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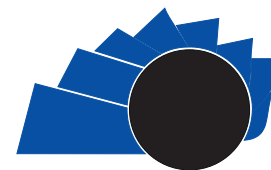
Visión Electrónica

A RESEARCH VISION

Design of a nursing call system: an alternative
Diseño de un sistema de llamado de enfermería: una alternativa

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ABSTRACT

In this article, it is proposed a prototype oriented to nurse-call, which allows to create and inform the request of emergency care of a patient to the public, by means of embedded devices like the Raspberry Pi and a Display Touchscreen LCD. The emergency call is carried out by means of a network of switches that activate a channel, then this signal is conditioned and processed to be transmitted by means of a serial bus RS-485, then the received message is decoded and shown on an LCD screen, finally the request information is stored in a database. Some experiments were conducted to evaluate the energy consumption, the rate of data loss, the scope, as well as tests to validate the scalability of the prototype. The results show that the proposal presents an increase in the demand of electric energy, mainly due to the characteristics of the technology used, however, the results show that the designed system allows to quantify the dynamic in the time of the nurse-call and is compatible with other similar systems.

RESUMEN

En este artículo se propone un prototipo orientado al llamado de enfermería el cual permite generar e informar la solicitud de atención de emergencia de un paciente al público por medio de dispositivos embebidos como las Raspberry Pi y un Display Touchscreen LCD. El llamado de emergencia se realiza por medio de una red de pulsadores que activan un canal; luego, esta señal es acondicionada y procesada para ser transmitida por medio de un bus serial RS-485; después, el mensaje recibido es decodificado y mostrado en una pantalla LCD; finalmente, la información de la solicitud es almacenada en una base de datos. Se realizaron experimentos para evaluar el consumo energético, la tasa de pérdida de datos, el alcance, así como pruebas para validar la escalabilidad del prototipo. Los resultados muestran que la propuesta presenta un aumento en la demanda de energía eléctrica debido, principalmente, a las características de la tecnología utilizada; sin embargo, los resultados muestran que el sistema diseñado permite cuantificar la dinámica en el tiempo del llamado a enfermería y es compatible con otros sistemas similares.

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1. Introduction

The nurse-call system has been widely used in hospitals and health centers, allowing communication between the issuer and the recipient of the request. There are many studies that report the benefits of this system for the user, for example, elderly patients in intensive care express that the nurse-call system is a determining factor that generates safety [1-3]. Other investigations conclude that it is important to attend the emergency request because the probability of patient falls is decreased and the feeling of satisfaction of the service is increased [4-5].

On the other hand, call systems have evolved according to the needs of the actors involved. The teams that operate under a nurse–patient paradigm offer a practical solution. There is a large number of developments in the literature that involve new elements in the design, these solutions allow people to manage the nurse-call by means of a mobile phone, it also reports the linking of sensors to quantify the response of the nurse, platforms where the patient can select the type of service that demands (supply of medicines, food, go to the bathroom, among others), application of the server client paradigm where it is possible to register and consult the dynamics of use of the nursing call among others [6-8]. Although these are based on real needs, the operating model does not involve other participants (relatives, visitors) who are interested in the patient receiving timely care [3]. Other systems tacitly link other participants in the model, by means of light indicators distributed throughout the unit or hospital department, which give notice about the room that demands medical service. Although no validation is reported with the end user, these developments present a design and validation process where the prototype's energy efficiency and high reliability are experimentally demonstrated. Although these developments inform the room that demands service, the message is presented in a simple way by means of a seven segment display, which is inefficient because this space could be used to announce other information related to the health center processes or services [9-11].In this document, a nurse-call system that adopts an alternative visualization module is proposed, this prototype allows to generate and inform the request for emergency care, allowing also to display other information of interest. The equipment uses a Raspberry Pi 3, a Touchscreen LCD Display, a database and an RS–485 communication channel. The results show that the prototype can quantify the dynamics of using the nurse-call as well

as being adaptable to other similar developments [9]. This document has been organized in four parts. The first one contains the modern systems operation history of nursing call. Second section introduces the methodology which describes every step of the system development: intercommunication, conditioning, signal processing, communication protocol, decoding, information storing in a database and its visualization. The third section describes the results given by the system operation tests, energy consumption readings and validation of communication channel operation. And the last one, shows the experience conclusions of this researching process.

