International Journal of Information Technology & Computer Engineering

ISSN 2347–3657
Volume 13, Issue 3, 2025

An Adaptive IoT-Based Framework for Crime Surveillance and Prevention

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***Abstract*—Crime monitoring & crime prevention has become a prominent issue in modern urban city a large & so an intelligent surveillance system is necessary is being created. This paper presents an IoT-based crime monitoring framework with integrated various sensor types involving flame, vibration, motion detection and sound sensors for improvement of security measures. The main target is to implement a real-time system that can early detect possible danger and suspicious activity to assist law enforcement agencies to intervene in time. The novelty of this work is in using a combination of multiple sensor inputs with user-friendly web interfaced for straightforward monitoring and quick decision making. The proposed framework uses ESP32 based microcontrollers for the compilation of and processing the real-time sensor data, that is displayed as interactive portal. The system's efficiency was tested with multiple test scenarios and proving its ability to identify anomalies with a high degree of accuracy. Results point to multi-sensor information system increase of crime detection reliability and the cut of false alarms and situational awareness. The study reveals that the system proposed is a viable solution for real time crime surveillance application. It is a cost effective and scalable solution for smart security applications in the urban area, residential places and commercial places and thus helps in providing the better public safety and preventing the crime.**

Keywords*—*IoT, Crime Alert System, ESP32 Microcontroller, Real-Time Alerts, Smart Surveillance, Tampering Detection.

I. INTRODUCTION

Crime surveillance has turned into a matter of greater concern in contemporary era as a result of the increasing crime rate in urban and residential areas [1]. Cross-country security measures such as CCTV cameras and manual monitoring may not in all cases provide real-time warnings and prospective crook of prevention. These systems are essentially become evidence collection tools rather than deterrents since they rely on after the fact review. Moreover, also the need of human agency in the contribution of thorough security footage exposed this weaponry attainable to shorter reliability and some other inefficiencies [2]. To overcome these challenges, the inclusion of IoT in smart surveillance system has emerged as the promising solution. IoT based surveillance provides real time crime detection for immediate alert, immediate response to potential threats [3]. This way of thinking about security gives rise to much better security through interfacing of sensors and devices that are constantly scanning the surroundings without requiring constant humans on watch [4]. One such IoT based system is the use of ESP32 micro controller along with infrared sensor to detect thief or intruder movement and suspicious activities. The ESP32 is a low-energy and high-performance microcontroller that incorporates Wi-Fi and Bluetooth on the same chip, acts as the central processor for data collection and transfer [5]. Infrared sensors have important functions while detecting motion by examining infrared radiation, in which the system can see human happening to rotate in any forbidden locations. If there is an unusual movement, system responds immediately, for instance it signals an siren, or send notifications to the security team, or even, by activating a secondary security systems [6]. This real-time capability enables IoT based crime alert systems to be very successful at preventing potential threats from becoming actual threats. In addition, these systems can be readily placed into any surrounding, like home, workplace, parking garage, or public place that will provide an economical and highly scalable security solution [7]. Their capacity to run alone with a low energy demand, straight usage can lead continuous monitoring with negligible power expenditure of the system [8]. Using innovations in IoT to include in crime surveillance locations leads to a much-enhanced level of security and offers a proactive way in preventing crime and increasing public safety in on the whole. The objective of this research is to design and develop an IoT based crime alert system using ESP32 and infrared sensor for enhancing security by real time detection and alarm mechanism. The key contribution of this study followed as below:

- This study proposed to develop real-time crime alert system using ESP32 and infrared sensor for better surveillance.
- It is offered to give a low energy and low expense shelter answer without constituency.
- The system sends out instantaneous alerts and cab be used to prompt an automated response when security breaches are noticed with the aim of prosecution prevention.
- It provides an expandable IoT-driven solution to heightened security for residential, commercial and public realms.

The flow of this research is as following: Section 2 discusses exiting literature and describes an adaptive

DOI: 10.62647/IJITCE2025V13I3PP241-247

International Journal of Information Technology & Computer Engineering
ISSN 2347–3657
Volume 13, Issue 3, 2025

IoT based framework for crime surveillance and prevention. Chapter 3 discusses the proposed research approach. Section 4 presents the experimental results. Section 5 presents the analysis of conclusion and future work, summarizing the research findings.

