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Surveillance System with Human Intrusion Detection

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Abstract:- Security in restricted areas is essential for protecting valuable assets, sensitive information, ensuring the safety from intruders. Traditional security systems have many limitations, where they cannot authenticate whether the entered person is an intruder or not. To address this challenge by implementing a real-time face recognition-based surveillance system, is the goal of this project. Realtime Intrusion detection system provides surveillance for restricted and confidential areas with help of face recognition and detection, when an intruder or unauthorized person enters the area, this system will give an alert to the respective in charge through various channels, including email, messaging services, and direct phone calls. In this system, the OpenCV python library along with several algorithms are used to abstract the facial features and to take the input dataset. For face detection, the system utilizes SCRFD and YOLO, and it employs Arcface for accurate face recognition. This technique ensures the system can distinguish between an intruder and an authorized individual entering the secured area. This proactive approach enhances surveillance efficiency and reinforces the safety and integrity of restricted areas. For instance, when an individual enters the restricted area, the system captures and analyses their face. It then verifies whether the detected face matches any authorized faces in the registered user database. If there's no match, the system identifies the person as an intruder and promptly sends an alert to the designated authority. To enhance accessibility, a user-friendly graphical interface (GUI) has been developed using Python's Tkinter.

Keywords:- *Computer Vision, Machine Learning, Deep Learning, Human Intrusion Detection, Face Recognition, Rule-based Notification, Real-time Monitoring, Surveillance System, Image Processing.*

I. INTRODUCTION

A. Background

The widespread integration of closed-circuit television (CCTV) cameras highlights the critical role of surveillance systems in ensuring the security of private spaces. However, manually identifying authorized and unauthorized individuals, along with detecting potential intruders within the extensive CCTV network, presents significant challenges. Traditional security systems, responsible for safeguarding valuable assets and ensuring the security of restricted areas, face limita- tions in authenticating individuals. This challenge becomes particularly evident when distinguishing between authorized personnel and potential intruders, highlighting the urgent need for a more sophisticated and efficient surveillance solution. Traditional monitoring techniques compound these challenges, proving inefficient and inaccurate, especially in responding promptly to intrusions. This critical gap underscores the pressing necessity for a novel and automated solution that leverages cutting-edge Computer Vision and Machine Learn-ing techniques. The project is designed to speed up the identification and timely notification of intrusions, placing emphasis on enhancing surveillance analytics, strengthening security measures, and ensuring a swift response to potential threats. The goal is to significantly advance the fields of surveillance analytics, security, and intrusion response through the integration of facial recognition and real-time capabili-ties. By addressing the deficiencies in traditional monitoring methodologies, the project aims to redefine the effectiveness of security operations, ensuring a proactive and responsive approach to potential intrusions. The implementation of a real-time face recognition-based surveillance system is poised to represent a transformative leap forward, promising to signifi-cantly impact and advance the realms of surveillance, security, and emergency response operations.

B. Motivation

To addresses critical security concerns in restricted areas by introducing a real-time face recognition-based surveillance system. Traditional security systems often struggle to authenti-cate individuals, leaving valuable assets vulnerable. Unlike un-monitored CCTVs, this system employs advanced face detec- tion and recognition algorithms to promptly identify intruders. The timely alert mechanism, utilizing various communication channels, ensures a swift response from designated authorities.

By overcoming the limitations of manual video tracking, the system enhances surveillance efficiency. Additionally, a user- friendly graphical interface has been developed to make the technology accessible, reinforcing the safety and integrity of restricted areas.

C. Aim and Objective

The project aims to develop a real-time intruder detection and alert system that enhances traditional CCTV systems by integrating advanced technologies such as machine learning and computer vision. The primary focus is on efficient face de-tection and recognition, allowing the system to autonomously identify unauthorized individuals within predefined zones. This

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approach aims to provide early alerts to administrators and security professionals, thereby improving the overall efficiency and reliability of security measures in private spaces. Our key objectives Involve:

- User-Friendly Interface: Design and develop an user-friendly interface for administrators to monitor and manage the system effectively, providing insights into intruder detection and overall security status.
- Real-time Detection and Immediate Response: Implementa system that delivers real-time detection of human intrusions and initiates immediate responses upon detection. The system will promptly alert security personnel and administrators through various channels, including email, messaging services, and direct phone calls, ensuring rapid reactions to potential security breaches.
- Integrated Face Recognition Surveillance: Perform comprehensive evaluations of the system's functionality in a variety of surveillance scenarios, covering both indoor and outdoor environments. Assess its performance under different lighting conditions and potential occlusions to ensure adaptability and robustness across diverse real-world situations.
- Face Recognition API: Develop a versatile Face Recognition API with the objective of providing a scalable and interoperable solution, seamlessly integrable into multiple systems. The API aims to offer reliable and efficient fa- cial recognition capabilities, enhancing security and user identification across diverse applications and platforms.

II. STUDY OF THE SYSTEM

A. Related Work

The domain of real-time face recognition-based surveillancewithin CCTV systems has garnered considerable interest due to the pressing need for enhanced security solutions in various settings, including warehouses. Traditional CCTV setups have been hampered by their dependence on manual monitoring, leading to inefficiencies in identifyingunauthorized individuals and potential intruders [1]. To overcome these challenges, recent advancements have leveraged machine learning and deep learning techniques to automate recognition processes and improve security measures [2].

