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NoIR Camera Based Security Surveillance System

Syamala Yarlagadda[1]; Niharika Nalluru[2]; Santhi Swaroop Tirumalasetti[3]; Mounika Uppuluri[4]; AnilKumar Akhil Perumprath[5]

[1]Department of IoT SR Gudlavalleru Engineering College Gudlavalleru, India
[2]Department of IoT SR Gudlavalleru Engineering College Gudlavalleru, India
[3]Department of IoT SR Gudlavalleru Engineering College Gudlavalleru, India
[4]Department of IoT SR Gudlavalleru Engineering College Gudlavalleru, India
[5]Department of IoT SR Gudlavalleru Engineering College Gudlavalleru, India

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Abstract: The NoIR Camera-Based Raspberry Pi Security system is an adaptive, intelligent security system that provides efficient, low-light monitoring. It reduces false alarms by using infrared sensitivity to provide day-and-night monitoring with advanced motion detection that can differentiate between objects, including people and animals. This technology is ideal for home security, animal tracking, and restricted access surveillance because it uses local, on-device processing to ensure data privacy, real-time responsiveness, and IoT integration for remote moni- toring. TensorFlow, which is adapted to run on the Raspberry Pi with TensorFlow Lite, is used in this system for object detection and identification. Effective edge processing is made possible by TensorFlow's lightweight models, which are essential for reducing latency and optimizing data privacy. Effective surveillance in low light and at night is made possible by the combination of NoIR imaging with AI-driven object detection. Future developments involve building a scalable network for wider industrial use, extending classification categories and using advanced facial recognition. Adaptability and security characteristics could be further enhanced with more cloud analytics and a deeper IoT integration.

Keywords: *NoIR Camera, Raspberry Pi, TensorFlow Object Detection and Edge Processing.*

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I. INTRODUCTION

In the evolving landscape of security and surveillance, real- time monitoring systems plays a crucial role in ensuring safety and situational awareness. The increasing need for effective and affordable surveillance in commercial, industrial, and residential settings have made automated security monitor- ing more and more crucial. Conventional security systems frequently use passive monitoring, which necessitates human involvement for threat analysis and video analysis. These solutions may be ineffective, though, which could result in security lapses and delayed reactions. This project offers an intelligent real- time security system that uses the YOLO11 object detection framework and integrates a NoIR (No In- frared) camera with a Raspberry Pi 5 to handle these issues.

The NoIR camera-based security system is a real-time system capable of capturing images in bright sunlight as well as in darkness conditions. Paired with a Raspberry Pi 5, this setup uses a NoIR camera module—with no infrared filter, the module can receive infrared light, enabling better vision in low-light conditions. This allows for 24/7 monitoring, and is especially useful for ensuring security breaches are getting detected in total darkness. Captured images and video streams were deployed to YOLO11 (You Only Look Once), a state-of-the-art deep learning-based object detection framework that enables the accurate identification and classification of multiple objects in real-time.

The working of the system is simply done by continuously monitoring video-captured frames and detecting motion or an object, which is prohibited. Security alert mechanism based on time: It will only notify the security personnel during critical hours in case of detection. This module sends notifications by email (SMTP protocol) and Telegram (Telegram Bot API), al- lowing instant alerts that include captured images. The system also records detected objects, allowing for further study and the accountability of security responses, as well as reducing false alarms. OpenCV's MOG2 filters out stationary objects, preventing us from receiving unnecessary notification.

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This security solution is well-suited for residential, commercial, and smart city applications. This compact system integrates night vision, real-time object detection, and automated alerting systems, increasing security with a cost-effective solution. Future enhancements may encompass optimized processing for efficiency, increased object database, and smarter edge AI integration to minimize cloud-based dependencies. Drawing on a combined wealth of experience and expertise in optimized low-light optics and imaging combined with machine learning and multi-core software design, the NoIR camera-based security system provides an intelligent and highly adaptable, real-time monitoring solution for any security capacity.

