden (we are trying to estimate the class  $z_i$  of each pixel  $i$ ), we will use the EM algorithm. This algorithm is divided in two steps:

1. **Step E** - From an initial value of the Gaussian parameters, estimate with equation (13) the probability that  $z_i = c_k$  for each pixel  $i$ .
2. **Step M** - Update  $\hat{\theta}$  by maximizing a modified likelihood function given by:

$$l'(\theta; y; z) = p(z_i = c_k|y_i, \hat{\theta}) \sum_{i,k} \log\left(\frac{1}{\sqrt{2\pi}\sigma_k} \exp\left(-\frac{1}{2}\left(\frac{y_i - \mu_k}{\sigma_k}\right)^2\right)\right), \quad (16)$$

where  $p(z_i = c_k|y_i, \hat{\theta})$  have been estimated in step E.

In order to update the Gaussian distribution's parameters, the equation (13) is derived with respect to  $\mu_k$  and  $\sigma_k$ , obtaining:

$$\frac{\partial l'}{\partial \mu} = \sum_{i,k} p(z_i = c_k|y_i, \hat{\theta}) \left(\frac{y_i - \mu_k}{\sigma_k^2}\right), \quad (17)$$

$$\frac{\partial l'}{\partial \sigma} = \sum_{i,k} p(z_i = c_k|y_i, \hat{\theta}) \left(\frac{\sigma_k^2 - (y_i - \mu_k)^2}{\sigma_k^3}\right). \quad (18)$$

By making each derivative equal to zero and solving each resulting equation, we found that:

$$\mu_k = \frac{\sum_{i,k} p(z_i = c_k | y_i, \hat{\theta}) y_i}{\sum_{i,k} p(z_i = c_k | y_i, \hat{\theta})}, \quad (19)$$

$$\sigma_k^2 = \frac{\sum_{i,k} p(z_i = c_k | y_i, \hat{\theta}) (y_i - \mu_k)^2}{\sum_{i,k} p(z_i = c_k | y_i, \hat{\theta})}. \quad (20)$$

### 2.3 Graphic User Interface

To allow the interaction between the user and the infrared image acquisition and processing system it is designed a graphic user interface, it allows creating an image and clinical database of a patient.

The interface has a main window where the relevant clinical data of each patient is inserted:

- Name,
- Gender,
- Age,
- Blood type,
- Weight,
- Size.

Once the data is stored, an option to continue to a new window will be offered, where the current view of the camera, a capture button, and the resolution and zoom options will be displayed. The user will chose the options that allows observing a preliminary vein distribution of the current section of the patient forearm, and the user will be able to capture the current image by a displayed button when it deems so. The captured image will be shown and in a popup window, it will be asked if the user wants to re-take the image, otherwise the interface's next window will be displayed.

In the new window the recorded image and a menu where the options to choose a contrast enhancement filter will be shown. This filter is going to be applied to the original image and the resulted image will be shown in this same window alongside the execution time. The user will have the option to refresh the image or to continue to the next step; in this case, the fourth interface's window will appear.

The fourth window, which one makes the segmentation an classification of the vein system, shows the contrast improved image and a menu with the two available classifiers (EM & FCM). Once a classifier is chosen, it will be applied, as a result it will be displayed the segmented image alongside the execution time; if the outcome image is not the expected one, a refresh option is available. Finally, the user will be asked if it is wanted to save all the images and data, outcome of the selected processing or if they are going to be discarded and the process will start over. In the case to choose to save the data, the user will have the option to continue with the image acquisition of a new region for the same patient or to input a new one or, if it is the case, to exit the program.

In Fig. 3 we show the GUI's flow diagram, where its case structures and blocks are displayed.

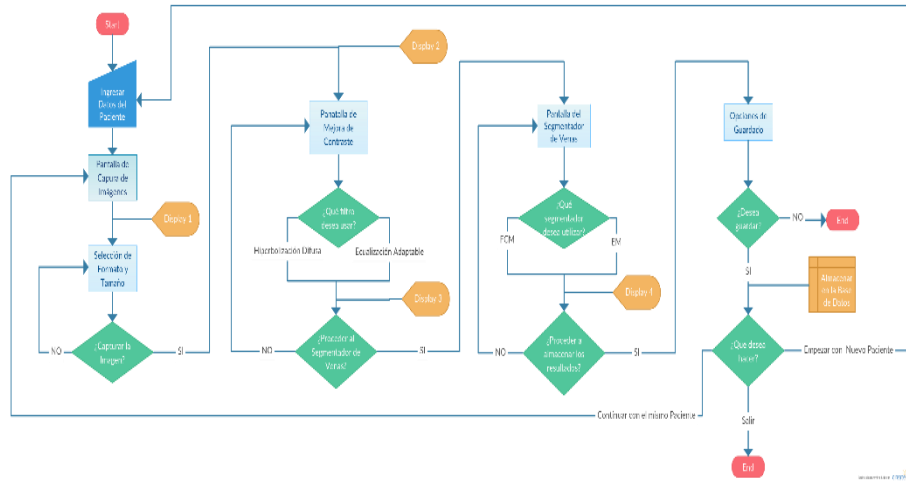


Fig. 3. Vein classification GUI's flow diagram.

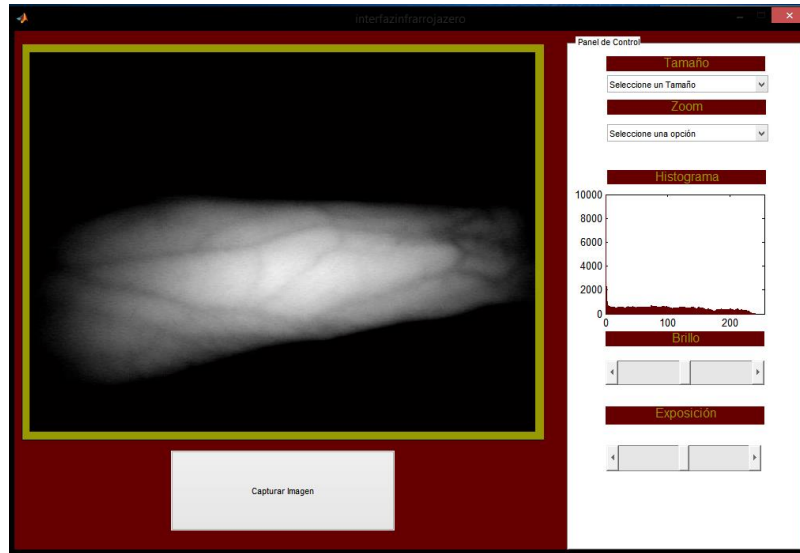
### 3 Results

From the proposed methodology a data set of an individual patient from the database is given, see Figure 4.

Fig. 4. Main Window where the patient clinical data is inserted.