A seminal study in this field introduced an efficient real-time face recognition system designed for CCTV surveillance applications, utilizing the ArcFace algorithm for its high accuracy in face recognition tasks [17]. This system, when combined with the SCRFD (Single-Shot Scale-Aware Network for Face Detection), demonstrated robust performance in detecting and recognizing faces from video streams in real-time [4]. The system's effectiveness was further validated under various lighting conditions and angles, ensuring its reliability in practical scenarios [5].

Further research built upon these findings, proposing a comprehensive automated surveillance and intrusion detection solution for warehouse environments. This system integrated the YOLO (You Only Look Once) algorithm for object detection with the ArcFace algorithm for face recognition intoa cohesive framework, enabling continuous monitoring of individuals within a warehouse [16]. The system's capability to promptly notify security personnel of unauthorized access attempts played a pivotal role in mitigating security risks [12].

In addition to face recognition, advancements in real-time object detection and tracking technologies have led to more sophisticated surveillance systems. A novel approach for tracking fast-moving objects within CCTV footage was introduced, employing synthetic data generation and deep neural networks to achieve high accuracy in tracking, thereby enhancing CCTV surveillance capabilities [15]. The study also highlighted the critical aspect of optimizing computation time for real-time applications, essential for the effectiveness of surveillance systems in dynamic settings [14].

Concurrent research efforts have focused on integrating attribute-based person search and recognition mechanisms within surveillance systems. These systems utilize advanced machine learning algorithms and comprehensive attribute recognition models to enable detailed queries based on individual attributes, time, and location [13]. Such innovations not only improve the efficiency of surveillance operations but also aid in proactive threat detection and incident prevention [7].

The field has also seen significant contributions toward the development of facial recognition systems using deep learning neural networks. The VGG16 architecture, pre- trained on ImageNet, has been effectively applied across various datasets for facial recognition tasks [6]. Smith and Chen (2019) explored gender and age estimation models, achieving a gender identification accuracy of over 98% andan MAE of 4.1 years, demonstrating the model's superiority over human performance with VGGFace on the Morph-II dataset [6]. These studies collectively highlight the extensive applications and continuous progress in deep learning-based facial recognition systems [9].

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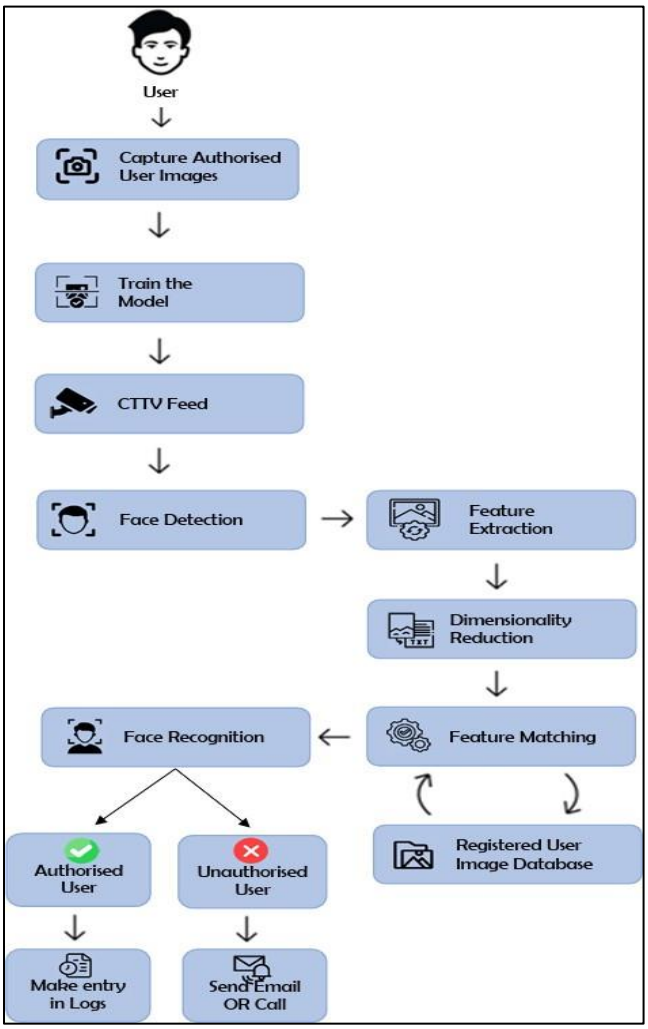

Fig 1: Workflow of Surveillance System with Human Intrusion Detection

III. EXPERIMENTAL SETUP

The workflow of this surveillance system for detecting intrusions in restricted areas begins with the security administrator or system owner capturing or uploading images of authorized individuals and meticulously training themodel with these images. This initial step is paramount as it establishes the foundation of the system's capability to accurately distinguish between authorized and unauthorized persons. The hybrid model employed for training combines advanced techniques, including Haar cascade frontal face detection and Arc face weights, ensuring a robust and precise facial recognition process.