2. Background

The nursing assistance call systems are technological tools widely used in health centers, clinics and hospitals. The first introduced systems were made of bells that sounded immediately after the patient pulled a cord. Then valves were tied to a doorbell to help the nurses knew where the patient's room was located [12, 17]. Clearly, the development of electromagnetic theory and electronic has replaced those analog systems (cord and valves), but it still retains the basic functions.

The basic equipment for this system is a telephone exchange, voice channel, pushbutton arrangement and a set of alarms that tell which rooms request service [14]. Others systems use the same client-server paradigm which quantifies the attention response of the nurse, monitors the patient's health and measures environmental variables to help the nurses by sending text message, programing dates to delicate patients, among others, however, there are cases when giving advices by messages can be stressful to the assistant staff [15,16]. Other developments prioritize the user's needs by looking for patient's call order to the infirmary, discriminating the exigency and the context of the request, so the nurse can evaluate the attention priority, therefore, giving better resource to the hospital by eliminating all kind of frustration and concern, unfortunately, some of these works are still in a prototype level of fidelity [8, 18].The emergency call systems in hospitals are using more and more resources to store and consult in real time the information generated when the request has been sent, this in order to register and analyze the data and so to be able to set up the help routine and do the respective settings. However, these models are under a patient-medical staff paradigm, ignoring other participant people like patient relatives. On the other hand, the technology used is based on cloud

computing, what makes hard to implement because sometimes there are not enough resources to use in these advanced systems [15, 17]. An alternative that introduces a simple solution which involves other participants for the emergency call attention model is repeating the attention request in many places of the hospital with the purpose of informing the people which room demands medical services in a determined moment by using an indicator light. The proposed methodology has the advantage, which, every person can read message without using another device, besides, shows how simple is the design method because is based on a modular method and uses easy access technology, allowing the technical staff to dock new hardware functions. While it shows experimentally the efficiency and reliability of the prototypes, there is still long way to develop a system that meets the requirements to solve all kind of situations presented in a health center [9-11]

3. Methodology and design

The methodology consisted of designing each of the stages of the instrumentation and measurement system presented in the block diagram of Figure 1, unlike the works presented in [9-11] this introduces the use of a database (DB) that records the requests for medical care by the user. On the other hand, a more dynamic user interface is incorporated with the purpose of linking other types of information (advertising, emergency alerts, institutional campaigns of the medical center), which is not possible to show in the previous works , due to limitations in the processing device and the display element used in the prototypes. Also, note how the storage of the information generated in the medical service request process can be directly related to the patient or their respective room, which is an additional element that introduces the present methodology.

3.1. INTERCOM

This is made up of an arrangement of switches in Pull-Down mode, which allow to generate the service request from the recovery room to the waiting room where the medical staff is. Secondly, there is a control element in charge of receiving the service request, interpreting it and enabling the respective channel. In Figure 2 a circuit model that summarizes the above process [9] is shown. This design preserves the number of inputs presented in [9].

Figure 2. Intercom Stage [9].
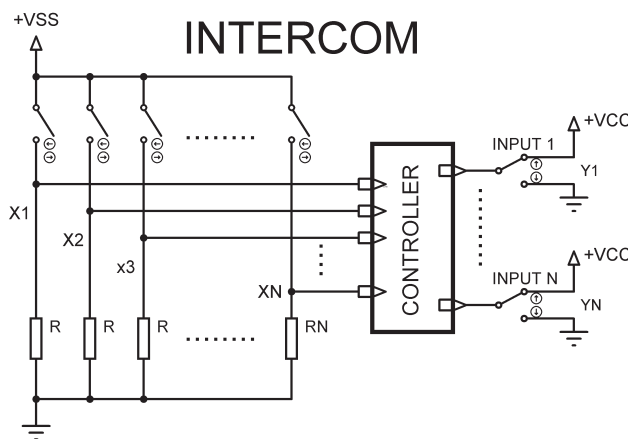
3.2. Signal conditioning, processing and communication protocol

