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# Smart Home Guard: AI-Powered Security System

**Ahana V. Korti[1], Bharat S. Simha[2], Priyankaa Y.[3], Sai Sagar S. Pastay[4], Nagananda R.[5], Venu Gopal B. T.[6]**

[1,2,3,4,6]Department of Electronics and Communication Engineering, RV Institute of Technology and Management (RVITM), Bengaluru, India.
[5]Research Scholar, PES Research Foundation, PES College of Engineering (PESCE), Mandya, India.

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**Abstract:** Home security has become a significant concern in recent years due to the increasing rates of burglaries and intrusions. This project focuses on developing a robust Home Security AI system that leverages facial recognition technology to enhance safety and security measures. The primary application areas for this system include residential homes, small businesses, and office buildings. With the global market for home security solutions expected to reach USD 78.9 billion by 2025, there is a growing demand for advanced and reliable security systems. Despite advancements in surveillance technologies, existing systems often fail to accurately identify intruders, leading to false alarms and compromised security. This project aims to address these issues by integrating state-of-the-art facial recognition algorithms with a real-time notification system, ensuring precise identification and immediate alerts.

**Keywords:** Home security, Artificial Intelligence, Raspberry Pi, Alert system



## INTRODUCTION

Home security has emerged as a crucial concern in contemporary society due to the rising incidents of burglaries and unauthorized entries. Traditional security measures, such as basic alarm systems and surveillance cameras, often fall short in providing comprehensive protection. They can produce a high rate of false alarms and may not offer real-time responses, which compromises their effectiveness [1].

The advancement of Artificial Intelligence (AI) and Machine Learning (ML) offers a promising solution to these challenges by enabling more sophisticated and reliable security systems. This project focuses on developing a Home Security AI system that integrates facial recognition technology with a motion detection mechanism to significantly enhance the accuracy and responsiveness of security measures. The system is designed to cater to residential homes, small businesses, and office environments. According to market projections, the global home security market is expected to reach USD 78.9 billion by 2025, underscoring the growing demand for innovative security solutions [2].

Key developments in AI and ML have revolutionized various sectors, including security. However, current systems often struggle with precise identification, leading to frequent false alarms and a general lack of trust in their reliability. To address these issues, our project employs a state-of-the-art facial recognition algorithm within a framework that activates only upon motion detection by a Passive Infrared (PIR) sensor. This dual-trigger mechanism ensures that the system is both energy-efficient and highly accurate, focusing its computational resources only when necessary.

The primary objective of this project is to create a reliable and efficient home security system that minimizes false positives and provides immediate notifications to users in the event of potential security breaches **[3]**. By leveraging cutting-edge AI technology and motion detection, this project aims to offer a scalable and adaptable solution that meets the diverse needs of modern security requirements.

## LITERATURE SURVEY

### Overview of Artificial Intelligence

Artificial Intelligence (AI) is a technology that enables computers and machines to simulate human intelligence and problem-solving capabilities. Independently or in combination with other technologies (e.g., sensors, geolocation, and robotics), AI can perform tasks that would otherwise require human intelligence or intervention. Examples include digital assistants, GPS navigation, autonomous vehicles, and generative AI tools.

As a field of computer science, Artificial Intelligence encompasses Machine Learning (ML) and Deep Learning (DL). These disciplines involve the development of AI algorithms modeled after the decision-making processes of the human brain, allowing systems to learn from available data and make

***Corresponding Author:** Venu Gopal B. T

increasingly accurate classifications or predictions over time [4,6].

**Facial Recognition**

Facial recognition is a method of identifying or verifying an individual's identity using facial features. Facial recognition systems can identify individuals in photographs, videos, or real-time surveillance and are widely used as a biometric security technology. Although primarily applied in security and law enforcement, its use is expanding into many other domains.

- **Haar Cascade Classifier:** The Haar Cascade classifier is an object detection algorithm used to identify faces in images. It employs machine learning techniques to train a cascade function using positive and negative image datasets. In this project, it detects the presence of faces within video frames.
- **Histogram of Oriented Gradients (HOG):** HOG is a feature descriptor used for object detection and image recognition. It captures edge and structural information, making it effective for identifying faces within an image.
- **Convolutional Neural Network (CNN):** CNNs are a class of deep neural networks widely used for analyzing visual imagery. Compared with HOG-based methods, CNNs generally provide more accurate face detection.
- **Face Encodings (Face Embeddings):** Face recognition maps a detected face to a **128-dimensional feature vector (embedding)**. This vector uniquely represents an individual's face and enables accurate face comparison and matching using deep learning models.
- **K-Nearest Neighbors (KNN):** The recognition process compares the detected face embedding with known embeddings using the KNN algorithm. The closest matching embedding determines the person's identity **[5]**.

