FaceTrace : Digital Portrait Construction and Identification

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ABSTRACT
In forensic science, it is seen that hand-drawn face sketches are still very limited and time consuming when it comes to using them with the latest technologies used for recognition and identification of criminals. In this paper, we present a standalone application which would allow users to create composites face sketch of the suspect without the help of forensic artists using drag and drop feature in the application and can automatically match the drawn composite face sketch with the police database much faster and efficiently using deep learning and cloud infrastructure.

Keywords**:** — Forensic Face Sketch, Face Sketch Construction, Face Recognition, Criminal Identification, Deep Learning, Machine Locking, Two Step Verification.

I. INTRODUCTION

Eyewitness facial sketches attempt to identify a suspect, however, these hand-drawn illustrations can take a long time to draw and are hard to match with existing surveillance videos, databases, or even law enforcement systems. Automation of suspect identification by digitizing hand-drawn sketches have been adapted in the past, but inaccuracies were still present. There are some applications that let users create composite sketches, but their limited selection of features and facial components that create unrealistic cartoon-like visuals greatly reduces their use in police investigations.

To combat these difficulties, we put forth an upgraded platform built on foundation of artificial intelligence with the goal of simplifying the process of identifying suspects through sketches. Unlike previous applications that provided a fixed list of facial features, our system allows users to add custom hand-drawn elements from uploaded images. With these features, the base set of features that the program uses will be more granular and detailed as compared to the stereotypical forensic sketches.

In addition, other law enforcement agencies will be able to upload already existing appeal sketches, which will help the system in recognizing the presented suspects.

With cutting-edge techniques in machine learning, the system will analyze facial data and sketches to learn from them. An important feature will be for the system to suggest related facial components which will allow users to create more accurate sketches in less time. This will allow law enforcement officers to create precise representations of suspects, and check them against historical or real time records with ease, and accuracy.

Our goal is to improve the reliability and effectiveness of forensic investigations by incorporating deep learning with cloud technology, an intuitive sketching interface, and specialized tools for identifying suspects.

II. RELATED WORK

A number of studies have delved into the construction and recognition of facial sketches using various methods. Dr. Charlie Frowd, along with Yasmeen Bashir, Kamran Nawaz, and Anna Petkovic, created a standalone application designed for generating and identifying facial composites. At first, this system proved to be just as time-consuming and intricate as traditional methods, where witnesses were shown several facial options and asked to pick the ones that resembled the suspect the most. The system then merged the chosen features to automatically predict the suspect's facial composite. This approach yielded encouraging results, with 10 out of 12 composites being correctly identified. The success rate was 21.3% when law enforcement helped the witness, compared to 17.1% when the witness worked on constructing the face alone.

Xiaoou Tang and Xiaogang Wang introduced a recognition technique that utilized a Multiscale Markov Random Field Model, enabling the conversion of sketches into photos and vice versa.

Their model broke down facial sketches into patches, initially synthesizing available photographs into sketches and then training the system to reduce discrepancies between the two formats, which improved overall recognition efficiency. They trained the model using 60% of the dataset, reserving the remaining 40% for testing. While the results were impressive, they didn't quite reach the anticipated accuracy levels.

Another significant method was put forward by Anil K. Jain and Brendan Klare, who developed a sketch-to-photo matching technique using SIFT (Scale-Invariant Feature Transform) descriptors. Their approach calculated the SIFT descriptor distance between face photos in the database and sketches. It began by applying a linear transformation to convert face photos, based on the model created by Tang and Wang, and then measured the descriptor distance between the sketches and the images in the database. They also took into account the distances between database images to enhance accuracy.

The findings showed that their dataset closely resembled that of Tang and Wang, but the enhancement in descriptor measurement really boosted the model's overall accuracy.

In a similar vein, P. C. Yuen and C. H. Man came up with a sketch-based face search technique. In this method, sketches were transformed into mugshots before being matched against a database using both local and global facial recognition variables. However, they faced challenges when trying to match mugshots with faces from databases like FERET and the Japanese database. Even though they managed to achieve a 70% accuracy rate, it wasn't quite precise enough for law enforcement needs.

One common drawback across all these methods was their dependence on front-facing sketches and photographs, which made it easier to align features between the two. But when a suspect's photo or sketch was oriented differently, these models had a tough time accurately identifying matches from the front-facing images in the database.

Other systems proposed for creating composite faces relied on picking facial features from various photographs based on witness descriptions. These features were then pieced together into a single face, but the final images often ended up inconsistent, making it hard for both human evaluators and algorithms to recognize them. Since each facial component came from a different source, the resulting composite frequently introduced discrepancies that complicated accurate suspect identification.