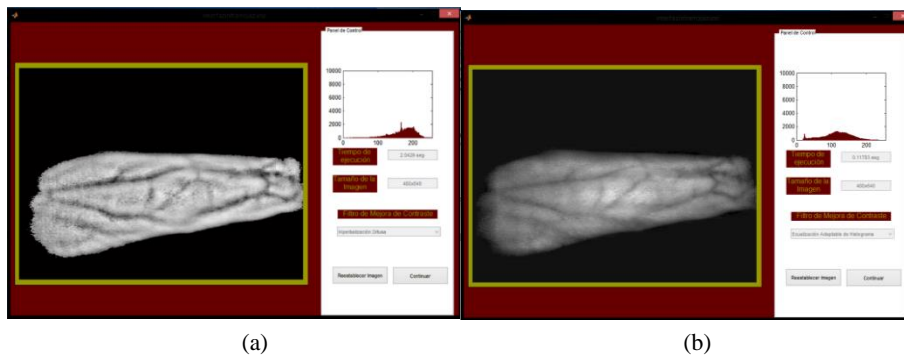
In Figure 5 the screenshot of the captured image is displayed, it appertains to a forearm's section. The window's main fields are image resolution (640x480), Zoom

(1x), and 0.5 to brightness and exposure. After selecting the image-capture option, the user will proceed to the contrast-enhancement selection window.



**Fig. 5.** Image acquisition's control window.

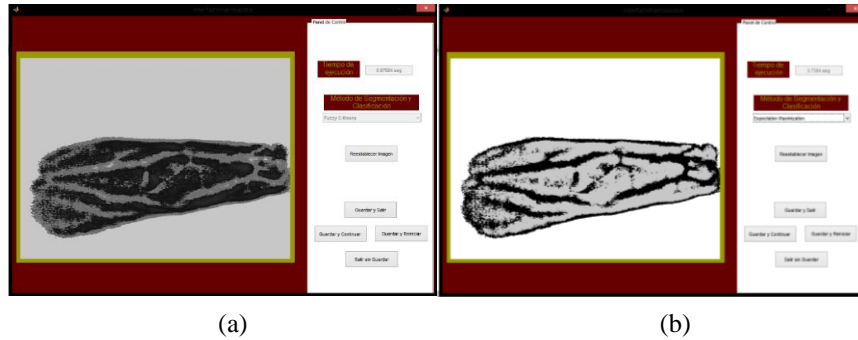
In Figure 6 the contrast improvement options are displayed, having available to methodologies: fuzzy hyperbolization and adaptive histogram equalization. In Figure 6a, the fuzzy hyperbolization is applied, having an execution time of 20.2 seconds. In Figure 6b, the adaptive equalization is used with an execution time of 0.12 seconds.



**Fig. 6.** Contrast enhancement's selection window (a) Fuzzy hyperbolization outcome (b) Adaptive equalization outcome.

The classification & segmentation panel is shown in Figure 7, which has two options to make this task. The resulting segmentation by FCM is presented in Figure 7a and in Figure 7b the corresponding to EM. In both options, the result is the

classification of the vein distribution and the execution times of 0.98 & 3.73 seconds, respectively.



**Fig. 7.** Classifier & segmentation selection (a) FCM (b) EM outcomes.

Finally, the user will decide if the results, with the selected options & parameters, are the expected and will have the option to repeat the process for the same patient in a new section. Other options are to input a new patient or to exit the application.

In Table 1, a comparison of the time parameters, obtained by the different algorithm's combinations of the study case is made.

**Table 1.** Execution times of each algorithm's possible combinations.

Contrast Filter	FCM	EM
Fuzzy Hyperbolization	2.12 s	5.77 s
Adaptive Equalization	0.19 s	3.85 s

## 4 Conclusions

In this paper, we presented a graphic user interface able to isolate the veins from near-infrared reflectography images and store them in a database alongside the clinical data of each patient. It had been used the methods of fuzzy hyperbolization & adaptive equalization to improve the contrast in the original images and two vein segmentation methods the FCM and the EM. The execution times and its easy operation indicate that the system can be used to assist the medical personnel in the venipuncture processes and to generate a database to keep tracking to each patient.

As future perspectives for this development, it will be considered its implementation in a portable continuous response device, which projects the final image upon the processed region.

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# Expert System as a Support Tool for Teaching Calculus

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**Abstract.** Expert systems are tools that can diagnose and correct the development of learning students helping improve their weaknesses determining their cognitive level. This paper aims to develop an expert system as a support tool for teaching Calculus using Bayesian networks as inference engine and records of semiotic representation for the base of probabilistic classifier. There are two stages: the first is to diagnose certain weaknesses in the student; the second allows to emphasize the way in which aspects of learning will be discussed and how the topics to be presented to reinforce the area.

**Keywords:** Expert systems, Bayesian networks, records of semiotic representation, probabilistic classifier.

## 1 Introduction

Applications of learning systems are quite extensive, there are several e-learning platforms that allow to structure content based on a variety of multimedia resources, however, have each element statically, do not make decisions or determine that element displayed on a given time; not check which is the most suitable, they not reasonably monitor user progress. This justifies the study of areas such as artificial intelligence applied to learning within the framework of e-learning, because in a number of contexts has been proven efficient operation [1].

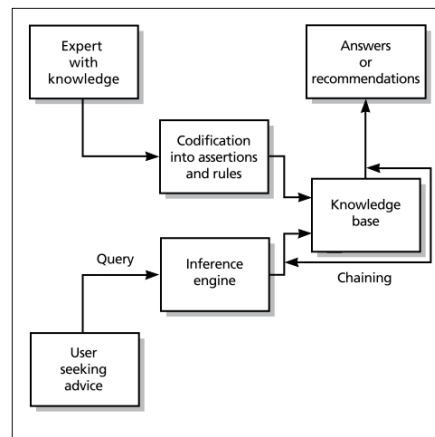
The field of expert systems (also associated with knowledge representation systems and knowledge engineering) are an important part of the field of Artificial Intelligence. In particular they represent knowledge in the domain expert (specialist), being employed, including, as a tool by the same expert [2]. In various areas of knowledge, these systems can diagnose and correct the development of learning students helping improve their weaknesses determining their cognitive level. This paper aims to develop a tool for teaching Calculus using Bayesian networks as inference engine and records of semiotic representation as the basis of probabilistic classifier.

## 2 Expert Systems

An expert system can be defined as a computer system that simulates human experts in a given area of expertise. As such, an expert system should be able to process and store information, learn and reason in deterministic and uncertain situations and communicate with users and / or other expert systems, make appropriate decisions, and explain why they have taken such decisions.

This kind of systems encode a knowledge base and reasoning rules to determine or conclude the solution of a particular problem. Are formed by various interrelated parts: a rule base, a base of facts, an inference engine and an user interface [3]. Figure 1 shows the traditional composition of an expert system.

The knowledge of the expert is represented by the rule base that are generally of the form  $R_i : Pr(x) \Rightarrow C(x)$ , where  $Pr(x)$  its a premise and  $C(x)$  a conclusion. The conditions of application of a rule are the premises and new knowledge are conclusions.



**Fig. 1.** Anatomy of an expert system.

## 3 Inference Engine: Bayesian networks

The inference engines used rules in various ways, in particular the method of reasoning will be based on probabilistic classification with Bayesian networks. This method is characterized by a multivariable representation of data to be processed, which allows to describe complex relationships of certain elements and nonlinear, they represent causal relationships, thus allowing handling uncertainty in events unobserved [4].

