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Performance Enhancement of IoT-Enabled Advanced ATM Security System

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Abstract

The ESP32 Microcontroller and ESP32-CAM Module-based ATM Theft Detection System is designed to enhance ATM security by detecting and preventing theft in real-time. As the system is being implemented, a vibration sensor, LDR sensor, and gyroscope sensor are used to track the ATM machine for unauthorized movement. If unusual movement is detected, the sensors indicate a potential threat and send signals to the ESP32 microcontroller, which has been programmed to analyze the data. Once the alert has been triggered, the ESP32 microcontroller has been communicating through UART with the ESP32-CAM module, which has been taking real-time images of the intruder. These images, along with the ATM's location are sent to the police stations and the bank manager through email and the Adafruit IO Application. As the situation is being handled, an automatic lock mechanism is activated to trap the intruder, while a buzzer sounds to alert the public. The ATM door will be unlocked later by the authorized personnel using the Adafruit IO app. It has been observed that this system has become a reliable solution for ensuring ATM security by providing quick response, real-time monitoring, and theft prevention. The results obtained from the simulations done in Arduino IDE and experimental prototype validates the proposed idea.

Keywords: ATM Theft Detection, ESP32 Microcontroller, ESP32-CAM Module, Real-time Monitoring and Adafruit IO

1. Introduction

The increasing cases of ATM thefts have highlighted the need for advanced security systems that can effectively detect and prevent unauthorized access in real-time. ATMs, being critical financial service points, require continuous monitoring and immediate response to ensure the safety of cash and user data. An effective ATM security system should include multiple sensors to detect any physical tampering, unauthorized access, or unusual movements around the machine.

In this work, an ATM Theft Detection System using the ESP32 microcontroller and ESP32-CAM module is presented. The system integrates a vibration sensor, LDR sensor, and gyroscope sensor to continuously monitor the ATM for any suspicious activities. Upon detecting unusual movements, the ESP32 microcontroller processes the sensor data and sends alerts through UART communication to the ESP32-CAM module, which captures real-time images of the intruder. The captured images, along with the ATM location, are sent to nearby police stations, bank managers, and security personnel through email and the Adafruit IO platform. Additionally, the system incorporates an automatic lock mechanism to secure the ATM door, preventing the intruder from escaping, while a buzzer alarm alerts the public. Authorized personnel can later unlock the ATM remotely using the Adafruit IO application, ensuring both security and operational flexibility.

A through literature survey has been carried out and some of the important contributions have been considered herein to arrive at the possible research gap. In the research contribution [1] a IoT-based ATM security system has been reported. The article demonstrates the use of the ESP8266 module, PIR sensor, LCD with I2C, and Telegram app for real-time monitoring and alert notifications to enhance ATM security. In another development [2] a IoT-based ATM crime prevention system using Raspberry Pi has been presented, incorporating a IR sensor, buzzer, and cameras for real-time theft detection, alerting authorities, and securing the ATM [3]. a biometric-based ATM security system has been demonstrated, utilizing fingerprint, face recognition, and OTP for secure transactions and integrating multiple bank accounts into a single ATM card [4]. an intelligent ATM protection system has been presented, utilizing Wireless Sensor Networks, USB cameras for real-time face recording, and tilt and vibration sensors to detect unusual activities, ensuring enhanced security and aiding law enforcement in theft prevention [5] an enhanced ATM security system has been discussed, incorporating face recognition, fingerprint identification, and physical attack detection sensors alongside traditional PIN authentication. The paper compares various security measures, highlighting their merits and demerits in preventing both physical and fraudulent ATM attacks [6] an ARM11-based ATM security system has been proposed, utilizing face recognition cameras, IR sensors, and gas release mechanisms to deter theft, with real-time alerts sent via GSM to authorities and alarm activation for enhanced protection.

The authors in [7] have presented an ATM security system using Raspberry Pi with inbuilt theft control mechanisms. The system employs face recognition for door unlocking and various sensors to detect suspicious activities. However, while the system ensures real-time monitoring and alerts through text messages, the use of multiple sensors may increase complexity and cost. Despite these challenges, the system enhances ATM security by automatically locking the door, activating alarms, and notifying owners during potential theft incidents [8].

An ATM security and energy-saving system may be built around an Arduino Uno as the core controller, integrating vibration sensors for theft detection, DC motors for automatic door locking, and buzzers for alarm activation. Infrared sensors are employed for automatic light control, ensuring energy efficiency. The proposed system enhances ATM security while optimizing power usage through smart sensor-based automation [9] An advanced ATM security system, titled ATM Theft Detection, Auto Arresting, and Intimation System, has been developed using Arduino UNO, PIR sensors, vibration sensors, and a DC motor. This system ensures continuous monitoring of the ATM, detecting theft attempts through sensor inputs. Upon detecting tampering, the DC motor automatically lowers the ATM shutter to prevent access, while real-time SMS alerts are sent to authorities. The integration of these components provides a proactive response to theft, enhancing public safety and protecting financial assets. This system offers a secure banking environment by enabling real-time monitoring, automated actions, and rapid notifications, significantly reducing the risk of ATM theft [10].

