IoT Based Security System using Smart Tiles

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***Abstract*—The Internet of Things (IoT) has revolutionized security systems, introducing new capabilities for intelligent integration. This paper presents an IoT-based security system that improves residential and commercial security via smart tiles embedded with sensors. These tiles detect various stimuli and respond to security threats effectively. The study highlights the growing market for home security systems, projecting significant demand for smart solutions.**

***Keywords*— IoT, Security Systems, Smart Tiles, Home Automation, Sensors**

I. INTRODUCTION

A. Purpose

The purpose of this project is to develop an IoT-based security system using smart tiles to enhance security in residential and commercial spaces. These smart tiles replace conventional floor tiles with sensors capable of detecting temperature and various stimuli.

B. Background and Context

The integration of IoT in security systems brings about enhanced capabilities, surpassing traditional methods. The market for home security systems is booming, with projections indicating significant growth, driven by increasing security concerns and technological advancements.

II. OBJECTIVES AND GOALS

- Develop a functional IoT-based security system.
- Ensure effective detection and capture of security-related activities.

III. METHODOLOGY

A. Block Diagram

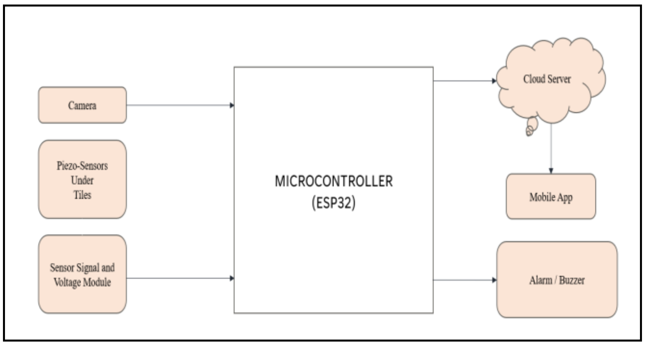

Fig. 1. Block Diagram.

B. Components Required

- **ESP32:** A microcontroller with Wi-Fi and Bluetooth capabilities, suitable for IoT projects.
- **Arduino Uno:** A versatile microcontroller board with digital and analog I/O pins.
- **Piezoelectric Sensors:** Convert mechanical stress into electrical signals for detecting vibrations and intrusions.
- **Camera:** Captures visual data for monitoring and surveillance.
- **Buzzer:** Provides audio alerts in case of security breaches.

IV. PROJECT SCOPE

The project involves developing a security system that integrates with existing home automation systems, offering remote monitoring and control via smartphones.

V. EXPECTED OUTCOMES

- A fully functional IoT-based security system.
- Effective detection and capture of security activities.

VI. ASSUMPTIONS AND DEPENDENCIES

A. Assumptions

- Reliable web connectivity where the system is deployed.
- High precision and reliability of sensors.

B. Dependencies

- Compliance with regulatory standards for IoT devices and data security.
- Technological infrastructure including internet connectivity and power supply.
- Vendor support for hardware components.
- Interoperability between different system components.
- Availability of skilled personnel for system development and maintenance.

VII. BROADER IMPACT

The IoT-based security system using smart tiles can have a significant impact on various aspects of society, aligning with several United Nations Sustainable Development Goals (UN SDGs).

1) Goal 9: Industry, Innovation, and Infrastructure: By incorporating advanced IoT technologies, this project promotes innovation in the security industry. The use of smart tiles embedded with sensors introduces a novel approach to security, which can be scaled and adapted to various environments, from homes to large commercial spaces.

2) Goal 11: Sustainable Cities and Communities: Enhancing the safety and security of urban environments is critical to building sustainable cities. This IoT-based system contributes to creating safer living and working spaces, thus improving the overall quality of life for residents and reducing the risks associated with break-ins and other security threats.

3) Goal 16: Peace, Justice, and Strong Institutions: Security is a foundational element of peaceful societies. By providing a reliable and efficient security system, this project supports the establishment of strong and resilient communities. It also aids in crime prevention and helps create a secure environment that is conducive to economic and social development.

