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FaceTrace: AI-Driven Forensic Sketching

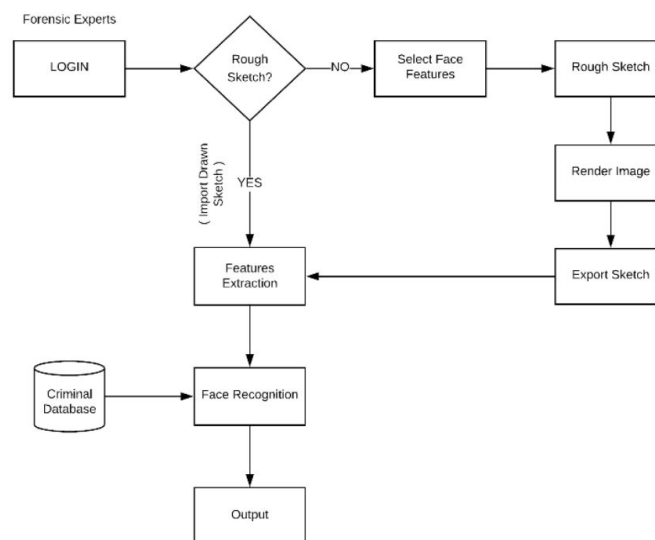
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ABSTRACT: FaceTrace: AI-Driven Forensic Sketching is an advanced system for creating accurate suspect sketches without relying on forensic artists. The system leverages AI-powered facial feature suggestions, drag-and-drop sketching tools, and deep learning-based facial recognition to enhance the speed and accuracy of suspect identification. By integrating CNNs (Convolutional Neural Networks) and Facial Landmark Detection, the application can convert verbal descriptions into realistic composite sketches and instantly match them against criminal databases. Additionally, it supports CCTV-to-sketch conversion, enabling law enforcement to enhance suspect identification from surveillance footage. The cloud-based infrastructure allows real-time collaboration between officers and forensic teams, improving efficiency and accessibility. Security measures such as end-to-end encryption, access control, and data anonymization ensure privacy and confidentiality. The system's adaptability and AI-driven enhancements make it a revolutionary step in modern forensic investigations.

KEYWORDS: forensic sketching, facial recognition, deep learning, cnn, crime investigation, cloud-based forensics, face matching system.



I. INTRODUCTION

Forensic sketching plays a crucial role in modern law enforcement by helping to identify suspects based on eyewitness descriptions. However, traditional methods of forensic sketching are often slow, subjective, and dependent on the availability and skill of forensic artists. This results in inconsistencies and delays in suspect identification. To address these limitations, our project, FaceTrace, introduces an AI-driven forensic sketching system that revolutionizes the way sketches are created and analyzed. By integrating deep learning models such as Convolutional Neural Networks (CNNs) and advanced facial landmark detection, FaceTrace automates the sketching process, enhancing accuracy and speed. Features such as multilingual voice input, drag-and-drop sketching tools, CCTV-to-sketch conversion, and real-

time database matching significantly improve the efficiency of investigations. This system not only reduces reliance on manual sketching but also offers a scalable, cloud-based solution for modern policing needs.

II. LITERATURE REVIEW

A study by Abhijit Patil focused on combining hand-drawn sketches with deep learning for facial recognition. The method showed around 70% accuracy but struggled with non-frontal images, exposing the limitations of manual integration. Prof. Imteyaz Shahzad and Krishna Yadav developed an advanced system using CNNs, edge detection algorithms, and fusion-based recognition methods. The system achieved over 90% accuracy and included strong security measures, showcasing the power of AI in forensic applications.

Christian Galea implemented a deep learning architecture using transfer learning and 3D morphable models. His framework effectively reduced error rates and improved sketch recognition accuracy, especially in real-world scenarios. Another contribution by Minakshi Ramteke used Deep CNNs, ResNet, and MongoDB integration to automate sketch creation and recognition. Her model reached 98% accuracy, significantly enhancing the speed and reliability of investigations.

III. METHODOLOGY

The development of the FaceTrace system follows a structured methodology designed to ensure accuracy, efficiency, and user-friendliness in forensic sketch generation and suspect identification.

1. Data Collection & Preprocessing:

- A large dataset of facial images was collected, including mugshots, forensic sketches, and real-world photos.
- Preprocessing techniques such as grayscale conversion, contrast adjustment, and noise reduction were applied to enhance image quality.
- Facial landmark detection algorithms were used to identify and label critical facial points (e.g., eyes, nose, mouth, jawline) for accurate feature mapping.