A Bayesian network represents a joint probability distribution on a 4-tuple  $(G, f_x, Q, \Theta)$ , where:

- $(G, f_x, Q)$  its a causal network,
- $G$  its an acyclic digraph,
- The set  $x$  of nodes  $G$  its defined by  $\{x_i | i \leq n\}$ , of random variables with  $r$  possible states and  $\Theta$  its a set  $\{\theta_i | i \leq n\}$ .

So the expansion of the joint distribution is:

$$P(Y|f, \dots, f_N) \simeq \prod_{i=1}^N p(f_i|Y) \cdot P(Y).$$

For the posterior probability of how it can be the status of variables in a Bayesian network, Bayes' theorem is used.

### 3.1 Probabilistic Classifiers as Artificial Learning

Learning from the perspective of Artificial Intelligence, it is considered as a process of induction of knowledge that allows us to generalize behaviors from an unstructured information provided in the form of examples incorporating design workable solutions to problems through the study of the computational complexity of these.

The computational analysis and performance of machine learning algorithms is a branch of statistics known as Computational learning theory. Different learning algorithms are grouped into a taxonomy based on the output thereof. Some types of algorithms are:

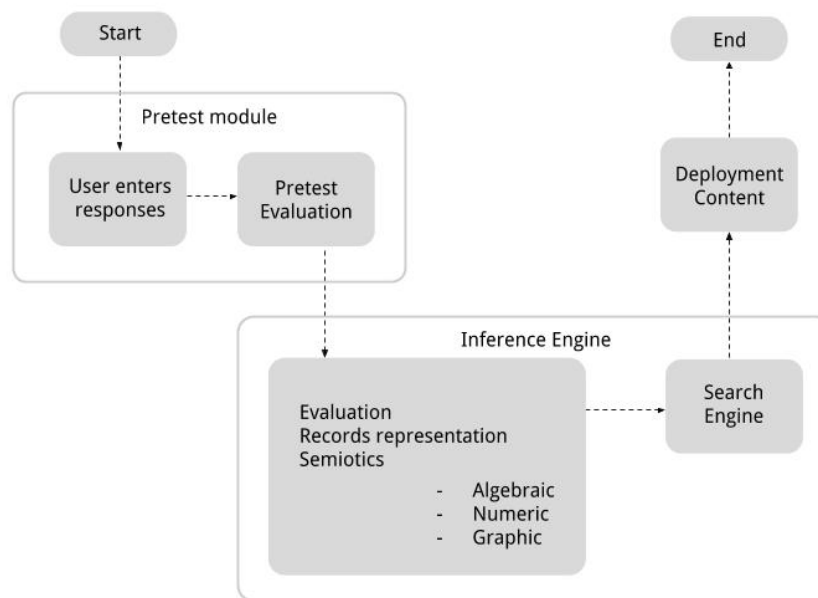
- **Supervised learning.** The algorithm produces a function that establishes a correspondence between inputs and desired outputs of the system. An example of this type of algorithm is the classification problem, where the learning system tries to assign a label or classify a series of vectors using one of several categories (classes). The knowledge base system consists of labeled examples above. This type of learning can be very useful in biological research problems, Computational Biology and Bioinformatics.
- **Unsupervised learning.** The entire process of modeling is performed on a set of examples formed only by system inputs. There is no information on the categories of those examples. Therefore, in this case, the system must be able to recognize patterns to assign labels to new entries.
- **Semi supervised learning.** This type of algorithms combine the above two algorithms to classify properly. Marked and unmarked data is taken into account.
- **Reinforcement learning.** The algorithm learns observing the world around him. Your input information is the feedback you get from the outside world in response to their actions. Therefore, the system learns based on trial and error.
- **Transduction.** Similar to supervised learning, but not explicitly constructed a function. Tries to predict future categories of examples based on input examples, their respective categories and examples new system.
- **Multitasking learning.** Learning methods using knowledge previously learned by the system face to face similar problems to those already seen.

### 3.2 Records of Semiotic Representation

Semiotic representations are representations that use signs, they can expressed in natural language or algebraic, graphs or figures geometric. These semiotic representations are the means through which a person can externalize their mental representations in order to make them visible or accessible to others. The ability to change the records of semiotic representation is necessary in the mathematics learning and the importance of coordinating the different registers of semiotic representation. Many difficulties experienced by students can be described and explained as a lack of coordination between representation registers, in particular graphic, numeric and algebraic [5].

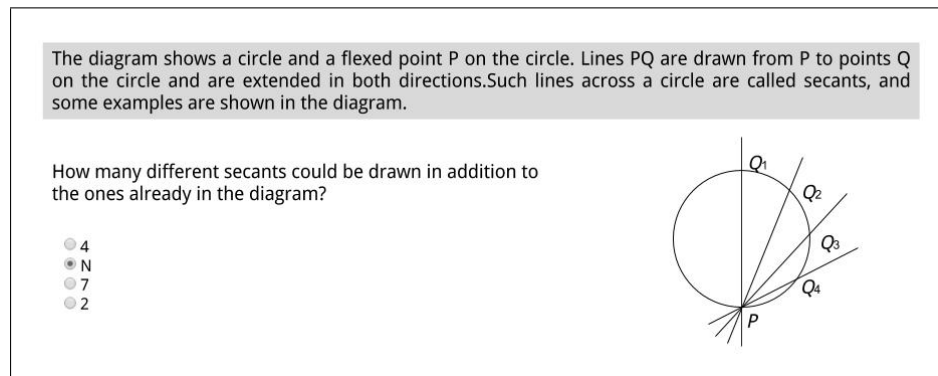
## 4 Methodology

The expert system has several components, modules and persistent entities. Optimization problems are working and interacting with students through a virtual tutor who tells the procedure to be followed at all times. As shown in Figure 2, the student begins to access the pretest module, where it presents a diagnostic test that, through various reagents, assesses student skills and deficiencies.



**Fig. 2.** Flow user action with the expert system.

Figure 3 shows an example of the graphical user interface (GUI) provided to the student to work with the pretest. This interface provides the user with the following elements: the problem statement, a descriptive picture, different options to choose in response to problem and mechanisms of recurrent asynchronous storage.



**Fig. 3.** GUI pretest for a record graphical representation.

To determine which register of semiotic representation has the highest efficiency is assigned a score according to the complexity of the reagent. The evaluation is carried out in the inference engine using probabilistic classification based on Bayesian networks.

The search engine takes the result of the inference drawn and creates a data structure ramified from a collection of associative structures that link resources, activities and teaching materials. This collection is stored in a database. Finally an exhaustive search is performed to determine the optimal route learning, that is to say, the set of suggested activities for the student.

#### 4.1 System Overview

The expert system consists of a set of applications and Web services that engage in the following modules:

1. **Users.** In this module the user has the ability to create your account, manage your profile, change personal data and set your preferences. To create an account requires an username, an email address and a password of at least 6 alphanumeric characters. The system accepts only valid email accounts and does not support existing usernames. Once the account is created, the system assigns by default the role of student and notifies the creation of the account to the user through email. The module also offers users the ability to create accounts with other roles with different access levels. The system administrator is the only user with privileges to create accounts with the

role of teacher and supervisor. This module is responsible for controlling the restricted access to the system.