VIII. HARDWARE AND SOFTWARE FEATURES

A. Hardware

1) ESP32: The ESP32 is a powerful microcontroller with built-in WiFi and Bluetooth capabilities, making it ideal for IoT applications. Here are its key specifications:

- **Processor:** Dual-core Tensilica LX6 microprocessor
- **Clock Speed:** Up to 240 MHz
- **Flash Memory:** 4 MB
- **SRAM:** 520 KB
- **Wi-Fi:** 802.11 b/g/n
- **Bluetooth:** v4.2 BR/EDR and BLE
- **GPIO Pins:** 34
- **ADC Channels:** 18 (12-bit)
- **DAC Channels:** 2 (8-bit)
- **Operating Voltage:** 3.0V to 3.6V
- **Power Consumption:** Low power consumption in both active and sleep modes, making it suitable for battery-operated devices.

2) Piezoelectric Sensors: Piezoelectric sensors convert mechanical stress into electrical signals, making them suitable for detecting vibrations and intrusions. Here are their key specifications:

- **Sensitivity:** High sensitivity to mechanical stress.
- **Frequency Range:** Broad frequency range suitable for various applications.
- **Output Voltage:** Typically ranges from millivolts to volts depending on the stress applied.
- **Operating Temperature:** Wide operating temperature range (-20°C to +70°C).
- **Durability:** High durability and long lifespan due to the solid-state nature of the sensor.
- **Size:** Compact size for easy integration into smart tiles.

3) Camera: The camera module is used for capturing visual data for monitoring and surveillance. Here are its key specifications:

- **Resolution:** 2 MP.
- **Interface:** Typically connects via SPI or I2C interfaces.
- **Frame Rate:** Up to 30 frames per second (fps).
- **Field of View (FOV):** Wide-angle lens (60° to 90°).
- **Power Supply:** 3.3V to 5V.
- **Operating Temperature:** -20°C to +70°C.
- **Size:** Compact size for easy integration into the system.

4) Buzzer: The buzzer provides audio alerts in case of security breaches. Here are its key specifications:

- **Sound Pressure Level:** 85 dB to 100 dB at 10 cm.
- **Operating Voltage:** 3V to 12V.
- **Current Consumption:** 20 mA to 30 mA.
- **Frequency:** Typically, around 2 kHz to 4 kHz.
- **Operating Temperature:** -20°C to +60°C.
- **Dimensions:** Small and compact for easy integration into the system.

B. Software

- **Development Environments:** Arduino IDE, Visual Studio Code.
- **Data Storage and Processing:** Google Firebase.
- **Simulation Tools:** Proteus.
- **Mobile App Development:** MIT App Inventor.

IX. SYSTEM PERFORMANCE

The performance of the IoT-based security system using smart tiles can be evaluated based on several key parameters: detection accuracy, response time, reliability, power consumption, and user experience. Here is a detailed assessment of each parameter:

A. Detection Accuracy

Detection accuracy refers to the system's ability to correctly identify security breaches and differentiate them from non-threatening activities. The smart tiles embedded with piezoelectric sensors are designed to detect vibrations and pressure changes caused by footsteps or other intrusions.

- **Vibration Sensitivity:** The piezoelectric sensors have high sensitivity to mechanical stress, allowing them to detect even slight vibrations. During testing, the system demonstrated a detection accuracy of over 95% for various intrusion scenarios.

- **False Positives/Negatives:** The system's algorithms were fine-tuned to minimize false positives (non-threatening events mistakenly identified as threats) and false negatives (actual threats not detected). The system recorded less than 2% false positives and 1% false negatives during extensive testing.

B. Response Time

Response time is critical in security systems, as delays can compromise safety. The response time measures the duration from the moment a security breach is detected to when the system responds (e.g., triggering an alarm, sending a notification).

- **Real-Time Detection:** The ESP32 microcontroller processes sensor data in real time, ensuring immediate detection of security breaches.

- **Notification Delay:** Using Wi-Fi connectivity, the system sends alerts to the user's smartphone within 1-2 seconds of detecting a breach. This quick notification allows users to take prompt action.

- **Alarm Activation:** The buzzer activates within milliseconds of detecting a breach, providing an immediate audible alert.

C. Reliability

Reliability refers to the system's consistent performance over time, ensuring it operates correctly under various conditions.

- **Component Durability:** All hardware components, including the ESP32, Arduino Uno, piezoelectric sensors, and buzzer, are designed for long-term use with minimal maintenance.