II. LITERATURE REVIEW

Using automation and cloud computing, a Raspberry Pi-based IoT-based smart surveillance system improves real-time monitoring. By lowering manual intervention and raising surveillance accuracy, the study emphasizes increased security efficiency [1]. Through decentralized processing, an Edge AI- enabled IoT architecture for smart home security enhances intrusion detection. For real-time threat detection, the research focuses on AI-driven automation, privacy improvement, and latency reduction [2]. Threat detection and anomaly recogni- tion are improved by a smart security system that uses machine learning and fuzzy logic. By enhancing intrusion response, adaptive AI models increase the intelligence and independence of the surveillance system [3]. An AI-powered camera system is made to use computer vision to detect traffic accidents in real time. By detecting collisions, unusual car behavior, and emergencies, the system speeds up reaction times and enhances traffic safety [4]. Applications for real-time security are improved when edge computing and artificial intelligence are combined. Localized AI processing enhances surveillance automation, reduces latency, and maximizes power usage [5]. An IoT and machine learning-based motion-triggered smart surveillance system distinguishes between human and non- human motions. This method improves real-time security monitoring, minimizes false alerts, and maximizes energy use [6]. Video analytics that protect privacy are the main focus of AI and edge cloud-enabled surveillance systems. The system maintains robust security and real-time threat detection while lowering latency through local data processing [7]. To improve remote monitoring, an Internet of Things- based security and surveillance system combines smart sensors and cloud computing. Real-time video analysis and automatic warnings for home and business applications are highlighted in the study [8]. Deep learning is used in a TensorFlow- based surveillance system to detect objects in real time. It reduces false alerts while effectively detecting suspicious activity and human presence [9]. Smart surveillance enabled by AI and IoT enhances crime prevention by means of cloud- based monitoring and automatic notifications. Scalable and affordable security technologies for threat detection and public safety are highlighted in the study [10].

III. METHODOLOGY

In order to perform real-time surveillance and object identi- fication, the technical approach for creating a security system based on NoIR camera combines hardware and software com- ponents. For reliable operation in low light, the system uses a Raspberry Pi 5 for processing and a NoIR camera to record real-time footage. This makes it possible for night vision. The YOLOv11 object detection framework serves as the foundation for the software implementation, which has been trained to identify and categorize a variety of items with an emphasis on human presence. The NoIR camera continuously feeds live video to the Raspberry Pi 5 as part of the image processing pipeline. To identify and categorize objects, frames are taken out at regular intervals and processed using the YOLOv11 model.

A time-based alert system detects human presence during predetermined crucial intervals and sends out messages via email, SMS, or telegram. Security and monitoring capabilities are improved by this feature. Annotated images are saved or shown for real-time monitoring, and all noticed objects are recorded for further examination. By utilizing the advantages of both software and hardware, the project shows a thorough approach to object identification and monitoring. Its uses span a number of sectors, including smart home automation, security.

IV. COMPONENTS

- *Raspberry Pi 5*

A major development in the Raspberry Pi series, the Raspberry Pi 5 was released in September 2023 and offers improved performance and features designed for a variety of uses. The 2.4GHz quad-core 64-bit Arm Cortex-A76 CPU at the heart of the Raspberry Pi 5 provides a 2–3× boost in CPU performance over the Raspberry Pi 4 predecessor. To accommodate different needs and price ranges, the device comes with three memory configurations: 2GB, 4GB, and 8GB of LPDDR4X-4267 SDRAM. The Raspberry Pi 5's dual 4Kp60 HDMI output and VideoCore VII GPU allow for simultaneous connections of multiple monitors and high-definition video streaming. Bluetooth 5.0/BLE and dual-band 802.11ac Wi-Fi offers strong wireless networking features. Numerous peripherals and accessories can be connected to two USB 3.0 and two USB 2.0 ports. High-speed wired network connections are guaranteed via a gigabit Ethernet connector. Additional hardware expansions, such as NVMe SSDs, are made possible by a PCIe 2.0 x1 interface, which improves storage capacity and performance.

