AI-POWERED MILITARY BORDER SURVEILLANCE SYSTEM USING FACE RECOGNITION AND MILITARY VEHICLE DETECTION

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Abstract: Border security remains a critical challenge, demanding continuous monitoring, rapid threat detection, and accurate identification of individuals and vehicles entering restricted military zones. Traditional human-based surveillance systems often suffer from fatigue, limited coverage, and delayed decision-making. To address these limitations, this project proposes an AI-powered real-time military border surveillance system integrating face recognition and military vehicle detection using advanced computer vision and deep learning techniques. The first module employs Haar Cascade and LBPH face recognition to authenticate authorized military personnel and automatically identify unauthorized individuals. Upon detecting an unknown face, the system captures the image, retrieves the GPS-based location, and sends an alert email to security authorities. The second module utilizes a YOLOv8 object detection model trained specifically for military vehicles, enabling accurate real-time detection and distance estimation using image-based measurements. The entire system is deployed on a Raspberry Pi–based edge computing platform, supporting 24/7 autonomous operation with minimal human intervention. The integration of real-time alerts, location tracking, automated evidence captures, and lightweight on-device inference significantly enhances situational awareness and strengthens border surveillance capabilities. This dual module AI system demonstrates a reliable, scalable, and efficient solution for modernizing military security infrastructure and reducing reliance on manual monitoring.

Keywords*:* AI Surveillance, Military Border Security, Face Recognition, Haar Cascade, LBPH, YOLOv8, Military Vehicle Detection, Distance Estimation, Raspberry Pi, Edge Computing, Real-Time Alerts, Deep Learning, Object Detection, GPS Integration, Automated Security System.

INTRODUCTION

National border protection is one of the most important responsibilities of any nation. Traditional surveillance systems depend on security personnel, CCTV monitoring, and manual verification processes. These approaches often suffer from limitations such as human fatigue, restricted coverage, delayed threat identification, and inconsistent monitoring performance.

Recent advancements in Artificial Intelligence (AI), Computer Vision, and Embedded Systems have enabled the development of intelligent surveillance solutions capable of autonomous operation. Deep-learning algorithms such as YOLOv8 provide real-time object detection, while Haar Cascade and LBPH algorithms enable efficient facial recognition suitable for resource-constrained embedded devices.

The proposed system combines facial authentication and military vehicle detection into a unified surveillance framework capable of detecting unauthorized personnel and suspicious vehicles in real time. The system operates on a Raspberry Pi platform and provides automatic alert generation with image evidence and location details.

applications.

NEED OF THE STUDY.

The protection of national borders and military restricted zones has become a critical challenge due to increasing security threats, unauthorized intrusions, and illegal movements across sensitive areas. Traditional surveillance systems primarily depend on manual monitoring by security personnel, which may lead to delayed responses, human fatigue, and reduced effectiveness during continuous operations. The growing complexity of modern security threats demands intelligent and automated surveillance solutions capable of real-time monitoring and rapid threat detection.

Recent advancements in Artificial Intelligence (AI), Computer Vision, and Embedded Systems have enabled the development of smart surveillance systems that can automatically identify suspicious activities. Technologies such as facial recognition and object detection provide enhanced situational awareness and improve the accuracy of security operations. However, many existing systems focus on either personnel authentication or vehicle detection separately, resulting in limited operational effectiveness.

The proposed AI-Powered Military Border Surveillance System integrates facial recognition for authorized personnel authentication and YOLOv8-based military vehicle detection into a single intelligent platform. The system continuously monitors surveillance feeds, detects unauthorized individuals and suspicious vehicles, estimates object distance, captures evidence, and generates instant alerts to security authorities. By automating the surveillance process, the system reduces dependence on manual monitoring while improving response time and overall security efficiency.

Therefore, the study is undertaken to develop a cost-effective, scalable, and intelligent surveillance framework capable of enhancing border security, protecting military installations, and supporting real-time decision-making for defense personnel.

RESEARCH METHODOLOGY

The proposed system adopts a hybrid methodology combining classical computer vision techniques and deep learning models to achieve real-time military border surveillance. The system integrates both hardware and software components to enable continuous monitoring, detection, and alert generation. It is divided into two major functional modules: (i) facial recognition for personnel authentication and (ii) military vehicle detection with distance estimation.

3.1 Facial Recognition for Personnel Authentication

This module is designed to identify individuals approaching the surveillance system and verify whether they belong to an authorized personnel database.

3.1.1 Data Acquisition and Dataset Preparation

A dataset of authorized personnel is created by capturing multiple facial images under varying environmental conditions such as illumination, pose, and facial expressions. Each individual is assigned a unique identity label, and images are stored in a structured directory format.

