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Development and implementation of a low-cost security system

Desarrollo e implementación de un sistema de seguridad de bajo costo

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One of the main security problems in Colombia is home burglary since most of the time these are left alone during working hours or other types of occupations. This article presents an analysis of the problem of home security due to theft, looking for an effective solution at a lower cost than those available in the market. This arises from the analysis of the figures given by the DANE and a solution is proposed using the ESP32 development board, the HC-SR501 motion sensor, and the RC522 RFID (Radio Frequency Identification) reader, which allows us to generate an economical and reliable security system with the implementation of the IoT (Internet of Things) to make it more versatile.

Keywords: ESP32, HC-SR501, IoT, lector RFID, security system

Una de las principales problemáticas de la seguridad en Colombia es el hurto a viviendas, dado que en la mayoría del tiempo estas quedan solas durante los horarios laborales u otros tipos de ocupaciones. En este artículo se presenta un análisis a la problemática de seguridad en las viviendas por hurtos, buscando una solución efectiva y con un costo menor a los que hay en el mercado. Este surge del análisis realizado a las cifras dadas por el DANE y se propone una solución haciendo uso de la placa de desarrollo ESP32, el sensor de movimiento HC-SR501 y el lector RFID (Identificación por radiofrecuencias) RC522lo que nos permite generar un sistema de seguridad económico, fiable y con implementación de las IoT (Internet de las cosas) para que sea más versátil.

Palabras clave: ESP32, HC-SR501, IoT, lector RFID, sistemas de seguridad

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Introduction

Most individuals spend a significant portion of their day outside their homes, whether it be for work or other activities. As a result, homes are often left unoccupied for extended periods, making them a prime target for burglars. To address this issue, a prototype of an intelligent security system was proposed to protect homes from intruders.

The prototype security system was developed using a combination of different technology components (Escobar et al., 2008). An RFID (Radio Frequency Identification) reader RC522, an infrared motion sensor HC-SR501, and the ESP32 development board were used to fabricate an automatic home security device. The RFID reader was used to detect the presence of authorized individuals, while the infrared motion sensor was used to detect the presence of any intruders. The ESP32 development board was used as the main controller for the system, and it was connected to a wireless application that was implemented through the Arduino IDE software (Martínez et al., 2013).

The proposed security system works by alerting the homeowner when the presence of an intruder has been detected. The system is designed to be automatically activated when the home is left unoccupied, and it can only be deactivated or turned off by authorized individuals using the RFID reader. This provides an added layer of security, as it ensures that only authorized individuals can turn off the system and enter the home.

The proposed security system is not only limited to the detection of intruders, but it can also be extended to other security features such as monitoring the temperature, humidity, and other environmental factors, as well as providing notifications to the homeowner in case of any emergency.

Based on the annual Colombian report presented in 2021, there were approximately 33,306 reports of residential burglary and as of September of this year, 20,275 have been reported. 275, according to data recorded by DANE (Medina, 2020), it is evident that this type of crime does not decrease with the passing of the years, since in 2012 a total of 22,349 cases were reported, figures that have been widely surpassed reaching records of almost double these with almost 40,000 residential burglaries in the same year (Medina, 2020).

One way to address the issue of security is through the implementation of security systems. This is a common recommendation made by authorities to citizens as a means of preventing crime and keeping individuals and their property safe. However, while the implementation of security systems may seem like an obvious solution, it is important to consider the potential barriers to access for many individuals.

One such barrier is cost. Security systems can be quite expensive, with prices ranging from as low as $86 for the most basic options to over $200 for more advanced systems. Additionally, many of these systems require a monthly payment for ongoing monitoring and maintenance. For many individuals and families, these costs may be prohibitively high and make it difficult for them to access the benefits of a security system.

In light of this, it is important to explore alternative solutions that can provide the same level of security at a lower cost. One such solution is the use of the ESP32 development board in combination with a PIR sensor (HC-SR501) and a password system. This system can be further enhanced by incorporating RFID technology using the RC522 sensor to create a "key" system that allows individuals to access their homes or other secure spaces.