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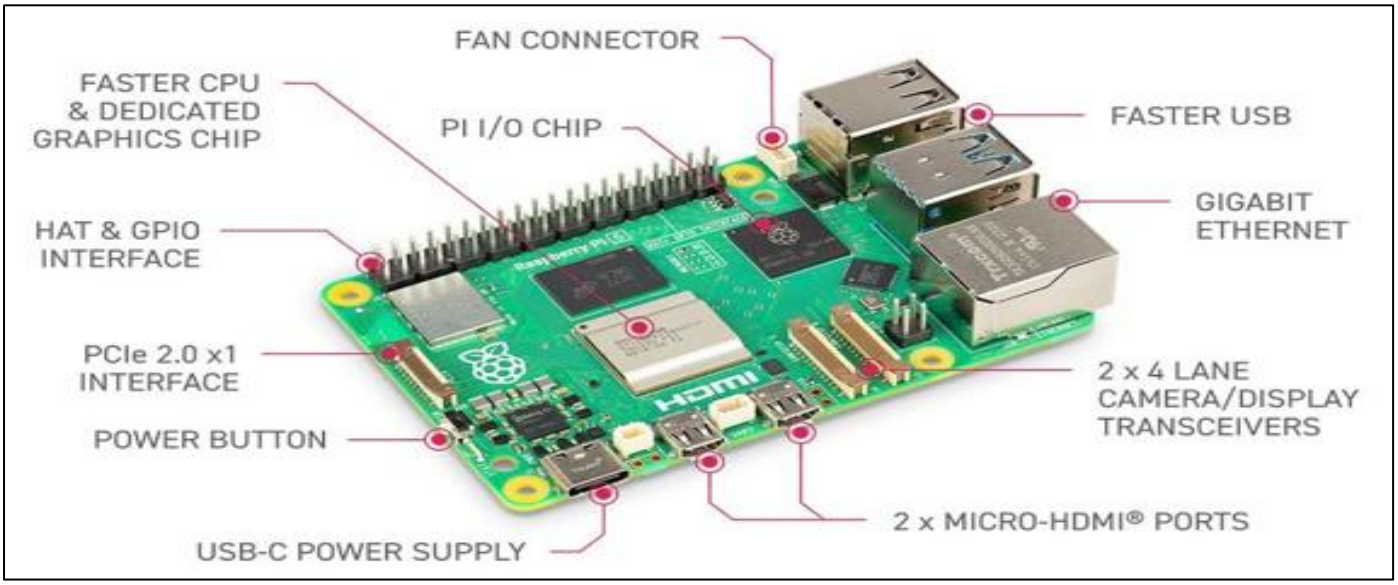

Fig 1 Raspberry Pi 5.

The Raspberry Pi 5, as shown in Fig.1, mainly includes a number of new features such as timekeeping without internet synchronization is made possible by an integrated RTC that requires an external battery. Simple power control is made possible with an integrated power button, which streamlines user engagement. Improved performance and functionality are provided by the in-house created RP1 I/O controller, which improves input/output processes.

➢ *NoIR Camera*

Raspberry Pi camera module 3 NoIR, as shown in Fig.2, is a strong, versatile camera made especially for Raspberry Pi devices. It can detect both visible and infrared light because it does not include an infrared filter. This characteristic makes it perfect for applications that require low light levels and at night, particularly when combined with infrared (IR) light sources. The camera can take images in areas with little to no visible light because it doesn't have an infrared filter. The camera is perfect for animal monitoring and nighttime security since it can capture clear pictures in total darkness when used with infrared illuminators. It has a better sensor than earlier generations, which results in sharper and higher-resolution images. Both high-quality still photos and high-definition (HD) video recording are supported.

Fig 2 Raspberry Pi Camera Module 3 NoIR-SEN-21736

The Camera Module 3 NoIR supports Raspberry Pi models with CSI (Camera Serial Interface) connectors and is made to work in harmony with the Raspberry Pi environment. Building unique IoT applications and edge AI solutions, such as security systems with object detection and identification, is made easy by this integration's simplicity. The camera module can be utilized in AI-driven applications for movement detection, object recognition, and environmental monitoring because it is compatible with the Raspberry Pi and AI frameworks like the YOLOv11 model. Because it enables real-time analysis on the device without relying on the cloud, this works extremely good with projects that need for smart surveillance.

V. IMPLEMENTATION

➢ *Block Diagram*

The block design shown in Fig.3 depicts a person detection system that uses a NoIR (No Infrared) camera, probably for monitoring at night or in low light. The NoIR camera first takes pictures, which are subsequently processed by the ”Frame Processing Module” to improve their quality or make them suitable for object recognition. The ”YOLO/Mobile Net Object Detection” module, which is the intelligence behind the system, uses a lightweight neural network (YOLO or Mobile Net) to recognize objects—more especially, people—in the frames. In order to decrease false positives, the ”Time-based Filtering Module” probably adds a temporal dimension to the detection by removing fleeting detections or requiring a person to be observed over a certain period of time. In order to ascer- tain whether a person is actually there, the ”Decision Logic” module evaluates the filtered detection findings. The ”Image Capture Module” takes and saves the appropriate picture if a person is verified. Lastly, the ”Notification and Alert System” sends out an alert, informing the appropriate staff about the individual that was found. The ”Decision Logic” feedback loop back to the ”Time-based Filtering Module” implies that the detection procedure is continuously improved depending on previous results.

