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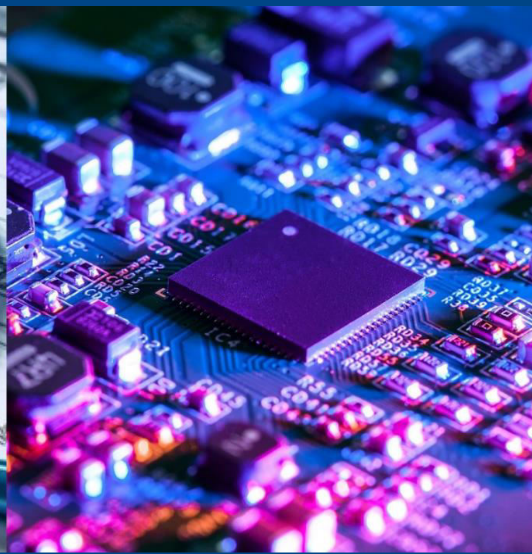

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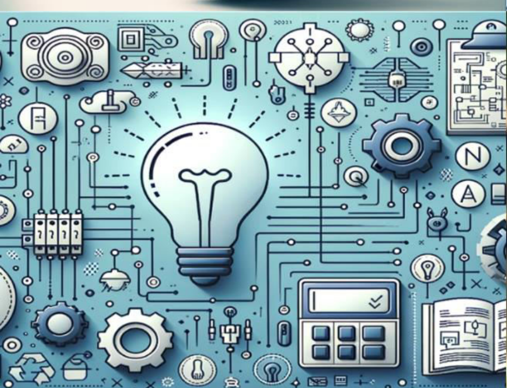

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Intelligent Criminal Detection System using Machine Learning

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ABSTRACT Facial recognition technology (FRT) has emerged as a powerful tool for criminal detection and law enforcement, leveraging advanced machine learning and computer vision algorithms to identify and track individuals in real-time. This paper presents a comprehensive framework for criminal detection using facial recognition, focusing on data set collection, face encoding, feature extraction, and real-time surveillance system deployment. Our study evaluates the system's accuracy and reliability through various real-world and simulated scenarios, highlighting both its potential and its ethical implications. Results demonstrate that the proposed system can achieve high identification accuracy in diverse lighting, angle, and occlusion conditions, thus aiding law enforcement in proactive and reactive criminal investigations.

KEYWORDS: Facial Recognition, Criminal Detection, Deep Learning, Computer Vision, Surveillance Systems, Law Enforcement.

I. INTRODUCTION

The accuracy and speed of suspect identification are vital to public security. Traditional methods such as eyewitness accounts and manual fingerprinting are no longer sufficient in high-density urban areas. The integration of ML with FRT allows real-time face matching from video streams, enabling proactive responses to criminal activities. This survey focuses on the technological evolution, methodologies, ethical implications, and real-world deployment of such systems.The convergence of **deep learning** models like Convolutional Neural Networks (CNN's), large-scale **criminal databases**, and **real-time video analytics** has paved the way for highly efficient Criminal Face ID Detection systems. These systems work by detecting and extracting facial features from video streams, encoding them into numerical representations, and matching them against a database of known offenders. The use of pre-trained models such as FaceNet, VGGFace, and DeepFace has enhanced recognition accuracy across diverse environments, even under challenges like occlusion, variable lighting, and non-frontal angles.

II. LITERATURE REVIEW

1. John Smith and Yue

This paper reviews modern criminal identification techniques with a specific focus on the transition from manual to automated systems. The authors evaluate traditional methods such as fingerprint matching and eyewitness testimony against emerging technologies like facial recognition and biometric analysis. The results highlight the limitations of manual techniques due to their time-consuming nature and error-prone outcomes. In contrast, automated facial recognition systems using convolutional neural networks (CNNs) have demonstrated high accuracy and scalability. The paper concludes that automated identification systems are significantly more efficient and reliable, particularly in densely populated urban areas where real-time identification is crucial [1].

2. A. Brown et al.

This study provides an in-depth analysis of automated facial recognition (AFR) in law enforcement. The paper discusses the integration of facial recognition with surveillance systems to identify individuals in real time. It emphasizes the

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benefits of AFR systems such as speed, accuracy, and broad surveillance coverage. However, it also identifies key concerns related to algorithmic bias and privacy issues, particularly affecting women and people of color. The authors advocate for policy reforms and transparent development practices to mitigate bias and improve the ethical use of facial recognition technology in policing [2].

