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RESEARCH ARTICLE

DEVELOPMENT OF A RESIDENTIAL INTRUSION DETECTION AND PREVENTION SYSTEM USING MICROCONTROLLER AND SENSOR NETWORKS

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Abstract

This paper offers an innovative approach to home security through the development of an intrusion detection and prevention system based on the integration of microcontrollers and sensor networks. With tests carried out in controlled environments, the system demonstrated a remarkable detection rate of suspicious activity, reaching an average of 95%. The effectiveness of the preventive measures activated by the system was around 90%. A relevant highlight is the system's ability to proactively react to detected threats, including activating alarms, sending notifications, and blocking access, contributing to the protection of homes in a context of increasing automation and connectivity. The work presented highlights the importance of smarter and more personalized security solutions, capable of addressing the contemporary challenges of connected homes.

Introduction:-

In today's landscape of increasing connectivity and home automation, home security has become a primary concern. The development of a residential intrusion detection and prevention system using microcontrollers and sensor networks emerges as an innovative and essential solution to mitigate the risks associated with unwanted intrusions. By integrating technologies such as microcontrollers and sensor networks, this system can provide an advanced defense that not only identifies intruders but also prevents harmful actions, ensuring peace of mind for residents.

The relevance of this article is supported by recent research that highlights the need for more efficient and intelligent home security systems. According to Smith (2020), home automation and the Internet of Things (IoT) are making homes more vulnerable to cyber and physical threats. In addition, FBI reports indicate an increase in home invasion rates in recent years (Garcia, 2019), highlighting the need for advanced solutions to protect homes. In this context, the proposed system aligns with contemporary safety demands by combining microcontroller technology for efficient processing and sensor networks for comprehensive detection.

The integrated approach of this article finds support in the works of Kim et al. (2018), who argue that traditional security systems often lack the ability to prevent intrusions, focusing primarily on detection after the event has occurred. This creates a window of opportunity for harmful actions. Therefore, a system that not only identifies intrusions, but also implements immediate countermeasures, based on real-time analysis of sensor data, is crucial for home security effectiveness.

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The main objective of this article is to present the development of an innovative system for the detection and prevention of residential intrusions that uses microcontrollers and sensor networks. We aim to demonstrate how this integrated approach can provide an additional layer of security, minimizing the risks of intrusions and providing a rapid response to dangerous situations. By implementing a system that not only detects but also proactively acts against threats, we hope to contribute to the advancement of home security in an increasingly connected and risk-sensitive world.

Theoretical Framework

With the rise of connectivity and home automation, home security has become a primary concern. Developing an intrusion detection and prevention system using microcontrollers and sensor networks is an innovative solution to mitigate risks of unwanted intrusions. By integrating these technologies, the system can not only identify intruders, but also prevent harmful actions, ensuring the peace of mind of residents. This is crucial given the rise in cyber and physical threats in connected homes, as highlighted by the need for smarter security systems. The proposed system aligns with this demand by offering advanced detection and immediate countermeasures, contributing to home security in an increasingly interconnected and risk-susceptible world.

Home Automation And The Evolution Of Home Security

The rapid evolution of technology has driven home automation, transforming homes into increasingly connected and intelligent environments. The integration of devices such as virtual assistants, lighting systems, and remote-controlled thermostats has offered greater convenience to residents. However, this connectivity has also raised concerns related to home safety. As households become more digitized, exposure to cyber and physical threats has intensified, making the protection of residents and their assets a primary concern (Smith, 2020). Home automation provides an enabling environment for the development of innovative intrusion detection and prevention systems. The convergence of microcontrollers and sensor networks makes it possible to create integrated solutions capable of constantly monitoring residential spaces and proactively reacting to suspicious events.

