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Safe Hostel: A Smart Security System for Girls Hostel Using AI and IoT

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ABSTRACT

Traditional hostel security systems are predominantly manual, reactive, and prone to errors, making it difficult to ensure reliable safety and prevent unauthorized access. To overcome these limitations, this paper presents "Safe Hostel," an intelligent AloT-based security system designed for real-time monitoring and automated decision-making in hostel environments. The proposed system employs a dual-layer architecture consisting of' an loT-based sensing layer for motion detection and data acquisition, and an AI-based processing layer for face recognition and activity classification. The system integrates Raspberry Pi 4B, ESP32, ESP32-CAM module, Raspberry Pi Camera, USB Microphone, and a 32GB SD card for efficient surveillance, communication, and secure data storage. The ESP32 module manages device coordination and wireless communication, while the Raspberry Pi 4B performs real-time face recognition and activity classification using MediaPipe and dlib libraries. The system generates 128-dimensional facial embeddings for accurate identity verification and classifies activities into five categories: Authorized Person, Unauthorized Person, Suspicious Activity, Normal Activity, and Emergency Situation. Experimental results demonstrate an overall accuracy of' 94%, with high precision and recall for authorized user detection. The proposed system is cost-effective, scalable, and suitable for real-time edge-based deployment in smart hostel security applications.

I. INTRODUCTION

Security in hostel environments, particularly in girls' hostels, has become a significant concern due to increasing incidents of unauthorized access and safety threats. Ensuring resident safety requires continuous monitoring, accurate identity verification, and immediate response mechanisms. However, conventional security methods such as manual attendance registers and ID card verification are still widely used, which are inefficient, time-consuming, and vulnerable to manipulation. Moreover, traditional hostel security systems are largely manual and reactive, relying heavily on human supervision, which increases the likelihood of errors, delays, and security breaches. Existing systems also lack real-time surveillance, intelligent decision-making, automated alert generation, and activity classification capabilities, and do not effectively utilize modern technologies such as A1tificial Intelligence **(Al),** Inter-net of Things (IoT), edge computing, and smart surveillance devices, thereby limiting their effectiveness. To address these limitations, this paper proposes "Safe Hostel," an intelligent AloT-based security system designed for real-time monitoring and access control in hostel environments, employing a dual-layer architecture consisting of an IoT-based sensing layer for data acquisition and an AI-based processing layer for face recognition and activity classification. The system integrates RaspbeITy Pi 4B, ESP32, ESP32-CAM module, Raspberry Pi Camera, USB Microphone, and a 32GB SD Card to enable efficient surveillance, communication, and secure data storage. The ESP32 module handles device coordination and wireless communication, while the Raspberry Pi 4B performs AI-based face recognition and activity classification using MediaPipe, OpenCV, and dlib libraries, generating 128-dimensional facial embeddings for accurate identity verification and classifying activities into five categories: Authorized Person, Unauthorized Person, Suspicious Activity, Normal Activity, and Emergency Situation. The proposed system enables real-time monitoring, intelligent surveillance, and automated alert generation, thereby improving hostel security, with experimental results demonstrating high accuracy and reliability suitable for cost-effective and energy-efficient deployment in smart hostel environments.

A. Major Contributions

The major contributions of the proposed "Safe Hostel" system include the development of an AloT-based smart hostel security framework integrating Raspberry Pi 4B, ESP32, ESP32-CAM module, Raspberry Pi Camera, USB Microphone, and Artificial Intelligence techniques for real-time surveillance and monitoring. The system employs a dual-layer architecture combining IoT-based sensing and communication with AI-driven face recognition and activity classification for intelligent access control. MediaPipe and dlib libraries are used for efficient face detection and 128-dimensional facial embedding extraction, enabling accurate classification of Auth01ized Person, Unauthorized Person, Suspicious Activity, Normal Activity, and Emergency Situation. Furthermore, the proposed framework supports real-time alert generation, automated event logging, intelligent monitoring, and rapid response during suspicious or emergency situations. The system is designed as a low-cost, energy-efficient, and edge-computing-based solution suitable for practical hostel security applications.