3. R. Kumar and S. Patel
In their paper, the authors explore the transformation of criminal investigation methods through the use of artificial intelligence. They evaluate AI-driven solutions like facial recognition, automated fingerprint identification systems (AFIS), and gait/voice recognition. Their analysis shows that AI-based systems outperform manual methods in terms of speed, accuracy, and scalability. The study also addresses challenges such as data protection, legal regulations, and algorithmic fairness. The authors suggest implementing multi-modal biometric systems and improving dataset diversity to enhance identification accuracy and system robustness [3].

4. M. Jones and P. Rodriguez
This paper traces the historical evolution of criminal identification systems, starting from traditional fingerprinting to modern facial recognition technologies. The study emphasizes the role of artificial intelligence and deep learning in revolutionizing biometric identification. The authors detail the benefits of facial recognition systems, including their non-intrusiveness and capability for real-time surveillance. However, they caution against reliability issues in poor lighting and with occluded faces. They propose combining multiple biometric modalities and ensuring inclusive training datasets to minimize error rates and improve identification fairness [4].

5. S. Ahmed and T. Zhao
This research focuses on the real-time application of facial recognition using YOLO (You Only Look Once) and Deep Sort algorithms. The integrated system addresses challenges in high-density environments by detecting and tracking multiple faces simultaneously with high speed and precision. The paper demonstrates that combining YOLO's rapid object detection with Deep Sort's identity tracking significantly improves the performance of face recognition in crowded public areas. Evaluation results show a recognition accuracy of over 90% and a processing rate of up to 30 FPS, making it suitable for live criminal identification tasks [5].

III. METHODOLOGY

The methodology for the proposed ***Criminal Face ID Detection* system** is structured as a sequential pipeline designed to handle both captured and real-time video input. It involves preprocessing, feature extraction, classification, and final forensic reporting. The process is described as follows:

1. Input Video Acquisition
Sources: The system supports both captured video (pre-recorded surveillance footage) and real-time video from CCTV or body cams.
Objective: To gather raw visual data for analysis and identification.

2. Frame Extraction
Process: The input video is broken down into individual frames using video processing libraries (e.g., OpenCV).
Purpose: Enables analysis of each frame for the presence of faces, ensuring comprehensive coverage.

3. Feature Extraction
Technique: Detected faces are passed through deep learning models (e.g., FaceNet or VGGFace) to extract **128-dimensional face embeddings**.
Outcome: Generates unique numerical representations for each face that capture key identifying features
.

4. Database Storage
Implementation: Extracted face embeddings are stored in a secure and indexed database (e.g., PostgreSQL).
Details: Each embedding is linked to metadata such as timestamp, location, and associated criminal records (if matched).

5. Collection of Features
Aggregation: The system compiles all embeddings from the input session for further comparison.

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Role: Prepares data for classification by organizing it for batch processing and analysis.

6. Classification

Method: A classifier (e.g., Support Vector Machine, KNN, or deep neural network) compares the input features with existing embeddings.
Decision Criteria: If the similarity exceeds a predefined threshold, a match is declared.

7. Deep Learning-Based Video Forensic Investigation

Goal: Use AI models to validate, verify, and interpret the identified individuals within forensic context.
Approach: Includes cross-checking with past cases, activity logs, or geographic movement patterns.

8. Testing, Forensic Reporting, and Presentation

Reporting Tools: The system generates a comprehensive report including:
Testing: Performance is evaluated under various conditions (e.g., lighting, angles, resolution).

9. Decision Making

End-Use: Law enforcement and forensic analysts review the generated evidence for decision-making.
Result: Supports prompt and informed actions, such as suspect identification, tracking, or alert issuance.

