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Face Sketch Construction and Recognition for Forensic

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***Abstract*: Face Sketch Construction and Recognition for Forensic project is platform aimed at assisting law enforcement in suspect identification. It provides a user-friendly drag-and-drop interface for constructing accurate facial sketches without requiring forensic artists. The system uses deep learning algorithm to match sketches against criminal databases, ensuring reliable and timely results. Designed to address the challenges of traditional forensic methods, it enhances the efficiency and accuracy of criminal investigations. By integrating technology with forensic science, this project contributes to improved suspect identification processes, supporting law enforcement in solving crimes more effectively and ensuring public safety.**
***Keywords*: Face Recognition, CNN, Face Embeddings, Feature Extraction, Face detection, Euclidean Distance, Thresholding, Face construction, Drag and drop interface.**

I. INTRODUCTION

The increasing crime rate presents significant challenges for law enforcement agencies, particularly with the reliance on traditional methods for suspect identification. One of the most common techniques used in criminal investigations is the creation of forensic sketches based on witness descriptions. However, Witnesses often struggle to recall precise facial features, leading to inaccuracies in the sketches. Moreover, the shortage of skilled forensic artists results in delays, particularly in urgent investigations. Machine learning provides promising suspect identification by facial recognition technology, powered by deep learning algorithms such as Convolutional Neural Networks (CNNs). This paper explores the potential of Machine learning in facial recognition highlighting its benefits in improving recognition outcomes.

II. LITERATURE SURVEY

[1] The paper "*Recognipro: Recognition and Construction of Forensic Facial Sketches*" explores a system that aids in criminal identification by using computer vision and deep learning to match hand-drawn sketches with digital face images. The system operates in two stages: face sketch construction, where users create sketches based on descriptions, and facial sketch recognition, where the system uses deep learning to match sketches with images from law enforcement databases. The system utilizes Deep Convolutional Neural Networks (DCNNs) for feature extraction, improving the accuracy of sketch-to-photo matching. This approach aims to enhance forensic investigations by providing a faster, more reliable identification tool for law enforcement.

[2] This paper "*Advanced Forensic Face Sketching and Recognition*." introduces an advanced forensic face sketching and recognition system that improves the traditional, time-consuming process of hand-drawn sketches used in criminal identification. The system leverages deep learning algorithms, including Convolutional Neural Networks (CNNs) to match sketches with police records accurately. Users can create composite sketches through an intuitive drag-and-drop interface or upload hand-drawn sketches, which are processed for recognition. The platform incorporates security features like machine locking, two-step verification, and centralized usage. The system significantly enhances forensic investigations by offering faster, more reliable identification, improving efficiency in law enforcement.

[3] This paper "*Forensic Face Sketch Construction and Recognition*" introduces an application aimed at improving the process of constructing and recognizing forensic face sketches. Traditional hand-drawn sketches are time-consuming and inefficient for matching suspects to existing databases. The proposed application allows users to

create composite face sketches using a drag-and-drop interface, upload hand-drawn sketches, and match them quickly using deep learning and cloud-based infrastructure. The system enhances efficiency by suggesting compatible facial features and improves accuracy in suspect identification. Security features like machine locking and two-step verification ensure privacy and protection, making it a valuable tool for law enforcement.

[4] The paper *"Recent Advances in Deep Learning Techniques for Face Recognition"* presents a comprehensive analysis of deep learning (DL) methods applied to face recognition (FR) systems, highlighting significant advancements in this field. The authors discuss 171 recent contributions, focusing on various DL techniques, algorithms, architectures, loss functions, activation functions, and datasets used for FR. The paper categorizes FR into two main types: face verification (1:1 matching) and face identification (1:N matching). It emphasizes the importance of feature extraction in FR systems, detailing how deep learning methods significantly enhance performance by learning discriminative face representations through hierarchical architectures. The study also examines challenges in FR, such as variations in illumination, expression, pose, and occlusion. It reviews key DL models, including convolutional neural networks (CNNs), autoencoders, generative adversarial networks (GANs), deep belief networks, and reinforcement learning. The paper explores various datasets commonly used in FR tasks and discusses future trends and potential improvements for DL-based FR systems.