3.1.2 Face Detection

Face detection is performed using the Haar Cascade classifier. Each captured frame is converted to grayscale to reduce computational complexity. The classifier scans the image and extracts facial regions for further processing.

3.1.3 Feature Extraction and Model Training

The Local Binary Pattern Histogram (LBPH) algorithm is employed for feature extraction. It converts facial images into local texture descriptors and generates histograms representing facial features. The model is trained using these descriptors and stored for real-time deployment.

3.1.4 Real-Time Recognition

During operation, live video frames are processed continuously. Detected faces are compared with the trained dataset using the LBPH recognizer. If a match is found within a predefined confidence threshold, the individual is classified as authorized; otherwise, the system flags the individual as unauthorized.

3.1.5 Location Retrieval

Upon detecting an unauthorized individual, the system retrieves location coordinates using a GPS module or network-based API services, depending on system configuration.

3.1.6 Alert Mechanism

An alert is generated for unauthorized access. The system captures the image frame, attaches location details, and transmits the information to security personnel via email notification.

3.2 Military Vehicle Detection and Distance Estimation

This module focuses on detecting military vehicles and estimating their distance from the surveillance system using deep learning and geometric computation.

3.2.1 Dataset Preparation and Model Training

A custom dataset consisting of various military vehicles (e.g., tanks, armored vehicles, and trucks) is collected and annotated using YOLO format. The dataset is used to train the YOLOv8 object detection model using the Ultralytics framework.

3.2.2 Real-Time Object Detection

The trained YOLOv8 model processes live video input to detect and classify objects. The model generates bounding boxes along with confidence scores for identified vehicles in real time.

3.2.3 Distance Estimation

The distance of the detected vehicle from the camera is estimated using camera geometry:

$$D = \frac{F \times H}{h}$$

Where:

D= Distance from camera
F= Focal length
H= Actual height of the object
h= Height of object in image

Camera calibration is performed in advance to determine the focal length for accurate estimation.

3.2.4 Alert Generation

When a vehicle is detected, the system captures the frame, computes the distance, and retrieves location data. An alert message containing the image, distance, and coordinates is sent to the concerned authorities.

3.3 Integrated System Workflow

Both modules operate simultaneously on the Raspberry Pi platform, enabling real-time monitoring and automated response. The system continuously captures input, processes data, performs detection and recognition, and generates alerts when abnormal activity is identified.

IV. RESULTS AND DISCUSSION

4.1 HARDWARE RESULTS AND DISCUSSION

4.1.1 Face Authentication Module

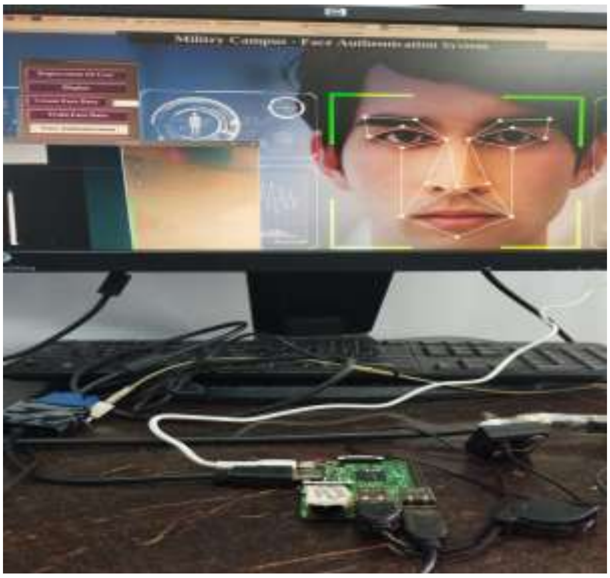

Image- 4.1.1 Hardware implementation

4..1.2 Vehicle Authentication Model

Image-4.1.2 Hardware implementation

1. Performance Evaluation

The system was tested under various environmental conditions including indoor, outdoor, and low-light scenarios.

- Face Recognition Accuracy: High accuracy achieved for registered personnel under normal lighting conditions
- Vehicle Detection Accuracy: YOLOv8 demonstrated strong performance in detecting military vehicles with high confidence

2. Real-Time Detection

The system successfully performed:Continuous monitoring at ~20–30 FPS (depending on model size)
Instant detection and classification of objects

3. Alert System Performance

- Email alerts were generated within seconds of detection
- Images and location data were correctly transmitted
- Buzzer activation occurred with negligible delay

4. Advantages Observed

- Reduced human dependency
- Faster response time
- Improved surveillance efficiency
- Low-cost deployment using Raspberry Pi

5. Limitations

  - Performance drops in extremely low-light or fog conditions
  - Accuracy depends on dataset quality
  - Limited processing power compared to high-end GPUs

6. Discussion

The integration of face recognition and vehicle detection into a single system provides a comprehensive surveillance solution. Compared to traditional CCTV systems, the proposed approach offers intelligent decision-making, automated alerts, and real-time threat detection.
The use of edge computing ensures faster processing and makes the system suitable for remote military border areas.

