Forensic Automated Composite Evaluation System Using Deep Learning for Sketch-to-Photo Suspect Identification

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***Abstract*— Facial sketching in forensic science is an important area in criminal investigations, especially when there is no photographic evidence of the suspect available. Conventional facial sketching is a time-consuming and subjective process that requires expertise in forensic sketching. However, it is not amenable to automation with digital identification systems. In this paper, we propose a Forensic Automated Composite Evaluation System (FACES) that allows investigators to create facial composites using a drag-and-drop interface and automatically search the law enforcement image database for a match. Our proposed system uses a deep learning-based pipeline that includes facial preprocessing with MTCNN, feature extraction with a pre-trained InceptionResNetV1 model, and similarity comparison with cosine similarity. The proposed system provides a ranked list of possible suspects, which is much faster than the manual process. The experimental results show high accuracy for full facial sketches and reasonable results for partial facial sketches, which validate the proposed system as an effective forensic identification tool.**

Keywords—Forensic sketching, Face Recognition, Deep Learning, Sketch-to-photo matching, Suspect Identification.

I. INTRODUCTION

Facial recognition has traditionally been one of the mainstays of criminal analysis, especially in cases where other biometric data, such as fingerprints, DNA, or video recordings, is not available. In these scenarios, eyewitness accounts become the only available information, and forensic facial sketches become an essential tool in which the human memory is conveyed through a pictorial representation of the suspect. For many years, this has been accomplished through the use of professional forensic artists who have manually analyzed verbal descriptions and recreated them as hand-drawn sketches. While this method has led to many successful cases, it is also very subjective, time-consuming, and artist-dependent [1], [3].

One of the significant drawbacks of the conventional forensic sketching method is the variability that is introduced by human interpretation. The reliability of the sketch is not only dependent on the memory of the eyewitness but also on the skills of the artist. This can lead to a significant variation in the sketches that are produced for the same description. Additionally, the process is not scalable, especially for law enforcement agencies that have a high number of cases to handle within a short time [4].

However, with the recent breakthroughs in computer vision and artificial intelligence, researchers have been looking into automated methods to address these issues. Deep learning methods, especially Convolutional Neural Networks (CNNs), have achieved tremendous success in face recognition problems by learning robust and invariant facial representations from large image collections. More recent works have furthered these developments to include sketch-to-photo matching, demonstrating that deep neural networks can successfully bridge the gap between hand-drawn sketches and actual facial images [7], [8], [11]. Some methods have even tried to create photorealistic images from sketches using Generative Adversarial Networks (GANs) before recognition [6], [9].

Although these models show promising results, many existing solutions based on deep learning are still not very practical for real-world forensic applications. These models require large amounts of training data, high computational power, cloud infrastructure, and technical expertise. These requirements are major hurdles for law enforcement agencies, especially in resource-constrained settings [4], [13]. In addition, many existing models are more concerned with accuracy than with usability and interaction with investigators, which are important considerations for forensic applications.

To fill these gaps, this paper proposes the Forensic Automated Composite Evaluation System (FACES), a system that combines a user-friendly sketching process with an efficient deep learning recognition system. Unlike existing systems that require the services of forensic artists, the proposed system enables investigators to create composite sketches using a drag-and-drop interface consisting of pre-defined facial features. This helps to eliminate subjectivity and ensures that composite sketches are created digitally in a standardized manner.

Once the composite sketch is generated, it is then automatically fed into a structured pipeline that includes preprocessing, facial alignment, feature extraction, and similarity-based matching against a police image database. By utilizing pre-trained deep learning models like InceptionResNetV1 and similarity metrics, the system is able to perform robust sketch-to-photo matching without requiring extensive retraining. Notably, the system is intended to support both complete and partial sketches, which is representative of real-world eyewitness accounts where only limited facial information may be remembered

The key importance of this research work is in its capacity to fill the gap that exists between the process of creating a forensic sketch and the contemporary digital identification process. The system combines human computer interaction with data-driven deep learning, which improves the efficiency, objectivity, and feasibility of identifying a suspect. This system is most appropriate for implementation in today's law enforcement environment, where quick decision-making is imperative.

II. Methodology

The proposed Forensic Automated Composite Evaluation System (FACES) has a structured and modular processing pipeline that takes an investigator-created facial sketch and generates a ranked list of possible suspect matches. The overall process of the system is shown in Fig. 1. The approach is intended to guarantee usability, efficiency, and robustness for both complete and partial facial sketches.

A. Composite Sketch Construction Interface

The system starts with a sketch construction interface designed for investigators to replace the conventional sketching process done by hand. Rather than depending on artistic talent, the interface is designed with a drag-and-drop functionality where facial features such as eyes, nose, lips, eyebrows, and hairstyles can be chosen and placed using a predetermined set of components.