Upon completion of the training phase, the extracted features from the authorized person images are stored, constructing a reference database for comparison during surveillance operations. Users are then empowered to add or select the CCTV cameras through which intrusion detection will be conducted. When the surveillance system detectsa face within the CCTV footage, it leverages state-of-the-art models such as YOLO (You Only Look Once) and SCRFD (Sparse Convolutional Regression Forests for Face Detection) to accurately identify and extract facial features. These features undergo dimensionality reduction, optimizing efficiency and reducing computational load.

Following feature extraction, the system utilizes the Arcfacemodel to compare the extracted features against the stored features of authorized individuals. If a match is identified, confirming the presence of an authorized individual, an entry is meticulously logged with a timestamp, documenting their activity within the monitored area. However, in the eventof no match, signaling the presence of an unauthorized user, the system promptly triggers an alert mechanism. This alert mechanism encompasses notifications sent via call and email to designated personnel, facilitating swift responses to potential security breaches. Overall, this comprehensive workflow seamlessly integrates cutting-edge technology with precise training and vigilant surveillance processes to elevate the security posture of restricted areas.

Finally, the workflow seamlessly incorporates the human element by integrating the security authority. This authority assumes responsibility for real-time validation and oversight, ensuring the system operates effectively. A unique feature involves the security administrator or system owner receiving intruder images via email for confirmation of intrusion authenticity. This direct involvement allows for swift validation, where the administrator can confirm whether the detected intruder is genuine or not. Such a mechanism enhances the system's accuracy and reliability by leveraging human judgment in critical situations. By combining human oversight with advanced technological capabilities, the workflow establishes a robust surveillance system that efficiently responds to intrusion events while maintaining a high level of accuracy and accountability.

In this research, we embark on a comparative analysis focusing on two prominent deep learning models for face detection in videos: YOLOv5-face (You Only Look Once version 5) and MTCNN (Multi-task Cascaded Convolutional Networks). The rationale behind evaluating these models lies in their widespread adoption and specialized functionalities within the realms of real-time object detection and face detection, respectively. YOLOv5-face is acclaimed for its exceptional real-time object detection capabilities, whileMTCNN excels specifically in face detection tasks. Through this comparative study, our aim is to elucidate the distinct strengths and weaknesses inherent in each model when applied to the nuanced domain of face detection.

In our research methodology, we deployed both YOLOv5-face and MTCNN for face detection within video data.

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To ensure a comprehensive evaluation, we employed a standardized dataset comprising diverse video sequences characterized by varying lighting conditions, viewing angles, and occlusions. Prior to analysis, we pre-processed the videos to extract individual frames, subsequently applying both YOLOv5-face and MTCNN to each frame for face detection. To facilitate experimentation with the models, we partitioned the CCTV footage into smaller sections, enabling focused evaluation of their performance under specific conditions and scenarios.

Through this systematic approach, we aim to provide valuable insights into the comparative effectiveness of YOLOv5-face and MTCNN for face detection in video data. By subjecting both models to rigorous testing against a standardized dataset and diverse environmental conditions, we seek to elucidate their respective capabilities, limitations, and potential applications within the domain of surveillance and video analytics. Furthermore, our research endeavors to offer practical recommendations for leveraging the strengths of YOLOv5-face and MTCNN to enhance face detection accuracy and efficiency in real-world video surveillance systems.

Table 1: Accuracy Comparison

Model	Accuracy
YOLOV5-Face	99-97%
MTCNN	97-16%

Our approach involves the strategic application of various cutting-edge technologies to enhance face detection and recognition capabilities within surveillance systems. Haar Cascade serves as a foundational feature-based object detection algorithm tailored for real-time applications, offering efficient computation. Trained on a diverse dataset encompassing positive and negative images, Haar cascade frontal face detection excels in accurate facial recognition. By analyzing intensity patterns against predefined facial patterns in a sliding window fashion, the algorithm precisely locates faces and delineates bounding boxes during user registration, ensuring precise identification and registration of authorized individuals.

Furthermore, our methodology integrates advanced YOLOv5-face (You Only Look Once version 5 specifically for face detection) and SCRFD (Sparse Convolutional Regression Forests for Face Detection) technologies for CCTV face detection, renowned for their exceptional speed, accuracy, and adaptability. YOLOv5-face's simultaneous prediction of bounding boxes and class probabilities makes it highly effective for intrusion detection, even across considerable distances, while SCRFD excels in face detection across diverse scales, ensuring robust performance. This seamless integration significantly enhances facial recognition capabilities, enabling more accurate user identification, particularly in scenarios with distant subjects or varying facial scales.