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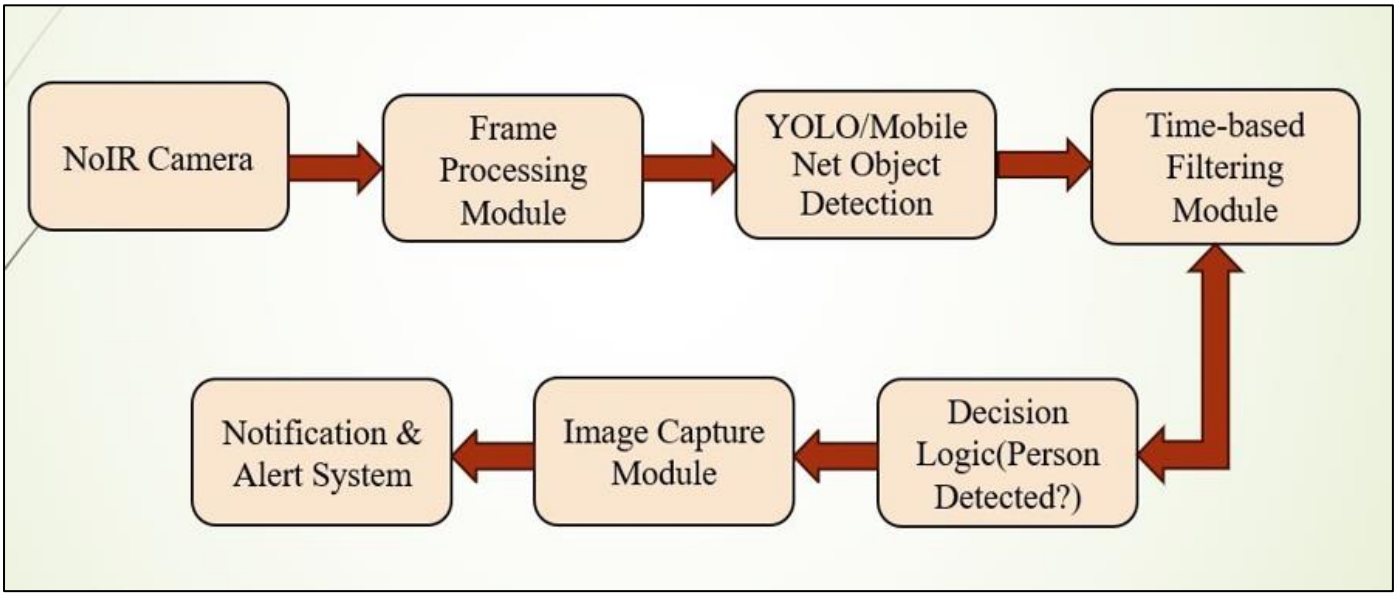

Fig 3 Block Diagram.

➢ *Hardware*

The NoIR camera-based security surveillance system's hard- ware implementation shown in Fig.4 is made to ensure ef- fective, real-time monitoring while using the least amount of power feasible. A Raspberry Pi 5, a NoIR camera module, and the required power and storage units are the main components of hardware. As the central processing unit, the Raspberry Pi 5 manages object recognition, image capture, and alert systems. With its upgraded GPU and processor, it is ideal for real-time execution of deep learning models like YOLO11. Furthermore, it can be easily integrated with a variety of sensors and communication modules because to its support for numerous USB ports and GPIO pins.

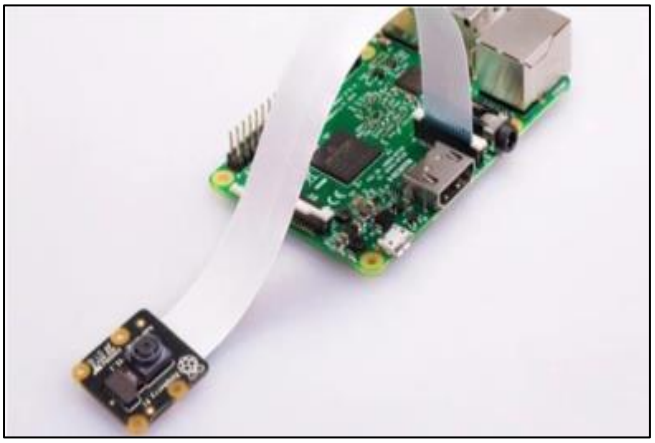

Fig 4 Hardware Setup

The NoIR camera module was selected because it can take pictures in both visible and infrared light spectrums, which guarantees efficient surveillance even in total darkness or low light levels. An infrared (IR) LED array is integrated to improve night vision capabilities, providing covert surveillance by illuminating the monitored area without visible light.