As a result, earlier methods turned out to be either inefficient, time-consuming, or overly complex for practical forensic use. Our proposed application, as mentioned earlier, aims to tackle these issues by bridging the gap between traditional hand-drawn sketches and modern composite techniques. It enables users to upload hand-drawn facial sketches and features, providing greater flexibility and accuracy in generating facial composites while enhancing the overall efficiency of suspect identification.

III. OVERVIEW AND FEATURES

A. Security and Privacy

When it comes to adopting new systems, ensuring security and privacy is a top concern for law enforcement agencies. That's why our application is built with strong measures to safeguard sensitive data and block unauthorized access.

Machine Locking: To keep things secure and prevent tampering, the application uses a dual-layer locking system that combines both software and hardware elements. This includes:

- **HD ID** – The unique volume serial number of the hard drive running the operating system.

- **NET ID** – The MAC address of the system's network hardware. Once the application is installed, it's locked to that specific system, ensuring maximum security.

Two-Step Verification: Each authorized law enforcement user will receive an official email ID for logging in. To boost security, a verification code will be sent to the user's registered mobile device or desktop, which they'll need to enter to complete the login process.

Centralized Usage: The application connects to a centralized server within the law enforcement department, where the database and key features are stored. If the system gets disconnected from the server, the application won't work, which helps prevent unauthorized access.

B. Backward Compatibility

One of the biggest hurdles in adopting new systems is the challenge of transitioning from old methods, which can waste time and resources. To tackle this, our application is designed to work seamlessly with traditional forensic techniques. Users can upload hand-drawn sketches into the system, where deep learning algorithms and cloud-based infrastructure will analyze and recognize suspects. This way, we ensure a smooth transition without making previous investigative methods obsolete.

C. Face Sketch Construction Using Drag-and-Drop

The application allows users to create accurate composite face sketches through an easy-to-use drag-and-drop interface. Users can pick from predefined facial features and adjust their size and position based on witness descriptions.

The human face is made up of several key features, like the shape of the head, the eyes, eyebrows, lips, nose, and ears. Plus, there are fun accessories like hats and glasses that you can add for a personal touch. This capability really boosts usability, making it easier for law enforcement to create realistic facial composites quickly and effectively.

Every facial feature when selected would open a wide range of options to choose from based on the requirement/description of the eye-witness. The machine learning algorithm would learn and in future try to suggest all the facial features which could suit the single selected feature and would try to help in completing the composite face sketch much sooner and much efficiently.

Fig. 1. Shows the sketch of the facial feature viz. Head

Fig. 2. Shows the sketch of the facial feature viz. Eyes

Fig. 3. Shows the sketch of the facial feature viz. Ears

Fig. 1. Face Feature – Head

Fig. 2. Face Feature – Eyes

Fig. 3. Face Feature – Ears

Such are the facial features which can be used in the application to create the composite face sketch of the suspect based on the description been provided by the eye-witness to the law enforcement and forensic department.

Fig. 4. User Interface of the application (with blank canvas)

Fig. 5. User Interface of the application
(with facial features been dragged on to the canvas)

The Fig. 4. shows the user interface of the application been presented to create composite facial sketch with the set of facial features on the right-hand side to be selected and tools for resizing, repositioning, saving, etc. are on the left- hand side.

Fig. 5. shows the user interface of the application with the facial feature been dragged on to the canvas from the right-hand side and to be used with other facial features to create a composite face sketch.

D. System Flow

The Fig. 6. Illustrates the overall flow of the system starting with the login section which ensuring the two-step verification process. Further the application can either be used with a hand-drawn sketch or a composite face sketch can be created using the drag and drop feature, Either of the images would then go under features extraction process which would help the application to apply image processing and computer vision algorithm and finally match the sketch with the database and then display the ratio of similarities between the sketch and the database photograph.