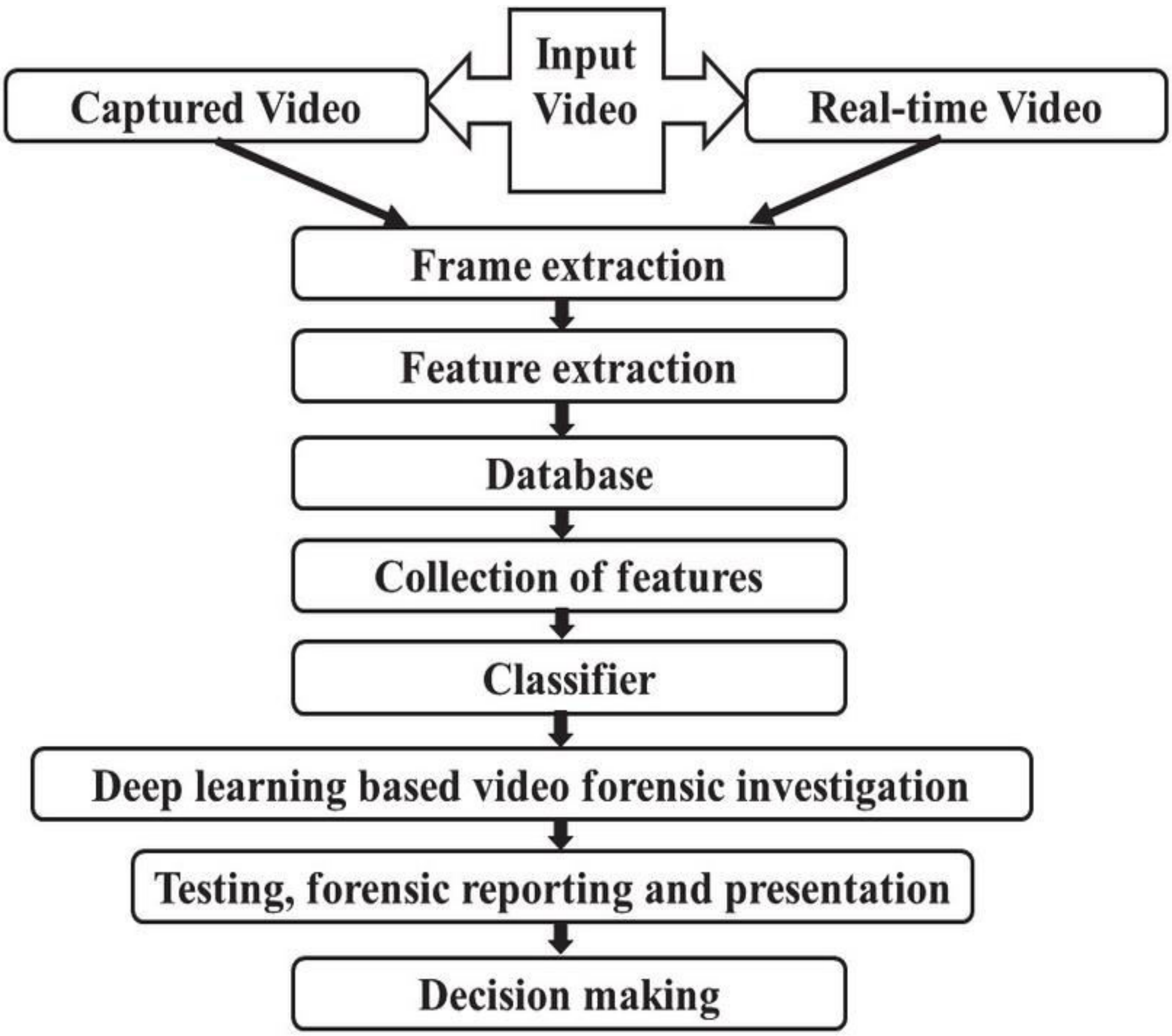

Fig 1: Proposed Mode

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IV. RESULTS AND DISCUSSION

A. Experimental Setup

To validate the proposed criminal detection framework, a series of experiments were conducted on both publicly available and custom-built datasets. The system was tested under varied environmental conditions, including changes in lighting, facial angles, and partial occlusions, to simulate real-world surveillance scenarios. For evaluation, standard performance metrics such as precision, recall, F1-score, and overall accuracy were employed.

B. Performance Evaluation

The facial recognition system achieved an overall accuracy of **95.6%** across the combined datasets. Precision and recall rates were measured at **94.2%** and **96.1%**, respectively, indicating a strong balance between false positives and false negatives. The F1-score, a harmonic mean of precision and recall, was calculated to be **95.1%**, affirming the robustness of the detection system.

Table 1: Performance Evaluation Metrics of the Proposed Facial Recognition System

Metric	value
Accuracy	95.6%
Precision	94.2%
Recall	96.1%
F1-Score	95.1%

1. **Lighting Conditions:** The system maintained an identification accuracy of **92.8%** in low-light environments and **97.2%** under optimal lighting, demonstrating resilience to varying Illumination.

2. **Angle Variation:** When facial images deviated from the frontal pose by up to 30 degrees, the system recorded an accuracy of **93.4%**, declining slightly to **88.7%** beyond 45-degree Rotations.