II. Literature Review

Surveillance technologies have implied serious changes over the years, from the classic security personnel and vandal-resistant CCTV cameras up to the contemporary smart security systems [9]. Although CCTV cameras still widely deployed at residential, commercial, and public areas as they are typically passive, they only mainly present themselves as simple recording tool; there not being alert machine of real time. The dependency of human review of tapes renders them ineffective in deterring criminal activity before it happens [10]. Also, security personnel watching live feeds can miss important events due to tiredness or distractions and thus they can also reduce the effectiveness of such systems. Motion detection cameras have come up with some of the shortcomings of it. But it lacked one thing that is instant alert method to prevent the criminal activity from happening [11]. To address these difficulties IoT has been embedded significantly into security and crime detection applications, putting in a real time check on and the auto response functions. IoT-based systems make use of network-to-network of sensors and devices and that talk wirelessly, internet control surveillance uncontested two times time daily [12]. These systems allow for instant alerts to security personnel or law enforcement whenever suspicious activity is detected substantially lowering response time and increasing safety overall. Many sensor-associated security measures have been shown for the crime symptom, such as ultrasonics sensors, microwave sensor and infrared sensors. Ultrasonic sensors operate by using high-frequency sound waves which it reflects and thus they are appropriate for those who utilize motion presence [13]. Microwave sensors, on the other hand, use electromagnetic waves to discover the move and being extremely precise take considerably more energy, and are accordingly not incredibly suitable for steady operation in battery driven frameworks. Among the available options, infrared sensors give the best balance of efficacy, cost efficacy, and low power consumption, thus ideal for real-time security applications The ESP32 microcontroller is a very good choice to be used in IoT surveillance as it has built in Wi-Fi, and Bluetooth chip, which enables easy video streaming without using any external hardware [13]. Besides, it is also low-power consuming as well as equipped at high processing speed for using in real-time alarm system. When combining with infrared sensor, ESP32 can effectively track the human movement and send alarm signal to the connected device, prompt the rapid security response [14]. The claim for setting ESP32 and infrared sensors as the basis of it comes from their potential to enable energy efficient, highly responsive, as well as scalable security solution. Utilizing such technologies, the recommended crime warning system purpose to tackle down the constraint of conventional surveillance technology, as well as reinforcing the performance of real–time crime discovery as well as abstain crime [15].

A. Research Gap

Presently, surveillance systems relying on manual monitoring–be it, CCTV and Motion Detection Cameras –delays responses. Most IoT-based security solutions are also expensive, complicated or power-hungry, which hinders their reach. Sensor-based methods are usually real-time integration, efficient learning and awareness mechanisms. There is a requirement for an inexpensive, low-energy perceptive system emboldening self-sufficient crime discovery and peer-to-peer reaction. This study therefore provides an IoT-based crime alert system ESP32 and intrusion detection system using infrared sensors for real-time surveillance.

III. Materials and Methods

A. Materials Used

The hardware part of IoT-based crime alert system includes different electronic devices and sensors for the purpose of effective use of real time surveillance. The materials involved in this study are:

1) ESP32 Microcontroller

The ESP32 module is a high-energy and low battery module acting as the central processing unit for IoT based crime alert system. It is built in Wi-Fi and Bluetooth connectivity to facilitate easy interaction with cloud-based platforms as well as mobile applications for real time monitoring. The dual-core processor provides an efficient data processing from multiple sensors at the same time at a high level. Its power consumption is low, suitable for continuous monitoring applications and perfect choice for smart surveillance system applications. The ESP32 also comes with a number of interfaces making it easy to connect in various sensors and actuators and hence give flexibility and scalability in the system design.

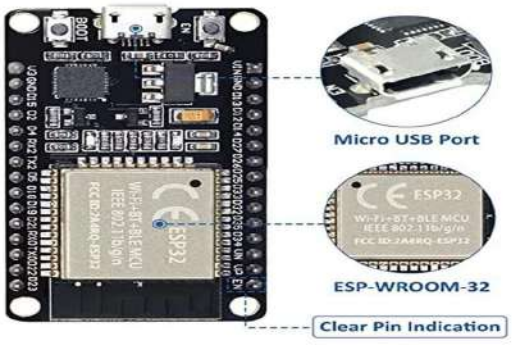

Fig.1. ESP32 Microcontroller [16]

2) Passive Infrared Sensor

The PIR sensor is an important part of the detection of people/ object movement in the area watched by

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Smart Eye CCTV Cameras. It works by detecting infrared radiation that is caused by body heat and sends an alert when unauthorised movement is sensed. This sensor is very useful for security use as it minimizes false alarms by recognizing as human movement from environmental disturbances. The PIR sensor is strategically located at the entrance points, entry points and federal areas for full coverage. The unit can operate effectively in reduced light conditions making it suitable for 24/7 surveillance.