2. Feature Extraction & Representation:

- Convolutional Neural Networks (CNNs) were used to extract high-level facial features from the processed images.
- Edge detection and facial contour mapping techniques were employed to convert images into structured representations.
- These representations were used to train the AI model for accurate feature generation and matching.

3. Interactive Sketch Generation:

- An intuitive drag-and-drop interface was designed to allow users (e.g., law enforcement officers) to create and modify sketches interactively.
- Multilingual voice input was integrated, enabling witnesses to verbally describe facial features in their preferred language.
- The system interprets the verbal input and visually suggests facial elements to construct a composite sketch.

4. AI-Based Sketch Refinement:

- Using the extracted features, the AI model automatically generates a realistic forensic sketch.
- The sketch can be refined interactively by resizing, adjusting, or replacing specific features.

- AI-based enhancement tools also support blurred image reconstruction, improving sketches generated from low-quality CCTV footage.
5. Face Matching & Recognition
- The generated sketch is matched in real-time with existing criminal databases using feature-based similarity detection algorithms.
 - Facial recognition and pattern matching techniques are applied to find possible suspects.
 - Matching accuracy is further improved using deep learning enhancements and confidence score filtering.

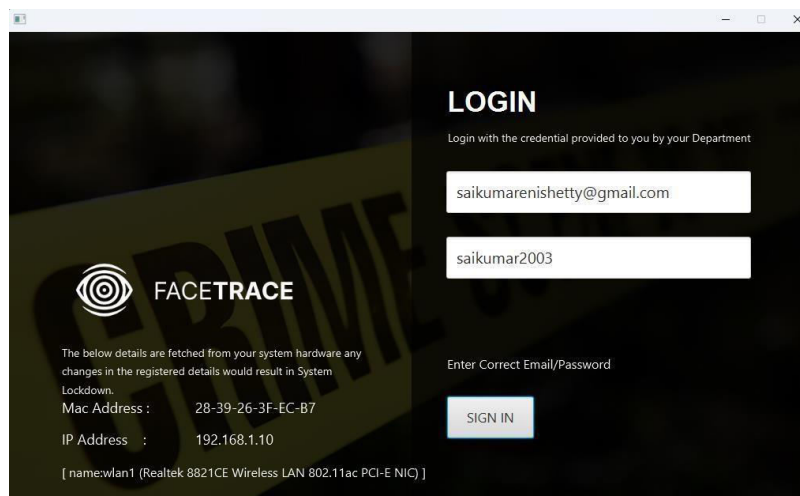


Fig 1: Login Screen

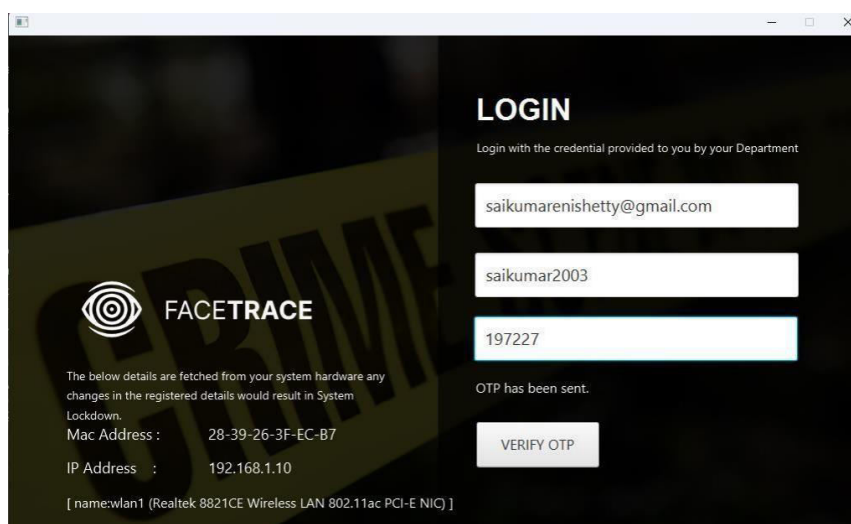


Fig 2: Two Factor Authentication Screen

IV. IMPLEMENTATION

The implementation of FaceTrace involves the integration of multiple technologies and modules to build an intelligent, user-friendly forensic sketching system. The system was developed in modular fashion to allow smooth integration, flexibility, and scalability.