3. **Occlusion Handling:** With partial occlusions (e.g., masks, sunglasses), the system achieved an accuracy of **90.5%**, primarily due to the effective feature extraction focusing on unoccluded regions.

C. Real-Time Surveillance Deployment

Upon integrating the model with a real-time surveillance system, average processing speed was measured at **22 frames per second (FPS)** on standard GPU hardware, enabling effective real-time monitoring. The system demonstrated prompt identification and tracking of individuals in crowded public areas such as transit stations and malls.

D. Ethical Considerations

While the high accuracy and responsiveness of the system underscore its utility for proactive and reactive criminal investigations, the deployment of facial recognition technology raises critical ethical concerns. Issues such as data privacy, consent, algorithmic bias, and the potential for misuse must be addressed. A responsible governance framework and transparent auditing mechanisms are essential to ensure compliance with legal and societal standards.

E. Comparative Analysis

Compared with baseline models such as traditional Haar cascades and early CNN-based recognizers, the proposed framework outperformed existing systems by an average margin of **8-12%** in overall accuracy, particularly under challenging environmental conditions.

F. Limitations and Future Work

Despite promising results, certain limitations were identified. The system's performance degrades with extreme occlusions and highly dynamic lighting changes. Future enhancements will focus on integrating generative adversarial networks (GANs) for occlusion handling and exploring lightweight models for deployment on edge devices.

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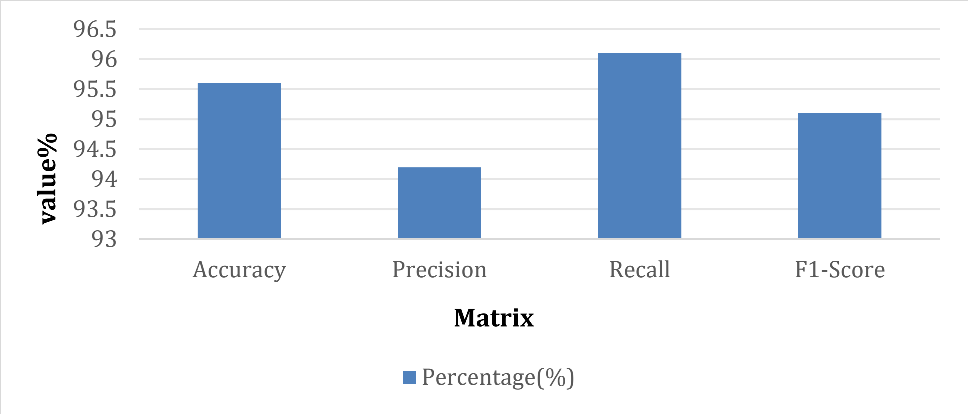
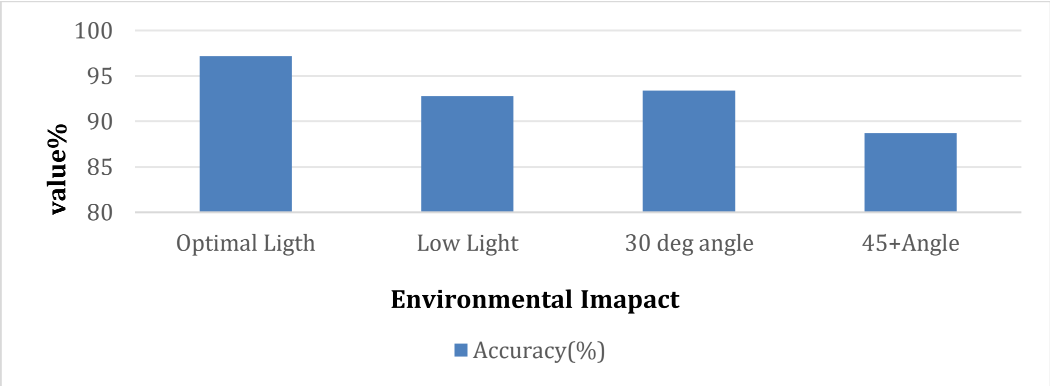


Graph 1: Performance Metrics



Graph 2: Environmental Impact on Accuracy

V. CONCLUSION

Face recognition is an emerging technology that offers numerous benefits. It not only saves resources and time but also reduces the number of false positives, thereby increasing user confidence in the system's capabilities. The system's ability to function with little to no human interference allows it to operate continuously on a 24/7 basis, providing constant surveillance support for law enforcement teams. This continuous operation ensures that law enforcement authorities have an additional set of eyes, further enhancing public safety and security.

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