In response to the rising incidents of bank and ATM robberies, an autonomous security system has been proposed to enhance protection in confidential areas. This system incorporates a vibration sensor to detect any unauthorized attempts to break the ATM locker. A hidden camera captures images of the intruder and uploads them to a server for use in investigations. Additionally, a DC motor automatically locks the ATM door, preventing the thief's escape, while a chloroform spray is activated to render the intruder unconscious. The system also utilizes GSM technology to send real-time SMS alerts to branch operators and police authorities, ensuring immediate response. By integrating real-time monitoring, automated defensive actions, and instant communication with authorities, this system significantly improves ATM security and aids in the prevention and investigation of theft incidents. This innovative approach provides a reliable and efficient solution to mitigate the risks associated with ATM robberies

The authors in the article [11] have focused their attention on the development of a secure ATM transaction system using fingerprint and RFID authentication. The proposed system introduces a two-phase verification process, where the original user scans their fingerprint after swiping their card, while an RFID-based method allows remote authorization through image verification and email alerts. Unauthorized transactions are prevented by requiring user confirmation via message, ensuring an additional layer of security. This system enhances ATM safety by combining biometric verification with real-time user notifications, effectively mitigating unauthorized access and fraudulent activities.

The authors in [12]. have developed an ATM theft prevention system using an 89s52 microcontroller that processes real-time data from vibration sensors. An H-bridge-driven DC motor locks the ATM door upon detecting unusual activity, while a real-time camera feed ensures continuous surveillance. Keil µVision tools are used for programming, and a Wi-Fi module sends immediate alerts to authorities. The system enhances ATM security by integrating multiple layers of protection, ensuring prompt detection and response to potential threats. The vibration sensor plays a crucial role in identifying forced entry attempts, triggering immediate countermeasures. The real-time camera provides live surveillance, aiding law enforcement in assessing the situation remotely. The Wi-Fi-enabled alert mechanism ensures rapid notification to security personnel, reducing response time. The use of an H-bridge-driven motor for automatic door locking prevents unauthorized access, adding an extra layer of security. The 89s52 microcontroller efficiently processes sensor data, enabling real-time decision-making. The system's architecture is designed for reliability and robustness, minimizing false alarms while ensuring accurate threat detection.

2. IOT-Enabled ATM Security System

Fig 1 shows the block diagram of the proposed system. The main section indicates the system's core, an ESP32 Microcontroller, which interfaces with various sensors (Vibration, LDR, Gyroscope) for theft detection. These sensors feed data to the ESP32, triggering actions based on programmed thresholds. Communication is facilitated via UART to an ESP32-CAM module, enabling image capture and transmission to relevant authorities (police, bank manager, security) via email and Adafruit IO. The ESP32 also controls a Relay connected to a Solenoid Lock for physically securing the ATM and a Buzzer for generating audible alerts. A Power Supply provides energy to the entire system, ensuring continuous operation. The diagram depicts a comprehensive security system integrating sensing, processing, communication, and control for ATM theft prevention.

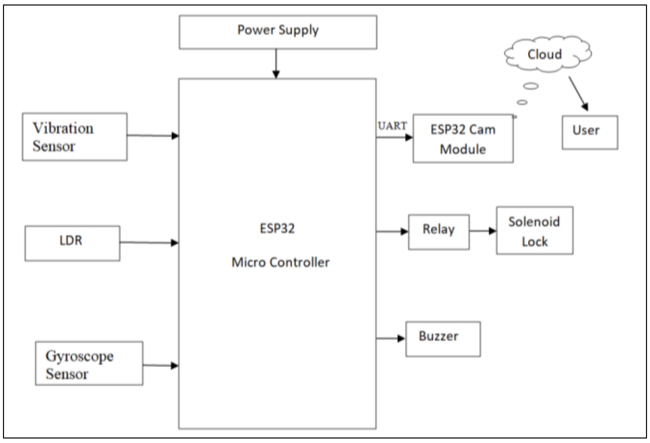

Fig 1: Block diagram of the proposed system

2.1 An Outline of the Proposed System

The proposed ATM theft detection system centers around an ESP32 Microcontroller, which acts as the system's centralized controller. Power is supplied to the system via a dedicated Power Supply unit. The system employs multiple sensors for comprehensive monitoring: a Vibration Sensor detects physical shocks or tampering attempts, an LDR monitors ambient light changes that might indicate unauthorized access, and a Gyroscope Sensor tracks any tilting or movement of the ATM itself. These sensors continuously feed data to the ESP32. Upon detecting suspicious activity, the ESP32 triggers a series of actions. It communicates via UART with an ESP32-CAM module, which captures images of the potential thief. These images, along with location data, are then transmitted via email and the Adafruit IO platform to designated recipients: nearby police stations, the bank manager, and security personnel. Simultaneously, the ESP32 activates a Relay, which in turn engages a Solenoid Lock, effectively trapping the intruder inside the ATM. A Buzzer is also activated to sound an alarm, alerting people in the vicinity. Authorized personnel can remotely unlock the ATM door later using the Adafruit IO app. The system aims to provide real-time monitoring, rapid response, and enhanced security against ATM theft attempts.