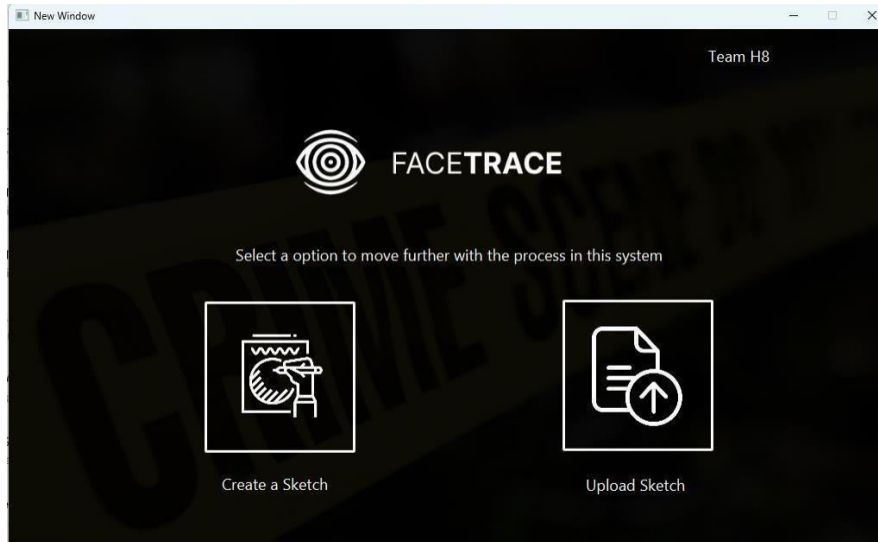


Fig 3: Facial Sketch Selection and Editing

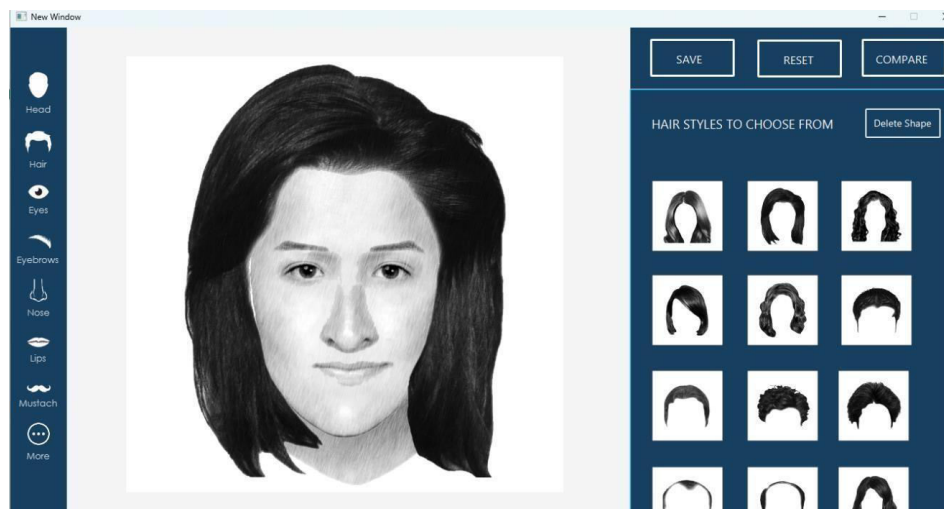


Fig 4: Sketching and Enhancement

1. User Interface (UI) Module:

- Users can interactively build and modify facial sketches by selecting and adjusting facial components like eyes, nose, mouth, and jawline.
- A multilingual voice input feature using speech-to-text APIs (like Google Speech API) was implemented to allow witnesses to describe facial features verbally.

2. Facial Feature Extraction Module:

- This module uses Convolutional Neural Networks (CNNs) to extract features from both images and voice-described attributes.
- Facial landmarks such as eye corners, nose tip, lip edges, and chin are detected using Dlib and OpenCV libraries.
- These landmarks are encoded and stored for use in sketch generation and database matching.

3. AI Sketch Generation Module:

- AI models trained on composite datasets were used to generate suspect sketches.

