

AI Forensic Image Generator and Recognition System

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Abstract - This paper presents an intelligent forensic system designed to enhance criminal investigations by addressing the limitations of traditional sketch-based identification methods. Conventional forensic sketching is often time-consuming, subjective, and highly dependent on skilled artists, resulting in inconsistencies and delayed suspect identification. To overcome these challenges, a web-based platform is developed using the Flask framework, providing a centralized and scalable solution for law enforcement agencies. The system integrates an interactive sketch constructor built with HTML5 Canvas and Fabric.js, allowing users to generate facial composites based on eyewitness descriptions. Additionally, a photo-to-sketch conversion module utilizes image processing techniques to standardize input formats from sources such as CCTV footage. The core component of the system is a deep learning-based face recognition engine that generates facial encodings and performs similarity-based matching with a criminal database. The system also incorporates secure data management through role-based access control and encrypted authentication mechanisms. Experimental results demonstrate improved accuracy, faster processing time, and enhanced reliability in suspect identification. This integrated approach significantly streamlines forensic workflows and supports more efficient and effective law enforcement operations.

Key Words: Forensic System, Face Recognition, Sketch Generation, Deep Learning, Image Processing, Criminal Investigation.

1. INTRODUCTION

In modern criminal investigations, identifying suspects quickly and accurately remains a significant challenge, particularly in cases where physical evidence such as fingerprints or DNA is unavailable. In such situations, law enforcement agencies often rely on eyewitness accounts to reconstruct the appearance of suspects. This has led to the use of forensic facial sketching, a technique that combines human memory with artistic interpretation to create visual representations of individuals. However, traditional sketching methods are time-consuming, subjective, and heavily dependent on the expertise of

skilled artists, which can result in inconsistencies and reduced reliability.

Another major limitation arises when these sketches must be compared with photographic databases. The difference in visual representation between sketches and real images, known as the modality gap, makes accurate matching difficult for conventional face recognition systems. Additionally, existing approaches often involve separate tools for sketch creation, image processing, and recognition, leading to fragmented workflows and inefficiencies.

To address these challenges, this work proposes an integrated forensic system that combines sketch generation, image processing, and automated recognition within a unified web-based platform. The system enables users to create digital facial composites through an interactive interface, while also supporting the conversion of real-world images into sketch-like representations to ensure consistency. Furthermore, a deep learning-based recognition module is employed to extract facial features and perform similarity matching with stored records.

By integrating multiple functionalities into a single system, the proposed approach reduces manual effort, improves identification accuracy, and accelerates the investigation process. This makes it a valuable tool for law enforcement agencies, particularly in scenarios where rapid and reliable suspect identification is required.

2. LITERATURE REVIEW

The development of forensic face recognition systems has evolved significantly with advancements in computer vision, psychology, and artificial intelligence. Early approaches in forensic investigations relied heavily on manual sketching techniques, where trained artists created facial composites based on eyewitness descriptions. Although this method provided flexibility, it was highly dependent on the skill of the artist and often resulted in inconsistencies due to subjective interpretation and memory limitations.

To overcome these challenges, mechanical systems such as Identikit and Photofit were introduced. These systems utilized predefined facial components like eyes, nose, and mouth to construct faces. While they improved the speed of sketch generation, they lacked realism and failed to accurately represent natural human facial structures. Later, digital composite systems such as FACES and E-FIT enhanced flexibility by allowing adjustments in facial features, brightness, and orientation. However, these systems still relied on feature-based approaches, which do not align well with how humans perceive faces holistically.

Recent research highlights the importance of holistic face perception, where humans recognize faces as a complete structure rather than as individual components. This led to the development of evolutionary and interactive systems that generate multiple face variations and allow users to refine results iteratively. Despite improved realism, these systems are computationally expensive and require advanced infrastructure.

In parallel, face recognition technology has advanced from traditional feature-based methods to deep learning-based approaches. Modern systems use convolutional neural networks (CNNs) to extract high-level facial features and generate numerical embeddings for accurate comparison. Models such as ResNet have significantly improved recognition accuracy and robustness under varying conditions such as lighting, pose, and expression.

A major challenge in forensic applications is heterogeneous face recognition, which involves matching sketches with photographic images. The difference in texture and detail between sketches and photos creates a modality gap that reduces matching accuracy. To address this, researchers have proposed image transformation techniques and feature extraction methods that focus on structural similarities.

Additionally, the integration of image processing techniques has improved data quality by enhancing images through noise reduction, edge detection, and normalization. Database management systems and security mechanisms such as role-based access control have also played a crucial role in ensuring efficient and secure handling of forensic data.