II. RELATED WORK

Recent advancements in smart security systems have emphasized the integration of A11ificial Intelligence (Al) and Internet of Things (IoT) technologies to enhance surveillance, monitoring, and access control capabilities. IoT-based systems enable real-time data collection using smart sensors and camera modules, while AI techniques improve intelligent decision-making through face recognition and behavioral analysis. Several research studies have explored different aspects of intelligent security systems. The deep learning-based intrusion detection approach presented in [1] improves cybersecurity analysis; however, it does not focus on real-time physical surveillance applications. Similarly, the survey on IoT-aided smart systems discussed in [2] highlights major security challenges but lacks practical implementation for real-time intelligent monitoring. An IoT-based video surveillance framework proposed in [3] enables continuous monitoring, although it does not incorporate advanced AI-based activity classification techniques. Furthermore, the microservices-based IoT security framework described in [4] improves scalability and system management but does not address visual recognition and intelligent surveillance tasks. Deep learning-based security applications discussed in [5] achieve high detection accuracy; however, they require significant computational resources and are not optimized for lightweight real-time deployment on embedded platforms such as Raspberry P i 4B and ESP32. In many existing systems, face recognition is implemented using the dlib library integrated with OpenCV, generating 128-dimensional facial embeddings for accurate identity verification, while MediaPipe is widely used for efficient real-time face detection. Modern surveillance frameworks also employ ESP32-CAM modules, Raspberry Pi Cameras, USB micro-phones, and SD card-based storage for edge-based monitoring and secure data management. From the literature analysis, it is observed that most existing systems focus either on IoT-based monitoring or Al-based recognition independently, with limited integration of Raspberry Pi 4B, ESP32, ESP32-CAM, and Al-based multi-class activity classification within a unified framework. Moreover, many existing approaches lack real-time alert mechanisms, intelligent event analysis, and hostel-specific monitoring features. Therefore, there is a strong need for an integrated, scalable, low-cost, and intelligent hostel security system capable of providing real-time surveillance, automated activity classification, and efficient access control.

TABLE I
COMPARISON OF EXISTrNG SYSTEMS AND RESEARCH GAP

Rer.	Existing Method	Limitation	Proposed System Contribution
[l]	CCTV-Based Surveillance	Lacks A I -based activity analysis	Provides AI-based activity classification
[2]	IoT Monitoring System	Docs not support face recognition	Integrates AJ-bascd face recognition
[3]	Traditional Face Recognition	High computational complexity	Uses lightweight real-time processing
[4]	IoT and AI Security System	No activity classification support	Enables muti-class activity detection

TABLE II
COMPARISON OF EXISTTNG AND PROPOSED SYSTEMS

Sysrem	AI-Based	IoT Support	Activity Detection
Existing System [1]	Supported	Not Supported	Basic Detection
Existing System [2"1	Not Supported	Supported	No Classification
Existing System [3]	Supported	Supported	Limited Classification
Proposed Safe Hostel System	Supported	Supported	Multi-Class Classification

III. SYSTEM ARCHITECTURE

The proposed "Safe Hostel" system adopts a dual-layer architecture for efficient and real-time hostel security monitoring. The first layer is an IoT-based sensing and communication module responsible for activity detection, system triggering, and data acquisition, while the second layer is an Al-based processing module responsible for face recognition and activity classification. The system integrates Raspberry Pi 4B, ESP32, ESP32-CAM module, Raspberry Pi Camera, USB Microphone, and a 32GB SD Card to enable intelligent surveillance, image capture, communication, and secure data storage_ The workflow is initiated when the ESP32 detects motion or activity and activates the ESP32-CAM and Rasp-berry Pi Camera for image acquisition. The captured data is transmitted to the Raspberry Pi 4B, where MediaPipe and dlib-based algorithms perform face detection, identity recognition, and facial embedding extraction. Based on the processed results, the system generates appropriate responses such as ale11 generation, unauthorized access detection, and event logging, ensuring real-time monitoring and enhanced security.