[5] The paper *"Forensic Sketch Reconnaissance Using Deep Learning"* proposes a deep learning-based system to enhance the process of criminal identification using facial sketches. Traditional methods of hand-drawing suspect sketches by forensic artists are time-consuming and limited by the availability of skilled professionals. The proposed system aims to create a user-friendly platform that allows law enforcement to quickly generate accurate facial sketches using predefined facial features. These sketches can then be compared to law enforcement databases for suspect identification, leveraging deep learning and cloud infrastructure for improved accuracy and efficiency. The platform also supports uploading hand-drawn sketches, converting them into usable digital features for matching. By automating the sketch-to-database matching process, the system significantly speeds up criminal identification and reduces dependence on forensic artists. The model also ensures data security and privacy while being backward compatible with traditional sketching methods.

[6] The paper *"Feature-based Sketch-Photo Matching for Face Recognition"* introduces a method for improving the accuracy of matching sketches with photographs in law enforcement applications. Traditional sketching techniques used to identify criminals based on eyewitness descriptions are often time-consuming and prone to errors. The proposed method enhances this process by employing feature-based matching, where both sketches and photos are analysed using two key feature extraction techniques: Histogram of Oriented Gradients (HoG) and Gray Level Co-occurrence Matrix (GLCM). These features are used to generate a feature vector that represents the facial characteristics in both sketches and photographs. By computing these features, the system increases the likelihood of correct matches and reduces mismatches. The experimental results demonstrate that the proposed feature-based approach outperforms other state-of-the-art methods in terms of accuracy when matching sketches to photos of the same individual. This method promises to be a more reliable and efficient tool for criminal identification and verification.

[7] This research paper "*A New Way for Face Sketch Construction and Detection Using Deep CNN*" presents a novel approach for face sketch construction and recognition using Deep Convolutional Neural Networks (CNNs). The study introduces an innovative program that allows users to easily create composite sketches via a drag-and-drop interface, eliminating the need for forensic artists. Using deep learning and cloud infrastructure, the generated sketches are cross-referenced against a police database for quick suspect identification. The paper demonstrates a CNN model that converts sketches into photorealistic images and applies transfer learning using a pre-trained VGG-Face model for accurate recognition. The method achieves an impressive 0.98 accuracy in identifying individuals from sketches, significantly improving forensic investigations by combining deep learning with modern criminal justice technologies.

[8] The paper "*Face Sketching and Prediction Application*" introduces an innovative solution for law enforcement to efficiently create and identify facial composite sketches. The application allows users to design sketches using a drag-and-drop interface, eliminating the need for professional forensic artists. It supports the upload of hand-drawn sketches, which are processed using deep learning algorithms to match suspects from a police database. The system

integrates cloud infrastructure for enhanced performance and includes features like centralized server security, and machine locking for data protection. By leveraging machine learning, the application improves sketch creation efficiency over time, enabling faster and more accurate suspect identification, addressing limitations of traditional face sketch recognition methods.