4.2 SOFTWARE IMPLEMENTATION

he developed system was designed to improve military campus security by combining two important safety modules after login:

4.2.1 Face Authentication Module
4.2.2 Military Vehicle Unknown Detection Module

After successful login, the user can access both pages separately. This makes the system organized and user friendly. One page is used for human identity verification inside the military campus, while the second page is used for border-side monitoring of unknown military vehicles.

4.2.1 Face Authentication Module Result

In the face authentication page, the system verifies whether the detected person is an authorized user or not. The output screen shows that the face authentication interface contains the following functions:

1. Registration of user
2. Display of stored records
3. Creation of face dataset
4. Training of face data
5. Face authentication
6. Exit option

When an authorized person is recognized, the system displays the stored details such as name, address, and contact information. This confirms that the authentication module is correctly matching the detected face with the trained database.
When an **unauthenticated or unknown person** appears in front of the camera, the system captures the image automatically and sends an alert email. The email contains:

1. Alert message indicating unauthenticated user detected
2. Captured face image as evidence
3. Date and time of detection
4. Location details

This proves that the system is capable of providing immediate notification to the concerned authority for quick action.

Image 4.2.1 Home Page

Image 4.2.2 Registration

Image 4.2.3 Login

Image 4.2.4 Face Authentication Page

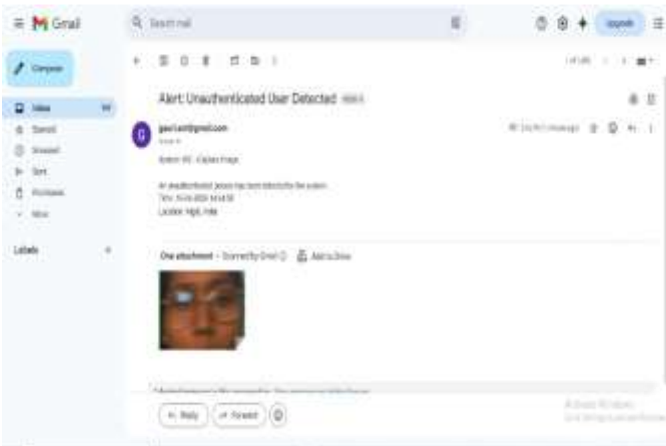

Image 7 Face Authentication Page

4.2.2 Military Vehicle Unknown Detection Result

The second module is used for identifying unknown military vehicles near the border or restricted area. The result screen shows that the system successfully detected an **unknown Armoured Fighting Vehicle (AFV)**. The system draws a bounding box around the vehicle and displays:

1. Vehicle class label
2. Confidence score

3. Estimated distance

In the shown result, the system detected the vehicle as an unknown armored fighting vehicle and estimated the distance as around **2.0 meters**. This indicates that the object detection model is working correctly and is able to provide both identification and distance information in real time. When an unknown military vehicle is detected, the system captures the detected frame and sends an email alert automatically. The alert email contains:

1. Warning message for unknown vehicle detection
2. Captured image of the detected vehicle
3. Vehicle name/class
4. Date and time
5. Location information

This confirms that the system not only detects suspicious vehicles but also stores visual proof and informs authorities instantly.

Image 8 Military Vehicle Detection Result Page

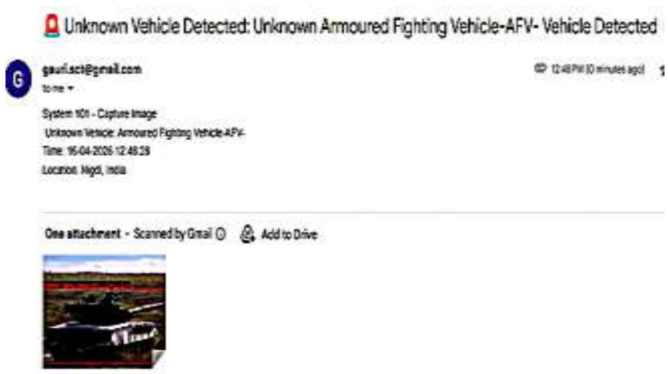

Image 9 Military Vehicle Detection Notification on Mail Page

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