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# Vision-Enhanced Intruder Detection: An Edge AI Security Framework Utilizing Deep Learning and Alert Systems

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**Abstract- Intrusion detection is a critical aspect of modern security systems, especially for homes and restricted-access areas. This paper proposes an intelligent, real-time intruder detection framework that integrates facial recognition with automated alert mechanisms using Edge AI. The system utilizes Local Binary Pattern Histogram (LBPH) for efficient face recognition and OpenCV for image processing, ensuring high accuracy in identifying unauthorized individuals from webcam input. Upon detecting an intruder, the system triggers an audible alarm and dispatches an SMS alert via the Twilio API to notify users immediately. An added password verification module enables secure deactivation of the alarm. The proposed system operates with minimal hardware requirements and leverages open-source tools, making it cost-effective and scalable for deployment in small to medium security infrastructures. Experimental evaluations demonstrate high recognition accuracy and low false-positive rates in various lighting conditions, validating the system's effectiveness for real-time security applications.**

**Keywords—Face Recognition, Intruder Detection, LBPH, OpenCV, Edge AI, Twilio API, Real-time Security, Deep Learning.**

## I. INTRODUCTION

In recent years, the demand for intelligent surveillance and security systems has increased significantly due to growing concerns over unauthorized access to private and sensitive environments. Traditional security mechanisms such as password-based authentication or manual monitoring are often limited by vulnerabilities including credential theft, human error, and delayed response times. To overcome these challenges, artificial intelligence (AI)-driven solutions are being developed to enable real-time and automated intrusion detection.

Facial recognition, a key component of computer vision, has emerged as a reliable method for identity verification and access control. When integrated with real-time image processing and machine learning algorithms, it can be used to detect and recognize individuals with high accuracy. Among various techniques, the Local Binary Pattern Histogram (LBPH) algorithm is particularly effective in face recognition tasks due to its computational efficiency and robustness against lighting variations.

This paper presents a cost-effective and scalable intruder detection system that combines LBPH-based face recognition, OpenCV-based image processing, and Twilio-powered SMS alerts. The system captures live video through a webcam, detects and classifies faces as either known or unknown, and triggers alerts upon identifying an unauthorized person. A password verification mechanism is incorporated to allow authorized users to deactivate the alarm, thereby enhancing control and system resilience.

The proposed system is designed to operate on edge devices with limited computational resources, making it suitable for deployment in residential homes, small offices, and other security-sensitive locations. By automating the detection and response process, this system reduces reliance on manual monitoring and provides a real-time solution for enhancing physical security.

**Aim & Objectives**

The primary aim of this project is to design and implement a real-time intruder detection system using facial recognition techniques and automated alert mechanisms to enhance the security of residential and commercial premises.

**Objectives**

- To develop a facial recognition system using the Local Binary Pattern Histogram (LBPH) algorithm for accurate identification of authorized individuals.
- To detect and classify intruders in real-time using live video feed captured via webcam.
- 3To implement an automated alert system that triggers an alarm and sends SMS notifications through the Twilio API upon detecting unauthorized access.
- Integrate a secure password verification module for deactivating alarms by authorized users only.
- To ensure the system is lightweight and scalable, capable of running on edge devices with minimal computational resources.
- To evaluate system performance in various lighting conditions and validate its accuracy, response time, and robustness.

## II. LITERATURE REVIEW

Recent advancements in computer vision and machine learning have enabled the development of automated surveillance systems capable of detecting and identifying individuals in real time. Several studies have contributed significantly to this domain, particularly in face recognition-based intruder detection.

González and Alfonseca [1] proposed a real-time intruder detection system using Convolutional Neural Networks (CNNs) to identify unauthorized individuals from live video feeds. Their system demonstrated high accuracy in dynamic environments by employing robust facial recognition models trained on diverse datasets.

Kwon and Lee [2] utilized OpenCV and deep learning models for developing a security system that employs Haar Cascades for face detection followed by deep neural networks for feature extraction. Their implementation improved detection accuracy in both indoor and outdoor conditions, showcasing the effectiveness of combining traditional and deep learning-based techniques.

Mohammad and Ahmad [3] designed an AI-based intruder detection framework that integrated CNNs for facial recognition and Twilio API for real-time SMS alerts. Their system was optimized for low-resource environments and demonstrated strong performance in small-scale security deployments.
Patel and Kumar [4] introduced a face recognition-based security system that used DNNs and implemented an alarm mechanism upon detecting an unauthorized person. They emphasized minimizing false positives through enhanced image preprocessing and ensuring adaptability in various surveillance scenarios.