The use of the ESP32 development board allows for a more affordable and accessible solution as it is relatively low-cost. Additionally, the PIR sensor is a cost-effective way to detect movement and the password system can be used to prevent unauthorized access. The RFID technology allows the system to recognize authorized users and grant them access, providing an added layer of security.

It is important to note that while this system may not be as advanced or feature-rich as some of the more expensive options on the market, it can still provide a high level of security at a lower cost. Additionally, by using open-source technology, it is possible to customize and improve the system to better meet the needs of specific individuals or communities.

The security system we seek to develop will implement one or more PIR sensor sensors HC-SR501 connected simultaneously to the ESP 32 development board, similar to the one observed in the article by (Saleh et al., 2018) or in this other article by (Masykuroh et al., 2021), unlike the automatic lock will not be implemented, the most similar to what we seek is observed in the article by (Wahyuni et al., 2021). In addition, to facilitate the activation or deactivation of this system an RFID reader will be implemented as a "Key" which could be observed in the article of (Rusyn et al., 2022) in which a locking system with the RFID reader RC522 was observed, The goal is that the infrared sensor system to detect heat samples moving to send a signal to the board which in turn through the program designed in Arduino IDE request to disable the security system through the password or the "Key", in case of not being disabled send a signal either to an alarm or a notification to a mobile application via a WIFI or Bluetooth signal.

Problem statement

Theft from homes or commercial premises is a common crime that has remained at a constant level over the years, as evidenced by data from various studies and surveys (Table 1). Despite a recent decrease in these figures, it is still a significant problem that affects many individuals

and businesses. One potential solution to help reduce this type of crime is the implementation of security systems. However, due to the high cost of many of these systems, this option is often only viable for those with significant financial resources.

Table 1

Annual residential burglary rates in Colombia (Policia Nacional, 2022)

Year	Number of residential burglaries
2018	47,373
2019	46,465
2020	32,324
2021	33,306
2022	23,484

Currently, many security systems include a wide range of complex components such as motion sensors, door and window opening detectors, and special functions such as notifications sent to mobile devices, automatic calls, and automatic locking. These features can be quite expensive and may not be accessible to individuals with limited financial resources. However, it is possible to replicate many of these features using cheaper components that are more affordable for those with fewer financial resources.

One example of this is the use of a simple motion sensor, such as the PIR sensor, which can detect movement and trigger an alarm or other response. This is a relatively low-cost component that can be easily integrated into a basic security system. Similarly, door and window opening detectors can be created using simple switch sensors, which can detect when a door or window is opened and trigger an alarm or other response.

Another potential solution is the use of open-source technology, which allows individuals to customize and improve their security systems to better meet their needs. For example, it is possible to use an ESP32 development board, which is a low-cost microcontroller that can be programmed to perform a wide range of functions, such as sending notifications to a mobile device or triggering an alarm.

Additionally, the use of a password system and RFID technology can enhance the security of the system, by allowing only authorized users to access the protected space. This can be a cost-effective way to ensure that only the right people have access to your home or business.

In conclusion, theft from homes or commercial premises is a common crime that remains a significant problem despite recent decreases in these figures. One potential solution to help reduce this type of crime is the implementation of security systems, however, the high cost of many of these systems makes them only accessible to people with large economic resources. By using cheaper components and open-source technology, it is possible to create a basic security system that is more affordable for those with less financial resources, therefore making it accessible for many people who can not afford the more advanced systems.

Methods

The development of a security dissuasive system requires the use of various components and technologies. The primary component of this system is the ESP32 30-pin development board, which serves as the central control unit for the system. This microcontroller board can be programmed to perform various functions and can be used to control and communicate with other components in the system.

Another key component of the system is the passive infrared (PIR) sensor HC-RC501, which is used to detect movement within the protected space. This sensor is designed to detect changes in infrared radiation and can be configured to trigger an alarm or other response when movement is detected.

In addition to the PIR sensor, the system also includes a 4x4 matrix keypad, which allows for the input of a password or other security code. This keypad can be used to arm and disarm the system, or to provide access to authorized users.