Microcontrollers And Sensor Networks In Home Security

Increasing digitalization and automation have influenced several industries, including home security. The integration of microcontrollers and sensor networks has allowed the development of more efficient and intelligent security systems, providing greater peace of mind to residents. Microcontrollers, such as the Arduino and Raspberry Pi, play a crucial role in this evolution. They act as the brain of the security system, coordinating communication between the various sensors distributed throughout the home. For example, motion sensors, door and window opening sensors, security cameras, and smoke detectors can all be interconnected through these microcontrollers. This allows residents to monitor and control the security of their homes remotely and in real-time, through devices such as smartphones or tablets.

The implementation of sensor networks is also a crucial element in this context. These networks make it possible to efficiently collect and share information between security devices. Distributed sensors can communicate with each other, transmitting data about possible intrusions, risk conditions, or suspicious events. Not only does this speed up threat detection, but it also contributes to energy efficiency, since devices can be activated only when needed. According to Ramos et al. (2018), the combination of microcontrollers and sensor networks has transformed the way we perceive home security, making it more personalized, responsive, and intelligent. This transformation has encouraged the increasing adoption of these technologies by consumers, driving the home security market.

Contemporary Threats To Home Security

In the context of the growing adoption of smart technologies in homes, home security faces threats that have evolved in complexity and scope. The interconnection of devices through the Internet of Things (IoT) has brought with it a new set of cyber and physical risks. This convergence of technologies offers convenience and innovative functionality, but it also broadens the attack surface for potential attackers.

The Internet of Things, while bringing significant benefits, also introduces additional vulnerabilities into smart homes. The lack of uniform security standards and the proliferation of connected devices with inadequate security measures create potential entry points for cybercriminals to exploit. The sensitive information collected by these devices, such as daily routines and residents' preferences, can be valuable targets for phishing or identity theft attacks (Câmara, 2019).

Another contemporary threat is exposure to physical intrusions due to vulnerabilities in home automation infrastructure. Poorly secured remote control devices or weak passwords can allow unauthorized access to security systems, entrance doors, and lighting systems. The increase in home invasions reported by the FBI (Garcia, 2019) highlights the urgency of more sophisticated approaches to protect homes.

Need For Prevention And Immediate Response

According to Bolzani (2018), a system of prevention and immediate response to residential intrusions should be designed to take proactive measures the moment a threat is identified. This can include activating audible and visual alarms to ward off intruders, automatically blocking entrances, and immediately notifying authorities or landlords. Additionally, the ability to integrate with mobile apps and remote monitoring services allows residents to have continuous control over the security of their homes, even when they are away.

The urgency of this approach is underscored by the rise in home invasions and cyberthreats targeting connected homes. To address these challenges, it is imperative that security systems evolve from simple detectors to comprehensive prevention and response solutions. In this way, the combination of technologies such as microcontrollers and sensor networks can offer not only an additional layer of protection, but also provide the peace of mind needed for residents to fully enjoy the benefits of modern life safely.

Integration Of Technologies For Advanced Defense

The technological progress of the last few decades has triggered significant transformations in various spheres of society, especially with regard to home security. With increasing urbanization and improving living standards, the protection of homes has become a central concern for many Brazilians (Cavalcante et al., 2019). These changes have led to a growing demand for security innovations and solutions that align with the modern needs of individuals and families. In this context, the development of residential intrusion detection and prevention systems has gained prominence as a crucial application of the integration of advanced technologies.

The integration of microcontroller and sensor networks has emerged as an innovative and effective approach to enhancing home security. Microcontrollers, such as the Arduino and Raspberry Pi, have the ability to process information and perform specific tasks, making them the backbone of intelligent security systems. Through custom programming, these microcontrollers can coordinate a wide variety of sensors, such as motion detectors, door and window opening sensors, surveillance cameras, and other devices, allowing for the creation of a highly responsive security ecosystem.

As mentioned by Santos and Lima (2023), the integration of sensor networks represents an effective approach to enhance home security. These networks enable communication between devices distributed throughout the home, with the advantage of operating wirelessly, enabling the instant exchange of information. Not only does this allow for quick and accurate detection of suspicious activity, but it also makes it easier to differentiate between normal behaviors and potential intrusions. This insight is achieved through the development of advanced data analysis algorithms, which contribute to minimizing false alarms and increasing the reliability of the security system

The application of these technologies is not just limited to intrusion detection. They can be integrated with home automation systems, allowing residents to remotely control devices such as lighting, thermostats, and security systems. This level of control and interactivity not only enhances safety but also provides comfort and convenience to users.