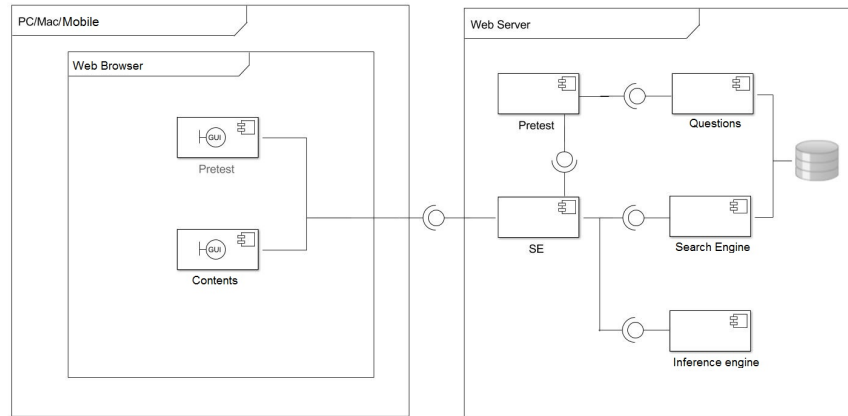
2. **Control of students.** It allows to monitor student progress by monitoring system access and viewing activity logs and pretests presented. It provides the user with the role of teacher the ability to generate reports and statistics showing the student's behavior on the platform. The roles of supervisor and administrator privileges feature in this module by default.
3. **Administration.** The user administrator role is the only one with access to this module. It allows management of secondary modules and specific components of search engine and inference. Enables the creation of accounts with higher privilege roles and activity monitoring them. Management roles and privileges associated with each role are managed in this section. It also allows the administrator to schedule frequent tasks.
4. **Management pretests.** Since this module creating, editing, and deleting query evaluation tests for the student is managed. The role of teacher has the privileges to access this module. By using monitoring each student activity associated with their respective pretest its provided. It also allows the display of the scores for each record representation by accessing the evaluation history. creation and editing of questions for each pretest, and generating reports and statistics is also possible.
5. **Content management.** Enables management activities, resources and learning materials enabling the creation and editing content paths. These routes will be used by the search engine to determine the learning path that suits the profile of each student. The inference engine is responsible for composing the profile based on the records of semiotic representation.
6. **Activity logs and backups.** This module has tools that allow the export of records stored in the database through the scheduling of full or partial backups in plain text with SQL format. By default, the administrator user accesses the backup module, however it is possible to enable export in excel format records activity and results of evaluation tests for other users. Similarly, the module provides functionality for audit activity logs of all system accounts.

## 4.2 Expert System Architecture

This architecture includes both business functionality encapsulated as standardization of communication infrastructure. The service is the central component and implements business functions.

In the architecture used (SOA) functionality is divided into services. These can be found distributed through various nodes in a network. The services combine to achieve a desired result and may provide data or be coordinated by other services.

Services, therefore, are the fundamental components of any SOA, largely replace the functionality of conventional applications and is characterized by a low degree of coupling, implement business functions and be isolated components that define their independent interfaces technical implementation environments.



**Fig. 4.** Expert system architecture.

They have two types of communication services:

1. Orchestration model. Defines the behavior and how to carry out the events so that they are monitored centrally.
2. Model choreography. It is based on the behavior to be observed before both parties to communicate.

Services in an SOA-based architecture must meet the following:

1. Be reusable.
2. Provide a formal contract.
3. They are loosely coupled.
4. Seek to "composition".
5. They can not have been.
6. They must be discovered to be used or consumed.

SOA is based on open standards like XML, JSON, SOAP, WSDL, REST, BPML, etc. In particular REST is an architectural technique Stateless, which works directly with the HTTP protocol, which means that the resources made requests (resources consumed and service) only have a system image formed by the action towards which performs the request through the respective connector, that is to say a client-server application is independent of the following requests.

REST is the protocol used for architectural development of distributed component of the proposed framework, this because REST shows the following advantages over SOAP:

1. Using HTTP protocol.
2. Support requests GET, POST, DELETE and UPDATE.
3. Possibility of using different data transfer formats such as XML or JSON.

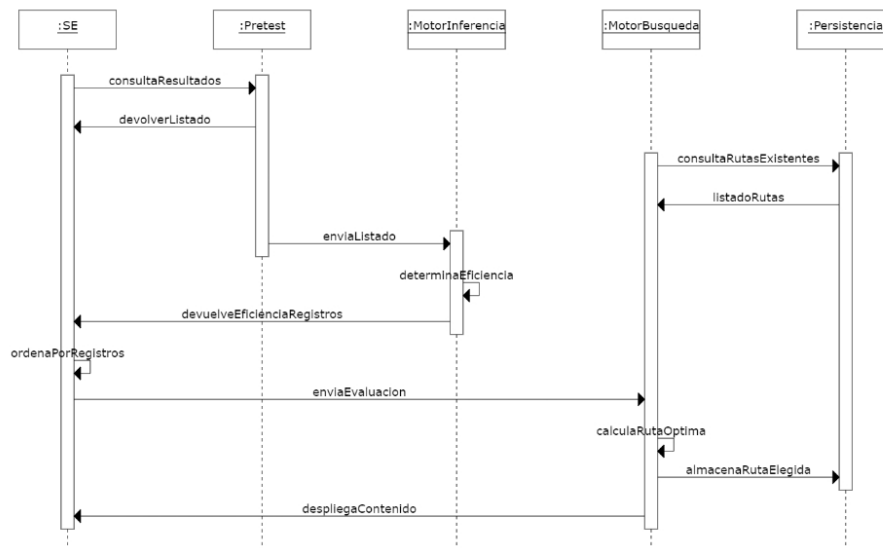


Fig. 5. Classification sequence and decision making (screenshot in Spanish).

4. REST services present less coupling SOAP.
5. Enough potential to work with any client application.
6. It not required to publish in WSDL.

## 5 Conclusions

Probabilistic classifiers used to implement inference engines in an expert system, allows a multivariable representation of data to be processed, which in turn displays a description of complex relationships of certain elements, considering also, the uncertainty management. By using records of semiotic representation (graphical, numerical and algebraic) as primary elements of classification, is parameterised an appropriate way to present aspects of learning paths the area to reinforce the student.

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# Scalable Automation System Based on Raspberry

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**Abstract.** This work consists of a scalable automation system divided into two parts; the first is the handling of variables such as lighting, air conditioning, curtains, etc. in hospitals or care for the elderly that allows the user to add, configure and control various electronic devices via a graphical interface or wired remote so you can tailor the environment to their needs. The second part consists of the constant monitoring of the variables temperature and heart rate of older people through the application; in order to send an alert to medical personnel in the area if these variables are outside the set range.

**Keywords:** Domotic, monitoring, raspberry, automatization.

## 1 Introduction

Currently the advances that have been in technology, this has been used to facilitate human life as we know have been applied in various areas such as education, medicine, transportation and entertainment among others. "The technology applied to home", known as Home Automation, integrating automation and information technology to improve the comfort, safety and welfare of households. However, the automation does not apply only in dwellings, also you can be applied in buildings and hospitals, by some-we mention places.