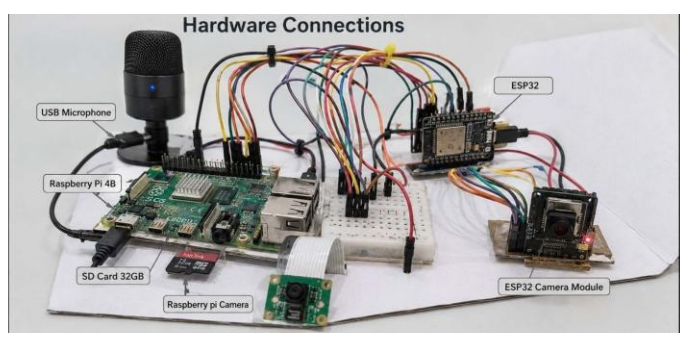

Fig. 1. Hardware Connection of Safe Hostel

A. Hardware Components

The proposed system employs lightweight, low-cost, and scalable hardware components to ensure reliable performance and efficient deployment in real-world environments. The Raspberry Pi 4B serves as the central edge-computing unit responsible for AI processing, face recognition, and system control. The ESP32 module provides IoT-based communication and device coordination, while the ESP32-CAM module and Raspberry Pi Camera are used for real-time image acquisition and surveillance. A USB Microphone is integrated to support audio monitoring and potential future enhancements such as voice-based authentication. Additionally, a 32GB SD Card is used for data storage, including captured images, datasets, system logs, and monitoring records, ensuring efficient and secure data management.

TABLE III
HARDWARE COMPONENTS USED IN THE PROPOSED SYSTEM

Component	Function
Raspberry Pi 4B	**Performs AI processing, face recognition, and system control.**
ESP32	Handles IoT communication and device coordination.
ESP32-CAM Module	Captures surveillance images and video streams.
Raspberry Pi Camera	Used for facial image acquisition.
USB Microphone	Supports audio monitoring and future voice-based authentication.
32GB SD Card	Stores datasets, logs, and captured surveillance data.

B. IoT Detection Layer

The IoT detection layer is responsible for real-time environmental monitoring and system activation. The ESP32 module continuously monitors the environment and triggers the ESP32-CAM module and Raspberry Pi Camera upon detecting motion or activity. The captured images are transmitted to the Raspberry Pi 4B for AI-based processing. This event-driven approach reduces unnecessary computation, improves energy efficiency, and ensures real-time responsiveness for hostel surveillance applications.

C. *Face Recognition Using AI*

The AI layer utilizes MediaPipe, OpenCV, and dlib libraries for face detection and recognition. MediaPipe is used for efficient real-time face detection, while dlib extracts 128-dimensional facial embeddings for identity verification. These embeddings are compared using similarity measures such as Euclidean distance or cosine similarity. Based on a predefined threshold, individuals are classified as Authorized or Unauthorized. All computations are performed on Raspberry Pi 4B to ensure lightweight, real-time, and accurate recognition suitable for edge deployment.

D. Alert Mechanism

The proposed system incorporates a real-time alert mechanism for handling security events. Upon detection of unauthorized access or suspicious activity, the system generates immediate alerts and logs event details with timestamps in the 32GB SD Card. These alerts are also transmitted to hostel administrators via the ESP32 communication module for timely response. Additionally, the USB Microphone enables future extension for emergency audio detection and voice-based alert systems, improving overall system reliability.

E. Dataset Description

The dataset consists of five classes: Authorized Person, Unauthorized Person, Suspicious Activity, Normal Activity, and Emergency Situation. Approximately 1000-1500 images were collected from 15-20 individuals under varying lighting conditions, angles, and distances to ensure robustness. Data was captured using Raspberry Pi Camera and ESP32-CAM modules in real hostel-like environments. The dataset was split into training and testing sets using an 80:20 ratio with balanced class distribution. All data, including images and logs, is securely stored in a 32GB SD Card for training, evaluation, and future analysis.