2.2 Vibration Sensor

Fig 2 shows the vibration sensor, which detects the mechanical shocks and converts movement into electrical signals, making it crucial for security applications. These sensors are commonly used in security systems, industrial applications, and structural health monitoring. In the ESP32-based ATM Theft Detection System, the sensor identifies unauthorized attempts to break into or move the ATM. If excessive vibration is detected, it sends data to the ESP32 microcontroller, which determines if an alert should be triggered. The ESP32-CAM module captures images of the intruder and transmits them with the ATM’s location via email and Adafruit IO. The system also locks the ATM door and triggers a buzzer to alert nearby individuals. Working with the gyroscope and LDR sensors, the vibration sensor enhances accuracy and prevents false alarms, ensuring real-time security and quick threat response. Its sensitivity can be adjusted to filter out minor disturbances such as accidental knocks. The integration of this sensor significantly reduces response time, making it a key component of the theft detection system.

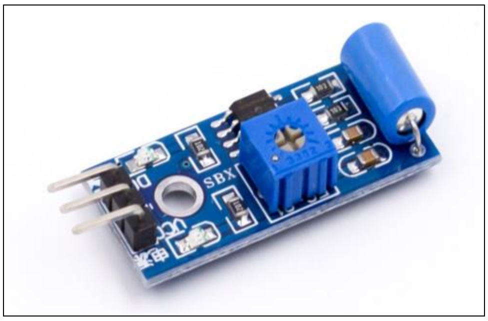

Fig 2: Vibration Sensor

2.3 LDR Sensor

An LDR (Light Dependent Resistor) sensor shown in the Fig 3 that detects changes in ambient light by varying its resistance. It is widely used in security systems and automatic lighting. The gyroscope sensor within the system detects any unusual displacement or movement of the ATM.. Sudden drops in brightness, caused by power cuts or tampering, indicate potential theft. When abnormal light changes are detected, the ESP32 microcontroller processes the data and triggers an alert. The ESP32-CAM module captures images and sends them via email and Adafruit IO to law enforcement and security personnel. The system also locks the ATM door and activates a buzzer to alert nearby individuals. Combined with vibration and gyroscope sensors, the LDR sensor enhances real-time theft detection and security response. Upon detecting any abnormal light changes or unusual movement, the ESP32 microcontroller processes the sensor data and takes immediate action. The ESP32-CAM module plays a critical role in visual surveillance by capturing high-resolution images of the surrounding area, potential intruders, or suspicious activities. These images are then transmitted via email and Adafruit IO to law enforcement agencies.

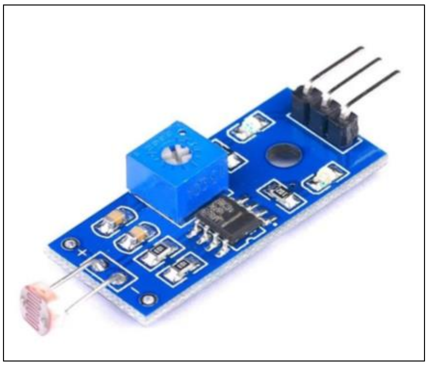

Fig 3: LDR Sensor

2.4 Gyroscope Sensor

A gyroscope sensor which shown in the Fig 4 that measures angular velocity and detects changes in orientation using MEMS technology. It is essential for motion tracking, stabilization, and security applications. The gyroscope sensor operates based on the Coriolis effect, which occurs when an object moving in a straight path experiences an apparent force due to rotation. Modern gyroscopes use MEMS (Micro-Electro-Mechanical Systems) technology, which consists of a tiny vibrating structure inside the sensor. The gyroscope sensor in the ESP32-powered ATM Theft Detection System monitors and detects any unexpected motion of the ATM machines. Since ATMs are fixed structures, any tilting or displacement could indicate tampering or theft attempts. The sensor continuously monitors orientation and sends real-time data to the ESP32 microcontroller, which processes it to detect unusual activity. If the movement exceeds a set threshold, the microcontroller triggers an alert, activating security measures. The ESP32-CAM captures images of the intruder and sends them via email and Adafruit IO. The system also locks the ATM door and triggers a buzzer to alert the public. The gyroscope sensor enhances security by reducing false alarms and working alongside the vibration and LDR sensors for accurate motion detection. It ensures real-time monitoring, quick threat identification, and improved law enforcement response. The gyroscope sensor enhances security by reducing false alarms and working alongside the vibration and LDR sensors for accurate motion detection.