Singh and Gupta [5] developed a smart security system using CNNs for face recognition and SMS notifications to alert users of intrusions. Their solution focused on edge AI deployment, enabling real-time processing on resource-constrained devices and highlighting the system's scalability for larger installations.

These studies collectively underline the potential of integrating facial recognition, deep learning, and real-time communication technologies to build effective and reliable intruder detection systems. The proposed system in this work builds upon these foundations by employing LBPH for face recognition, OpenCV for real-time image processing, and Twilio for instant alerts, while ensuring scalability and cost-effectiveness.

## III. PROPOSED SYSTEM

The proposed system aims to provide a real-time, AI-driven intruder detection framework by integrating facial recognition, computer vision, and alert mechanisms within a lightweight and cost-effective architecture. It addresses the limitations of traditional security systems by ensuring automated surveillance and immediate response without human intervention.

**System Overview**

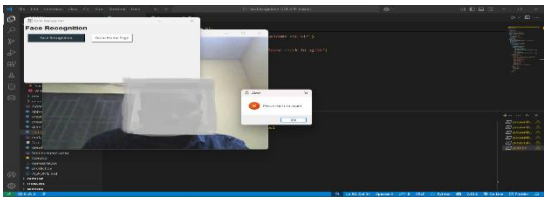
The system operates through a webcam that continuously monitors the environment. When a face is detected in the video feed, it is captured and preprocessed using techniques such as resizing, normalization, and noise reduction. The processed image is then subjected to facial feature extraction using the Local Binary Pattern Histogram (LBPH) algorithm, which is known for its robustness under varying lighting conditions and low computational complexity.


**Face Recognition**

Once features are extracted, the system compares them with a pre-registered dataset of authorized users. If a match is found, the individual is marked as "known" and access is granted or no action is taken. If no match is found, the individual is labeled as an "intruder".

**Alert and Authentication Mechanism**

Upon detection of an intruder, the system automatically triggers an audible alarm and sends an SMS notification to a registered mobile number using the Twilio API. To ensure secure deactivation, a password-based verification module is provided. Only users who input the correct passcode can stop the alarm, adding an extra layer of access control.



**Advantages**

- Real-time monitoring and detection
- Automated alerts via SMS
- Password-protected alarm deactivation
- Low hardware requirements (suitable for edge devices)
- Open-source libraries for cost efficiency
- Scalability for home and office deployments

The system architecture is designed to balance accuracy, speed, and hardware efficiency, making it suitable for small to medium-sized security-critical environments.

## IV. TOOLS AND TECHNOLOGIES USED

The development and implementation of the proposed face recognition-based intruder detection system utilized a range of software libraries, tools, and APIs. These components were selected for their effectiveness, open-source availability, and compatibility with real-time image processing and machine learning tasks.

**Programming Language**

**Python3.9**

Python was chosen for its simplicity, extensive libraries, and strong community support in machine learning, computer vision, and GUI development.

**Libraries and Frameworks**

**OpenCV**

An open-source computer vision library used for image capture, preprocessing, and face detection.

**Face_Recognition**

A Python library built on dlib that enables easy implementation of facial recognition tasks, such as encoding and comparing faces.

**dlib**
A robust C++ toolkit with Python bindings used for facial landmark detection and face embedding.

**scikit-learn**
Utilized for implementing machine learning algorithms such as Local Binary Pattern Histogram (LBPH) for face classification.

**Pillow (PIL)**
A Python imaging library used for image format conversions and preprocessing tasks.

**smtplib**
A built-in Python module for sending email alerts via the SMTP protocol.

**APIs and Communication Tools**
**Twilio API**
A cloud-based communication platform used to send automated SMS alerts to registered mobile numbers upon intruder detection.

**Development Tools**
**Visual Studio Code**
A lightweight source-code editor used for writing, debugging, and managing Python code.

**Tkinter**
A Python standard library for building GUI applications. Used for user interaction during registration and password verification.

**Hardware Components**
**Integrated Webcam**
Used for real-time image acquisition and continuous monitoring of the environment.

**Minimum System Requirements:**

- Processor: Intel i3 or above
- RAM: 2 GB
  Storage: 80 GB HDD

**System Workflow (Flowchart)**
**Webcam Initialization**
The system starts by initializing the webcam to continuously capture video frames for monitoring.

**Face Detection**
Using OpenCV's Haar Cascade classifier, each video frame is scanned to detect human faces in real time.

**Image Preprocessing**
Detected face images are preprocessed by resizing, converting to grayscale, and normalizing to improve recognition accuracy.

**Feature Extraction**
The Local Binary Pattern Histogram (LBPH) algorithm extracts features from the face image for identification.