**Simple Mail Transfer Protocol (SMTP)**

Simple Mail Transfer Protocol (SMTP) is a protocol used for exchanging email messages between mail servers. It is an essential component of email communication and operates at the application layer of the TCP/IP protocol suite.

SMTP is responsible for transmitting and receiving email messages. In this project, the **Python smtplib library** is used to access the owner's email account and automatically send notification emails to the designated recipients whenever an intrusion is detected.

# METHODOLOGY

The materials required for this home security system include a HC-SR501 Passive Infrared (PIR) sensor for motion detection and a USB camera for capturing images upon detecting motion. A Raspberry Pi 4 Model B serves as the central processing unit, interfacing with all hardware components while executing the required software.

A microSD card (32 GB or higher) is used to install the Raspberry Pi operating system and store captured data. A reliable power supply ensures uninterrupted operation of the Raspberry Pi. Additionally, jumper wires and a breadboard are used to connect the PIR sensor to the Raspberry Pi's GPIO pins.

The project also requires a stable Wi-Fi or Ethernet connection to support internet-based functionalities. The software environment includes Python along with libraries such as OpenCV for facial recognition and smtplib for sending email notifications.

These hardware and software components collectively enable the development of an efficient and intelligent AI-based home security system. The methodology is explained step by step below.

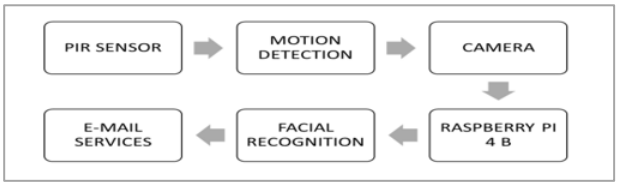


**Fig. 1:** Block Diagram of the Project

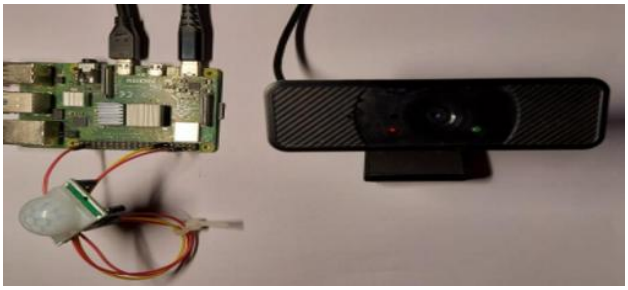

**Fig. 2:** Hardware Setup

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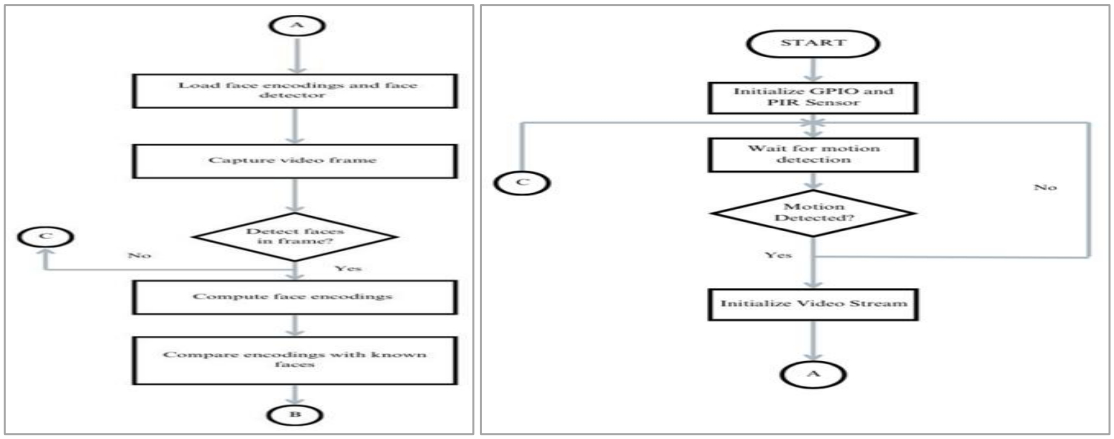


**Fig. 3:** Flowchart

# RESULTS

**Motion Detection**

The first component evaluated was the motion detection capability of the PIR sensor. The sensor was connected to the Raspberry Pi and continuously monitored for motion. Whenever motion was detected, the system successfully initiated the subsequent processing stages. The PIR sensor demonstrated reliable and consistent performance throughout testing.