Hospitals and care centers aim to always buy the best technology both manage to offer patients an environment comfortable and pleasant to meet your needs, without neglecting the medical care they require; so it is necessary to monitor people to know their status at any time without the attendant go to the room can use that time in patients who need urgent medical attention.

Commercially there are several companies in the market that offer automation products. However, it was observed that hospital automation systems currently focus on patient monitoring and automation environment; but do not cover all areas; i.e., only specialize in either monitoring or automation. So our system aims to combine control of some variables such as light, temperature, curtains, among other environments (rooms); as well as patient monitoring and alerting medical personnel if there is a problem.

On the other hand, existing home automation systems are static systems, i.e., are programmed to fit the user, but once programmed cannot easily change, so if the user changes a system component, this must be reprogrammed, process often expensive

because it requires the programmer to go to the location to make changes in programming (within the device).

Therefore, the developed system provides the user the ease of adding new devices to the system and display an alert if there is a serious problem in some areas; for example, if there is smoke, an audible alert is activated and the user is notified by the application that is being detected smoke in certain area.

Another advantage over existing systems is the possibility to add more microcomputers to increase system capacity, thus if the place where the system is installed it after a while only to be acquired, connect and configure expands devices to work with those already installed previously.

The main beneficiaries of our system will be both medical institutions such as hospitals, retirement homes, places for special care, etc. and homes where required or desired to maintain control and / or monitoring of electronic devices place.

The following sections discuss the proposal of a scalable automation system (section 2) will be described and results are presented in the third section and the conclusions and future work in section four of this work.

## **2 Proposal Scalable Automation System**

The system developed consists of four applications:

1. **Application of Raspberry:** Its purpose is reading the different sensors connected via XBee modules and control actuators in the rooms, in addition to constantly communicate the client application to the server status variables of patients and rooms via web services.

The patient census variables are:

- Body temperature. The patient's temperature is acquired constantly.
- Heart rate. The patient's heart rate is measured constantly.
- Help button. The patient can activate the help button when you require personalized medical care.

In addition an alert notification will be sent if the patient acquired variables are not within the parameters established in the patient module; this alert will notify the medical staff and the head of floor area.

2. **Application Administrator:** This application is responsible for managing the system; such as add, modify, and delete:

- Users.
- Dispositives.
- Areas.
- Rooms.
- Modules patient.
- Modules room.

3. **Client Application:** This application will monitor the variables temperature and heart rate of patients in an area; besides having the ability to change the status of

the devices associated with rooms in the area; likewise provide a tool to add, view and edit notes on a patient's overall purpose.

4. **Configuration Application:** This application is used by the administrator to modify the individual configuration of modules and patient room.

### Users

As users of the system, four users are defined:

1. **Patient:** The patient may use a wired control or a mobile application for managing variables within their environment (room) and notify any problems to medical personnel through a help button, each patient will have an associated module containing a unique ID in order to identify at all times in addition to census temperature and heart rate.
2. **Medical Staff:** The medical staff can view the information of the variables (temperature, heart rate and alarm status and emergency aid) of all patients being acquired by its respective module; You can also add and view notes general purpose patients can define whether the note is visible or not for them, in order to be able to deal personally sensitive issues; eg diagnosis of a terminal illness. This will be done from the mobile application and access the system through a username and password.
3. **Head of Floor:** The floor manager will have a username and password to access the system; you can add new patients also display the information of patients assigned in your area as well as view the notes of these patients and may also set up communication with the server.
4. **Administrator:** The administrator is the only user who can configure the system, and manage users and system components, adding, modifying and deleting, areas, rooms, beds, Devices and Users.

### System Architecture

The system architecture, Figure 1 shows the basic layout of the system, which is composed of five parts:

1. **Server:** This is where it is hosted database connection services both users, areas, devices and patients.
2. **Client:** they are mobile devices that communicate with the system via the local area network; have an application which allows you to control an environment which is accessed from a code room or in the case of medical personnel log so that they can perform various activities such as monitoring patient variables.
3. **Raspberry:** Stores the core application system, which is responsible for obtaining the information from the various modules connected to the system at that time and synchronize them with the database using web services. This application is managed by the floor manager.
4. **Module Patient:** A controller card where the sensors are connected to obtain the patient's vital signs as well as the help button if the patient needs personalized care.
5. **Control Module Room:** This controller card contains the environmental control modules which allow the handling of actuators and temperature sensors, presence, smoke and humidity of the room.

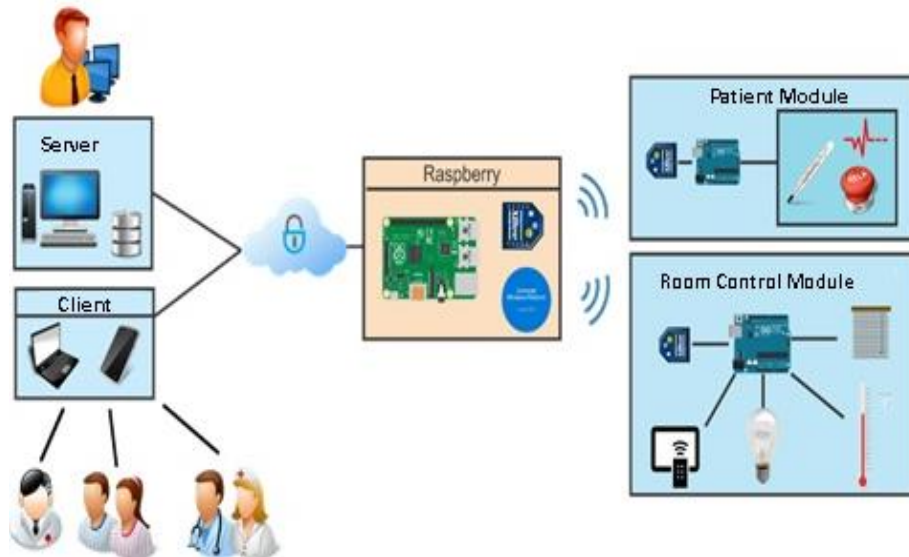


Fig. 1. System architecture.

### Patient module

The patient module is responsible for notifying the state of the variables thereof, and if required assistance or have any kind of difficulty. It consists of an Arduino Nano, one XBee-S2 indicators in LED module, an LCD display, a key button for medical staff and a detachable sensor module. The module has a unique ID.

The LCD display allows us to monitor the patient's condition locally even when there is no network available ZigBee and if you have temperature or high pulse or low. LEDs indicate the same way if the patient needs help, or reading any of its variables is outside the set range. Only alerts can be disabled using button key carrying the doctor, in order to prevent the patient clear the alert.