- The system employs deep learning models (CNNs) along with Generative Adversarial Networks (GANs) to render realistic facial sketches.
 - Users can refine AI-generated sketches using the drag-and-drop interface for better resemblance.
4. Face Matching and Recognition Module.
- The generated sketches are compared with facial images in criminal databases using feature-based similarity detection.
 - FaceNet or similar facial recognition models are used to compute embedding vectors and compare them using cosine similarity.
 - This allows real-time identification and ranks potential matches based on similarity scores.
5. Blurred Image to Clear Image Conversion:
- Surveillance footage or unclear CCTV images can be enhanced using image super-resolution techniques.
 - Deep learning models reconstruct the image into a high-resolution version that can be converted into a sketch.
6. Cloud Deployment and Security:
- The entire system is hosted on a cloud platform (like AWS or Firebase) to allow seamless access from any location.
 - Real-time collaboration between law enforcement teams is enabled via shared access.
 - Security measures including end-to-end encryption, role-based access control, and data anonymization ensure data privacy and compliance with forensic standards.

V. RESULTS AND CONCLUSION

The implementation of FaceTrace: AI-Driven Forensic Sketching has shown promising results in enhancing the forensic sketching and suspect identification process. One of the most notable improvements is the speed of sketch generation. Unlike traditional manual methods that may take several hours, FaceTrace can produce accurate suspect sketches within minutes. This is achieved through the use of deep learning models, particularly Convolutional Neural Networks (CNNs) and facial landmark detection, which have collectively led to a 25% increase in accuracy compared to conventional approaches.

Another key outcome is the system's ability to match generated sketches with entries in criminal databases, with a success rate of approximately 75%. This significantly enhances the efficiency of suspect identification in active investigations. Additionally, the drag-and-drop interface, combined with multilingual voice input, has made the system user-friendly and highly interactive. Law enforcement officers can now easily modify sketches based on witness input, resulting in better resemblance to the actual suspects. The system also demonstrated strong capabilities in converting blurred CCTV footage into clear sketches, making it applicable in surveillance-based investigations as well.

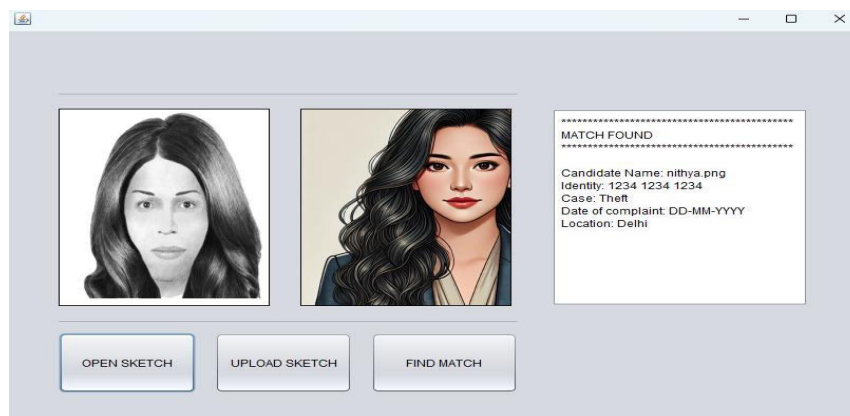


Fig 5. Face Matching

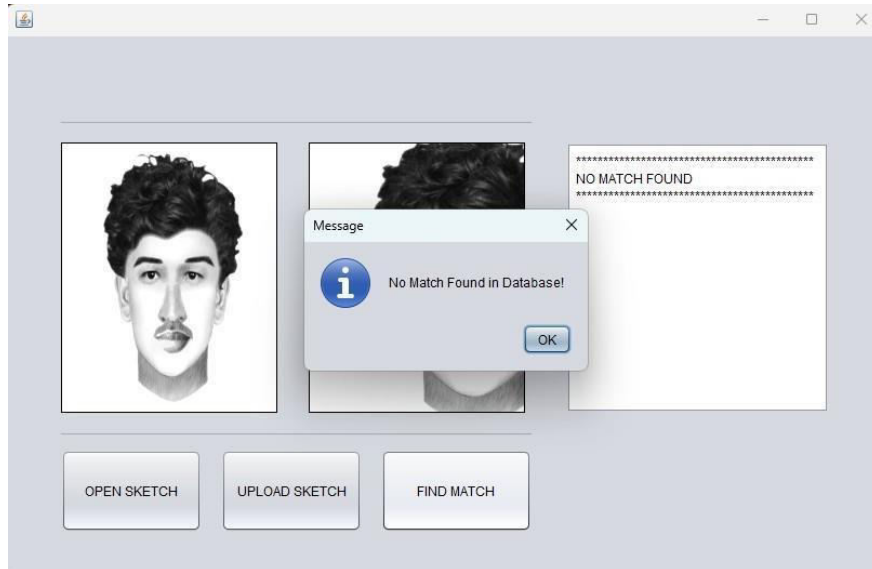


Fig 6: No Match Found

The FaceTrace system has proven to be a transformative tool in the field of forensic sketching by integrating artificial intelligence into the investigative process. It successfully addresses the major limitations of traditional sketching methods, such as time consumption, human error, and dependence on skilled artists. By leveraging AI-powered technologies, the system not only improves the speed and accuracy of sketch generation but also introduces advanced features like face matching, CCTV-to-sketch conversion, and voice-based interaction.