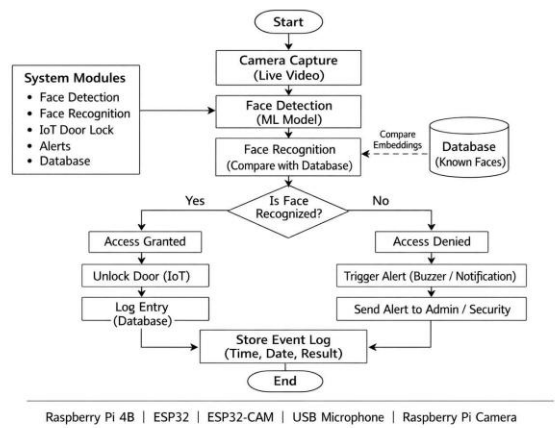

Fig. 2. System Workflow

IV. RESULTS AND DISCUSSION

The performance of the proposed "Safe Hostel" system is evaluated using standard classification metrics such as precision, recall, and Fl-score. The evaluation is conducted on a dataset consisting of five classes: Authorized Person, Unauthorized Person, Suspicious Activity, Normal Activity, and Emergency Situation. The experimental results demonstrate that the proposed AIoT-based framework achieves high accuracy and reliable real-time hostel security monitoring, making it suitable for practical deployment in secure and smart hostel environments.

The proposed system achieves an overall accuracy of approximately 94%, indicating efficient performance for real-time hostel surveillance applications. The Authorized Person class attains perfect precision and recall values of 1.00, demonstrating highly accurate face recognition and identity verification. Similarly, the Unauthorized Person and Normal Activity classes exhibit high classification performance, validating the effectiveness of the AI-based recognition framework

TABLE IV
PERFORMANCE EVALUATION METRICS OF THE PROPOSED SYSTEM

Class	Precision	Recall	Fl-Score	Support
Authorized Person	1.00	1.00	1.00	600
Unauthorized Person	0.97	0.95	0.96	300
Suspicious Activity	0.94	0.90	0.92	300
Normal Activity	1.00	0.93	0.96	450
Emergency Situation	0.91	0.82	0.86	200

implemented using MediaPipe and dlib. However, the Emergency Situation class records a comparatively lower recall value of 0.82 due to the limited number of training samples and the complexity of real-world environmental conditions. This limitation indicates that increasing dataset diversity and incorporating additional emergency scenarios can further improve the classification performance of this category, thereby enhancing overall system robustness.

A. System Response Time and Cost

The proposed "Safe Hostel" system achieves an average response time of approximately 1.2-1.8 seconds, including image acquisition, face detection, facial embedding generation, and activity classification, ensuring near real-time monitoring suitable for practical hostel security applications. The overall hardware cost is estimated to be approximately INR 12,000-18,000, including Raspberry Pi 4B, ESP32, ESP32-CAM module, Raspberry Pi Camera, USB Microphone, and 32GB SD Card. The use of lightweight edge-computing hard-ware makes the system cost-effective, scalable, and energy-efficient for real-world deployment, making it suitable for practical smart hostel security applications.

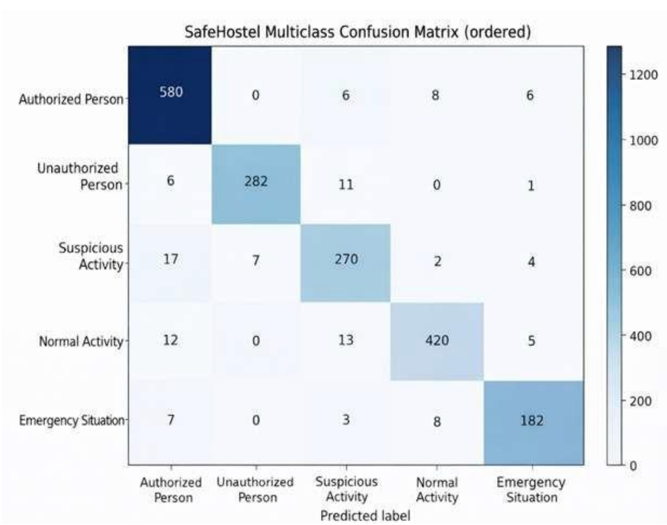

Fig. 3. Confusion Matrix for Five-Class Classification

The confusion matrix shown in Fig. 3 illustrates the classification performance across all five activity classes. Most predictions are concentrated along the diagonal elements, indicating connect classification results. Minor misclassification is observed between Suspicious Activity and Emergency Situation classes due to overlapping behavioral characteristics. The proposed system employs 128-dimensional facial embeddings generated using the dlib library for accurate distance-based face matching, thereby improving recognition consistency and overall system reliability.