This stage is constituted by an array of operational amplifiers in voltage follower configuration, connected with a set of optocouplers in Pull-Down mode. Then the WN signals, which are equivalent to Y N, are received by the Processing stage, which is formed by a microcontroller where

Figure 1. Block diagram of the methodology.
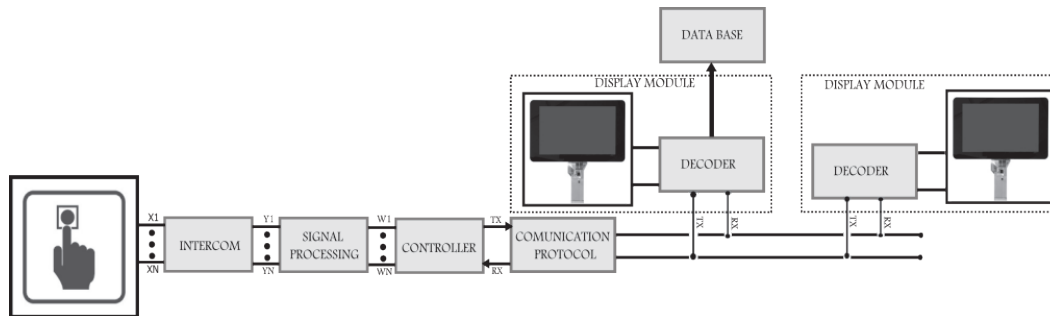
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the information is captured, processed, encrypted and transmitted to the communication bus, with which it is built a point-to-multipoint network and thus be able to connect additional display elements. The communication rule used was the RS-485 serial standard because it allows to communicate up to 32 devices to the communication channel, it can operate in Full Duplex mode and allows data transfer up to 1.2 Km. The above is summarized in the circuit diagram of Figure 3 [9 -10].

3.3.Decoding and visualization

In this, an embedded system is used, which receives the encrypted information from the controller through serial communication. Then is decoded to be shown on a Display the room requesting assistance service. The embedded system used is a Raspberry Pi 3 model B, because it contains several necessary components in a common computer, this has the ability to perform tasks at the level of a desktop PC. The display used was an LCD–7" Touchscreen that is compatible with the Raspberry Pi 3, Figure 4 shows the block diagram of this stage.

3.4.Database

In this work we introduce a DB that records the requests for medical attention by the user thanks to the characteristics of the Raspberry. This was created through the MYSQL software, using the phpMyAdmin.php, which provides ease in the configuration and handling of the information contained in the DB (see Figure 5).

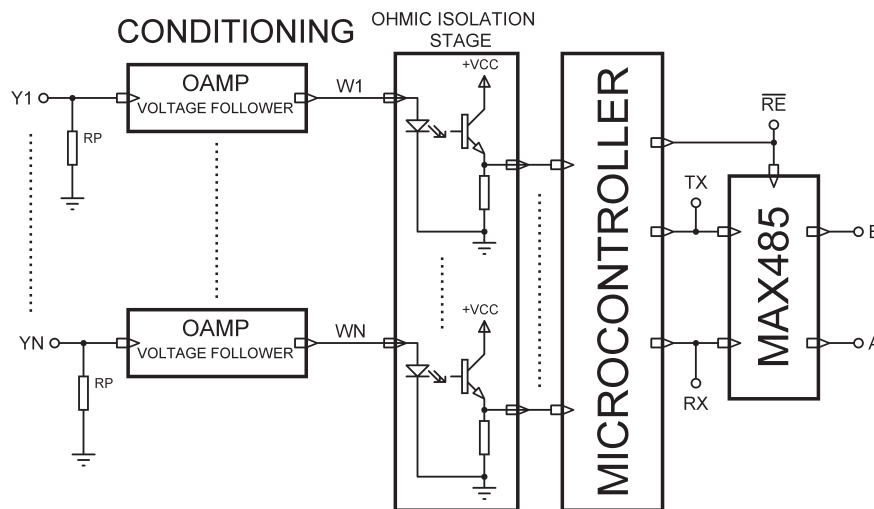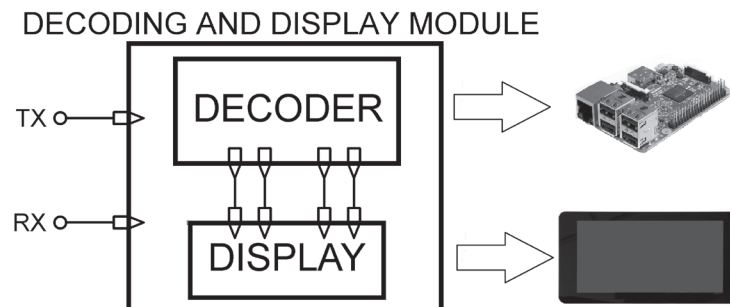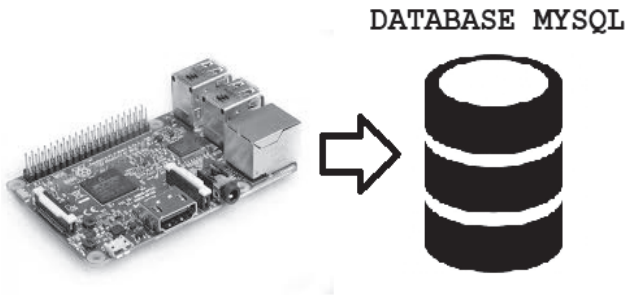**Figure 3.** Signal conditioning stage, controller and communication protocol [9–11].