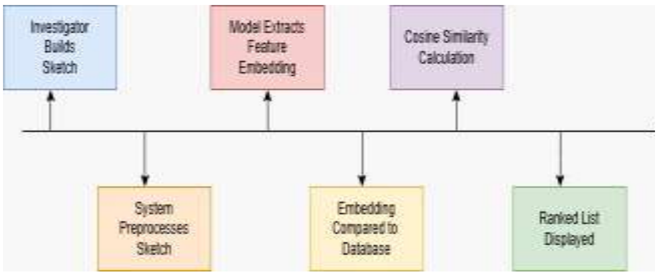

Fig. 1. Overall Workflow of the Forensic Automated Composite Evaluation System (FACES)

Each facial feature is digitally standardized, which ensures consistency in size and orientation during the assembly of the sketch. This method not only makes the sketching process easier but also ensures that the digital input is consistent, which is ideal for automated analysis. The standardization of the sketching process ensures that the system provides a consistent input for deep learning-based analysis, as has been shown in previous works [1]–[3].

B. Image Preprocessing and Face Alignment

After the composite sketch is completed, it is subjected to a preprocessing step in order to prepare it for the extraction of features. This is done by first performing the usual image processing steps using OpenCV, such as noise removal, resizing, and intensity normalization. The image is then converted to grayscale to minimize the differences in modalities between sketches and color photographs in the database. Face detection and alignment are important for successful recognition. Hence, a Multi-Task Cascaded Convolutional Network (MTCNN) is used for facial region detection and alignment of key points like eyes and nose. The alignment of facial features in sketches and database images helps in improving the reliability of feature extraction, as the facial features are aligned properly. The architecture of MTCNN used in this process is shown in Fig. 2 [5].

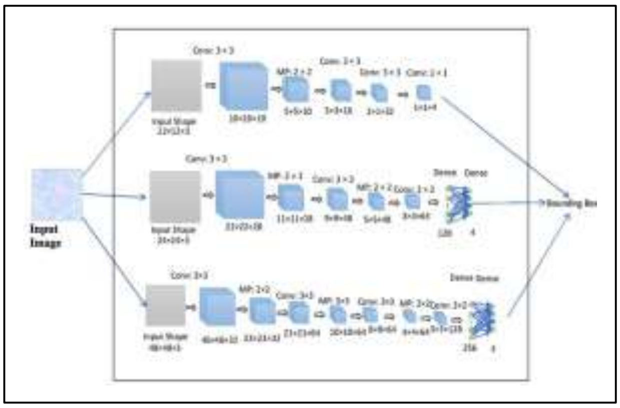

Fig. 2. MTCNN-Based face Detection and Alignment Architecture

C. Extraction Using Deep Learning

The preprocessed and aligned sketch is then fed into a pre-trained InceptionResNetV1 model to derive distinctive facial features. The InceptionResNetV1 model, which is based on the FaceNet model, represents the facial image as a fixed-length 128-dimensional embedding, which is invariant to artistic differences between sketches and photos.

Fig. 3. InceptionResNetV1 Architecture for Deep Facial Feature Extraction

The obtained embedding is a numerical representation of the face, similar to a biometric signature. Because of its robustness to modalities, the embedding representation makes it possible to compare sketches and real images without synthesizing sketches from photos. The structure of the InceptionResNetV1 model is shown in Fig. 3 [5], [6].

D. Sketch-to-Photo Matching and Database Integration

The facial embedding obtained from the sketch is then compared with the embeddings of all the images that are stored in the police database. In order to compare the embeddings efficiently, the cosine similarity measure is used

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as the matching function, as it has been shown to be effective in face recognition problems [7]. To enable scalability and efficient querying, all database images are preprocessed in advance, and their embeddings are stored in an indexed SQL database.

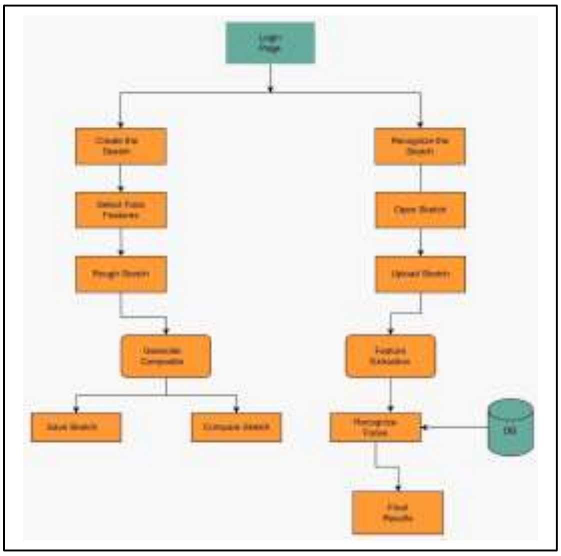

Fig. 4. Application Workflow and Suspect Matching Interface

This enables the avoidance of repeated deep learning inference in the database during each query, thus improving response time. Based on similarity scores, the system provides a ranked list of candidate matches, with higher-ranked entries indicating stronger identity matches. The final results are presented to the investigator through an intuitive interface, showing the top-ranked suspect images along with their similarity scores. The complete application workflow, from sketch creation to result presentation, is shown in Fig. 4.