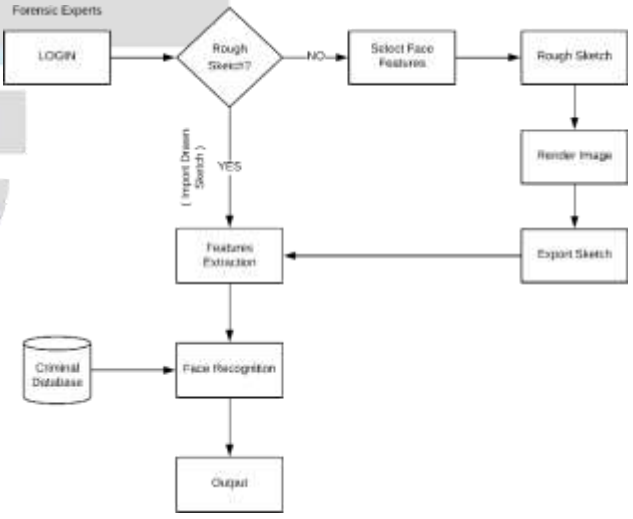


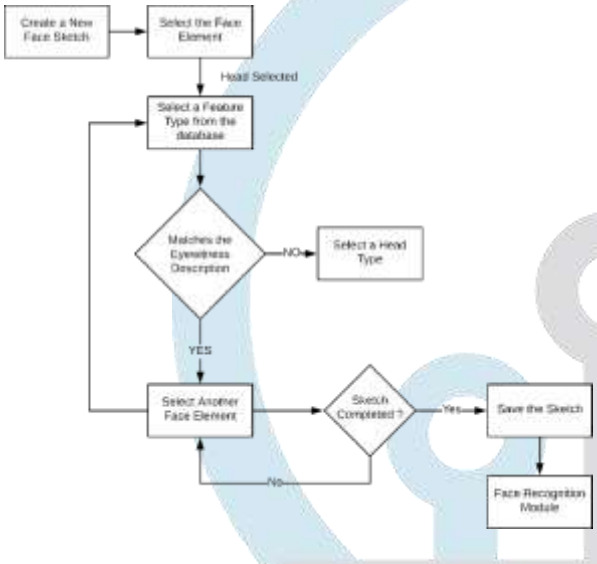
Fig. 6. System Flow of the application

IV. OVERVIEW AND FEATURES

In this application, Operations is performed in two stages.

A. Face Sketch Construction:

The flowchart outlines the user experience on the platform designed for crafting an accurate face sketch from a provided description. The dashboard is built to be intuitive and user-friendly, so there's no need for professional training, which ultimately saves valuable time and resources for law enforcement.



Dashboard and Modules

The dashboard features five main modules:

Canvas (Central Module): Located at the heart of the dashboard, the canvas acts as the workspace where different facial components come together to form a sketch.

Face Element Categories: To make the sketching process easier, facial elements are grouped into categories like head, nose, hair, eyes, and more. These categories are conveniently displayed in a column on the left side of the dashboard. When a user clicks on a category, they can see various facial structures related to that category for selection. This organized approach helps avoid confusion and leads to a more accurate depiction of the suspect's face.

Face Elements Selection (Right Module): Each category includes multiple elements, allowing users to pick the ones that best match the eyewitness description. In the future, the platform plans to use machine learning to recommend the most relevant facial features based on previous selections and available data, enhancing both accuracy and efficiency.

Element Placement: After selecting elements, they appear on the canvas and can be fine-tuned for precise positioning. To keep things realistic, elements follow a set placement logic—like ensuring that eyes are always positioned above the nose, no matter the order in which they were selected.

Enhancement and Controls: Users can refine their sketches with options like erasing incorrectly chosen elements. The right panel contains essential controls, including buttons for clearing the entire canvas and saving the final sketch. Sketches can be saved as PNG files either on the local machine or a centralized law enforcement server.

B. Face Sketch Recognition:

The flowchart for sketch recognition lays out the steps the platform takes to pinpoint a suspect based on a facial sketch. The dashboard is designed to be straightforward and user-friendly, making it easy to navigate without needing any specialized training, which ultimately boosts efficiency for law enforcement.