Figure 4. Decoding and visualization module.

Source: own.

Figure 5. Database module.

Source: own.

The table contains different fields that store the information by using the following structure: N. Register that stores the number of calls, ID is the number of the room and Date_Hour is the date and time of the call, as shown in Figure 6.

Figure 6. Configuration of the MYSQL Database.

Source: own.

3.5.Algorithms

The system operates under two algorithms that capture, encode, transmit, receive, decode and inform the room that requests medical service, thus the software is implemented in the Processing stage and in the Decoder section. In this document we keep the paradigm used in [10] for the algorithm of the Processing stage. For the Decoder, the procedure shown in Figure 7 is developed, this is responsible for receiving the serial bus information, if the reception was correct (Ok_Tx = 1), it decodes, informs and stores the number of the room in the DB that requested medical service. This algorithm was implemented in the C ++ language, for the user interface development the QT Creator tool was used [19-21].

Figure 7. Algorithm of the decoding and visualization system.

```
Input Data{Data_Tx, Ok_Tx : 0}
Output Display(t), DataBase(t)

Begin
 do
   If(Ok_Tx : 1)
    Display(t) -> Decoder(Data_Tx)
    DataBase(t) -> Decoder(Data_Tx)
   else
    Display(t) -> 0
  while(True)
end
```
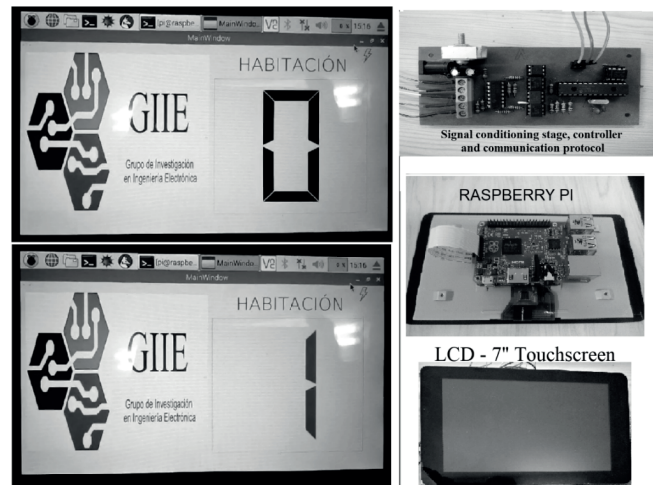
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4. Results

To evaluate the operation of the equipment under real conditions, an attempt was made to emulate the conditions of a hospital, as described in the work [10], except that, in this work, a serial communication was used, not a wireless one. The tests were carried out in the building of the Electrical Engineering program of the Technological University of Pereira. Then, a visualization module was installed using the proposed design and the operation of the system was observed with the LCD screen and the Raspberry Pi 3, Figure 8.