Table 1: Summarization of various authors

Authors	Dataset	Tools used	Algorithms used	Observations
V. Rodin and A. Maksimov [1], 2024	A large dataset comprising a variety of facial sketches and their corresponding photographs.	Python Programming Language	Convolutional Neural Networks (CNNs).	The application demonstrated significant improvements in recognizing faces from sketches with an accuracy rate of approximately 90%.
Bin Sheng, Ping Li, Chenhao Gao [2],2024	The dataset was pre-split into 2 sections: train data, contains approximately 80% of total images, and valid data which contains approximately 20% of total images.	TensorFlow, OpenCV	Generative Adversarial Networks (GANs)	The application demonstrated significant improvements in recognizing faces from sketches.
Hamed Kiani Galoogahi and Terence Sim [3],2022	Real-World Face Databases and Custom Dataset for Features	Dlib, Google Cloud	Scale-Invariant Feature Transform (SIFT)	By combining deep learning models with facial landmark extraction, face sketches can be efficiently compared to real-world photos in the database.
M. Turk and A. Pentland [4],2021	Datasets like VGG Face, Mega Face, and CASIA-Web Face are also used for training deep learning models to recognize faces.	TensorFlow and PyTorch	Deep Reinforcement Learning (DRL) models, like those applied in Fair Loss and ADRL (Attention-aware Deep RL), are used to optimize face recognition models by selecting the most relevant features.	The combination of Cloud Infrastructure and Deep Learning accelerates the training and deployment of face recognition models at scale, allowing real-time performance with large datasets.
Hamed Kiani Galoogahi and	Generated facial features or synthetic	SQL databases to store facial images,	Generative Adversarial	Ensuring that the sensitive data (such

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Terence Sim [5],2021	face sketches based on predefined features (eyes, ears, nose, mouth) that help train the system to create recognizable face sketches.	sketches, and associated metadata for fast querying and recognition	Networks could be used to generate realistic face sketches from a set of predefined features	as face images and sketches) are securely stored and processed, likely through encryption techniques and secure cloud infrastructure.
Zhang, X., & Zhang, H [6], 2021	This dataset contains both hand-drawn sketches and photographs of the same individuals, which is ideal for training deep learning models that focus on face sketch recognition and matching.	OpenCV is used for pre-processing the sketches and images, including tasks such as resizing, normalization, and edge detection. It also supports facial feature extraction, which is crucial for deep learning-based sketch.	GANs can improve the quality of the generated sketches, ensuring they more closely resemble real faces, enhancing the accuracy of the matching process.	The use of CNNs and transfer learning allows the system to recognize facial features more precisely, improving the chances of correctly identifying suspects from sketches.
Simonyan, K., & Zisserman, A [7], 2020	The dataset is valuable for training deep learning models to learn the relationship between hand-drawn sketches and real face images.	OpenCV is employed for pre-processing images (such as resizing, normalization) and performing facial feature extraction, which is a key step before applying deep learning models for recognition.	GANs are powerful in generating realistic-looking images, which can be beneficial in improving the quality of sketches created by the user.	The deep learning-based sketch recognition system provides higher accuracy compared to traditional manual methods. The use of CNNs and transfer learning ensures precise sketch-to-photo matching, leading to fewer false identification.
hl G da Vitoria Lobo N won [8], 2020	It contains paired sketches and photos of faces collected from real subjects, providing the essential data for training and evaluating feature-based matching techniques.	Python was used for implementing algorithms and feature extraction. Libraries like OpenCV, Scikit-Image, and NumPy are widely used for tasks such as image transformation, feature computation, and machine learning	This method is used to extract textural features from images by considering the spatial relationship of pixel intensities	The feature-based approach of combining HoG and GLCM features resulted in higher accuracy compared to traditional methods for sketch-photo matching.

III. METHODOLOGY

Methodology for Recognition

1. Setup and Preprocessing

➢ Initialize Flask Application: The Flask app is set up to handle HTTP requests for uploading images, displaying the results, and performing the recognition task.

➢ Create Directories: The application ensures that necessary directories (static/uploads for uploaded files, static/photos for stored sample images) exist.

➢ Database Initialization: An SQLite database (image_details.db) is created to store metadata (filename, name, age, date of birth) associated with the sample images for later reference.

➢ Sample Images: ample images are pre-processed and stored with metadata in the databases.

2. User Uploads Sketch

➢ User Uploads Sketch Image: The user uploads a sketch image via the web interface. The uploaded file is saved with a unique timestamp to avoid overwriting files.