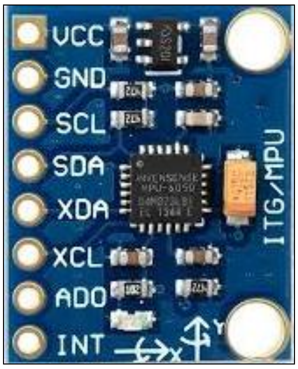

Fig 4: Gyroscope Sensor

2.5 ESP32 Microcontroller

Fig 5 shows the ESP32 microcontroller which is a powerful, low-cost, and energy-efficient microcontroller with built-in Wi-Fi and Bluetooth capabilities. It is a powerful, low-cost device with built-in Wi-Fi and Bluetooth, ideal for IoT and security applications. The centralized microcontroller processes the data from the vibration, LDR, and gyroscope sensors to detect unauthorized movement. If suspicious activity is detected, it communicates via UART with the ESP32-CAM module, which captures intruder images. The ESP32 then sends alerts, along with the ATM's location, via email and Adafruit IO to law enforcement and security personnel. It also locks the ATM door and triggers a buzzer to warn the public. With its real-time processing and communication capabilities, the ESP32 ensures quick response and effective security, making it a key component in preventing ATM theft. Its dual-core processing allows efficient multitasking, ensuring all security features operate simultaneously. This seamless coordination between sensors and communication modules makes the ESP32 an essential part of the ATM security system.

Fig 5: ESP32 Microcontroller

2.6 ESP32 CAM Module

The ESP32-CAM module is shown in the Fig 6, which is a compact and powerful camera module based on the ESP32 microcontroller, featuring built-in Wi-Fi and Bluetooth connectivity. It supports OV2640 and OV7670 camera sensors, allowing it to capture high-resolution images and stream video in real-time. This module is widely used in surveillance, IoT security systems, and automation applications due to its low power consumption and wireless capabilities. When the vibration, gyroscope, or LDR sensors detect any unusual movement, the ESP32 CAM is triggered to capture images of the potential intruder. It then sends these images, along with the ATM's location, to the police, bank managers, and security personnel via email and Adafruit IO. With wireless connectivity, the ESP32-CAM enables remote monitoring and ensures real-time security alerts. Its image processing and IoT features provide crucial visual evidence, making the system more effective in preventing ATM theft. The ESP32-CAM module operates efficiently even in low-light conditions, ensuring that images captured during nighttime theft attempts remain clear. Its integration with Adafruit IO allows seamless data transmission and storage for future reference. The module additionally supports motion detection algorithms that can enhance automated threat identification.

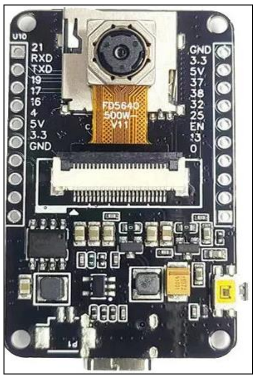

Fig 6: ESP32 Cam Module

2.7 Relay Module

Fig 7 shows the relay module, which is an electrically operated switch that allows one circuit to control another, enabling low-power signals to control high-power devices. It typically consists of an electromagnet that, when energized, closes or opens the switch. Relays are widely used in automation systems, security applications, and machinery control due to their ability to safely handle high-voltage components. In the ATM Theft Detection System, the relay manages the activation of the automatic locking system to secure the ATM door during suspicious activities. When unauthorized movement is detected, the ESP32 microcontroller triggers the relay to lock the door, trapping the intruder. The relay also activates the buzzer to alert the public and law enforcement. Additionally, it allows the ATM door to be remotely unlocked via the Adafruit IO app by authorized personnel. The relay ensures safe operation between low-power control circuits and high-power security devices, enabling automation and enhancing the system's overall security.

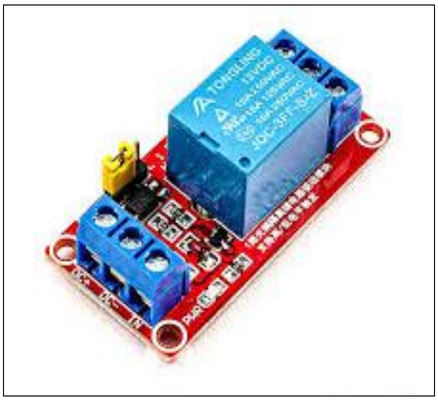

Fig 7: Relay Module

2.8 Solenoid Lock

A solenoid lock that is shown in the Fig 8, which is an electromechanical device that uses an electromagnetic solenoid to control the locking and unlocking of a mechanism. When an electric current is applied to the solenoid, it generates a magnetic field that moves a plunger, engaging or disengaging the lock. When the sensors (vibration, LDR, or gyroscope) detect suspicious activity, the ESP32 microcontroller triggers the solenoid lock to lock the ATM door, effectively trapping the intruder inside. The lock can be remotely unlocked via the Adafruit IO application by authorized personnel, ensuring quick intervention and enhanced security. The solenoid lock thus plays a crucial role in preventing theft and ensuring real-time control of the ATM's security. It consists of a solenoid coil, a movable plunger, a spring, and a locking mechanism. When activated, the solenoid controls the movement of the plunger, enabling or restricting access. The solenoid lock operates with high reliability and fast response time, making it ideal for security applications.