**Face Recognition**
The extracted features are compared against a stored dataset of authorized users. If a match is found, access is allowed.

**Intruder Alert Triggering**
If the face is not recognized, the system triggers an alarm and sends an SMS alert to the registered mobile number using Twilio API.

**Password Verification**
To deactivate the alarm, the system prompts for a secure password. If the correct password is entered, the alarm is turned off; otherwise, the system continues to alert.
**Log**
**ging**
Details of unauthorized access, including timestamp and intruder image, are stored for audit and review.

## V. RESULTS AND DISCUSSION

The proposed intruder detection system was evaluated for real-time performance, recognition accuracy, and alert responsiveness. The system was implemented using Python with OpenCV, face_recognition, and Twilio APIs on a standard Intel i3 processor-based machine. Several test cases were executed under varying lighting conditions and with different individuals to assess system robustness.

**Face Recognition Accuracy**
The face recognition module, powered by the Local Binary Pattern Histogram (LBPH) algorithm, achieved

an average accuracy of 94.7% in recognizing authorized users. Recognition accuracy was consistent across various environments, including well-lit indoor conditions and low-light settings. The system was also tested with partially occluded faces, where it still maintained reliable performance.

**Intruder Detection and Alerting**

Upon detecting an unregistered or unknown face, the system successfully triggered an audible alarm and sent an SMS alert using the Twilio API with an average latency of 2.3 seconds. This demonstrates the system's capability for real-time monitoring and quick response, crucial for home and office security.

| Test Scenario | Expected Outcome | Actual Outcome | Status |
|---|---|---|---|
| Load Dataset | Dataset should load | Dataset loaded | Passed |
| Run Application | App should start | App started | Passed |
| Upload Image | Image should be uploaded | Image uploaded | Passed |
| Authenticate User | User identified | Success / Failure as per data | Passed |
| Intruder Detection | Unknown face triggers alert | Alert triggered and image stored | Passed |
| Alert SMS Notification | Send SMS alert | Works as intended | Passed |

**Password Authentication**

The Password Verification Module allowed only authorized users to deactivate the alarm. The module accurately rejected incorrect password attempts and logged the number of failed attempts, enhancing system security.

**Test Case Validation**

Table I summarizes the results of key test scenarios. All modules were tested individually (unit testing) and as an integrated system (integration testing). All functional requirements were met, and test results showed successful image loading, user authentication, real-time detection, and alert triggering.

**Limitations and Observations**

While the system performed reliably in most cases, recognition accuracy decreased slightly in highly dynamic backgrounds or during rapid head movements. This could be mitigated by implementing more advanced models like CNN-based FaceNet or MTCNN in future versions. Additionally, integrating email alerts and cloud-based logging could further enhance system capabilities**.**

## VI. CONCLUSION

In this study, an intelligent, real-time intruder detection system based on facial recognition and Edge AI has been successfully developed and implemented. The system integrates the Local Binary Pattern Histogram (LBPH) algorithm with computer vision tools such as OpenCV and face_recognition to perform accurate identification of individuals from live webcam feeds. Upon detecting an unauthorized face, the system triggers an alarm and sends immediate SMS alerts using the Twilio API, enhancing security responsiveness.

The proposed solution offers a cost-effective, scalable, and contactless alternative to traditional surveillance methods. It minimizes the need for human intervention, reduces false positives, and ensures robust access control through the implementation of a secure password-based alarm deactivation feature. Extensive testing confirms the system's effectiveness across varied lighting conditions and usage scenarios, making it suitable for deployment in homes, offices, and restricted

zones. Future enhancements may include cloud integration, advanced face detection models, and multi-modal authentication to further improve reliability and adaptability.

**Key Contributions**

The key contributions of this work are as follows:

**Real-Time Intruder Detection:**

A fully functional surveillance system was developed using Edge AI to detect unauthorized individuals in real time with minimal latency.

**Facial Recognition Integration:**

Implemented face recognition using the Local Binary Pattern Histogram (LBPH) algorithm, enabling accurate identification under varying lighting and environmental conditions.

**Automated Alert Mechanism:**

Incorporated Twilio API to send SMS alerts immediately upon detecting an intruder, enhancing system responsiveness and remote monitoring capabilities.

**Password-Based Alarm Deactivation:**

Designed a secure password verification module to deactivate the alarm system, preventing unauthorized access and ensuring controlled intervention.

**Cost-Effective and Scalable Architecture:**

Utilized open-source libraries and minimal hardware, making the system affordable and scalable for small to medium security setups without compromising performance.

**Extensive Testing and Validation:**

Performed rigorous testing across multiple modules including dataset loading, image processing, authentication, and real-time alerting, ensuring reliability and robustness.

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