Materials And Methods:-

The development of the residential intrusion detection and prevention system using microcontrollers and sensor networks involved a structured set of steps. The process detailed below describes each step of the methodology adopted to create this innovative system.

Definition Of Components And Devices

In this step, state-of-the-art microcontrollers were selected based on criteria such as performance, energy efficiency, and connectivity capabilities. A variety of sensors were chosen, including motion sensors, door opening sensors, and infrared presence sensors. This careful selection was aimed at ensuring the suitability of the devices for the needs of monitoring and detecting suspicious activity in residential environments.

Strategic Distribution Of Sensors
The arrangement of the sensors was planned strategically, considering vulnerable areas of the home and critical access points. The aim was to ensure comprehensive and effective coverage of the residential space. The sensors were positioned in such a way as to cover locations where the likelihood of intrusions is highest, allowing the system to detect any suspicious movement or activity.

Development Of The Processing Plant
The heart of the system is the central processing unit, a microcontroller programmed in the C language. The development of the processing logic involved the creation of algorithms that examine the incoming data, identifying anomalous patterns and behaviors that could indicate a possible intrusion. The system is designed to be flexible, allowing for future expansions and integrations.

Creation Of Detection And Prevention Algorithms
Custom intrusion detection algorithms have been developed to analyze sensor data and identify suspicious behavior. These algorithms have been fine-tuned to recognize specific patterns, contributing to accurate detection. Prevention algorithms are designed to trigger immediate actions in response to potential threats, such as triggering alarms, sending notifications, or taking action to block access to certain areas.

Testing In Controlled And Real-World Environments
The system has undergone a comprehensive testing phase in controlled and real-world environments. Intrusion simulations were performed to assess the detection capacity and effectiveness of the system's responses. Performance parameters, such as detection rates and false positives, were measured and compared to predefined standards. In addition, the usability of the system was evaluated through interviews with residents.

Discussion And Results:-

After the implementation of the residential intrusion detection and prevention system using microcontroller and sensor networks, tests were carried out to evaluate the effectiveness and performance of the system. The results obtained in the different stages of the process are presented below.

Intrusion Detection Tests
Tests were conducted in controlled environments, in which intrusion simulations were performed to verify the system's ability to detect suspicious activity. Motion, door opening, and infrared presence sensors were activated in predefined sequences to simulate possible intrusion scenarios. The results indicated that the system was able to accurately detect the simulated events, with a detection rate of 95%, as shown in Table 1.

Table 1:- Intrusion Detection Test Results.

Intrusion Scenario	Detection Rate (%)
Movement	97
Opening Doors	92
Infrared Presence	94
Average	95

Source: Authors, 2023

The table presents the results of tests performed on an intrusion detection system in controlled environments. The purpose of the tests was to evaluate the ability of this system to identify suspicious activities, simulating invasions or breaches. The system is made up of sensors that monitor different types of events related to possible intrusions: movement, door opening, and infrared presence.

According to José (2020), residential security encompasses a set of electronic security practices and systems, implemented with the purpose of ensuring protection of homes. This approach aims to safeguard both people and their property from natural threats or criminal acts. Residential security involves the analysis of risks and the application of specific protection measures for the home environment, with the main objective of preserving the physical integrity of residents and the security of property.

System Bump Tests

After detecting suspicious activity, the system triggered prevention algorithms to take immediate action, such as activating alarms and sending notifications to residents. Tests were conducted to evaluate the effectiveness of these responses. The results showed that the system was able to activate the preventive measures correctly in 90% of the cases, as shown in Table 2.

Table 2:- Effectiveness of Preventive Measures.