Fig 8: Solenoid Lock

2.9 Buzzer

Fig 9 shows the buzzer, which is an electronic device that produces sound or noise, typically used as an alarm or warning signal in various security applications. The sound from a magnetic buzzer is produced by the movement of the ferromagnetic disk in a similar manner to how the cone in a speaker produces sound. It generates a loud, attention-grabbing sound when activated, alerting people to potential danger or abnormal activity. Buzzers are commonly used in intrusion detection systems, safety mechanisms, and emergency signaling. In the ATM Theft Detection System, the buzzer serves as an alert to nearby people when unauthorized activity is detected. When the sensors activate the ESP32 microcontroller, the buzzer sounds to warn the public and prevent further tampering. The buzzer serves as a warning signal, increasing the chances of intervention and preventing further theft or damage. By providing an auditory alert, the buzzer ensures a quick response, helping law enforcement and security personnel take swift action and improving public safety.

Fig 9: Buzzer

3. Results and Discussion

The implementation of the Mail Alert System, Adafruit IO Application, and Face Recognition significantly enhances ATM security by enabling real-time monitoring, rapid response, and intelligent threat detection. The Mail Alert System ensures that law enforcement and bank officials receive instant notifications via email whenever suspicious activity is detected, allowing them to take immediate action. The Adafruit IO Application facilitates seamless data transmission and remote monitoring by storing and displaying real-time sensor data, enabling security personnel to track ATM status from anywhere. Additionally, Face Recognition helps in identifying intruders and distinguishing authorized users, reducing false alarms and enhancing security accuracy. By integrating these technologies, the system creates a multi-layered security approach, combining sensor-based detection with AI-driven facial recognition and cloud-based surveillance. This ensures prompt threat identification, swift intervention, and effective deterrence against ATM theft attempts, ultimately improving overall security and response efficiency.

3.1 Experimental Prototype Model

An experimental prototype has been built to validate the proposed idea. A photograph of the experimental setup of the proposed system is shown in Fig 10.

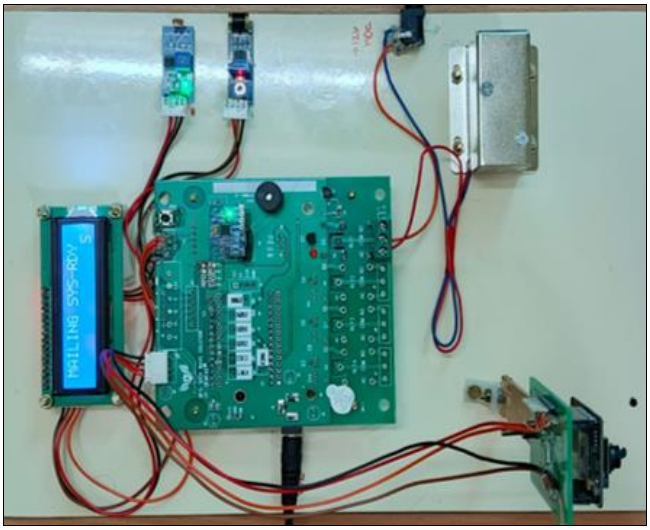

Fig 10: Photograph of the experimental setup

In the IoT-enabled advanced ATM security system, the ESP32 microcontroller serves as the central processing unit, managing data from multiple sensors and triggering security actions. The vibration sensor, LDR sensor, and gyroscope sensor are interfaced with the ESP32 to detect physical tampering, unauthorized access, and motion anomalies. The ESP32-CAM module is integrated to capture images upon suspicious activity, enhancing surveillance capabilities. A relay module controls the solenoid lock, ensuring secure access control. The buzzer is connected to provide an alert during unauthorized activities. An LCD display is used to show system status updates. The entire system is powered by a regulated power supply, ensuring stable operation. Communication between sensors and the ESP32 microcontroller is facilitated via GPIO pins, UART, and I2C interfaces. The collected data is transmitted to a cloud platform via Wi-Fi for real-time monitoring and alert notifications to authorities. This integration enhances ATM security by enabling remote supervision and instant threat response.

3.2 Network Architecture

Fig 11 shows the network architecture of the proposed system, which integrates various sensors and communication modules for real-time ATM theft detection. The ESP32 microcontroller interfaces with vibration, LDR, and gyroscope sensors via UART communication to detect unauthorized activities. The system utilizes MQTT protocol for wireless data transmission between the ESP32, Wi-Fi module, and IoT cloud, enabling remote monitoring through a web UI or mobile app. SMTP and POP/IMAP servers facilitate email notifications to alert authorities upon detecting a security breach. Additionally, the Wi-Fi controller with a camera captures images, while the solenoid lock, relays, and buzzer provide security actions in response to threats.