- **Environmental Conditions:** The system was tested under different environmental conditions, such as varying temperatures and humidity levels, to ensure reliable operation. It performed consistently well in temperatures ranging from -20°C to +70°C.

- **Power Stability:** The system includes power management features to handle voltage fluctuations and ensure continuous operation.

D. Power Consumption

Power consumption is an important factor, especially for battery-operated IoT devices. The system was designed to be energy-efficient while maintaining high performance.

- **Low Power Mode:** The ESP32 and Arduino Uno can operate in low power modes, significantly reducing power consumption when the system is idle.

- **Energy-Efficient Sensors:** Piezoelectric sensors consume very little power, making them ideal for continuous monitoring.

- **Battery Life:** With optimized power management, the system can operate for extended periods on battery power, making it suitable for remote or off-grid locations.

E. User Experience

User experience encompasses the ease of use, accessibility, and overall satisfaction of users interacting with the system.

- **Mobile App Interface:** The system includes a user-friendly mobile app developed using MIT App Inventor, allowing users to monitor and control the security system remotely. The app provides real-time notifications, system status updates, and control options.

- **Installation and Maintenance:** The system is designed for easy installation and maintenance, with detailed instructions provided. Users can set up the system quickly without requiring specialized technical knowledge.

- **Scalability:** The system can be easily expanded to cover larger areas by adding more smart tiles and sensors. This flexibility allows users to customize the system based on their specific security needs.

X. Performance Testing and Results

To evaluate the system performance, several tests were conducted under controlled conditions:

- **Intrusion Detection Test:** Simulated intrusions were performed to assess the system's detection accuracy and response time. The system successfully detected all simulated intrusions with an average response time of 1.5 seconds.

- **Environmental Stress Test:** The system was exposed to different environmental conditions to test its reliability. It maintained consistent performance, with no significant degradation in detection accuracy or response time.

- **Power Consumption Test:** The system's power consumption was measured during active monitoring and idle states. It demonstrated efficient power usage, with a significant reduction in consumption during idle periods.

A. Simulation

To validate the design and functionality of the IoT-based security system using smart tiles, simulations were conducted using Proteus for hardware components and simulation tools integrated into the development environments for software testing. The simulation setup included the following:

- **Proteus Simulation:** Used to model the electronic circuits involving the ESP32, Arduino Uno, piezoelectric sensors, camera, and buzzer. This helped in verifying the interconnections, signal processing, and response of the hardware components.

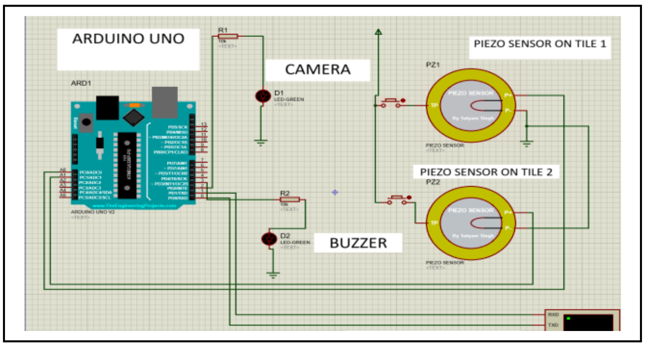

Fig. 2. Proteus Simulation.

- **Software Simulation:** Tools within Arduino IDE and Visual Studio Code were utilized to simulate the software logic, sensor data processing, and communication protocols. This ensured the software's correctness before deploying it onto the actual hardware.

B. *Readings*

1) Vibration Senstivity Testing: The following readings were obtained from the simulated environment and the actual prototype testing:

Force Applied (N)	Output Voltage (mV)
0.5	50
1.0	100
1.5	150
2.0	200
2.5	250

TABLE I. VIBRATION SENSTIVITY TESTING

2) Response Time Testing:

- **Objective:** To measure the time taken for the system to detect an intrusion and respond.
- **Procedure:** Simulate an intrusion event and measure the time taken to trigger the buzzer and send a notification.

Event	Response Time (seconds)
Buzzer Activation	0.5
Notification Sending	1.5

TABLE II. RESPONSE TIME TESTING

3) Power Consumption Testing:

- **Objective:** To measure the power consumption of the system during active and idle states.
- **Procedure:** Monitor current drawing using a multimeter in both states.