**Figure 8.** Operation of the system presented.

Source: own.

Figure 9 shows the result of a test performed on a day of operation, it consisted of generating the call requests at random during the day. This procedure was applied for another time window obtaining the results of the Figure 10. In Figure 11 the total number of emergency calls are summarized discriminated by room.
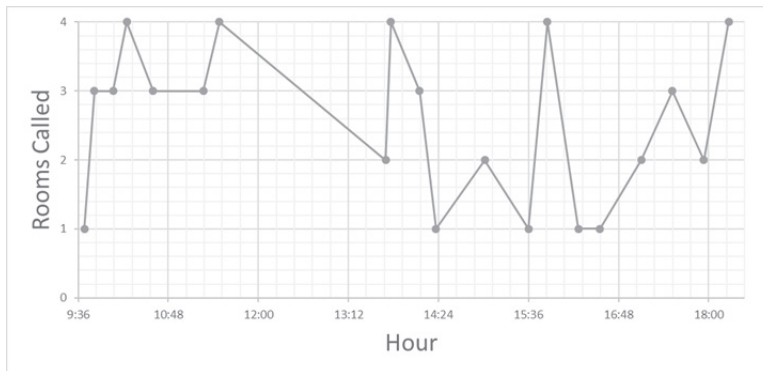
The graphs shown in Figure 9 and Figure 10 show the dynamic of the user's use of the prototype, that

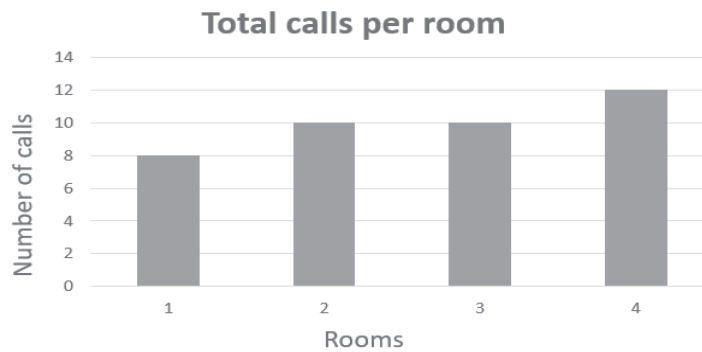**Figure 9.** First day of test summary of attention of room vs time.
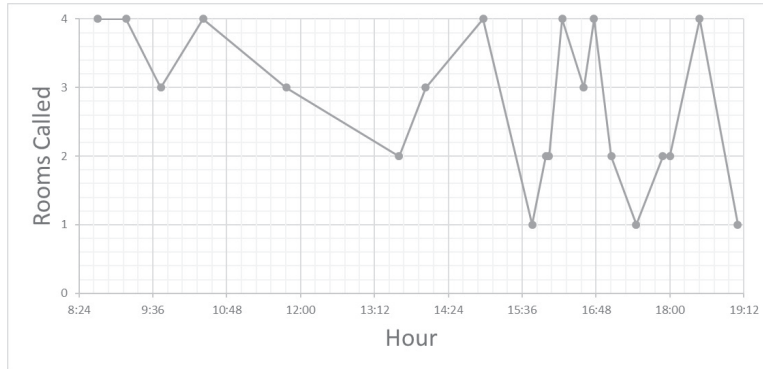
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Figure 10. Second day of test summary of attention of room vs time.

Source: own.

Figure 11. Bar chart of the number of calls.

Source: own.

is, the number of requests generated as a function of time. This result is interesting as a validation tool because it would allow to correlate the total number of requests with the quality of the service provided expressed by the patient [5]. In addition, Figure 12 shows the MYSQL database that contains a history of each of the calls.