With the rise of web technologies, modern forensic systems are increasingly being developed as web-based platforms using frameworks like Flask, enabling accessibility, scalability, and ease of deployment. The combination of artificial intelligence, image processing, and web-based interfaces has led to the development of more efficient and reliable forensic systems.

Overall, existing research highlights the need for an integrated solution that combines sketch generation, image processing, and automated recognition. The proposed system builds upon these advancements to provide a unified and efficient platform for improved suspect identification.

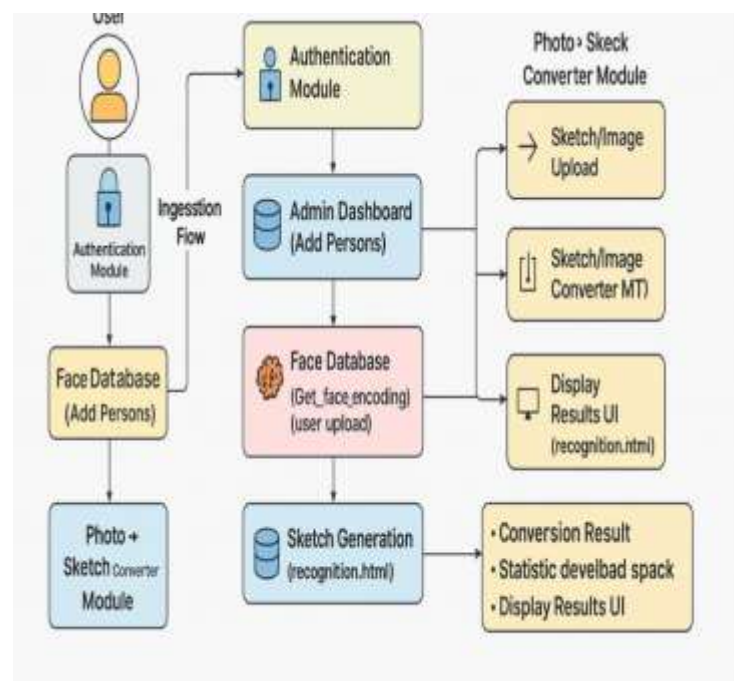
3. SYSTEM IMPLEMENTATION

3.1 Introduction

The system implementation phase focuses on transforming the conceptual design of the proposed forensic system into a functional application. It involves integrating multiple technologies, including web development frameworks, image processing libraries, and machine learning models, to create a unified platform. The system is designed using a modular approach, where each component performs a specific task while maintaining seamless interaction with other modules. A web-based architecture is adopted to ensure accessibility, scalability, and ease of deployment.

3.2 System Architecture

The proposed system follows a web-based architecture consisting of three main layers: the frontend, backend, and database layer. The frontend is developed using HTML, CSS, and JavaScript, providing an interactive user interface for sketch creation and system interaction. The backend is implemented using the Flask framework in Python, which handles request processing, business logic, and communication between modules. The



database layer is managed using SQLAlchemy, enabling efficient storage and retrieval of user data, suspect records, and facial encodings.

3.3 Tools and Technologies Used

The system is developed using a combination of modern tools and technologies to ensure efficiency and reliability:

- **Python:** Used as the core programming language for backend development.
- **Flask:** A lightweight web framework used to handle server-side operations.
- **OpenCV:** Used for image preprocessing and sketch conversion.
- **Face Recognition Library:** Extracts facial features and performs matching.
- **SQLAlchemy:** Manages database operations and data storage.
- **HTML, CSS, JavaScript:** Used for designing the user interface.
- **Fabric.js:** Enables interactive sketch construction using canvas.

3.4 System Modules

The system is divided into several functional modules, each responsible for a specific task:

3.4.1 Sketch Construction Module

This module allows users to create facial composites using an interactive interface. It is implemented using HTML5 Canvas and Fabric.js, enabling users to add, resize, and manipulate facial features such as eyes, nose, and mouth. This reduces dependency on manual sketching and improves accuracy.

3.4.2 Image Processing Module

The image processing module converts real images into sketch-like representations using OpenCV techniques such as grayscale conversion, edge detection, and Gaussian blurring. This helps reduce the difference between sketches and photographs, improving recognition performance.

3.4.3 Face Recognition Module

This module uses deep learning techniques to extract facial features and generate numerical encodings. These encodings are compared with stored data using similarity measures to identify potential matches. The process is fast and efficient, enabling real-time identification.