The system also includes an RFID reader and recorder module, the RC522 RFID reader, and the recorder. This module allows for the use of RFID technology to provide an added layer of security. RFID tags or cards can be assigned to authorized users, and the system can be configured to only grant access to individuals with the proper RFID tag or card.

ESP32

The ESP32 development board is a powerful and versatile tool for creating a wide range of projects, particularly those related to the Internet of Things (IoT). At its core, the ESP32 is a microprocessor that is capable of running a variety of programs and controlling various sensors and modules. One of the key advantages of the ESP32 is its ability to connect to both Wi-Fi and Bluetooth networks, which allows for a high level of flexibility and control in projects.

The built-in Wi-Fi connection allows for efficient and economical control of sensors and modules, as it allows for communication and data transfer without the need for additional hardware or cables. This can greatly simplify the design and implementation of projects and make them more cost-effective. The Bluetooth connection allows the ESP32 to communicate with other devices wirelessly, enabling the development of projects that require a low-power, short-range wireless connection.

The ESP32 development board is widely used in IoT projects, as it allows for the creation of smart devices and

systems that can be controlled and monitored remotely. This opens up a wide range of possibilities for automating processes, collecting and analyzing data, and creating new applications and services.

HC-RC501

The HC-SR501 PIR sensor is a passive infrared motion sensor that is designed to detect movement within a specific range and field of view. The sensor is equipped with a Fresnel lens which helps to focus the infrared radiation, and has a detection range of 3 to 6 meters and a detection cone of 110°. This allows the sensor to detect movement within a specific area, making it a useful tool for security and automation applications.

The sensor has a continuous output of 3 seconds to 5 minutes, and the detection time can be adjusted by two potentiometers. This means that the sensor can be customized to meet the specific needs of a particular application, whether it's for a short-term or long-term detection.

The HC-SR501 operates on a voltage of 3.3 V to 5 V, which gives it a high output (3.3 V) when detecting moving heat samples, such as a person or an animal. This high output signal can then be used to trigger an alarm or other response, such as activating a camera or locking a door.

RC522

The RC522 module is a versatile and compact device that is designed for reading and recording RFID tags. It utilizes a modulation and demodulation system that operates at a frequency of 13.56 MHz, which is a commonly used frequency for RFID technology. The module is powered by a 3.3 V supply and utilizes the SPI protocol for communication. This allows for fast and reliable data transfer between the module and the host device. The module is small and lightweight, making it easy to integrate into a variety of projects and applications. Additionally, it is designed to be low-power, making it suitable for use in battery-powered devices. Overall, the RC522 module is an excellent choice for those looking to implement RFID technology into their projects.

Development procedure

The development of the security system requires a systematic and organized approach. One effective method for achieving this is by utilizing a flowchart, such as the one shown in Fig. 1, to guide the development process. To aid in the development process, the Wokwi simulator will be used. The Wokwi simulator is a powerful tool that allows developers to write, test and debug code in a virtual environment. The simulator is designed to be user-friendly and easy to use, making it an ideal choice for developers of all skill levels. By using the Wokwi simulator, developers can ensure that the code they are writing is compliant with what is established in the flowchart and that it will function correctly when implemented in the final system.

The operation of the code, starts with the detection of heat samples in motion (Presence), when a presence is detected a signal is sent to the ESP32 which initiates a process to identify if a key is entered, an RFID Tag is approaching or is deactivated by a command sent through a telegram message and verify if these are correct, in case an incorrect key is entered or a wrong Tag is entered, 1 failed attempt is counted, when 3 attempts are completed, it takes more than 30 seconds to enter the correct key, Tag or a command to activate using the telegram bot, a deterrent alarm is triggered for 1 minute, once the minute is over, the system returns to the initial stage (Presence detection); On the other hand, when the correct password or tag is entered, the system goes into a sleep state, waiting for the password to be re-entered to return to the initial state. In addition, thanks to the fact that the ESP32 has integrated Wifi, a Bot was implemented via Telegram with which the system can be managed.