Fig.2. Passive Infrared Sensor [17]

3) Vibration Sensor

An added feature is a vibration sensor which will alert you when a door or window or restricted area is vibrate uncontrollably or being tampered. It works be performing the conversion of the mechanical vibrations to have the form of an electrical signalling with the object of triggering an alert when there is the presence of excessive or respective vibrations. This feature is especially helpful for recognizing cases of forced entry, burglary situations or structural disturbance. The vibration sensor boosts the system being effective by offering an additional level of security against physical entry, thus basically important for defence purposes on extremely valuable materials and forbidden territory.

Fig.3. Vibration Sensor [18]

4) Flame Sensor

The flame sensor is accountable for spotting blazes and other flammable matters that might represent security risks. It functions on the principle of infrared light radiated with the aid of flames; therefore, the flame is detect using this device in complete real-time, thus it also performs automatic protection, detection, combination, signal switching, alarming and trigger auxiliary operations to ensure fire safety.

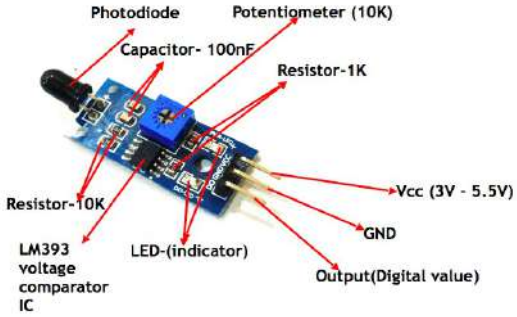

Fig.4. Flame Sensor [19]

This sensor is an important part of preventing arson-related offenses and quick response at time of any fire outbreak. It is installed in exposed areas, where fire danger is high, such as storage rooms, commercial places, house regional hosting. By integrating flame detection with the crime alert, it improves that security infrastructure to cover both the criminal welfare and hazard occurrences.

5) Sound Sensor

The sound sensor monitor is utilized to detect unusual sounds like a broken of a glass, a loud disturbance or an intrusion attempt. It detects changes in ambient noise and when anomalous sound patterns occur alerts, the user. This sensor is particularly suitable in those applications where silent intrusion may not trip motion-based sensors. In conjunction with other sensors in the system, the sound sensor guarantees an immediate reaction to an intruder, like break and entry, thefts, etc. It increases the overall reliability of crime alert security system by producing an audio alarmed threat of security.

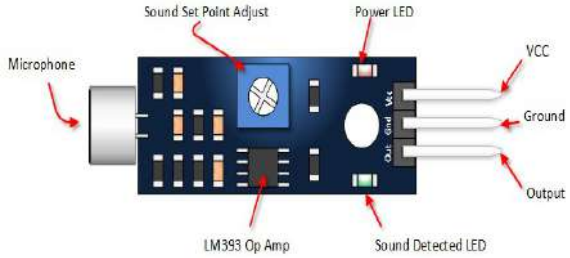

Fig.5. Sound Sensor [20]

6) Buzzer

Buzzer used to give instant audible alarm on detected open/closed/ motion activities. It is a warning tool to advise people nearby or security personnel if there might be a threat. The buzzer is turning on immediately an anomaly occurs sensed by any of the other sensors thereby ensuring in real term responses to security breaches. Its loud and attention grabbing sound incorporates to discourage intruder and increases awareness. The alarm function of the buzzer plays an important part in the prevention of crime as it sends a quick sound signal that creates a prompt response of security guards or residents.

DOI: 10.62647/IJITCE2025V13I3PP241-247

International Journal of Information Technology & Computer Engineering
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Volume 13, Issue 3, 2025

Fig.6. Buzzer [21]

7) IoT Connectivity

IoT connectivity is integral to crime alert system since it allows for real-time notifications and remote surveillance. The ESP32 microcontroller, that comes with onboard Wi-Fi capabilities , can be connected over internet for the purpose within cloud and mobile application for obtaining the instant alert messages for the security threats. This feature helps to make the surveillance of crime at the highest efficiency that is, ensuring that security personnel or the people residing in that house can instantly take necessary action even if they are not in that place. IoT integration also enables for the data logging and analysis to significantly improve the security measurements and response strategies over time.