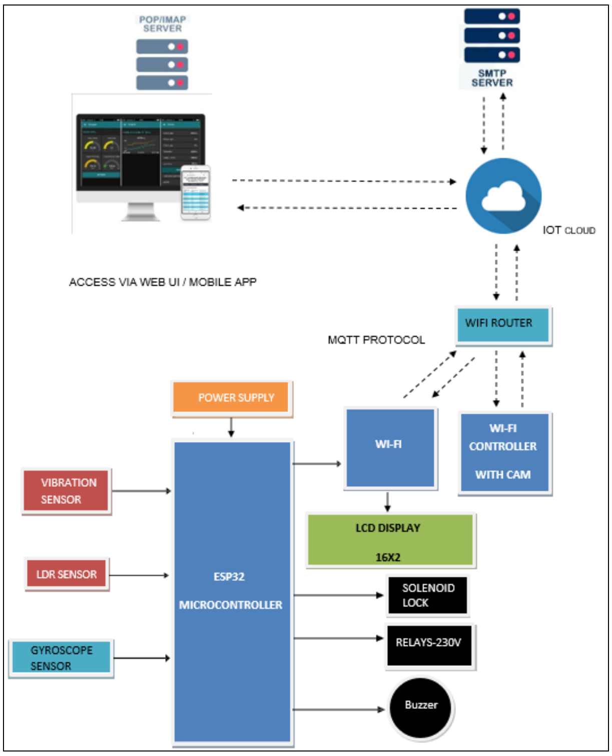

Fig 11: Network Architecture

The block diagram illustrates an ATM Theft Detection System utilizing an ESP32 microcontroller, integrated with various sensors, Wi-Fi modules, and cloud-based servers for real-time monitoring and alerting. Networking plays a crucial role in this system, enabling seamless data transmission between the hardware components and cloud infrastructure. The ESP32 microcontroller is interfaced with sensors like vibration, LDR, and gyroscope through UART (Universal Asynchronous Receiver-Transmitter), which facilitates serial communication by transmitting data bit by bit without requiring a clock signal. The system employs the MQTT (Message Queuing Telemetry Transport) protocol for lightweight and efficient communication over the internet. MQTT is a standards-based messaging protocol, or set of rules, used for machine-to-machine communication. Smart sensors, wearables, and other Internet of Things (IoT) devices typically have to transmit and receive data over a resource-constrained network with limited bandwidth. MQTT is ideal for IoT applications as it uses a publish-subscribe model, allowing devices to exchange data through a central broker, ensuring reliable delivery even with low bandwidth. The Wi-Fi controller with a camera captures real-time images, transmitting them via Wi-Fi to the IoT cloud for storage and analysis. SMTP (Simple Mail Transfer Protocol) is used to send alert notifications, such as emails, to concerned authorities whenever suspicious activity is detected. The Simple Mail Transfer Protocol (SMTP) is a technical standard for transmitting electronic mail (email) over a network. Like other networking protocols, SMTP allows computers and servers to exchange data regardless of their underlying hardware or software. Additionally, the POP (Post Office Protocol) and IMAP (Internet Message Access Protocol) servers facilitate email retrieval and synchronization across multiple devices. This integration of networking protocols ensures efficient communication, real-time monitoring, and immediate action, making the ATM Theft Detection System robust and reliable. The functional Flow Chart of the Proposed System is shown in the Fig 12.

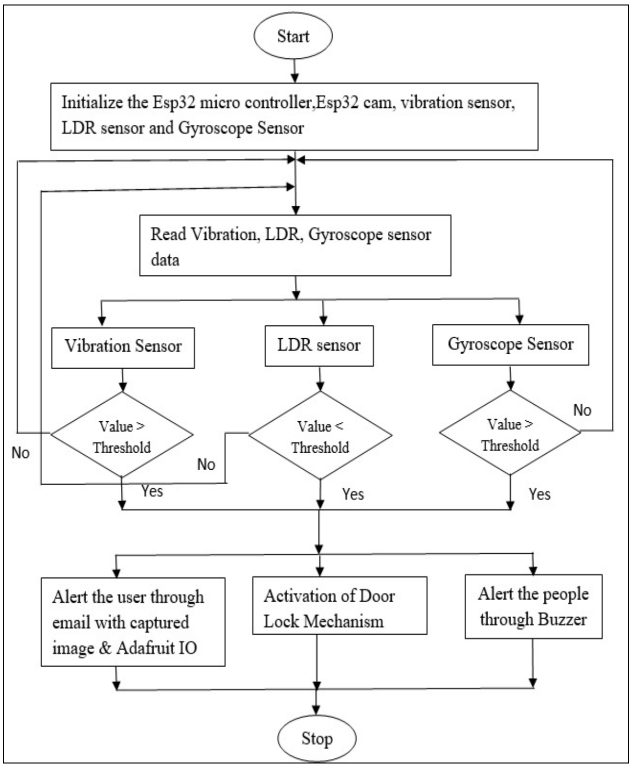

Fig 12: Functional Flow Chart of the Proposed System

3.3 Email Alert

In our proposed work, an alert mail system is implemented to notify nearby police stations and bank managers in case of an ATM theft attempt. When the sensors detect unauthorized movement, the ESP32 microcontroller processes the data and triggers the ESP32-CAM module to capture real-time images of the intruder. These images, along with the precise location of the ATM, are automatically sent via email which is shown in the Fig 13 that alerts the law enforcement and bank officials, ensuring immediate awareness. This alert system plays a crucial role in enabling quick response actions, helping authorities to assess the situation and take necessary measures.