➢ Preprocess the Sketch Image: The uploaded sketch is resized to 150x150 pixels to standardize the input image size, ensuring consistency in the input data.

3. Extract Facial Features (Facial Embedding)

➢ Extract Facial Features from the Sketch: The uploaded sketch is processed using the face_recognition library, which detects the face and extracts the facial encoding (embedding). The encoding is a high-dimensional vector that uniquely represents the face's features (such as distances between eyes, nose shape, etc.). The face_recognition.faceencodings() function returns a 128-dimensional vector for each face detected in the image. If no face is detected, an exception is thrown.

➢ Extract Facial Features from Sample Photos:
Similarly, each stored photo in the PHOTO_FOLDER undergoes the same process: facial feature extraction using face_recognition.faceencodings().

4. Compare Sketch Features with Stored Image Features

➢ Calculate Euclidean Distance: The facial embedding (feature vector) extracted from the uploaded sketch is compared to the embeddings of all stored sample images using Euclidean distance.

➢ Euclidean Distance Formula:

$$\text{Distance} = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2}$$

Where x_i and y_i represent corresponding elements of the two facial encoding vectors (for the sketch and the photo).

➢ The smaller the distance, the more similar the faces are. This helps determine how closely the sketch matches each stored image.

➢ Thresholding: Once the distances are computed, they are compared against a threshold (e.g., 0.6). If the minimum distance is below the threshold, it indicates a valid match. If no match is found with a sufficiently low distance, the system informs the user that no match was found.

5. Return the Best Match or No Match

➢ Sort the Matches: The computed distances are sorted in ascending order, with the closest match being the one with the smallest distance.

➢ Display the Best Match: If a valid match is found (i.e., the minimum distance is below the threshold), the metadata (name, age, date of birth) of the best match is retrieved from the database using the filename. The system then renders the result on the web page, showing the name, age, and photo of the matched individual.

➢ Handle No Match: If no match is found (i.e., all distances exceed the threshold), the system informs the user that no match was found.

6. Render Result

➢ Render Web Page: Based on the result (either a match or no match), the appropriate HTML template (result.html) is rendered, displaying the result to the user, including the best-matching image (if found).

The face recognition feature in the code relies on deep learning models for facial encoding. These models typically use convolutional neural networks (CNNs) trained on large datasets to detect faces and generate embeddings. Specifically, the face_recognition library internally CNN-based models for face detection and embedding extraction.

Methodology for Constructing a Face Tool

1. Feature Category Selection:
- The user is presented with multiple buttons, each representing a different category of facial features (e.g., Eyes, Nose, Hair, Lips, Eyebrows, etc.).
- The user selects a category to view the available facial features.

2. Display Available Features:
- Each facial category (like Eyes, Nose, etc.) has a predefined set of image assets stored on the server.
- When the user selects a category, the corresponding images of facial features are fetched and displayed as thumbnails in a grid layout.
- The user sees different options for features like various styles of eyes, noses, hair, etc.

3. Feature Drag and Drop:
- The user selects a feature of image by dragging it.
- When the user drags an image of a feature (e.g., a pair of eyes), the image becomes movable. The user can drop this image onto a canvas (a blank area representing the face).
- The selected feature is placed on the canvas.

4. Adjust Position of Features:
- The user places the feature image (e.g., eyes) on the canvas.
- The user can drag the feature to adjust its position on the canvas, aligning it with other facial features for a natural look. The user can also move it around to experiment with different placements.
- The feature is positioned where the user places it.

5. Continue Adding More Features:
- The user repeats steps 2 to 4 for other facial features like nose, lips, eyebrows, etc.
- The user continues selecting, dragging, and placing various facial features (e.g., nose, lips, etc.) until the face is complete. Each feature is positioned according to user preference on the canvas.
- The face begins to take shape on the canvas.

6. Optional Feature Removal:
- The user may want to remove a feature.
- The user can drag any feature off the canvas to delete it.
- The feature is removed, and the user can continue working.