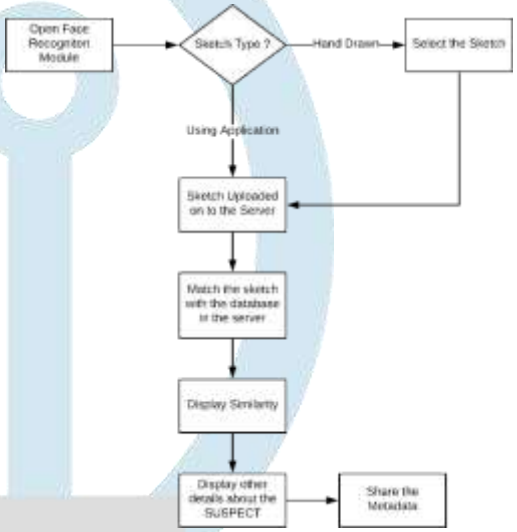


Fig. 8. Flow Chart for Recognizing a sketch in the application

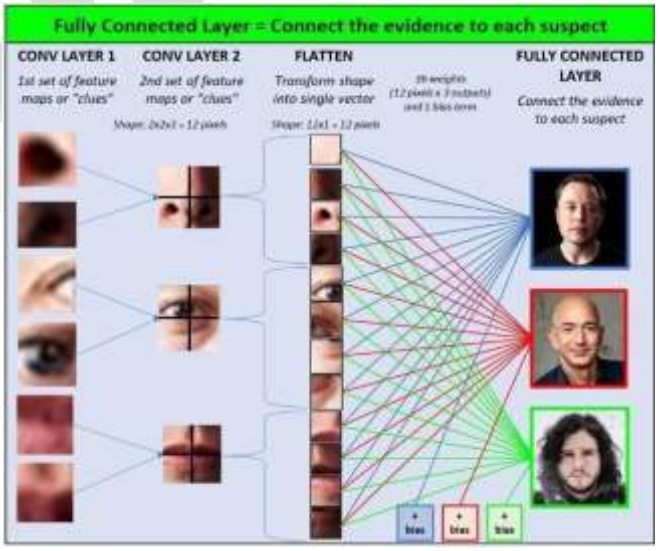


Fig. 9. Feature extraction bythe Platform

Feature Extraction and Database Preparation Before the recognition process can kick off, the platform needs to organize and prepare the existing law enforcement records to ensure compatibility. This includes:

Training the Recognition Algorithm: The platform connects to the law enforcement database, breaking down each stored facial photograph into smaller parts. These features are then tagged with unique identifiers, allowing for more accurate matches during searches.

Server-Based Processing: To keep sensitive data secure, the recognition module operates solely on law enforcement servers. Users can upload either a hand-drawn sketch or a composite created on the platform, and the uploaded sketch is processed within this secure environment.

Face Sketch Mapping and Matching

After a sketch is uploaded, the system goes through these steps:

Feature Mapping: The algorithm analyzes the uploaded sketch, pinpointing and extracting key facial features. This mapping process is illustrated in the figure below.

Database Matching: The extracted features are then compared to the pre-tagged entries in the database to find a potential match.

Match Identification: When a match is found, the system presents the identified face along with a similarity percentage and additional details from the law enforcement records. The matched results are displayed on the dashboard for further analysis, as shown in the final figure.

Fig. 10. Face Sketch been mapped on the Platform

This organized approach significantly improves accuracy and efficiency in identifying criminals, bridging the gap between traditional forensic sketching and cutting-edge AI-driven facial recognition.

Fig. 11. Face Sketch matched to Database Record

V. RESULTS & CONCLUSION

The project titled 'FaceTrace Digital Portrait Construction and Identification' has been carefully crafted, developed, and thoroughly tested with real-world applications in mind. From the very first splash screen to the final data retrieval stage, our top priorities have always been security, privacy, and accuracy throughout the entire development process.

On the security front, the platform has shown outstanding performance by effectively preventing unauthorized access. It successfully blocked any attempts to use the system when the MAC Address and IP Address didn't align with the credentials stored in the database. Plus, the OTP verification system ensured that previously generated OTPs couldn't be reused, generating a fresh OTP every time the page was refreshed or a user tried to log in again. This guarantees a strong authentication process.

When it comes to accuracy and speed, the platform has truly impressed during both the face sketch construction and recognition phases. Extensive testing across various scenarios and datasets revealed an average accuracy rate of over 90%, with a confidence level hitting 100%. This level of performance stands out when compared to existing studies in the field.

Moreover, the platform brings to the table unique and innovative features that boost both security and accuracy, distinguishing it from similar research and proposed systems. These advancements make it an incredibly efficient and reliable tool for law enforcement, significantly enhancing the processes of forensic sketching and suspect identification.

VI. FUTURE SCOPE

The 'FaceTrace Digital Portrait Construction and Identification' project is currently designed to work within a specific framework, mainly concentrating on creating face sketches and matching them with facial images found in law enforcement databases.

That said, the platform has a lot of room for growth, with the potential to incorporate cutting-edge technologies and broaden its application in various situations. One exciting upgrade could be the addition of 3D mapping and imaging techniques, which would allow for facial sketch recognition in video feeds. This would enable the system to match forensic sketches with faces captured in surveillance footage, including live CCTV streams, making it much easier to identify suspects in real-time.

Moreover, connecting the platform with social media could greatly enhance both the speed and accuracy of the recognition process. In today's digital age, social media is a treasure trove of data, and linking forensic sketch identification with these platforms would significantly increase the chances of finding accurate matches, thereby streamlining investigations.

In summary, these future improvements could bring about unique and innovative features, distinguishing the platform from other studies and systems in this area. By continually enhancing its security, accuracy, and flexibility, the system could become an essential resource for law enforcement agencies around the globe.

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