III. Results And Discussions

The Forensic Automated Composite Evaluation System (FACES) is a web-based system that incorporates composite sketch creation, facial component recognition, and criminal database management. The main goal of the implementation is to find out whether investigators can efficiently build facial composites from eyewitness accounts and identify suspects through a deep learning-based facial component recognition system.

In order to test this system, a set of experiments were carried out using the entire composite sketch as well as the facial components. Three key factors were evaluated during the evaluation process of this system. These factors are the usability of the composite sketch generation interface, the accuracy of the facial component recognition system, as well as the effectiveness of the database management/authentication mechanism. All these experiments were carried out in order to test real-life scenarios that are encountered during the investigation of criminal activities.

It can be noted from the results shown in the images that the system developed in the research can efficiently integrate the sketch generation interface with the sketch analysis. This could improve the efficiency of the suspect identification task carried out by the investigators. The images shown in Fig. 5-Fig. 9 represent the work flow of the operation of the system that has been developed.

A. Authentication and Secure Access

However, as the system handles sensitive information about criminals, it is a must to include security as a requirement. The authentication interface, as shown in Fig. 5, is designed to allow only authorized individuals to access the system. Users must authenticate themselves by providing valid information, including a username and password. Once authenticated, access is given to the main dashboard of the system, allowing investigators to proceed with sketch creation, recognition analysis, etc. This authentication method will ensure that unauthorized access of critical information is restricted and the usage of the forensic system is regulated. Through the secure login and access, the confidentiality and integrity of the criminal database will be ensured.

Fig. 5. System Authentication Interface

B. System Home Interface

Fig. 6, below is the major landing interface of the system, which is titled "Forensic Automated Composite Evaluation System Using Deep Learning for Sketch-to-Photo Suspect Identification." The major landing interface of the system is the point of entry of the system. The major landing interface of the system offers investigators access to the major features of the system. The home page of the system is made to have a simple interface to enable investigators to navigate the system during the course of the investigation.

Fig. 6. System Home Interface Of The Forensic Facial Interface Platform

On the home page, the investigator is given a choice between two main options: "Create Composite" or "Analyze & Identify." If the investigator chooses to create a composite, they can create a facial sketch of the suspect by choosing different facial features based on the description given by the eyewitness. However, if the investigator chooses to analyze and identify the suspect, they can analyze the composite sketch they created and match it with the records they have in the criminal database.

In addition to the above major features, the homepage has information regarding the system's capabilities, such as the use of artificial intelligence for recognition, real-time analysis, and database storage. These features point to the technological basis of the system, which is based on forensic identification. The design of the interface is such that the required module is easily accessible for the investigators.

C. Composite Sketch Construction Module

The composite sketch generation interface is shown in Fig. 7. This section enables investigators to create a representation of a suspect's face based on the given facial components that are stored within the system. In place of drawing the sketch, investigators can select facial components to create a composite face.

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Fig. 7. Composite Sketch Creation Interface

The system has various facial components such as eyebrows, nose, lips, and hair. Each of the components is shown in a selection panel, where the investigators can choose the component that best matches the description given by the eyewitness. Once the component is chosen, it is automatically placed in the sketch area, where it is combined with other facial components to form a complete face.

This mechanism of dragging and selecting offers a number of advantages over conventional forensic sketching techniques. It eliminates the need to rely on skilled artists in forensic sketching, makes the procedure more standardized, and reduces the time needed to create suspect sketches. After a suspect sketch is drawn, it is possible to save the generated composite image using the Save Image feature.

D. *Facial Component Recognition Results*

Facial component recognition is also supported by the system, enabling the identification of suspects based on the analysis of particular facial features in cases where a complete sketch of the face is not possible. This facility can be useful if witnesses recall particular facial features.

The results of the recognition for the facial component are depicted in Fig. 8. In this experiment, the sketch of the nose was uploaded as input. The image was then processed using the recognition pipeline of the deep learning method, where the image was first preprocessed.