3.4.4 Database Management Module

The system uses SQLAlchemy to manage data storage, including user information and suspect records. Facial encodings are stored in the database for quick retrieval and comparison, ensuring efficient performance even with large datasets.

3.4.5 Authentication and Security Module

Security is ensured through role-based access control and password hashing using Bcrypt. Only authorized users can access specific functionalities, maintaining data confidentiality and system integrity.

3.4.6 Admin Dashboard Module

The admin module provides a centralized interface for managing system operations. Administrators can add, update, or delete suspect records and monitor system activity, ensuring smooth functioning.

3.5 Working Principle

The system operates through a sequence of steps. Initially, the user creates a sketch or uploads an image. The input is then processed using image preprocessing techniques to enhance quality and standardize the format. Next, the system extracts facial features and converts them into numerical encodings. These encodings are compared with stored database records using similarity measures. Finally, the system displays the most relevant matches based on similarity scores, allowing users to identify potential suspects efficiently.

3.6 Advantages of the System

- ☐ Reduces dependency on manual sketching
- ☐ Improves accuracy of suspect identification
- ☐ Provides faster processing compared to traditional methods
- ☐ Integrates multiple functionalities into a single platform
- ☐ Ensures secure and controlled access to sensitive data
- ☐ Supports real-time analysis and decision-making

4. METHODOLOGY

4.1 Overview

The proposed system follows a structured and iterative methodology to ensure efficient development and accurate performance. An Agile-based approach is adopted, where the system is divided into smaller modules such as sketch construction, image processing,

database management, and face recognition. Each module is developed, tested, and refined independently, allowing continuous improvement and early detection of errors. This approach ensures flexibility, scalability, and better system reliability.

4.2 Data Collection and Preparation

The system uses two primary types of data: facial images (mugshots) and user-generated sketches. These datasets form the basis for training and recognition. Before processing, all images undergo standardization steps such as resizing, grayscale conversion, and normalization to ensure consistency. Face detection techniques are applied to extract relevant facial regions, removing unnecessary background information. This preprocessing improves the accuracy and efficiency of the recognition system.

4.3 System Setup

The system is implemented using a web-based architecture. The frontend is developed using HTML, CSS, and JavaScript, providing an interactive interface for users. Fabric.js is used to enable dynamic sketch construction through a canvas-based environment. The backend is developed using Python with the Flask framework, which handles request processing and communication between components. The database is managed using SQLAlchemy for efficient data storage and retrieval.

4.4 Forensic Recognition Processing Pipeline

The system follows a multi-stage pipeline to convert raw input into meaningful results. Each stage performs a specific function, ensuring accuracy and efficiency.

4.4.1 Input Acquisition

The system accepts input in two forms: user-generated sketches and uploaded images such as photographs or CCTV captures. This dual-input capability increases flexibility and usability in real-world scenarios.

4.4.2 Image Preprocessing

Input images are enhanced using techniques such as grayscale conversion, noise reduction, resizing, and normalization. Face detection is applied to isolate the facial region. These steps ensure uniform input and reduce variations caused by lighting, pose, and background.

4.4.3 Feature Extraction

Deep learning models are used to extract important facial features and convert them into numerical representations known as embeddings. These embeddings uniquely represent each face and enable efficient comparison.

4.4.4 Model Inference

In this stage, the extracted features are compared with stored database encodings using similarity measures. The system identifies potential matches based on predefined thresholds, eliminating the need for manual comparison.

4.4.5 Similarity Analysis

The system calculates similarity scores using distance metrics such as Euclidean distance. The results are ranked based on similarity, and the most relevant matches are displayed to the user for decision-making.

4.5 Adaptive Recognition Mechanism

To improve accuracy, the system incorporates adaptive techniques such as photo-to-sketch conversion, which reduces the gap between different input formats. Feature normalization ensures consistency across images, while threshold-based filtering eliminates weak matches. These mechanisms enhance the robustness of the system in real-world conditions.