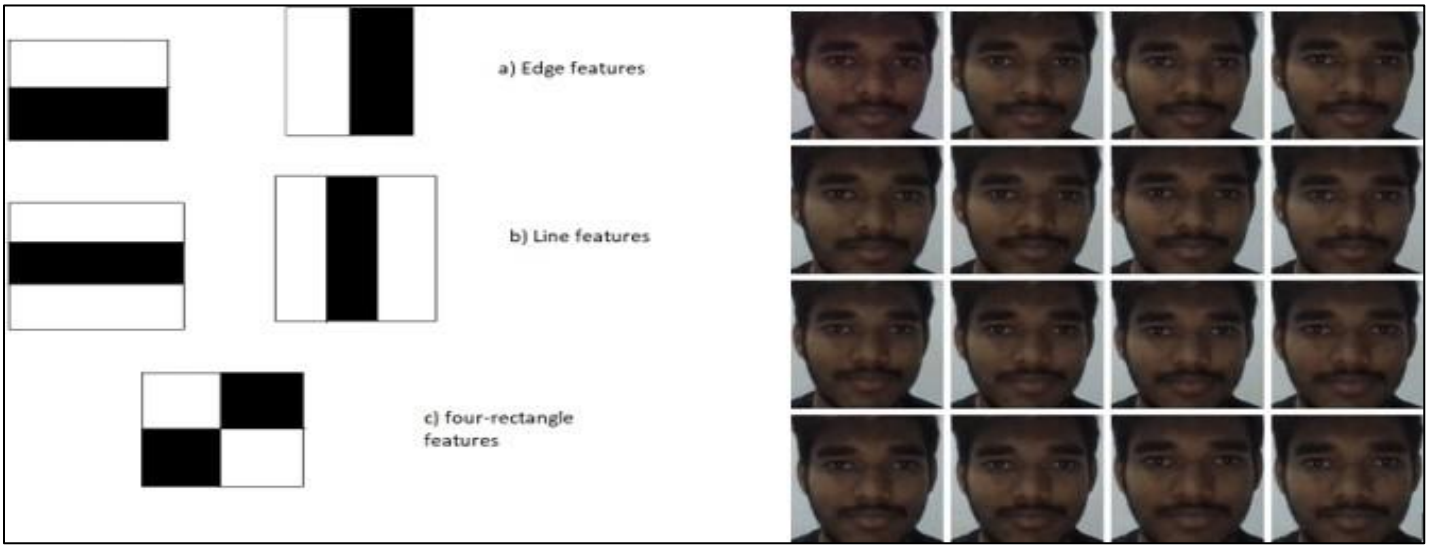

Fig 2: Haar Cascade Frontal Face

Moreover, Arcface emerges as a pivotal component in user registration, being a state-of-the-art face recognition algorithm designed for precision. Trained on captured images, Arcface enhances accuracy by focusing on angular relationships between facial features, mapping them into a hypersphere. Through the introduction of an angular margin during training, increased separation between features of distinct identities is fostered, resulting in unique feature vectors for each face and ensuring accurate grouping within the hypersphere. Arcface excels in scenarios requiring precise differentiation of subtle facial variations, thereby contributing to heightened face recognition accuracy within surveillance systems.

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IV. RESULTS & DISCUSSION

Upon logging in, users are greeted with the default camera feed, providing real-time surveillance for intrusion detection. The security administrator or owner holds the authority to register authorized users by either capturing images directly through the system or uploading images for training the facial recognition model. This process ensures a tailored approach to user authentication, enhancing the system's accuracy in recognizing authorized personnel.