The functional prototype can be seen in Fig. 2, which shows the ESP32 board, the HC-RC501 sensor, the RC522 module, the matrix keyboard, and the 16×2 LCD screen.

Results

During the sensor tests, it was observed that the device has a wide detection range, which is an important feature for a security system. It was also noted that when the device is first activated, it may be triggered 1 or 2 times during the first minute of operation. This is likely due to the device adjusting to its surroundings and fine-tuning its sensitivity.

When it came to mounting the prototype, the team encountered a small issue. The ESP32 board has 30 pins, but they were a little short, which made it necessary to mount and program the 4×4 matrix keyboard as a 4×3 matrix. This left the team with only 3 free pins that could be used as input. This limitation could potentially impact the system's flexibility, as it would limit the ability to add more motion sensors or other types of sensors, such as a magnetic sensor for doors or windows.

To overcome this limitation, the team decided to implement a system through IoT that allows the alarm to be activated or deactivated through the use of a Telegram bot. As shown in Fig. 3, the bot sends messages that can be used to control the alarm remotely. This allows the user to easily arm or disarm the system, even if they are not physically present. This can be especially useful for those who are away on vacation or at work, as it provides an added level of control and peace of mind.

Overall, the sensor tests showed that the device has a wide detection range and some minor issues were encountered during the prototype mounting, but the team was able to

Figure 1

Flowchart of the control scheme.

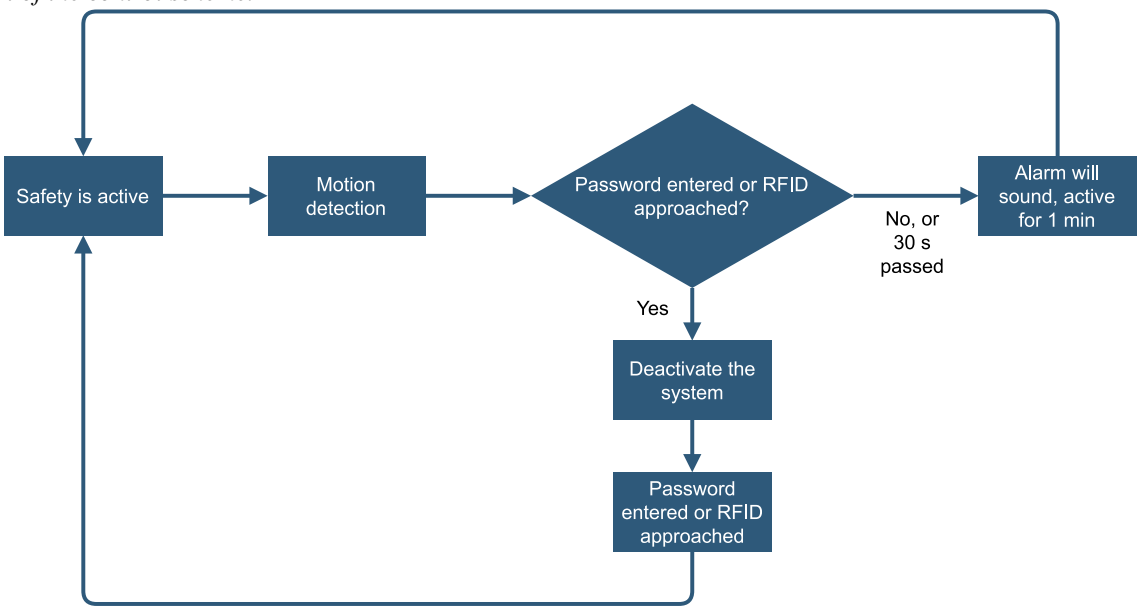
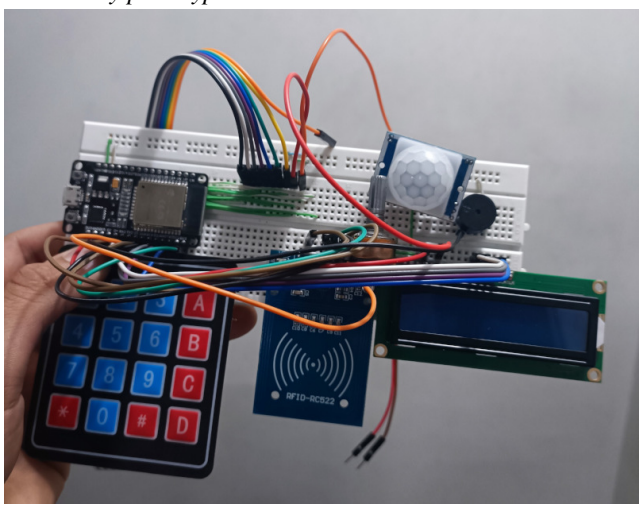