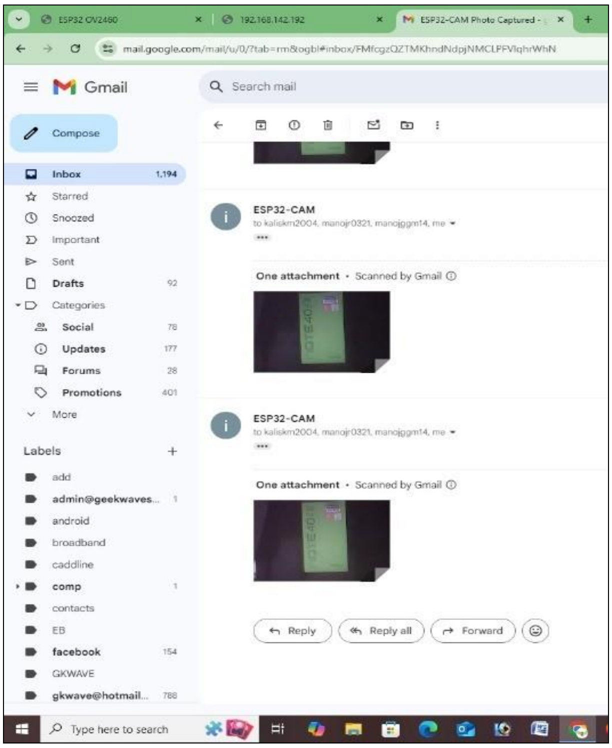

Fig 13: Email Alert

The implementation involves integrating SMTP (Simple Mail Transfer Protocol) with the ESP32 module, allowing it to send emails through an SMTP server. The email contains essential details, including timestamped images and GPS coordinates of the ATM, making it easier for security personnel to locate the incident site. This approach ensures that theft incidents are reported instantly, reducing delays in intervention. Furthermore, the system is designed to operate efficiently with minimal latency, ensuring that alerts are dispatched in real-time. To enhance reliability, error-handling mechanisms are implemented to verify successful email transmission and resend alerts if necessary. The ESP32 module is programmed to handle multiple sensor inputs simultaneously, optimizing response accuracy. Additionally, encryption techniques can be integrated to secure sensitive data during transmission, preventing unauthorized access. This comprehensive approach strengthens ATM security, offering a proactive solution to deter theft attempts effectively.

3.4 Adafruit IO Application

Fig 14 shows the Adafruit IO, which is a cloud-based service designed to simplify data management and connectivity over the Internet. As a managed platform, it eliminates the need for users to handle infrastructure maintenance, providing a seamless experience for data storage and retrieval. Beyond basic data management, Adafruit IO offers real-time data visualization and interactive online displays, making it a powerful tool for various applications. The platform is designed with a strong emphasis on ease of use, enabling simple data integrations with minimal programming effort. It supports client libraries that facilitate interactions with its REST and MQTT APIs, allowing efficient data communication.