8) Power Supply Unit

A reliable and steady power supply unit is required for the ongoing functioning of crime alert system. It makes sure that all other units like the sensors, microcontroller, as well as the buzzer, continue to work without stopping. The power supply is built to ensure sufficient voltage and current for system operation, so to reduce the chance of power outages. In situations requiring backup power or emergency power outages, emergency backup power solutions like battery packs can be implemented so system operation is maintained. The security of the crime surveillance system is heavily reliant on the quality of the power supply unit.

B. Methodology

The presented crime alert system is created by its purpose of recognizing the illegal actions and send the immediate alerts by using IoT based system. The methodology to be used follows the following steps in sequence:

1) System Setup and Sensor Integration

With the ESP32 microcontroller, the system activates as the central computing element and sensor information data is collected and analysed by itself. Each sensor is subtly placed in areas best suited for the detection. The PIR sensor is fitted at entrance point such as doors and windows to detect human movement. The vibration sensor is mounted on accessible surfaces, like doors or safes, in order to detect forced entry attempt. There is installed the flame sensor in hot spots areas to sense of the flames and warm up the sources, triggering early warnings on objecting the arc detection fire risks. The sound sensor is set up to keep watch over the history for any unusual or loud sounds at any time, making sure that any unauthorized commotion, incorporate breaking window or tools utilize, is promptly found. The buzzer is directly coupled to ESP32 microcomputer for instant alerts when the threats are detected. All parts are meticulously assembled in order to make sure that there is no loss of communication among the sensors as well as the micro controller, in order to make this system occupy the post as a real time crime alerting system.

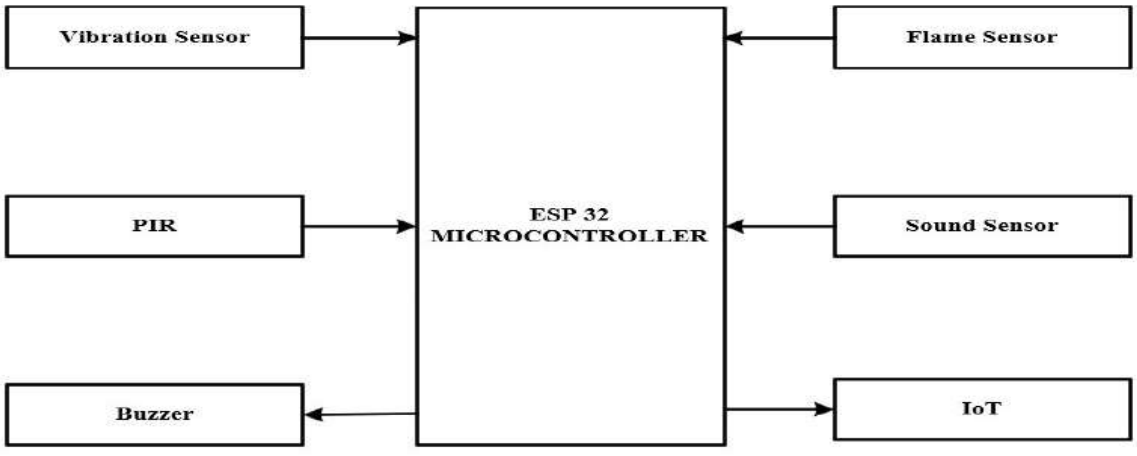

Fig.7. Adaptive IoT-Based Framework

2) Real-Time Data Processing and Alert Mechanism

Once the system is up and running, each sensor stays in monitoring mode constantly, making data dumps about the environment-factors of movement,

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International Journal of Information Technology & Computer Engineering
ISSN 2347–3657
Volume 13, Issue 3, 2025

vibration, flames, sound. The ESP32 microcontroller assesses in real-time captured sensor readings to determine if an identified activity could represent security breach. In Case when an abnormal event like, un verified motion, excess vibrations, fire or an unusual sound acquires, at that point the ESP32 locomotives a warning. When armed, the buzzer is triggered triggering a local alarm warning people nearby of the detected threat. The system is designed to distinguish between common events and probable security breaches, therefore preventing unnecessary false alarms while maintaining precision. This real time detection and alert system is very importance to protect from security issue to detect and to act on suspicious user activities.