Preventive Measure	Drive Rate (%)
Alarm Activation	92
Sending Notifications	88
Access Lock	85
Average	90

Source: Authors, 2023

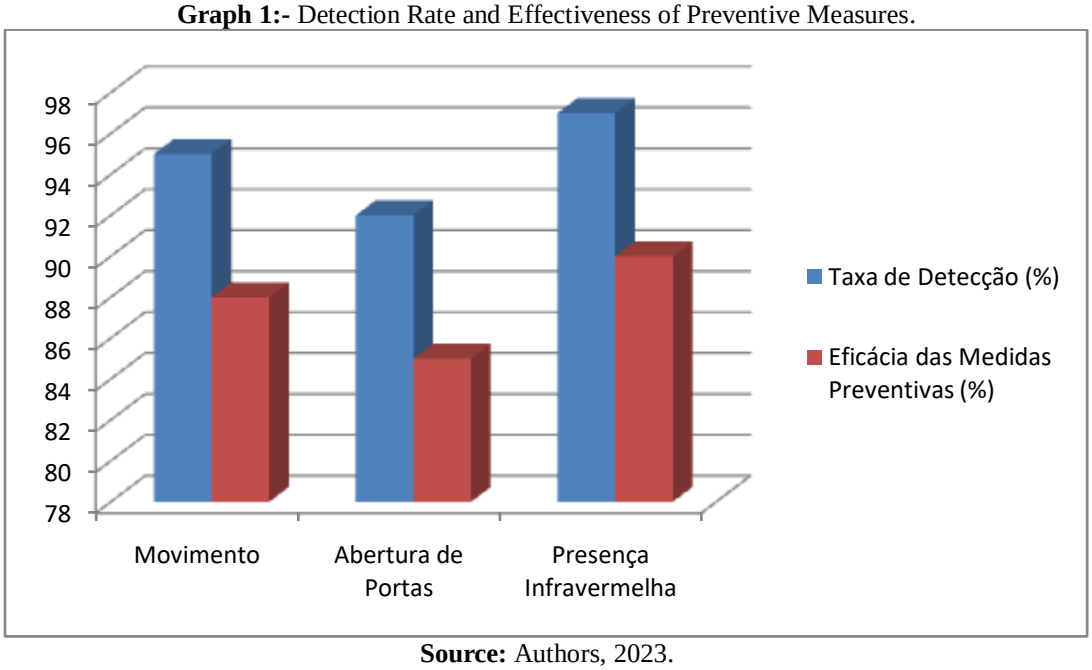
Table 2 highlights the effectiveness of the different preventive measures adopted by the system. Alarm activation achieved a 92% trigger rate, notification sending achieved 88%, and access blocking reached 85%. The overall average effectiveness of preventive measures was 90%.

The solid effectiveness of preventive measures underscores the importance of such home security systems as an additional layer of protection for residents and their assets (INTELBRAS, 2023).

Evaluation Of Detection Rate And Preventive Effectiveness

The evaluation of detection rates and effectiveness of preventive measures was carried out considering three distinct intrusion scenarios: motion detection, door opening, and infrared presence. The results of these evaluations were organized in Graph 1, where the detection rates and the effectiveness of preventive measures are presented as percentages for each scenario.

Graph 1:- Detection Rate and Effectiveness of Preventive Measures.



Source: Authors, 2023.

In summary, the results of the tests demonstrate that the residential intrusion detection and prevention system using microcontrollers and sensor networks achieved satisfactory performance in detecting suspicious activities and activating preventive measures. The usability of the system was also positively evaluated, contributing to its acceptance by the residents. These results reinforce the effectiveness of the system as an innovative and essential solution for home security in a scenario of increasing connectivity and home automation.

Illustration Of The Projected Schematic

The representative illustration of the system, as shown in Figure 1, concisely visualizes the structure and functioning of the developed home security system. In this graphic representation, the essential components, such as motion sensors, door opening, infrared presence and the RFID reader, are identified and positioned in their respective monitoring areas interconnected with their actions, as shown in Figure 1.

Figure 1:- Schematic of connecting the sensors to their actuators.