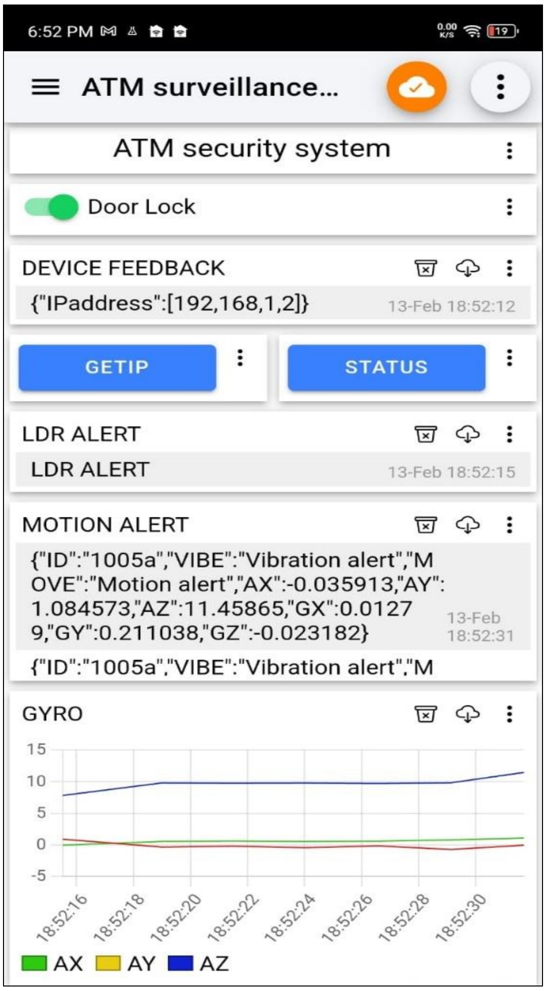

Fig 14: Adafruit IO Application

The Adafruit IO application plays a crucial role in our proposed work by enabling real-time data transmission and remote monitoring of the ATM security system. When the ESP32 microcontroller detects unauthorized movement through sensors, it communicates with the ESP32-CAM module, which captures images of the intruder. These images, along with the ATM's location, are sent to security personnel, bank managers, and law enforcement via the Adafruit IO app. The app provides a centralized platform where authorized personnel can access live updates and alerts instantly. Additionally, it facilitates remote control, allowing authorized users to unlock the ATM door after verifying the situation. The system ensures rapid response by delivering real-time notifications and images, improving situational awareness. Through the Adafruit IO interface, security officials can monitor multiple ATMs simultaneously, enhancing overall surveillance efficiency. The app also aids in automating emergency responses, such as triggering alarms and activating security measures.

3.5 Face Recognition

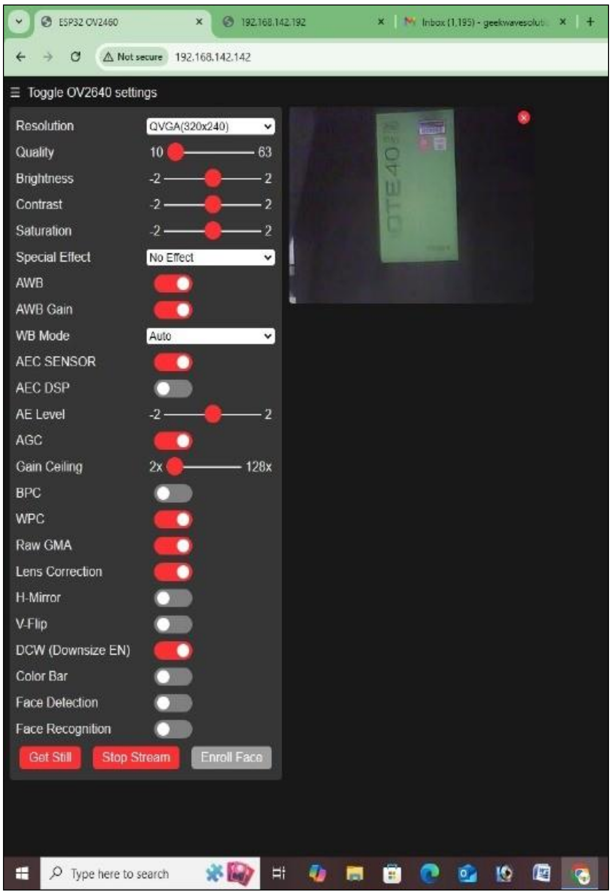

Fig 15: Face Recognition

The live monitoring and face recognition system in our proposed work is shown Fig 15 that ensures the continuous surveillance of the ATM using the ESP32-CAM module. When unauthorized movement is detected, the camera captures real-time images, which are analyzed for face recognition to identify potential intruders. If a match is found, the system alerts authorities, providing critical information on repeat offenders. Captured images, along with the ATM's location, are sent via email and the Adafruit IO app to security personnel for immediate action. This feature enhances situational awareness, allowing law enforcement to respond quickly and prevent theft. Additionally, face recognition helps differentiate genuine users from suspects, reducing false alarms. The system also activates an alarm and locks the ATM door, trapping the intruder until authorized personnel intervene. By integrating real-time monitoring and intelligent recognition, the proposed work significantly strengthens ATM security.

4. Conclusion

The ATM Theft Detection System using the ESP32 Microcontroller and ESP32-CAM module provides an effective and reliable solution for enhancing ATM security. By integrating multiple sensors such as vibration, LDR, and gyroscope, the system can detect unauthorized movement and trigger immediate security responses. The real-time monitoring and face recognition features allow for quick identification of intruders, while the ESP32-CAM captures and transmits images to law enforcement and bank officials. The use of the Adafruit IO application enables seamless remote monitoring and control, allowing authorized personnel to take necessary actions, such as unlocking the ATM door. Additionally, the automated email alert system ensures that police stations and bank managers receive real-time notifications, including images and location details, for prompt intervention. The incorporation of a buzzer alarm and automatic door-locking mechanism further prevents the intruder's escape, enhancing the security response. The system's ability to provide instant alerts and live updates significantly reduces theft risks and improves ATM surveillance. By utilizing Arduino IDE for simulations and testing, the proposed idea has been validated for real-world applications. This proposed work demonstrates a cost-effective and scalable approach to ATM security, integrating IoT technology for smarter theft prevention. The automation of emergency responses and secure communication channels make it a robust solution for financial institutions. Overall, the proposed work ensures enhanced security, faster response times, and a more effective approach to ATM theft prevention.

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