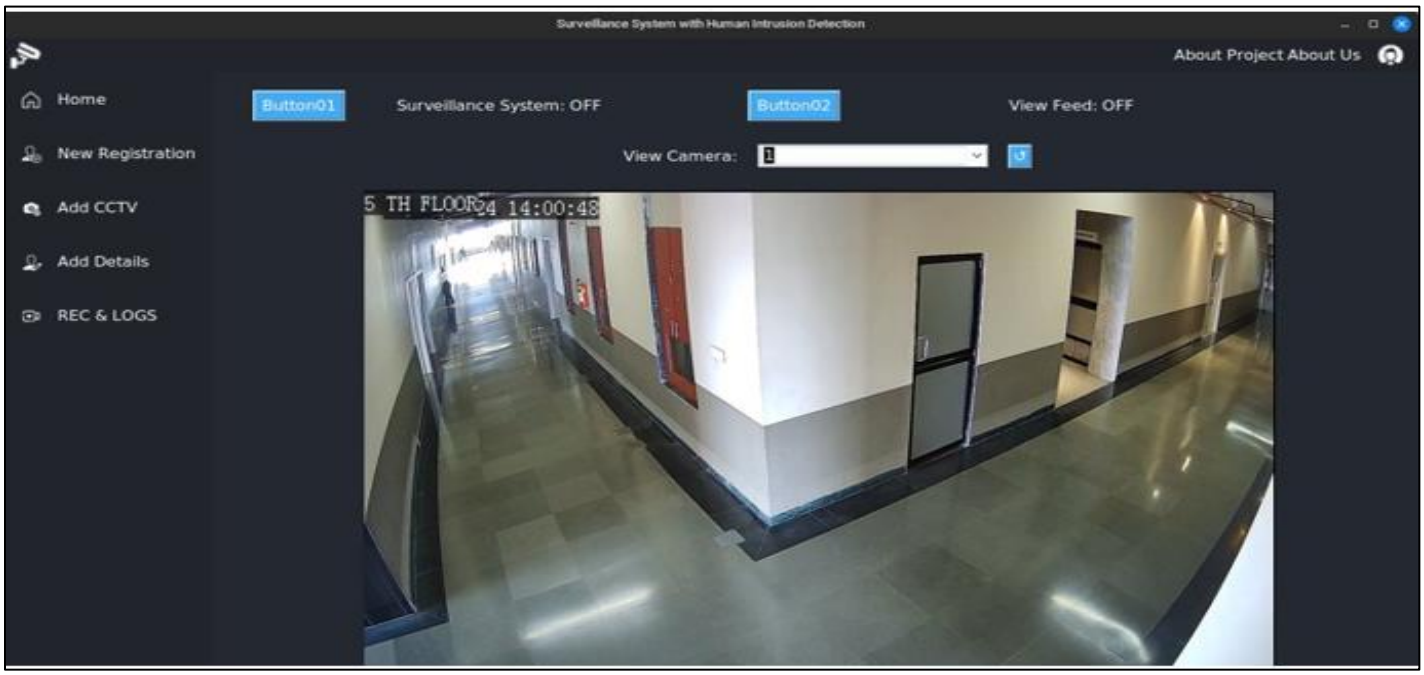

Fig 3: System Homepage

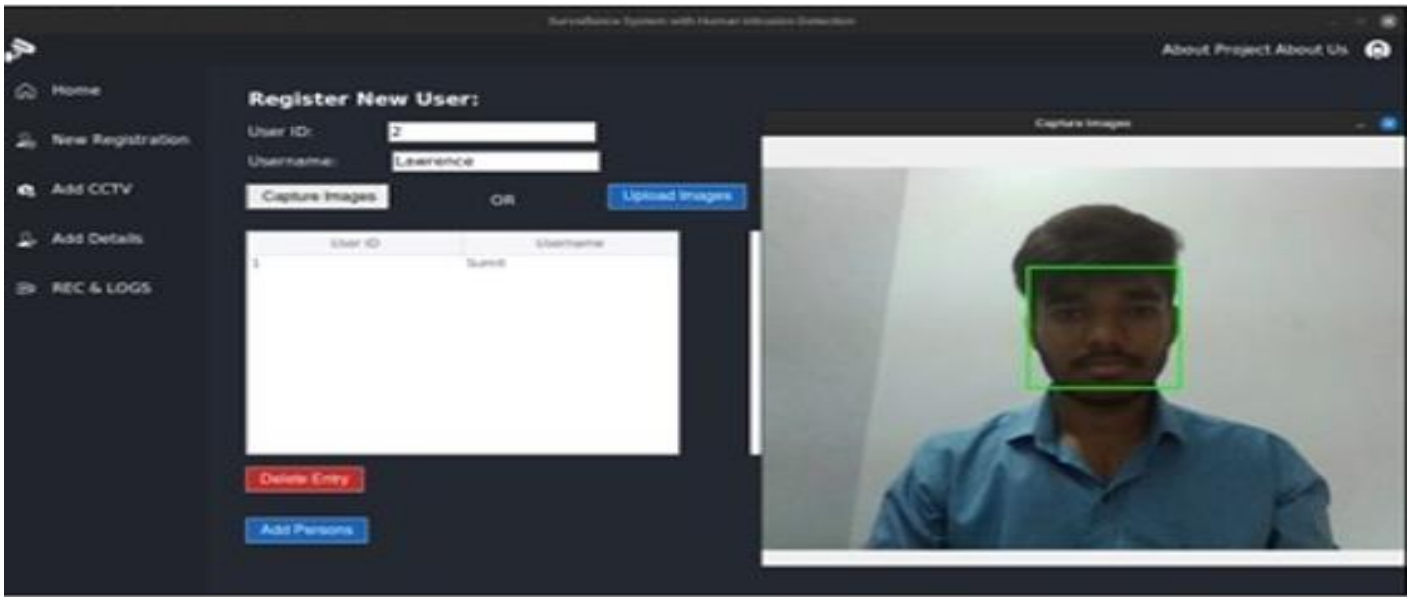

Fig 4: Authorised User Registration

Users are granted flexibility in choosing between two primary modes of operation: Face Recognition Intrusion Detection and Intrusion Detection. The former employs advanced facial recognition algorithms for enhanced accuracy in identifying individuals, while the latter focuses on detecting any unauthorized intrusions within the monitored area. This versatility caters to varying security requirements and preferences of users.