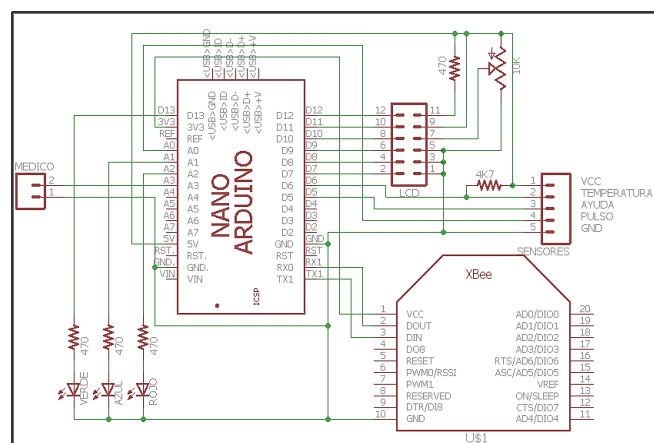


Fig. 2. Schematic module patient.

### Room module

The room module is in charge of census variables Room and manage the status of the actuators. It is designed in a modular way allowing you to connect and disconnect 2 modules using 2 digital outputs, one of which supports PWM on both channels and 4 digital output modules, 2 of which support PWM. This modularity and the possibility to configure the Arduino make the room module can control subsequent designs requiring minimal or no changes in the minimum hardware and software changes.

This module includes a base for connecting the XBee and a voltage regulator which allows regulated output of 5V up to 1A, just as you have a Molex 2051 6-pin connector which allows the connection of a sensor card and PRT-00116 connector 6-way for connecting a wireless keyboard which allows use of the module even if there is a network problem.

The census module of the room is a module that integrates the use of temperature sensors, relative humidity, presence and smoke, in addition to handling an actuator for Buzzer or LED depending on the type of alarm required.

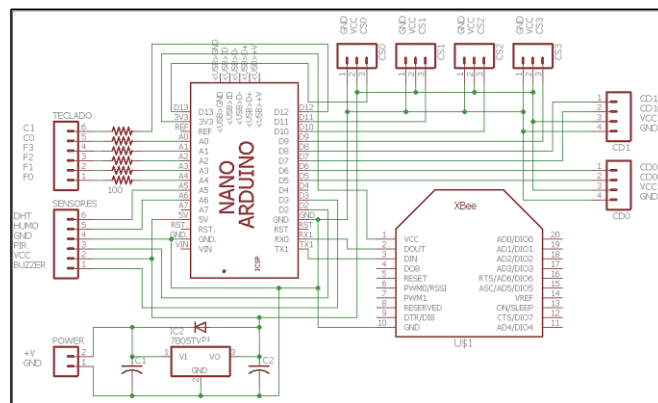


Fig. 3. Schematic room module.

### Communication frame

For communication between applications and modules or patient room, a frame composed with the following elements were designed:

- ID Arduino,
- ID Area,
- Patient indicator plot,
- Patient Temperature,
- Heart rate,
- Alarm Help,
- Emergency alarm,
- Frame Indicator Room,
- Room temperature,
- Room humidity,
- Time since last reading,

- Alert of smoking,
- State of the actuators.

As we can see, in this plot we integrate all acquired values, both the patient and the room and the status of devices connected to the room. However it is important to note that all fields are sent without differentiating the module that sends this to standardize the size of the plot only that frame indicators defined what information will be used for each.

### **Web Services**

A web server implemented in language services was used python using the platform django rest framework, these services ensure the consistency of all operations performed on our database and maintain coordinated our "Raspberry", "App Mobile" applications and "Administrator" to work together in our system.

The answers and requests to the server are made using JSON objects containing the requested information and / or issued later to be serialized or deserialized to obtain the information. These objects use HMACs to validate their authenticity.

Management services (high, low and changes) were performed and frequent consultation services such as the status of devices in the room or the temperature and heart rate of patients.

## **3 Results**

The resulting system was applied in areas of the School of Computing of the IPN; with what was observed system functionality realized in a real room.

By implementing this system, we note that it has a delay of about 1 to 2 seconds to send signals on / off devices; but the system meets the functionality to what was proposed, in addition to the synchronization between the application of mobile application Raspberry and these in turn with the room modules and patient achieved.

On the other hand, from the census temperature and heart rate of several people through our system, and comparing with other commercial sensors; we noted that temperature has a difference of  $\pm 0.1$  degrees between the two sensors, and heart rate as to variations in the census depend on the position in which the sensor is placed in the patient.

## **4 Conclusions**

Unlike home automation systems for existing hospitals, it was possible to integrate part of device control room and monitoring variables heart rate and temperature of the patient in a single system that alerts the medical staff when the patient variables are outside established ranges, plus alert if any smoke in one of the rooms the area so that they can notice of a fire and make evacuate the building to avoid accidents.

On the other hand, the aim of developing a system using Raspberry Pi microcomputer, which allows patients to monitor and allows the user to control the devices in a controlled physical environment that adapts to user needs was achieved.



This system is a scalable system because it is designed so that if the place where this or will be installed the system grows in relation to users and areas, only simply add more a microcomputer in the event that a new area is added, or add a new patient module if you need to monitor a person more and add a new room module if only increase the rooms that are to be controlled.

Among the features of the system developed we find that it is an adaptable system, because not only can be applied to hospitals or care for the elderly; with small changes you can adapt the system to be applied in a room or home school.

Finally we can say that is a system fault tolerant because even though if for some reason fails to operate the mobile application, the application of Raspberry or server the user can continue to control the devices in the room using the keyboard or you can view the status of patient variables using the LCD located on the module that each patient brings.

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# Displacement Estimation in Micro-photographies through Genetic Algorithm

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**Abstract.** The displacement calculation from a pair of images, is a problem without a robust and complete solution. This is due to the several factors that are involved. Particularly in displacement estimation of micro-metric objects on micro-photography, is complicated by dimensions and scales involved. Usually, the process to estimate the displacement comprehends two things: (a) reference zones and similarity criterion of the region of interest in a pair of images [13]. In micro-photography images, selecting which regions must be candidates to track is a complicated task due to the level of texture on the image and the light conditions involved. For this reason, normally some error criterion are built, however the numeric method for estimate the displacement no warrant the convergence in a solution that represent physically the observed displacement because they usually fall in local minimum. For this reason, this work presents a proposal based on a Monte Carlo method Index Search, implemented as an evolutionary algorithm [5] which allows to examine the metric-space searching the better solution for the displacement calculation on micro-photographies. Experimentally, a piece of graphite has displaced in controlled increments in the order of millimeters. The results obtained are compared versus the real displacements on the micro-metric table, characterizing the system error.

**Keywords:** Sub-pixel displacement, micro-photography, genetic algorithm.

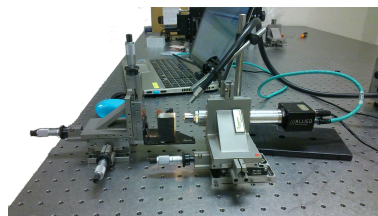
## 1 Introduction

In several of vision systems, the displacement calculation as primitives to the analysis the behavior of objects of interest, results relevant and complicated. However, the literature shows that an efficient estimation is an open problem, due to the existence of several factors that are involved. These factors can be from environmental affectations (lighting conditions) to instrumentation affectations

(signal-noise relation, sensibility, or manufacturing errors) preventing the correct estimation of displacement [11]. The displacement calculation typically is shown as an optimization problem [15,8], where the target function is a similarity function among the region of interest in the reference image and the image with the displaced object[4]. As it is assumed that the domain of metric space is continuous, a numeric method is defined, that typically is an approach of the Taylor series [1,9]. After this, the different estimation methods of displacement are criteria adjusted for specific conditions of application.