➢ *Software*

For real-time monitoring and classification, the NoIR Camera-Based Security System makes use of the YOLO11 object detection paradigm. High-accuracy object recognition, especially of human presence, is ensured by YOLO11, an upgraded version of the You Only Look Once (YOLO) se- ries. The NoIR camera continuously feeds live video to the Raspberry Pi 5 during picture acquisition, which starts the system's software pipeline. Individual frames are taken out of this video feed for additional processing. The YOLO11 model then analyzes these frames to identify and categorize objects in the scene. A time-based alert mechanism is incorporated to improve security, ensuring that an instant alert is set off if a person is identified within a specified time interval. Email, SMS, and other forms of communication can be used to send notifications.In order to provide effective monitoring and security response, all detected objects and events are also recorded for record-keeping reasons, and annotated frames can be saved or shown in real-time for visualization.

VI. INTEGRATION AND WORKFLOW

A NoIR camera continuously records video data to pro- vide a live feed in low light conditions at the start of the workflow shown in Fig.5. The Raspberry Pi 5 serves as the processing unit and receives this video stream. In order to produce a continuous stream of distinct images for analysis, the Raspberry Pi periodically separates frames from the video. The YOLOv4 (You Only Look Once) object detection model, which is especially made for real-time object detection, is then applied to each extracted frame. YOLOv4 recognizes and labels a variety of objects in the image, including people, cars, and animals, using deep learning techniques. Even in complicated environments, this procedure enables the system to identify particular objects and classify them precisely.

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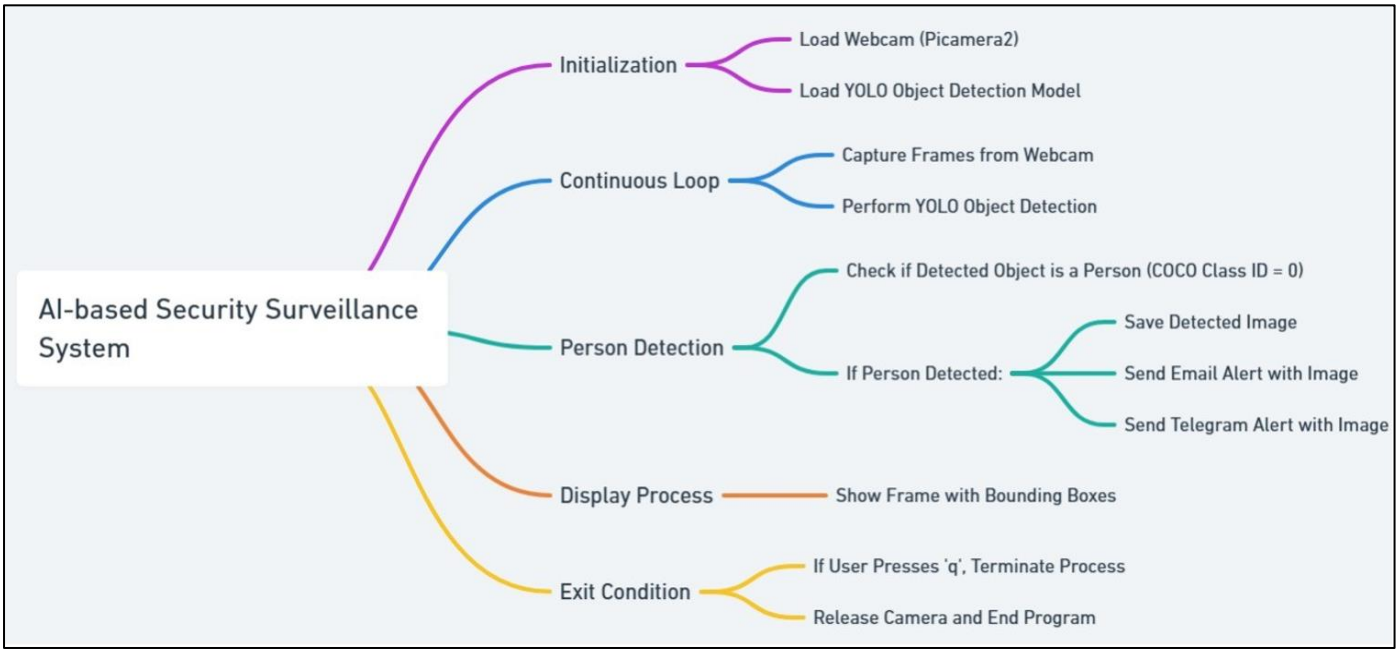