On the other hand, readings of energy consumption of the module shown in Figure 4 were made, which in permanent mode was approximately 220 mA. This value is significantly higher when compared to the one reported in [9], which is 4 mA, the difference lies mainly in two elements, first the technology used, as well as the low energy

Figure 12. History of the so called guards in the Database.
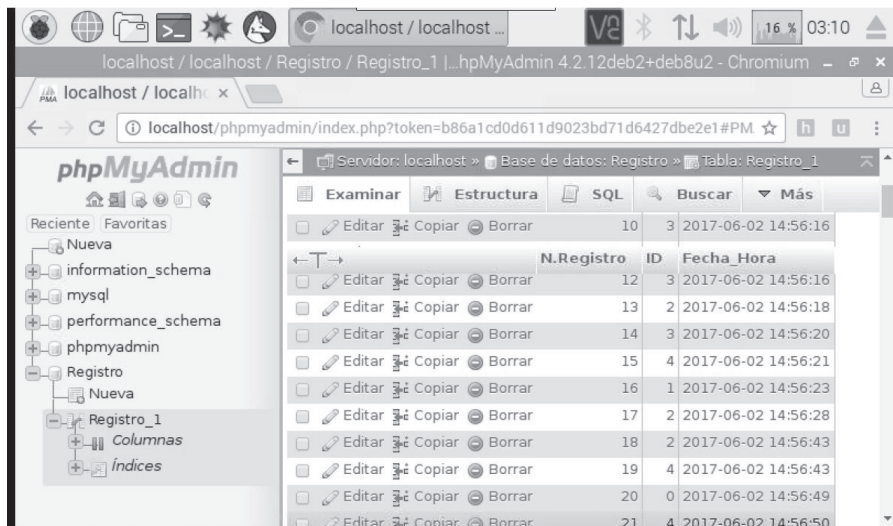
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consumption strategy that is implemented in [9]. Clearly the use of a hardware with lower computing capacity and the use of a simple indicator leads to a lower consumption of electrical power, on the other hand in [9-10] it is feasible to implement a strategy to activate the hibernation mode of the prototype, because the Wake Up times are negligible and therefore do not influence the operation of the system at the time a nurse-call originates, on the other hand the developed proposal presents an important electrical current consumption because to manage the hibernation mode of the Raspberry affects the operation of the system, because the Wake Up time can take several seconds, which can not be accepted because the message must be shown instantaneously.

On the other hand, a test was performed to validate the operation of the RS-485 communication channel in order to verify if the prototype can be expanded, for this the display module proposed

in [9] was implemented, this was interconnected to the serial bus, then the system transmitted the nurse-call request to the new indicator, this result is important because the prototype is able to recognize any luminous indicator compatible with the communication channel, giving flexibility to the use of another technology. Finally, distance tests and loss of data packets were performed, obtaining results that can be seen in Table 1.

Table 1. Results of the number of packets received with different distances.

Distance [m]	Taken packets with the current methodology (%)
17.5	100 ± 0.00
46.5	100 ± 0.00
104.7	100 ± 0.00

Source: own.

5. Conclusions

In the present work, a prototype was presented for the nurse-call, which operates under a paradigm patient–nurse–other participants. The development introduces the use of a dynamic indicator that allows to display other type of information, as well as a processing element with higher performance, this allowed the articulation of a DB for the registration of nurse-call requests, in addition the design is compact according to the compatibility that exists in the technology used.

Based on the results, the system is able to record the number of requests, as well as the time it was generated. This information is important for the health center to carry out studies and build new strategies aimed at the improvement of the service.

When analyzing the energy consumption, it increased significantly in contrast to the one reported in [9], this is due to the hardware used that has greater computing capacity associated with its peripherals and supplies power to an LCD screen with a considerable energy consumption. On the other hand, the operation of the RS-485 communication protocol with other compatible modules constituted with other technologies was validated, this result is important to guarantee the scalability of the system. Although the system was not tested in a hospital, the results suggest that the system is reliable, safe, scalable, modular, characteristics necessary to operate in a clinical stage, and on the other hand, the results shown in Table 1 are similar to those reported in the literature, it stands out that there is no loss of information, this is due to the hardware features that support the Raspberry for handling serial communications. For future work, it is necessary to quantify the response time of the nurses, as well as the implementation of a tool that allows to send text messages, notifications, alarms, emergency calls to the nurses' mobile phones, on the other hand, the implementation of an IoT may be interesting in order to remotely monitor the dynamics of the platform use, as well as to facilitate the maintenance routine or system errors detection.

6. Acknowledgments

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