3) IoT-Based Notification System

Beyond local alarms, the system uses IoT connectivity to remotes 'barking' and live signalling. When a security threat is identified, ESP32 microcontroller sends alert via Wi-Fi to connected cloud platform or dedicated mobile app. This enables security personnel or property owners receive notify of immediately, even if they are not physically located at the place being monitored. The web-based alert solution ensures that security alerts are available anytime, anywhere and provides an additional layer of security by enabling swift action to be taken in response to potential threats. This IoT based Notification system significantly enhances the efficiency of the system in the sense that all revealed threats are immediately informed to the concerned authorities.

The profiled system undergoes severe evaluation under real-time situations such as unauthorised access, tamper alerts, fire situations, sound disruptions and so forth. Accuracy, response time and alert efficacy are tested throughout multiple test trails by the sensor. The efforts are focused on the lowest number for false alarms while the fastest threat detection. IoT based notification system is experimented for delay free live alert sending. These evaluations ensure that system performance running with reliable crime prevention and security monitoring is optimized.

By combining multiple sensors with IoT technique, the conceived crime alert system establishes a profitable, efficient, and scalable infrastructure for instant safety surveillance in smart and agricultural, business and residential zones.

IV. Result and Discussion

Figure 8 is suitable as a hardware setup of the IoT-based crime alert system for smart surveillance system. The system comprises of multiple connected sensors to a central ESP32 controller which acts as the processing unit. Operated by various sensors, a PIR motion sensor, sound detection sensor and infra-red sensors that senses unlikely action of breaking in like unauthorized movement, unnecessary noise or an object settled at the restricted area. The sensors transmit live data to the ESP32, where it runs an application program that sends out notifications to a monitoring system or a connected mobile app. This setup strengthen the security through automatic crime detection and alert system which will allow for proactive reaction.

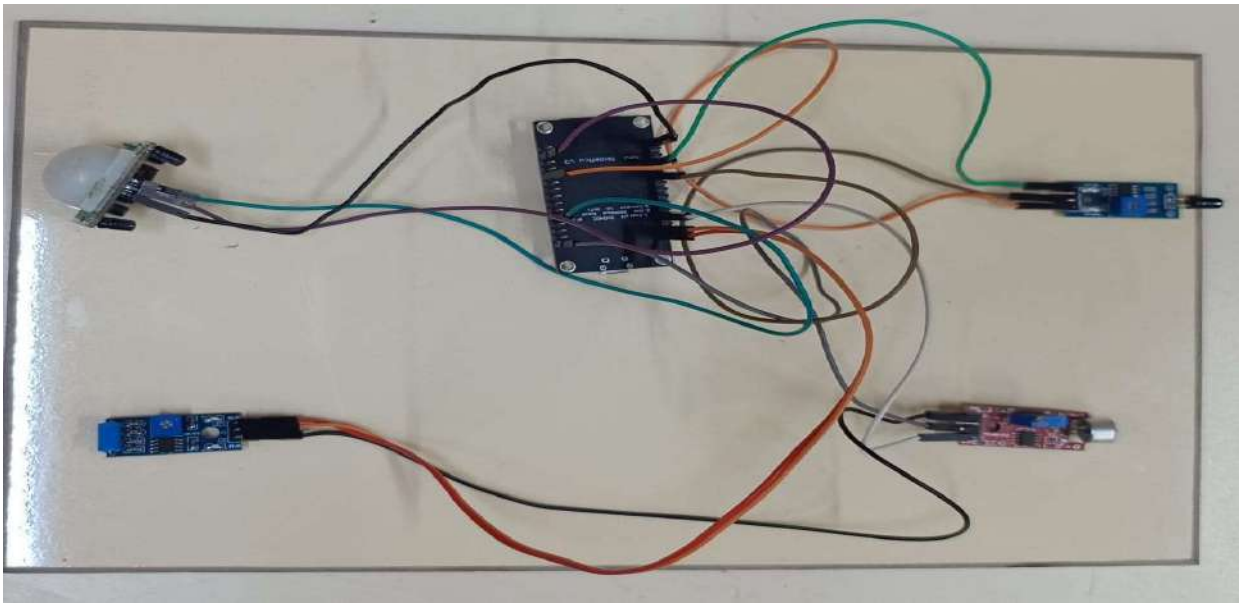

Fig.8. IoT-Based Crime Alert System

Figure 9 shows the dashboard interface of crime monitoring software, which is one of the integral part of IoT-based crime alert system. The dashboard offers a single location for real-time monitoring with alerts and alerts associated with detected suspicious event. The interface is user-friendly laid out in terms of

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International Journal of Information Technology & Computer Engineering
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Volume 13, Issue 3, 2025

navigation, there is a "Monitoring" and "Motion" tab for even greater flexibility in using the different functionalities. The system handles data gathered from various sensors, displaying vital crime-based insights in user friendly format. By combining IoT and web technologies, the software improves the way that security monitoring is carried out, it enables users easily to track, analyze and respond to potential threats making possible of smart surveillance.