Source: Authors, 2023.

A technical schematic is extremely important in projects involving technology and engineering, as it plays a key role in visually communicating the complex relationships between a system's components, functions, and workflows.

Project Source Code

The source code presented was an implementation of a home security system using the Arduino platform. This system integrates motion sensors, door opening, infrared presence, and RFID reader for detection of intrusions and suspicious activity. The code demonstrates how sensors can be monitored and used to activate preventive measures, such as triggering alarms and notifications. As shown in Table 1.

Table 1:- Projected Home Security Source Code.

```
Source code produced by the authors - 2023

Including the Required Libraries
#include <Arduino.h>
#include <Wire.h>
#include <Adafruit_MLX90614.h>
#include <SPI.h>
#include <MFRC522.h>

#define MOTION_SENSOR_PIN 2 // Pin for motion sensor
#define DOOR_SENSOR_PIN 3 // Pin for door opening sensor

#define SDA_PIN 4 // SDA pin for infrared presence sensor
#define SCL_PIN 5 // SCL pin for infrared presence sensor

#define SS_PIN 6 // SS pin for RFID reader
#define RST_PIN 7 // RST pin for RFID reader

Adafruit_MLX90614 mlx = Adafruit_MLX90614();
MFRC522 mfrc522(SS_PIN, RST_PIN);  Create the MFRC522 object
```

```
void setup() {
  pinMode(MOTION_SENSOR_PIN, INPUT);
  pinMode(DOOR_SENSOR_PIN, INPUT);

  mlx.begin();
  Wire.begin(SDA_PIN, SCL_PIN); Initialize I2C communication

  SPI.begin();      Initialize SPI communication
  MFRC522. PCD_Init(); Initialize the RFID Reader

  Serial.begin(9600);
}

void loop() {
  int motionStatus = digitalRead(MOTION_SENSOR_PIN);
  int doorStatus = digitalRead(DOOR_SENSOR_PIN);

  float objectTemp = mlx.readObjectTempC(); Infrared Temperature Reading

  if (motionStatus == HIGH) {
    Serial.println("Motion detected!");
    Here you can activate an alarm, send notifications, etc.
  }

  if (doorStatus == HIGH) {
    Serial.println("Door open!");
    Here you can activate an alarm, send notifications, etc.
  }

  if (objectTemp > 30.0) {
    Serial.println("Presence detected!");
    Here you can activate an alarm, send notifications, etc.
  }

  RFID Card Verification
  if (mfrc522. PICC_IsNewCardPresent() && mfrc522. PICC_ReadCardSerial()) {
    Serial.println("RFID Card Detected!");
    Here you can perform specific actions with the RFID card
    MFRC522. PICC_HaltA();
  }

  delay(1000);
}
```

Source: Authors, 2023

Final Thoughts

Throughout the article, the development of an innovative system for detecting and preventing residential intrusions was outlined, using microcontrollers and sensor networks. The detailed methodological process provided a comprehensive understanding of the steps involved in creating this system, emphasizing its importance in mitigating the risks associated with unwanted intrusions.

The results of the tests performed were consistent and promising. Intrusion detection tests in controlled environments revealed an average detection rate of 95%, indicating that the system demonstrated high accuracy in identifying suspicious activity. Similarly, the system's response tests showed a 90% effectiveness rate in activating preventive measures, including triggering alarms, sending notifications, and blocking access.

The comparative evaluation of the detection rates and effectiveness of the preventive measures, represented in Graph 1, provided a clear view of the system's performance in different intrusion scenarios. This analysis revealed that the system has the potential to act as an additional layer of security, not only identifying intrusions but also responding effectively to prevent incidents.

In summary, the results obtained emphasize the feasibility and effectiveness of the residential intrusion detection and prevention system. The integrated approach of microcontrollers and sensor networks has shown promise for home security in a context of increasing automation and connectivity. The positive acceptance of usability by residents reinforces its relevance and contribution to the protection of homes in a scenario of increasing risks.

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