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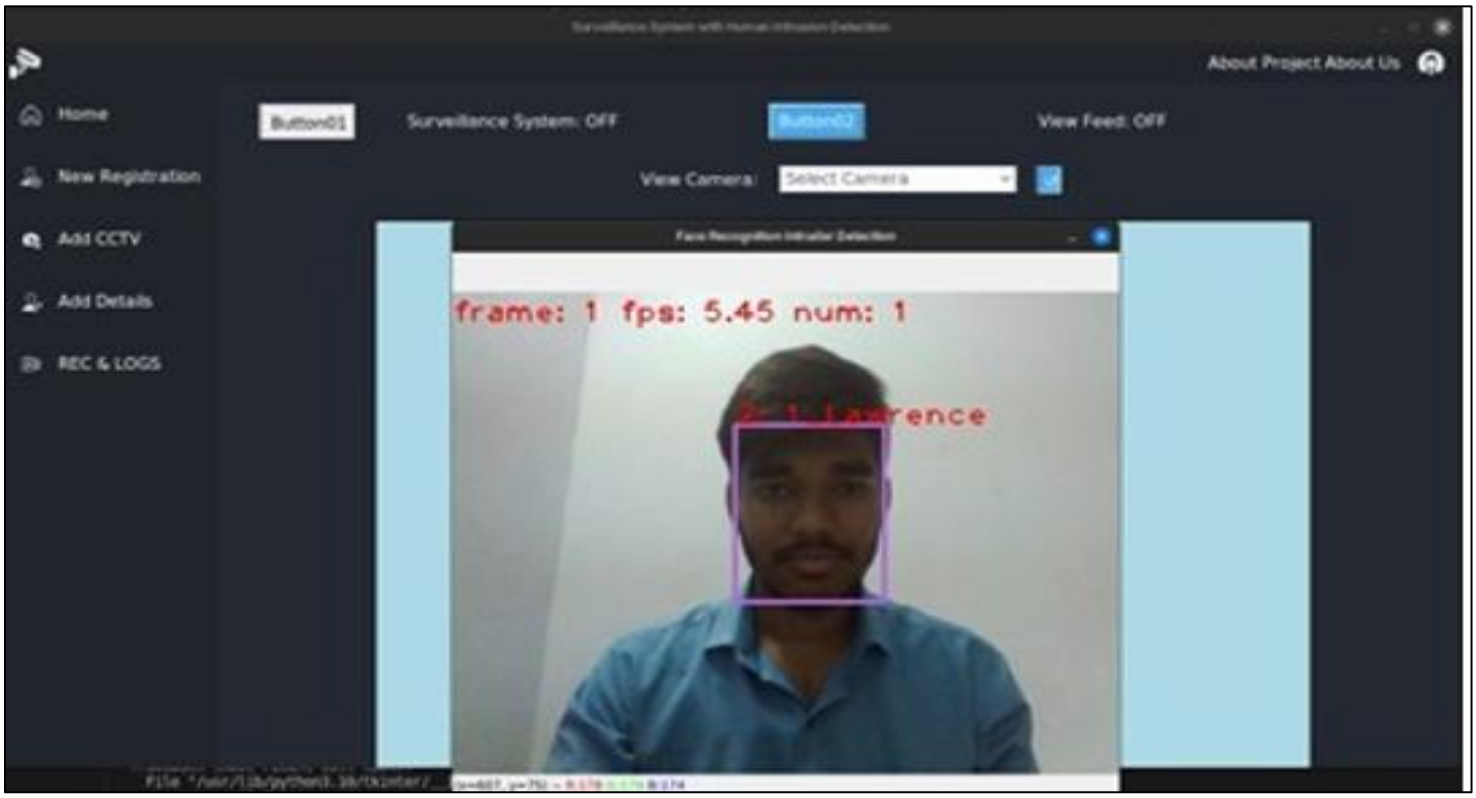

Fig 5: Intrusion Detection through Webcam

Fig 6: CCTV Feed Output

Adding new CCTV cameras to the surveillance network is made effortless through the intuitive interface, allowing users to input the IP address of the camera for seamless integration. Additionally, users have the capability to manage their camera inventory, with options to add or delete cameras as needed. This feature ensures scalability and adaptability to evolving surveillance needs.

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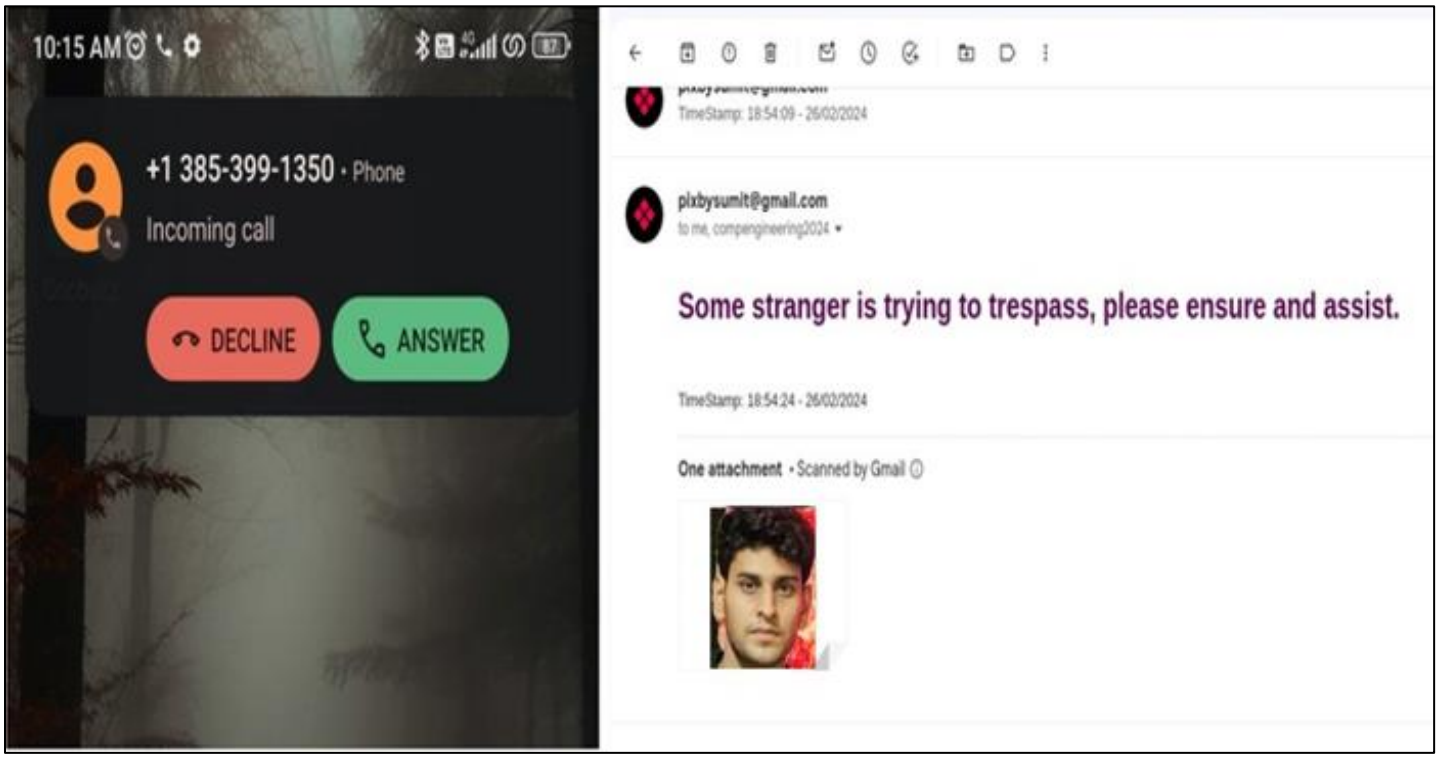