Fig 5 Workflow

The alert system ensures that immediate action can be taken in response to potential security threats or unusual activities. It also tracks all detected objects over time, creating a compre- hensive log of activities that can be used for post-event analy- sis, providing valuable insights into detected objects and their movements. Continuous monitoring ensures that the system remains vigilant, allowing for ongoing surveillance even after an initial alert. If a person is detected within a specified time period, the system triggers the alert module, which is designed to notify relevant authorities, such as security personnel or law enforcement, depending on the nature of the detection.

VII. RESULTS

➢ *Object Detection and Classification*

To recognize and categorize items in real time shown in Fig.6, the system makes use of YOLOv11, a deep learning-based object identification model. You Only Look Once, or YOLO, is renowned for its effectiveness and precision in identifying several objects in a single picture. In this project, the model is trained to identify and classify preset items in the monitoring region, including people, cars, and other pertinent entities. YOLOv11 on the Raspberry Pi 5 processes the frames that are captured by the NoIR camera. Because of the model's quick inference capabilities, security staff are certain to get insights into detected activity right away. By differentiating between various item kinds, lowering false alarms, and increasing reaction accuracy, the categorization feature improves situational awareness.

Fig 6 Object Detection and Classification.

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➢ *Email Notifications*

The Simple Mail Transfer Protocol (SMTP) is used by the security system to incorporate an automated email notification system shown in Fig.7. When a predetermined object, like a person, is detected by the YOLOv11 model within a certain amount of time, the system sends the appropriate recipients an email notice after capturing the pertinent frame. Important information is included in the email, such as a timestamp and an attached picture of the incident that was discovered. This eliminates the need for continuous manual monitoring by enabling security staff to remotely confirm the warning. The monitoring system and end users can communicate easily which guarantees real-time updates. An extra degree of pro- tection is offered by email notifications, which keep track of occurrences that are recognized and can be analyzed at a later time.