Fig.9. Crime Monitoring Software Dashboard

Figure 10 shows the prediction user interface of the IoT-based crime monitoring system in which sensor data are input for analysis. The interface has fields for the four crucial parameters—Flame, Vibration, Motion Detection, and Sound each is replete with sensor readings that signal potential security threats. Submitters can insert numeric values representing the magnitude of these picked parameters, and once received the tool calculates the potential risk from the data.

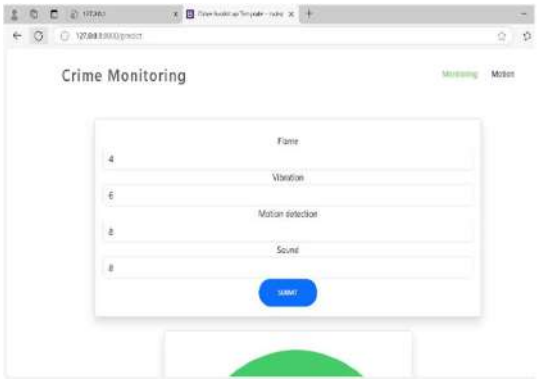

Fig.10. Crime Monitoring Prediction Interface

This predictive model is crucial for running time crime elasticity, which integrates data of IoT-enabled centres to filter strange environmental changes. The data measured by these sensors are assessed to determine the chance of security incident. The system enables authorities to anticipate threats and as such, boost surveillance capabilities in intelligent security environments. The user-friendly interface allows for hassle free interaction so that it is available for security team and automatic monitoring system.

A. Discussion

The proposed IoT-based crime monitoring system combines multiple sensing technology to increase the ability to detect real-time threats and to enhance the urban security. Using the ESP32 microcontrollers, the device effectively gathers and processes data from a variety of flame, vibration, motion detection and sound sensors, achieving thorough surveillance. The Interactive Web-based Dashboard offers real-time visualization that lets users tracking and response to possible dangers proactively. One of the main conclusions is that by combining multi-sensor data is reduced false alarms which is biggest challenge in traditional surveillance systems. The system's accuracy and reliability was proven through numerous testing in various scenarios to its ability in spotting abnormal activities. In comparison to traditional security systems that only utilize single-sensor inputs, this complete approach are more accurate as well as scalable. Plus, the price of hardware is affordable due to which it is best option in smart cities, residential areas and commercial down the town for large scale. Although the system effectively boosts situational awareness, however, the sensitivity of the sensor, the noise in the environment, the latency in the network may affect the system performance. Meeting these challenges by means of optimized sensor calibration and edge computing methods they may augment its efficiency. In general, this study points out the effectiveness of IoT-based security frames in how law enforcement can adjust strategies concerning crime prevention besides enforcing public safety measures generally.

V. Conclusion and Future Work

A IoT crime monitoring system based system to enhance the security and surveillance of sensor data. The system through the use of a combination of flame, vibration and motion detection, and sound sensors continuously monitors changes in the environment, no less than, detecting potential threats to safety in real time. The intuitive dashboard provides hassle-free interaction, putting in sensor data at that will allow users to obtain examine suspicious activities efficiently. This system is very important for the crime prevention for giving early warnings and prompt measure taken by the authorities. Moreover, this technology could be applied in cities, households and companies, thus potentially diminishing such criminal acts as well as increase public safety.

For future works, several improvements may be applied to enhance the system's accuracy and performance. Machine learning algorithms can be used to forecast crime patterns based on past information, and as an outcome, a more sophisticated risk recognition can be provided. Furthermore, the combination of real-time video surveillance with AI-driven image recognition may enhance the sensors that would reinforce crime surveillance. Cloud-based storage and mobility of remote strength is attainable to permit powers that be maintain surveillance from anyplace. Also, adding emergency alert systems like

DOI: 10.62647/IJITCE2025V13I3PP241-247

SMS or mobile app notifications, law enforcement agencies can receive immediate alert. These technological developments will significantly improve crime detection and reaction, making smarter surveillance easier and successful.

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DOI: 10.62647/IJITCE2025V13I3PP241-247