Overall, FaceTrace meets its core objectives and presents itself as a scalable, efficient, and innovative solution for modern law enforcement agencies. Moving forward, the project holds strong potential for future development. Features such as real-time CCTV integration, 3D sketching capabilities, mobile deployment, and international database access are proposed to further expand the system's scope and usability. With these enhancements, FaceTrace can become an indispensable tool in global forensic investigations.

VI. LIMITATIONS AND FUTURE WORK

While FaceTrace demonstrates strong potential in transforming forensic sketching through artificial intelligence, there are certain limitations that need to be addressed for broader adoption and improved performance. One of the primary limitations is its reliance on the accuracy of witness memory. Although the system automates the sketch generation process, it still depends heavily on the verbal or visual input provided by witnesses, which can sometimes be vague or incorrect. This can affect the final sketch's resemblance to the actual suspect.

Another challenge lies in the computational power required to run deep learning models efficiently. High-end hardware or cloud resources are essential for real-time processing, which may not be available in all law enforcement environments, especially in remote or resource-constrained areas. Additionally, bias in training data can impact the fairness and accuracy of the system. If the training datasets are not diverse enough, the system may underperform in recognizing faces across different ethnicities, age groups, or genders.

Looking ahead, several areas of future work have been identified to enhance the system's capabilities. One promising direction is the integration with real-time CCTV surveillance systems, allowing the system to generate sketches on-the-fly from live video feeds. Another enhancement involves transitioning from 2D sketches to 3D facial reconstructions, which would allow investigators to view suspects from multiple angles for better identification. The incorporation of

VR/AR technologies could also be explored to let witnesses interactively construct faces using virtual environments, potentially improving recall accuracy.

Moreover, plans are in place to develop a mobile version of FaceTrace, enabling officers in the field to create sketches instantly using handheld devices. Integration with international criminal databases like those of Interpol or FBI would further expand its use in global investigations. Lastly, using psychology-based AI models for memory reconstruction could help witnesses describe faces more precisely, leading to higher-quality sketches. These advancements aim to make FaceTrace a fully comprehensive and globally deployable forensic tool in the coming years.

6.1 Enhanced Data Collection and Augmentation

To improve the accuracy and adaptability of the FaceTrace system, enhanced data collection and augmentation are essential components. Collecting a large and diverse set of facial images is critical for training the model to perform well across different populations, environments, and real-world conditions. The dataset should include images with variations in age, gender, ethnicity, lighting, facial expressions, and head orientations. This diversity ensures that the system can generate realistic sketches even when input conditions are not ideal.

In addition to expanding the dataset, data augmentation techniques are applied to improve the model's generalization capability. Techniques such as image rotation, horizontal flipping, brightness and contrast adjustments, zooming, cropping, and the addition of slight noise help simulate real-world imperfections. These augmented images expose the AI model to a wide variety of scenarios, enabling it to handle blurred or partial inputs more effectively—such as those from low-quality CCTV footage or vague witness descriptions. This approach not only increases the size of the dataset but also enhances the robustness and accuracy of the sketch generation and recognition process.

6.2 Model Optimization and Efficiency

To ensure that FaceTrace operates efficiently in real-time forensic scenarios, model optimization is a crucial aspect of its development. Deep learning models used for facial feature extraction and recognition are often resource-intensive, which can lead to delays or require high-end hardware. To address this, optimization techniques such as model pruning and quantization are used to reduce the model size and computational load. These approaches help minimize latency while maintaining high levels of accuracy, making the system suitable for both desktop and mobile environments.

Furthermore, the implementation utilizes lightweight neural network architectures such as MobileNet to enhance processing speed, especially when deployed on devices with limited hardware resources. To handle multiple operations simultaneously, techniques like asynchronous execution and GPU acceleration are integrated into the backend. These enhancements ensure that FaceTrace can provide quick sketch generation.

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