Fig. 8. Facial Component Recognition Result

This embedding was then compared with the embedding of the criminal's face stored in the criminal database using cosine similarity. The best match was identified as David Kim Nose Match with a similarity of 85.92% and a distance score of 3.62. This shows that the face recognition model can accurately match incomplete facial sketches with facial images to aid investigators with leads during investigations.

E. *Criminal Database Management*

The criminal database management interface is shown in Fig. 9. This module enables investigators or authorized individuals to store criminal records, which can be used by the recognition system. Each record comprises important suspect information, including name, age, facial picture, and description of the criminal record.

Fig. 9. Criminal Database Management Interface

For instance, the screenshot above indicates that the record contained the suspect's details, "JYO" at the age of 21, together with the suspect's photograph and the description of the criminal record, "Most Wanted Butcher." This allows the investigator to have a data management system that can be used in the automatic identification of the suspect.

When a new suspect image is uploaded, the system will automatically create a facial embedding using the deep learning model. These are stored along with the suspect information and are used during the recognition analysis. This helps the system perform fast similarity comparisons and ensure efficient database searching.

F. *Performance on Partial Sketches*

In real-world scenarios, the eyewitness may only be able to recall some parts of the face rather than the complete face. For the above reason, partial sketches with selective parts were also tested.

TABLE I. MATCHING PERFORMANCE UNDER DIFFERENT SKETCH CONDITIONS

Detection Type	**Average Similarity (%)**	**Range (%)**	**Observation**
Full-Face Detection	93	91-95	High Accuracy with complete sketches
Partial-Face Detection	71	67-75	Moderate Accuracy; Useful for lead Generation

With the above restrictions, the average similarity score was reduced to 71%, with a range from 67% to 75%, as shown in Table I. Though the performance was not as good as the complete face detection, the system was still able to produce meaningful candidate lists.

This reduction in similarity is expected due to the incomplete representation of features. However, the capacity of the system to sustain moderate matching performance ensures that the information learned in the embeddings still discriminates, even with incomplete input. In practice, this outcome is helpful in narrowing the pool of suspects rather than providing conclusive evidence.

G. *Experimental Performance Analysis*

The proposed "Forensic Automated Composite Evaluation System " is validated in such a way that it is compared with actual photographs. In the proposed "Forensic Facial Composite Evaluation System," "Machine Learning Model" is used to transform the sketches and photographs into "feature embedding." Finally, "Cosine Similarity" and "Euclidean Distance" methods are used for comparison. The proposed system is successful in achieving an average similarity of 89.6%, thus proving the efficiency of the proposed system.

TABLE II. PERFORMANCE EVALUATION OF SKETCH RECOGNITION

Metric	Avg.value Mapped similarity(%)	Mapped Distance	Avg.Inference Time	Avg.Database Build Time
value	89.6%	2.71	0.46 s	10.2s

This is because it has been able to show the importance of 2.71 as a measure of the proximity between the images' feature embeddings. The average time it takes to draw an inference was found to be 0.46 seconds, indicating that it can operate effectively for speed and, consequently, for facial matching.

The database's build time of 13.2 seconds indicates that it can operate effectively for the purpose of storing facial features.

IV. CONCLUSION

This paper has presented the concept of the Forensic Automated Composite Evaluation System (FACES), which is a deep learning-based framework for modernizing the conventional approach to suspect identification through the use of forensic facial sketches. The conventional approach to suspect identification using facial sketches is heavily dependent on the expertise of a forensic artist and is a highly subjective approach. The need for modernization was realized with the FACES approach.

In addition, the system architecture supports the processes of preprocessing, facial alignment via the MTCNN model, feature extraction via a pre-trained InceptionResNetV1 model, and database query via the cosine similarity method in a unified and scalable way. As can be seen from the experimental results, the system presents good performance in terms of recognition, with an average similarity of 93% for full facial sketches and to a certain extent for partial sketches. This proves the validity of the concept of using the embedding-based method for sketch and photo matching.

Apart from the accuracy of the recognition, the main contribution of the current work is related to its applicability. In particular, the proposed framework reduces the need for artistic skills, improves the speed of the shortlist of suspects, and allows the incorporation of the proposed system into a structured police database. In that way, the proposed system can be used as a decision support tool, helping the investigator to be more efficient.

Even though performance is reduced in a partial sketch situation, useful investigative leads are offered. Areas of future research could involve the improvement of robustness for incomplete sketches via hybrid GAN-based image enhancement, increasing the training datasets to enhance generalization, and adding explicable artificial intelligence techniques to increase trust in image matching.

Overall, this research indicates that deep learning techniques can be integrated with a more human-centered approach to interface design to potentially increase the efficiency, scalability, and objectivity of identification-based forensic systems. The FACES framework that the authors present is an important advancement towards more data- driven, technology-based approaches to criminal investigation that can actually be applied to the real world.

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