In a particular case, the displacement measure in micro-photography, provides no invasive tools for the analysis of microscopic phenomena. However, in this situation is required the use and dynamic selection of regions to estimate the displacement of the objective due to that the basic geometry can not be pre-defined as reference. This situation generates the need of schemes to determine automatically the most probable zones to measure the displacement. For that situation the problem of the displacement calculation in a pair of micro-photographies, obtained from the emission of structured light, it has been observed that the use of classical methods has the consequence that is not robust and repetitive in situation where the metric space has sub-optimum solutions. For that reason, it is proposed the use of evolutionary algorithms, to avoid the convergence in sub-optimal solutions that affect the repeatability of the method.

Finally, the methodology used in this work consist in use a New-Port basis, with mechanical movement in the three axes  $(x, y, z)$ , that holding a rough surface that allows to have texture in the captured image, figure [7].

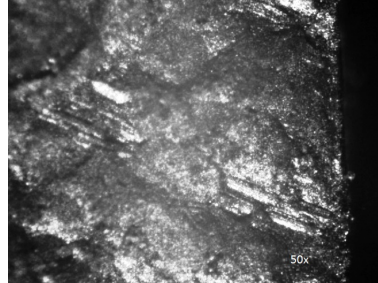


**Fig. 1.** Experimental arrangement used for take images and analyze displacement.

Then the New-port basis is installed on an optical table to reduce the external vibrations. Manually the displacement in the objective are established, this allows to know physically such displacements, taking only as restrictions that such displacements between the pair of cameras do not allow to leave the field of view of the same. For each displacement images are taken after and before to displacement applied. For experimental purposes each displacement is of  $\delta = 10$  micrometers, images are taken, manually moving the micrometers in the New-port basis with a step of 10 micrometers along of only one axis.

The methodology can be described as follows:

1. Capture of the reference image  $I_1$ .



**Fig. 2.** Image used in experimentation of displacement calculation, 50x.

2. Displacement of the micrometer screw, for constant interval
3. Capture image with displacements  $I_2$ .
4. Estimate zones to track using as criterion the local information of tensor of color intensities. with high probability areas for being trackable.
5. Displacement estimation by Newton-Raphson (comparison purposes) and Genetic Algorithm (Proposal).
6. Analysis of the Distribution of displacement estimated.

The displacement process defined by Shi and Tomassi [13] is denoted in next equation:

$$I(x, y, t + \tau) = I(x - \xi(x, y, t, \tau), y - \eta(x, y, t, \tau)), \quad (1)$$

where  $\delta = (\xi, \eta)$  is the displacement of point  $x = (x, y)$ .

## 2 Selection of Features and Displacement Estimation

Once given a pair of images, the features with high probability to be trackable are detected. In the literature there are several approaches to select trackable features [10,2]. In this article, we propose to use those features which make feasible that tracking method have more probability to be consistent.

Trackable features are those which represent a corners in sense they represent regions with texture information in two orthogonal axis, which it make possible to warrant that the displacement equation will be good-behaved.

The corners represent an appropriate set of features that are invariant to scale and rotation, which gives versatility to be used as global features. In the case of stereoscopy, can define global references to the content of the field of vision allowing them to be robust and reliable.

An algorithm for detecting the corners must consider some important aspects such as:

- Corners detected must be representatives.
- Image noise must not influence the detection of true corners.
- Fast execution to allow implementation in a low computational cost.

There are several approaches that are able to meet these characteristics where Most of them are based on measuring the value of the gradient at the point which is considered as potentially corner[3]. According to [13], you can determine the quality of the tracking feature using as a measure the dissimilarity between a tracking feature in the first image and the same tracking feature in the image displacement. In the following equation image we have a  $J$  and a displacement  $d$ .

$$J(Ax + d) = J(x), \quad (2)$$

where  $A$  it is the matrix of the following equation deformation and  $d$  the displacement vector:

$$A = \begin{bmatrix} \sum E_x^2 & \sum E_x E_y \\ \sum E_x E_y & \sum E_y^2 \end{bmatrix}. \quad (3)$$

Most of the algorithms used for detection of corners use the criterion of the first or second derivative on the image on the  $x$  or  $y$  axis as an approximation of the gradient value.

The gradient of a continuous function  $f(x, y)$  is a vector and its magnitude expresses the rate of change per unit distance in the direction of the vector. The objective of the gradient operators is to detect changes in gray levels taking place in small areas or regions. The gradient and magnitude expressed by:

$$grad[f(x, y)] = \left[ \left( \frac{\partial f}{\partial x} \right), \left( \frac{\partial f}{\partial y} \right) \right]^T, \quad (4)$$

$$|grad[f(x, y)]| = \left[ \left( \frac{\partial f}{\partial x} \right)^2 + \left( \frac{\partial f}{\partial y} \right)^2 \right]^{\frac{1}{2}}. \quad (5)$$

Methods based on the first derivative as the gradient operator, the methods are more proliferation within the community of image analysis and computer vision. Are based on one edge each other there is a discontinuity in the function of the image intensity, i.e. if the derivative of the intensity values of the image is a maximum.

Prewitt operators are based on the estimated gradient module using 3x3 masks. The two operators in the x-axis direction and the y-axis direction are [12]:

$$\frac{1}{3} \begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix},$$

$$\frac{1}{3} \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}.$$

These operators have good response in the horizontal and vertical edges, are very sensitive to noise, provided the magnitude and direction of the edge, on the other hand have disadvantages such as poor response diagonal edges, slow calculation and width of the border in several pixels [6].

The displacement that searches images can be equally treated as optical flow, so for this reason is that this technique is used.

It is proposed to use the information matrix  $[G^T G]$ , also known as tensor structure to determine the best points to track. Then  $\lambda_1$  and  $\lambda_2$  are the eigenvalues of  $[G^T G]$  and it is considered that a point is candidate to represent a feature for tracking if  $\min[\lambda_1 \text{ and } \lambda_2] > \lambda_\epsilon$ , where  $\lambda_\epsilon$  is a threshold by the user, according to this defined, the corners of moving objects are good points to track [13].

The sum of squared differences is a measure of proximity between two consecutive images of a video sequence:

$$SSD(u, v) = \sum_{i \in L} [g_1(r_i + V_i) - g_2(r_i)]^2. \quad (6)$$

Matching methods, locally is the displacement vector  $V = [u, v]$  between two images  $g_1$  and  $g_2$  for a certain position  $r = [x, y]$  by minimizing the function:

$$SSD(V) = \sum_{s \in W} \omega(s) \times [g_1(r + s) - g_2(r + s + V)]^2, \quad (7)$$

where  $\omega(s)$  it is the weight function. In this function SSD, the sum is performed of a window size  $(2k + 1)^2$  centered  $r = [x, y]$  and  $s$  are the points within  $\omega$ .