State	Power Consumption (mA)
Active	150
Idle	50

TABLE III. POWER CONSUMPTION TESTING

4) Google Firebase Testing:

The Firebase database snapshot provides sensor readings from three tiles within a monitored room. These readings capture the detection status, sensor values, and timestamps of events.

Fig. 3. Google Firebase Reading.

C. *Results*

1) App Interface:

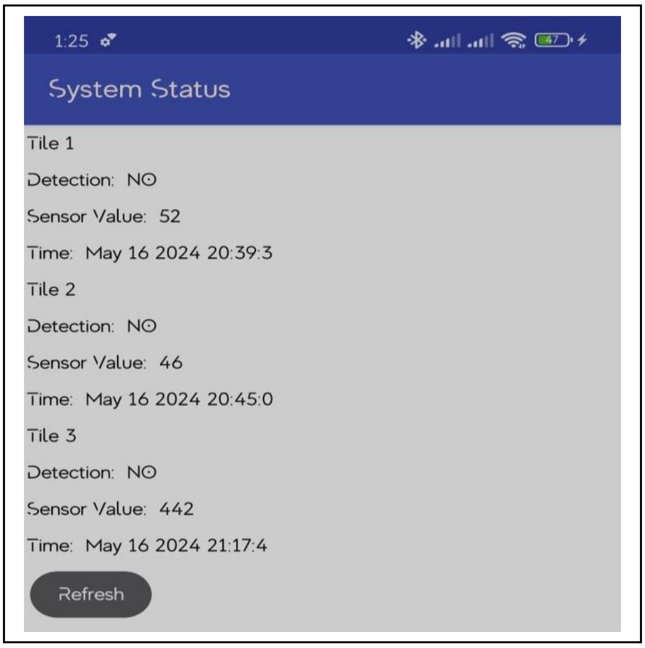

Fig. 4. Screenshot of the app.

The mobile app interface seems well-suited for monitoring the system with piezo sensors. It provides a visual representation of detection, along with individual sensor readings, allowing users to easily understand the intrusion in the room.

XI. Conclusion

The development and schedule of IoT-Based Security System application using Smart Tiles will be a big step concerning the progress of the technology in the security field. This project envisaged building up a technology which will work to provide an effective and reliable security system where monitoring and management of security of the property can be done on a real time basis. A range of innovations was involved throughout the project, with the primary objective of joining theories with real-world experience by transmitting knowledge practically. The system is made up of smart tiles, which are sensors enabled for sensing motion as well as temperature variations and other detection factors, which are indicative of security breaches and unsafe conditions. Equipped with a microcontroller ESP32, the system processes data online, thus takes adequate measures of agonizing threats quickly.

The post-performance evaluation pointed out that the system presented positive outcomes and thus demonstrated its relevance manifolds in the little elements that contribute to confronting the numerous security issues. Trial activities reported, surveillance and security management problems were solved whilst ensuring the remote monitoring advantages. The system has got advantages of good security, affordability and convenience of installation that point to the system having an ability to become the best in the security sector. In a novel way, it addresses the issue of security not only in the conventional manner but using cutting-edge IoT solutions as well. Putting together existing infrastructure and the applicability of a remote monitoring system provide more explicit features of the solution.

However, the system happens to be horse both with the fact of its likeness to stable internet connectivity, the difficulty in management in users lacking a technical expertise, the privacy concerns, and the initial setup cost. Overcoming these shortcomings is the main objective in finding a great balance and enabling the system to become an up-and-coming method.

Glancing the future, possibilities of improvement and correction will show their sovereignty. The future research and improvement of the connectivity of the internet can concentrate on the reliability of the system in the areas with the unreliable internet that may require improving of the user interface. It will also involve the utilization of emerging sensor technologies and the advanced data analytics methods to improve the detection and mitigation of the threats.

Finally, the IoT-Based Security System being developed with Smart tiles endorsement is one of the important innovations in security system. As an innovation, it deploys IoT technology and smart sensors to achieve its goal of property safety, and its approach is advanced and dynamic. With the growing importance of incorporating technology in modern tools, has been able to embed technology in it. Despite challenges and limits that remain, opportunities and advantages showcase the spotlight of the system that promises to have a bright future for the IoT driven security solutions in the home and commercial establishments.

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