4.6 Testing and Validation

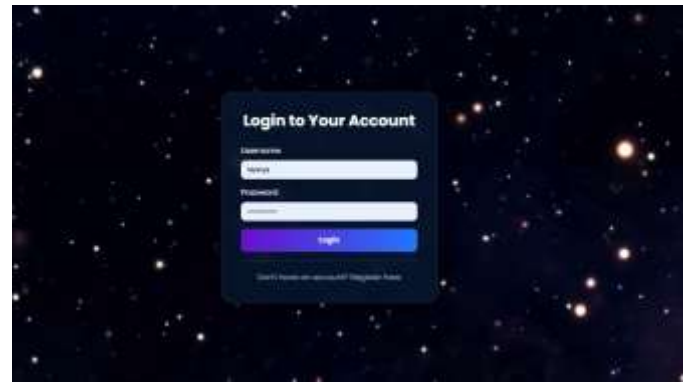
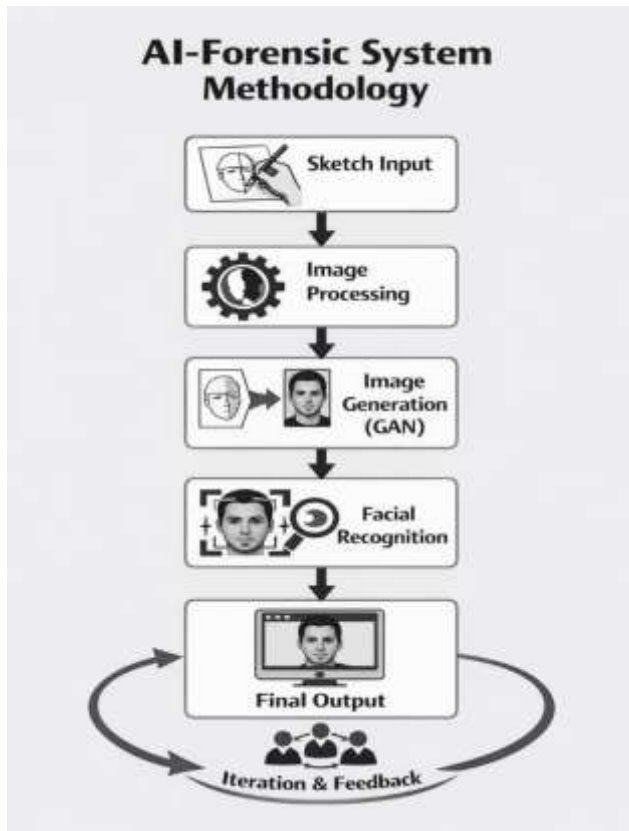
The system is tested using multiple approaches to ensure reliability and performance.

4.6.1 Testing Approach

Unit testing is performed on individual modules, followed by integration testing to ensure smooth interaction between components. User testing is also conducted to evaluate usability and interface design.

4.6.2 Performance Metrics

The system is evaluated using metrics such as accuracy, precision, recall, and processing time. These metrics help assess the effectiveness of the recognition process.



4.6.3 Validation Results

Experimental results show that the system achieves high accuracy and significantly reduces the time required for suspect identification compared to traditional methods.

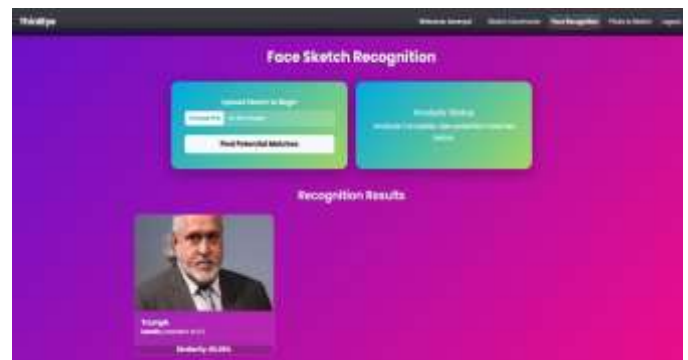
4.6.4 Error Analysis

Errors may occur due to poor image quality, incomplete sketches, or lighting variations. These issues are analyzed and addressed through improved preprocessing and model refinement.

5. RESULTS AND DISCUSSION

The proposed forensic system was evaluated for its ability to identify suspects using both sketches and photographic inputs. The integration of image processing and deep learning techniques significantly improved recognition accuracy compared to traditional methods. The system was able to extract facial features efficiently and perform fast similarity matching, making it suitable for real-time applications.

Experimental results indicate that the system reduces identification time and minimizes human dependency. It also provides more consistent and reliable results when compared to manual sketch-based approaches. However, performance may be affected by low-quality inputs, variations in lighting, and incomplete sketches. Overall, the system demonstrates strong potential in enhancing forensic investigation processes.



6. CONCLUSION

This paper presented an AI-based forensic image generation and recognition system that improves suspect identification using sketches and images. By integrating sketch construction, image processing, and deep learning-based recognition into a single platform, the system enhances accuracy, reduces manual effort, and speeds up the investigation process.

The proposed system provides a practical and efficient solution for law enforcement agencies. In the future, the system can be further improved by using larger datasets, advanced deep learning models, and real-time surveillance integration to achieve even higher accuracy and performance.

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