Many correspondence-based methods perform a search for a displacement vector  $(u, v)$  in a finite set of pairs and select the pair that minimizes the SSD function. This method will have no problems derivatives but the accuracy of the method is limited by the discretization of the search space. (This paper has also proposed an interpolation on the pixels to provided better accuracy).

The method of minimum squares detection [14], it is to find the displacement  $\hat{V} = [\hat{u}, \hat{v}]$  that minimizes residuum:

$$\sum_{i \in W} [g_n(r_i + \hat{V}) - g_{n+1}(r_i)]^2, \quad (8)$$

where  $W, (W \subset L)$  It is a small image window, centered on the point for which we want to calculate the optical flow or displacement. It applies expansion in Taylor series and an overdetermined system is obtained:

$$\begin{pmatrix} D_x g_n(r_1) & D_y g_n(r_1) \\ D_x g_n(r_2) & D_y g_n(r_2) \\ \vdots & \vdots \\ D_x g_n(r_n) & D_y g_n(r_m) \end{pmatrix} \begin{pmatrix} \hat{u} \\ \hat{v} \end{pmatrix} = \begin{pmatrix} -D_t g_n(r_1) \\ -D_t g_n(r_2) \\ \vdots \\ -D_t g_n(r_m) \end{pmatrix}. \quad (9)$$

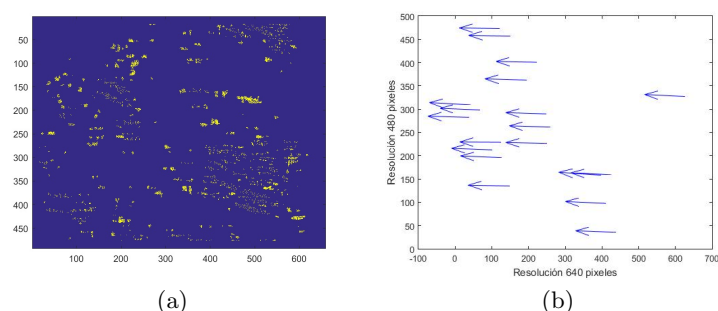
In matrix form,  $G\hat{V} = e$ , whose solution is given by least-squares:

$$\hat{V} = [G^T G]^{-1} G^T e. \quad (10)$$

### 3 Displacement Estimation using Genetic Algorithm

As it has been described in above paragraphs, firstly were determined the tracking feature; next the offset is calculated. However we found that in the method of

Shi-Tomasi when he meets a local minimum, this method terminates the pursuit of solution converges. However the value of the solution may not exactly represent the solution that will represent the physical displacement. This is the metric space may have several local minimum just satisfy the convergence criterion. To warrant a better convergence, we need a method such that analyze a local minimum searching which of them represent the most probable solution to the similarity target function.



**Fig. 3.** Figure illustrate a) some features labeled as trackable features; b) Estimated vectors associated to the displacement of trackable features.

For this the use of a genetic algorithm is a search method based on probability directed proposed. Under a condition it can be shown that the algorithm converges in probability to the optimum. That is, by increasing the number of iterations, the probability of having optimal in the population approaches 1. Genetic algorithms use a direct analogy with the natural behavior, working with a population of individuals, each of which represents a feasible solution to a given problem.

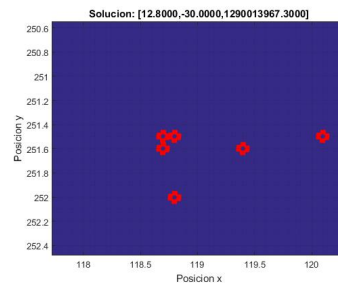
Each individual is assigned a value or score. In nature this would amount to the degree of effectiveness of an agency to compete for certain resources. The greater the adaptation problem will be more likely to be selected for breeding, crossing their genetic material with another individual similarly selected. This crossing will produce new offspring individuals of the above, so a new population of possible solutions is produced, which replaces the previous one. Thus the genetic algorithm to optimal solution.

For the passage from one generation to the next a series of genetic operators are applied:

1. Initialization. The initial population is generated randomly constituted by a set of chromosomes (encoding), which represent the possible solutions of the problem.
2. Evaluation. Establishes a numeric measurement for apply an aptitude function to know how viable is the solution being encoded.



3. Stop condition. Usually two criteria are used: Genetic Algorithm run the maximum number of iterations (generations) or stop when there is no change in the population.
4. Selection. The selection algorithms are responsible for choosing which individuals will have opportunities to reproduce and which not.
5. Crossover. Once the individuals are selected, these are recombined to reproduce the offspring that will be inserted in the next generation.
6. Copy. Consist on the copy of one individual to the next generation. The percentage of copies from one generation to the next is relatively reduced.
7. Mutation. The mutation is often used in conjunction with the crossover operation. The mutation often used is the random replacement.
8. Replacement. The best individuals are selected to create the new population.



**Fig. 4.** Solutions Genetic algorithm for a single feature.

When a feature has a displacement lower than a pixel. The local information of intensities causes that they might be altered. The alteration is according to the perceptual displacement minor to a pixel. The intensity of alteration give us information about the displacement lowers than a pixel, which for us correspond to sub-pixel displacements. In terms of tracking algorithm the way to locate which is the real displacement, the color intensities are re sampled using an interpolator to estimate lower displacement. In our case, the interpolators play a role to estimate color intensities when a  $\delta$  for each component is lower than the unity, providing a way to estimate sub-pixel displacement. In our scenario each pixel represent in dimensional measures to 7.2 micrometers (which is the size of the pixel in the camera that was used, Prosilica GC650. Then regions that may have a characteristic, however as no information metric space has, the interpolator is responsible for estimating the local area to help find that minimum.

## 4 Results and their Analysis

In Table 1 are the values of the magnitudes of the displacement vectors with the method of Shi-Tomasi [13], for each of the selected features.

**Table 1.** Data table the norm of the estimated displacement for a pair of images.

6.7613	6.7837	6.6731
6.2555	6.5389	6.6887
6.9316	6.5080	6.7008
6.7347	6.7112	6.6313
6.8778	6.8008	8.9727

We note that Table 1, the median final displacement was 6.7542 pixels with the first method. The results in Table 2 are to apply genetic algorithm once you have selected tracking features, the median is 6.7112 pixels.

**Table 2.** The data table of the norm estimated displacement standard for a couple of images.

6.81	6.42	6.51	7.20	6.82
6.92	7.00	6.80	6.80	6.92
6.90	28.85	7.20	6.52	6.60
6.50	6.82	6.52	7.30	6.61
7.02	6.92	7.02	6.40	6.92
14.04	7.00	6.80	6.82	7.20

## 5 Conclusions

The genetic algorithm allows for an alternative solution through an evolutionary process rather than a system based on the Taylor series method. This enables displacement of robust and efficient convergence avoiding local minimum are detected. For the specific case of micro-photography images it has a median 6.7542 displacement, using a traditional scheme. However it was observed that using another method for calculating displacement (genetic algorithm) can improve the approximation of displacement, since having the step of mutation, can begin to randomly generate solutions closer to the real, from which we obtained for a single feature a median is 6.7112.

As future work is the generalization of the algorithm with different sequences and also improve tracking feature.

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