**Observation:** The PIR sensor effectively detected motion (**Fig. 4**), triggering the subsequent processes without noticeable delay.

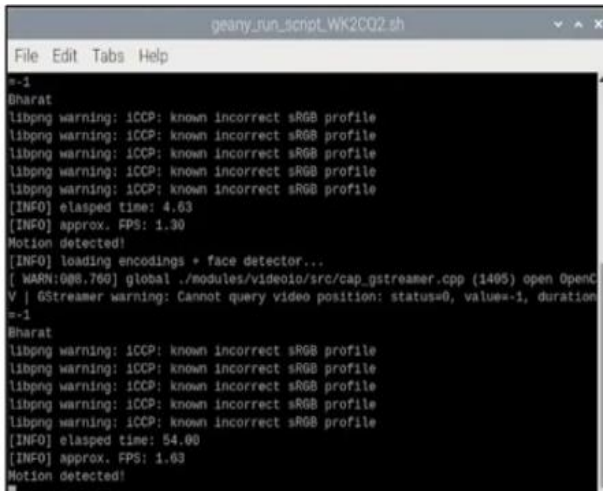


**Fig 4:** PIR Sensor Motion Detection Output

**Image Capture**

Upon detecting motion, the USB camera automatically captured an image. The integration between the PIR sensor and the camera functioned seamlessly. The captured images were successfully stored in the designated directory on the Raspberry Pi.

**Observation:** The USB camera consistently captured clear, high-quality images (**Fig. 5**), providing sufficient image quality for the subsequent facial recognition process.

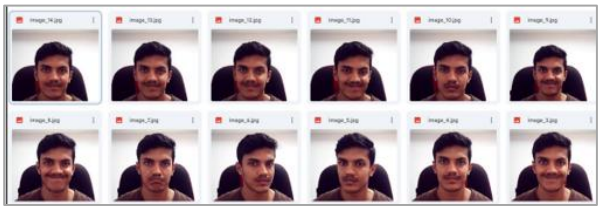

**Fig 5:** Image Capture using theUSB Camera

**Face Recognition**

Face recognition was performed on the captured images using OpenCV. The pre-trained Haar Cascade classifier was used for detecting faces in the images. The recognition system was able to detect faces with high accuracy, identifying known individuals from the training dataset.

**Observation:** The face recognition system successfully identified faces under various lighting conditions and from different angles, demonstrating the robustness of the chosen algorithm.

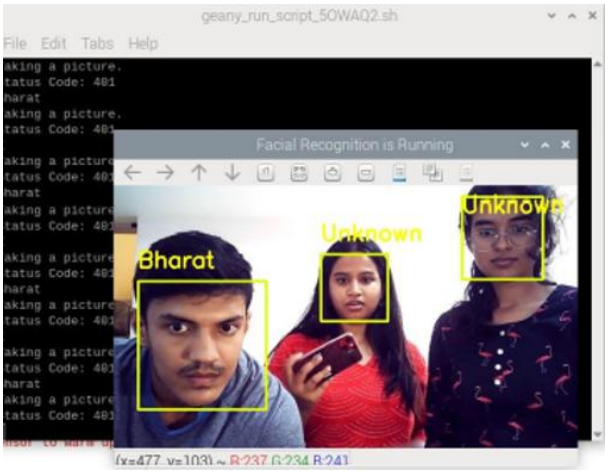


**Fig 6:** Face recognition Output

**Email Notification**

Once a face was detected, an email notification was sent to the user with the captured image attached. The SMTP protocol was used to send emails through a configured

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Gmail account. The email notification system worked reliably, delivering alerts promptly to the user.

**Observation:** The email notification system effectively alerted the user in real time. Each email included the timestamp and the captured image, allowing the user to take immediate action if necessary.