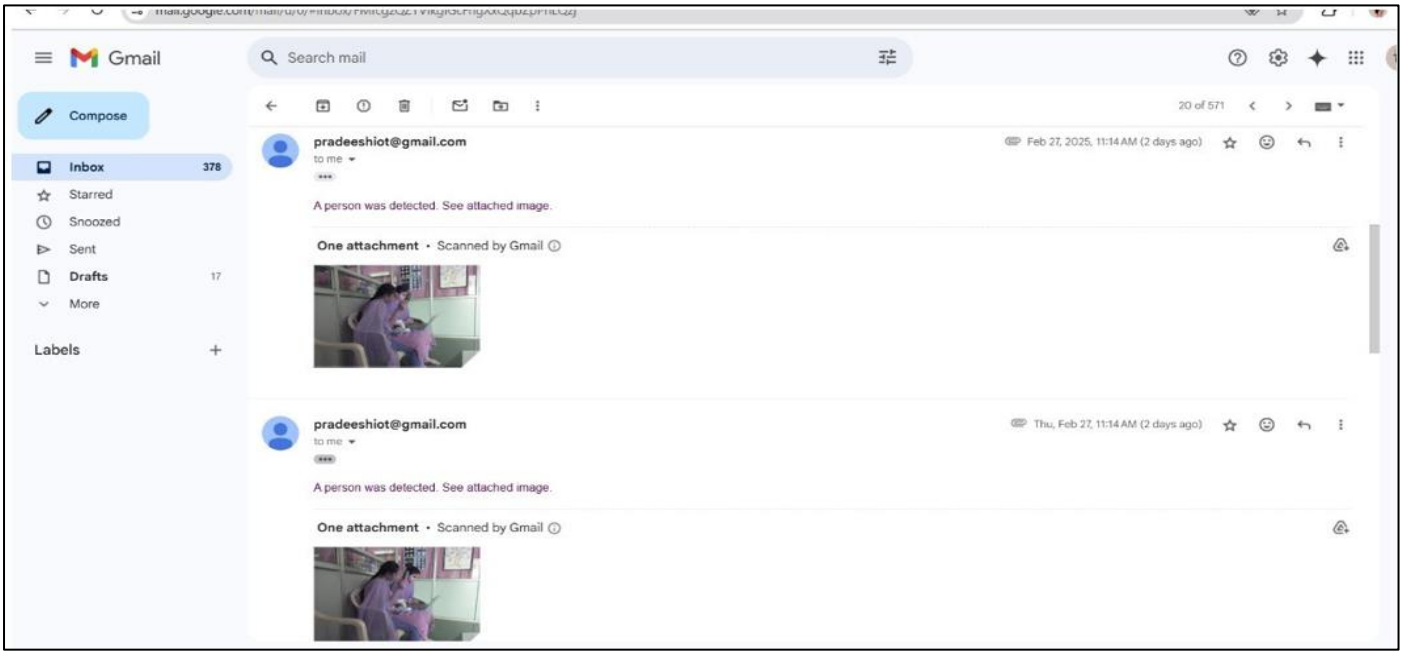

Fig 7 Email Notifications.

➢ *Telegram Bot Status*

Leveraging the Telegram messaging app, the system uses the Telegram Bot API to deliver real-time notifications shown in Fig.8. Through the direct delivery of real-time warnings, including acquired images, this feature improves the surveil- lance system's response. to specified recipients or security staff. The system sends a message with information like the detection time, object classification, and an image attachment for validation whenever it detects an incursion or preset object. Regardless of the recipient's location, security notifications are delivered instantly thanks to Telegram's quick and secure messaging service. Telegram also offers customizable setups, such as the ability to set up secret channels, groups, or individual messages for alerts. Telegram messages offer a more immediate and engaging way to keep an eye on security incidents than email alerts provide.

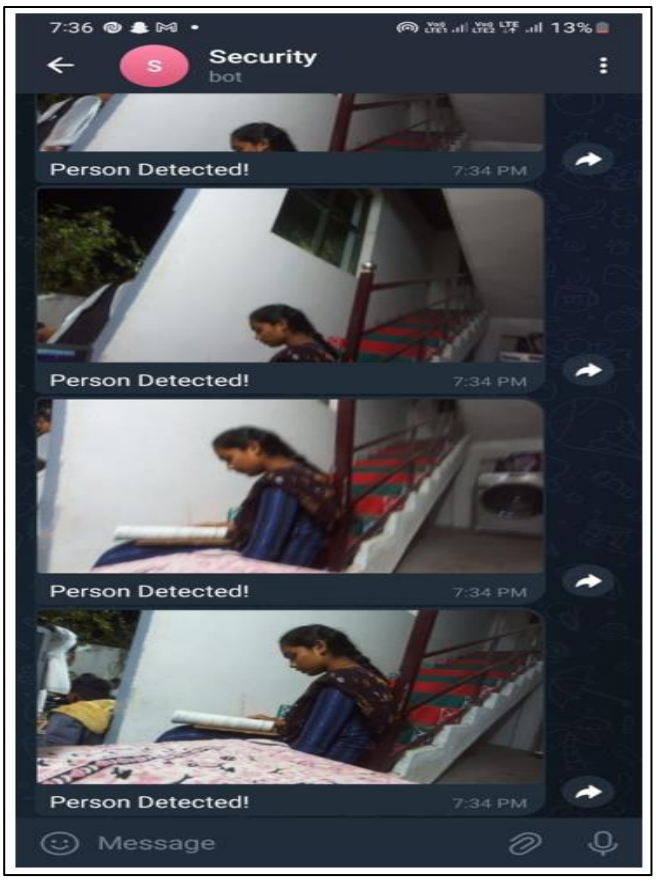

Fig 8 Telegram Bot Status.

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VIII. CONCLUSION

In conclusion, the YOLOv11-powered NoIR camera-based security system, which is based on a Raspberry Pi 5, offers a reliable and adaptable real-time surveillance solution. The sys- tem ensures quick and precise detection of security breaches by combining night vision capabilities with advanced object detection and classification. Its capacity to distinguish between different objects improves situational awareness and reduces false alarms. It is also very effective for residential as well as commercial applications because real-time image-based noti- fications enable quick responses. The system's effectiveness, dependability, and versatility make it a useful security solution that precisely and automatically handles modern surveillance challenges.

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