Figure 2

Laboratory prototype.



overcome them by implementing an IoT system through a Telegram bot, which provides a convenient and flexible way to control the alarm remotely. Despite the limitation of 3 usable input pins, the team will keep an eye on the possibility to add more motion sensors or other types of sensors in the future, to improve the overall security and performance of the system.

Conclusion

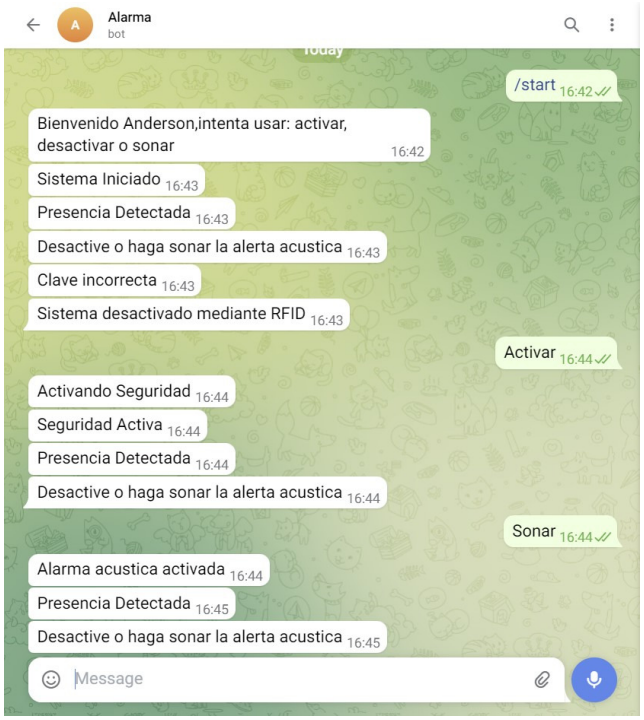
We have successfully developed a low-cost security system that is more affordable compared to traditional systems, with an approximate cost of $20 USD. While this is a significant achievement, there are some limitations to the system as it is currently designed. One limitation is the use of a development board that is short on pins, which reduces the flexibility to add additional features. In the case that more features are needed, we would opt to use the ESP32 version of the board, which has 38 pins, which would provide more options for expansion.

Another advantage of the system is the use of low-consumption components, which allows for the option of adding an external battery to the system. This would allow the security system to continue operating even in the event of a power outage, providing added protection for the protected space. Additionally, the system includes an IoT component, which allows for the activation or deactivation of the alarm via Telegram. This allows for the ability to keep a record of who deactivated the alarm in the case that it has been physically disabled, providing an extra level of security and access control.

The system can be configured to send notifications to the user's mobile device or even call the owner in case of an intrusion, this would allow the owner to take action immediately in case of an emergency. Additionally, if the alarm is triggered, it can trigger an automatic lock system that would prevent intruders to access the protected space.

Figure 3

Bot messages on Telegam.



In conclusion, we have developed a low-cost security system that is more affordable compared to traditional systems. Despite the limitations of the development board used, the system is still functional and provides a good level of security. The low consumption of components allows for the addition of an external battery, providing protection even in case of power outages, and the IoT component allows for remote activation and deactivation of the alarm, as well as providing access control and record keeping, making it a versatile and cost-effective solution for security.

The video in the following link shows how the security system works.

https://youtu.be/pLQFtftzxXE

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