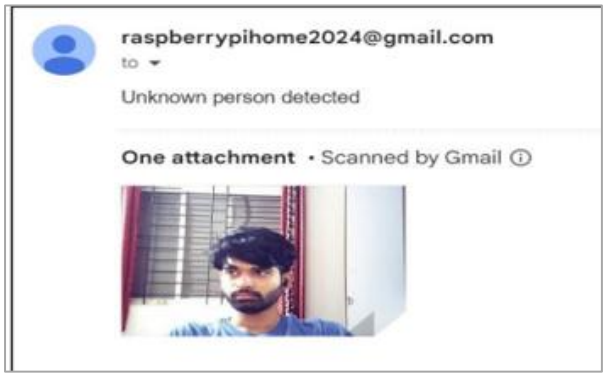


**Fig 7.** E-mail when an unknown person is detected

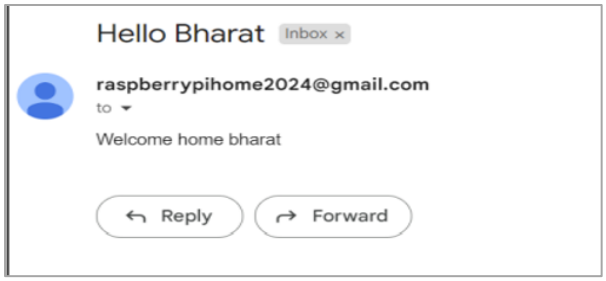


**Fig. 8.** E-mail when a known person is detected

**Overall System Performance**

The integrated home security system demonstrated high efficiency and reliability throughout the testing phase. The motion detection, image capture, face recognition, and email notification processes worked in harmony to provide a robust security solution. The system was tested under various scenarios, including different lighting conditions, multiple motion events, and varying distances.

The project successfully met its objectives by creating a multi-layered security system using AI technologies. The use of a Raspberry Pi 4 Model B as the central hub proved effective, and the system's modular design allows for future enhancements and scalability. The overall performance was satisfactory, with all components functioning as intended and delivering timely notifications to the user.

## CONCLUSION

The development of a home security system integrating a PIR sensor, USB camera, Raspberry Pi 4 Model B, face recognition, and email notifications has proven to be a successful and effective solution for enhancing home security. The system's capability to detect motion, capture images, recognize faces, and send email alerts ensures a multi-layered approach to security, addressing the limitations of traditional single-level systems.

Throughout the testing phase, the system demonstrated high reliability and efficiency. The PIR sensor effectively detected motion, triggering the USB camera to capture images promptly. The face recognition algorithm, implemented using OpenCV, successfully identified faces under various conditions, thereby reducing the occurrence of false alarms. The email notification system, leveraging the SMTP protocol, provided timely alerts to the user, allowing immediate action to be taken when necessary.

This project underscores the potential of integrating IoT and AI technologies to create intelligent and scalable security solutions. The Raspberry Pi 4 Model B, serving as the central processing unit, proved to be an excellent choice due to its computational power and flexibility. The modular design of the system allows for easy updates and enhancements, making it a future-proof solution.

There are several potential areas for future enhancements and research to improve the functionality and effectiveness of the home security system:

- **Enhanced Face Recognition:** Implementing more advanced face recognition algorithms, such as deep learning-based methods, could further improve accuracy and reliability. Integrating a larger and more diverse dataset for training can also enhance the system's ability to recognize faces under different conditions.
- **Integration with Smart Home Devices:** Expanding the system to integrate with other smart home devices, such as smart locks, lights, and alarms, can provide a more comprehensive security solution. For example, triggering smart lights or alarms upon detecting an intruder can act as a deterrent.
- **Cloud-Based Data Storage and Processing:** Incorporating cloud services for data storage and processing can enhance the system's scalability and performance. This approach would enable remote access to security footage and allow more complex processing tasks to be offloaded to the cloud.
- **Mobile Application:** Developing a dedicated mobile application can provide users with a more user-friendly interface for monitoring and controlling the security system. Push notifications, live video streaming, and remote control functionalities can be included in the application.
- **Integration of Additional Sensors:** Adding more types of sensors, such as door/window contact sensors, glass-break sensors, and smoke detectors, can provide a more holistic approach to home security. These sensors can be integrated into the existing system to enhance its capability to detect various types of security threats.
- **AI-Driven Analytics:** Implementing AI-driven analytics can provide users with insights and patterns related to security events. Machine learning

***Corresponding Author:** Venu Gopal B. T

algorithms can analyze data to identify unusual activities and predict potential security breaches.

- **Voice Assistant Integration:** Integrating the system with popular voice assistants such as Amazon Alexa or Google Assistant can provide users with voice-control capabilities, enhancing ease of use and accessibility.

In conclusion, the home security system project has laid a strong foundation for a reliable and intelligent security solution. The successful implementation of the core functionalities demonstrates the feasibility of integrating IoT and AI technologies to enhance home security. The future scope of the project offers numerous opportunities for further development and innovation, making it a promising area for ongoing research and improvement.

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***Corresponding Author:** Venu Gopal B. T