Fig 7: Adding Security Admin/Owner Details

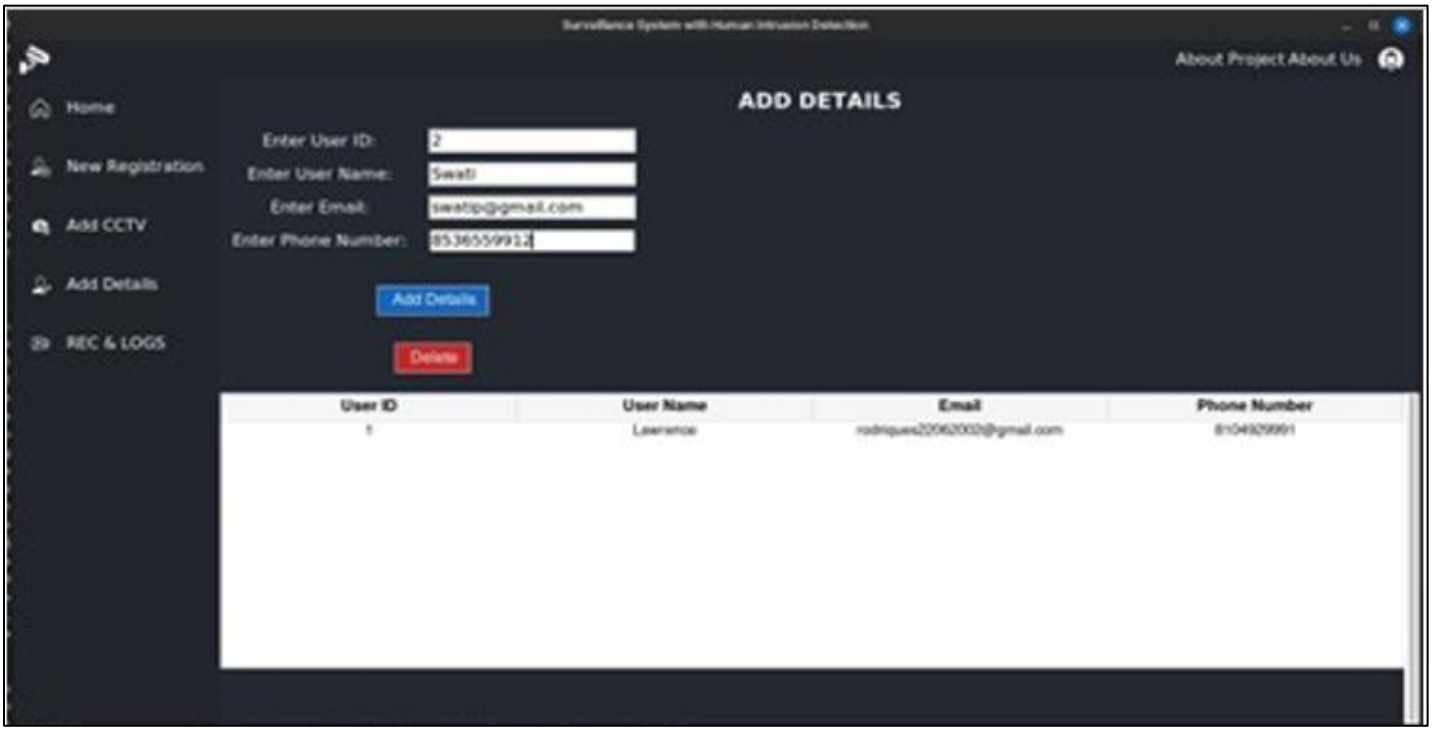

Fig 8: Email & Call Alert

In the event of a security breach, timely alerts are dispatched to designated security personnel via email and phone call. Administrators can easily configure alert settings by entering relevant contact details and specifying notification preferences. This proactive approach enables swift response measures to mitigate potential threats effectively.