B. Performance Graph

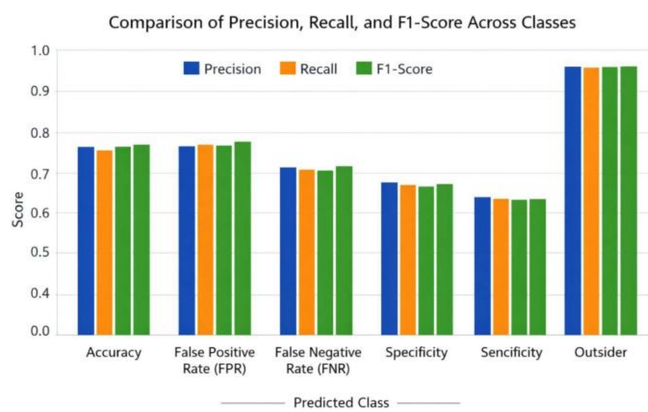

Fig. 4. Comparison of Precision, Recall, and Fl-Score Across Classes

Fig. 4 presents the performance comparison of precision, recall, and Fl-score across all activity classes. The graph shows consistently high values for most classes, while slightly lower performance is observed for the Emergency Situation class due to limited training samples and complex real-world conditions. Overall, the results confirm that the proposed "Safe Hostel" system achieves reliable and accurate performance for real-time hostel surveillance applications.

V. LIMITATIONS

The proposed "Safe Hostel" system has certain limitations that may affect its performance under specific environmental conditions. The accuracy of the face recognition module may decrease in low-light environments or when facial images are partially occluded. Similarly, variations in camera angle, facial orientation, and image quality can negatively impact recognition performance. The overall system pe1fornance is also dependent on the quality and diversity of the training dataset; insufficient or imbalanced training samples may reduce classification accuracy for unknown individuals and emergency situations. In addition, minor processing delays may occur when multiple faces are detected simultaneously. The system also relies on a continuous power supply and stable network connectivity for efficient monitoring and ale11 transmission, where any interruption may affect overall system reliability. Furthermore, since the system stores facial images and surveillance records in a 32GB SD card, data privacy and security remain critical considerations during real-world deployment.

VI. CONCLUSION AND FUTURE WORK

The proposed "Safe Hostel" system provides an intelligent and efficient security solution by integrating Internet of Things (loT) devices with Artificial Intelligence (Al) techniques for real-time monitoring and decision-making. The system effectively detects and classifies different activities within the hostel environment through a dual-layer architecture consisting of an IoT-based sensing layer and an AI-based recognition layer. Experimental results demonstrate the reliability and effectiveness of the proposed system, achieving an overall accuracy of 94% with perfect precision and recall for the Authorized Person class. Furthermore, the use of low-cost and energy-efficient hardware components such as the ESP32 microcontroller, ESP32-CAM module, Raspberry Pi 4B, Raspberry Pi Camera, and USB Microphone makes the system cost-effective, scalable, and suitable for practical deployment in hostel environments. The integrated real-time alert mechanism further enhances hostel security by enabling immediate response to unauthorized access and suspicious activities.

Future work may include the development of a mobile application for real-time monitoring and instant notifications, integration of cloud-based storage for secure data management and remote accessibility, and the implementation of advanced AI models with predictive analytics for improved detection of suspicious behavior. Further enhancements may also focus on improving recognition performance under challenging environmental conditions such as low illumination and occlusions, optimizing edge computing for reduced latency, and strengthening data privacy and security mechanisms. Overall, the proposed "Safe Hostel" system demonstrates significant potential to improve safety and security in hostel environments by providing a reliable, intelligent, and affordable monitoring solution.

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