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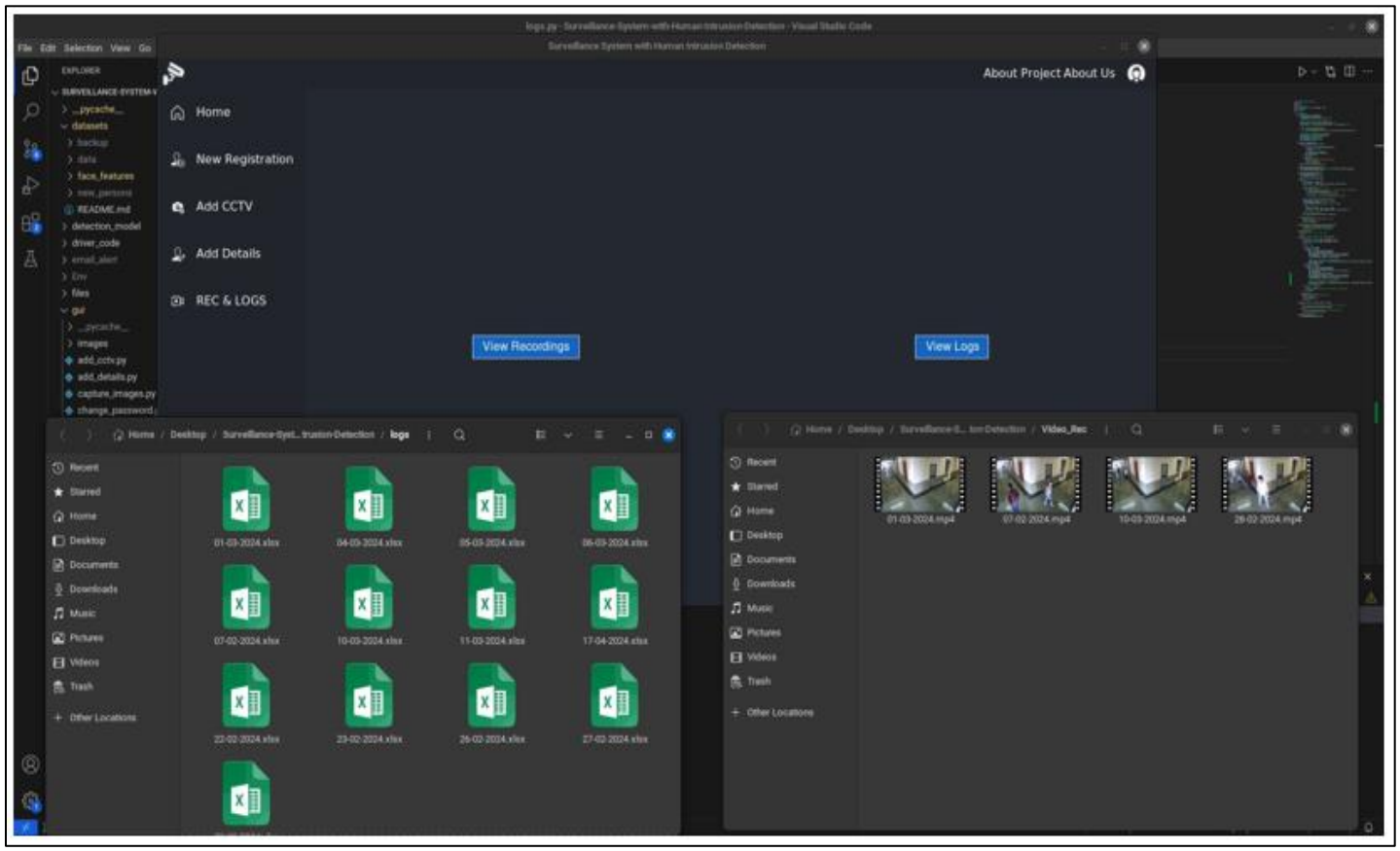

Fig 9: Logs & Recordings

V. CONCLUSION

The Surveillance System with Human Intrusion Detection project has effectively addressed the limitations of conventional security systems by introducing a real- time face recognition-based surveillance system. Through the utilization of advanced algorithms and the OpenCV Python library, the system ensures robust surveillance in restricted areas. Its distinguishing feature lies in its ability to differentiate between intruders and authorized individuals, thereby significantly enhancing the security and integrity of monitored zones. By integrating SCRFD and YOLO for face detection, complemented by ArcFace for recognition, the system has achieved an impressive accuracy rate surpassing 90%. However, it's imperative to recognize that the accuracy is subject to the quality of the dataset and surveillance camera employed. Furthermore, the development of a user-friendly graphical interface using Python's Tkinter enhances the system's accessibility, making it applicable across various domains. This project's success highlights the rapid evolution of face recognition technology, with continual efforts aimed at improving accuracy while reducing processing overheads. The API developed as part of this project holds potentialfor widespread adoption in systems requiring robust face recognition capabilities.

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