7. Save and Export Final Image:
- Once the user has constructed the face and is satisfied with the arrangement, they click on a "Save Image" button.
- The entire canvas with all the features is captured as an image. The image is then converted into a downloadable format (e.g., PNG).
- The user can download the final constructed image of the face.

Flowchart

Fig.1 presents a detailed flowchart depicting the process involved in the forensic face sketch construction and recognition system. The process begins with forensic experts initiating the system, which first checks if a rough sketch of the suspect's face is available. If the rough sketch is not available, the user is prompted to select various face features (such as the eyes, nose, mouth, etc.) to construct the rough sketch of the face. Once the rough sketch is created, the system proceeds to the feature extraction phase, where distinct facial features are identified and extracted. After extracting these features, the next step is the face recognition process, where the system matches the constructed sketch against a criminal database to identify possible matches.

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If the rough sketch is already available from an external source, the system allows the user to directly import the sketch, bypassing the feature selection and rough sketch creation steps. In this case, the imported sketch is rendered, and the image is processed further for recognition. Additionally, the sketch can be exported for further use, such as for analysis or sharing with law enforcement agencies. The final output of the system provides the recognition results, which may include potential matches from the criminal database.

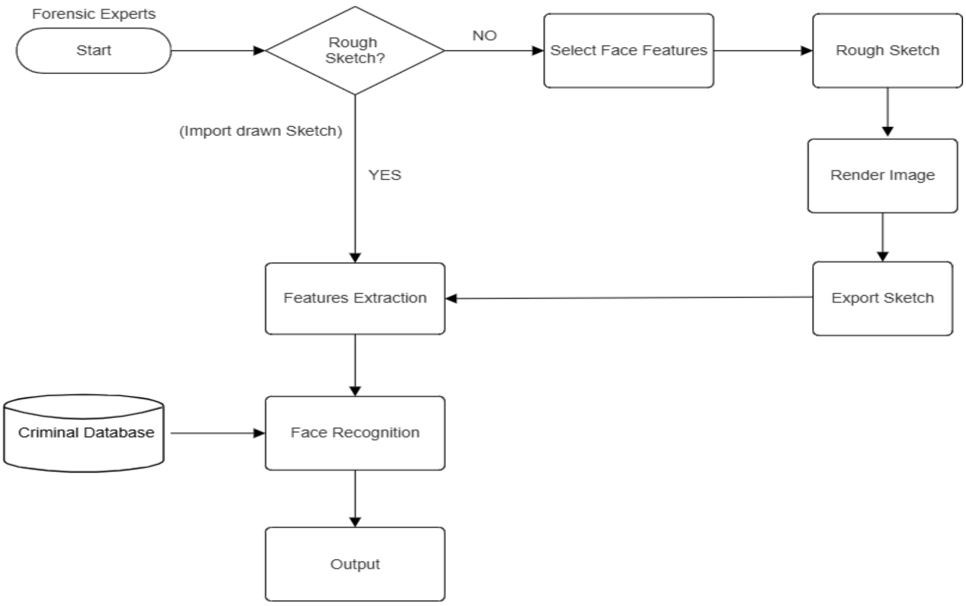

Fig. 1. System architecture

The flowchart in Fig. 2 outlines the process for creating and saving a face sketch using an interactive canvas. The process begins with initializing the face sketch, where the system sets up an empty canvas for the user to start creating their desired face sketch. Once the canvas is prepared, the user is prompted to select various face elements such as eyes, nose, mouth, and head shape from predefined options provided in the system. After selecting a face element, the user clicks and drags it onto the canvas. The user can position and adjust these face elements to create the desired facial features, ensuring that each feature is placed in the correct position. As the user continues to adjust and move the face elements on the canvas, they can release the mouse once they are satisfied with the placement.

The process continues with the user being prompted to repeat the process of selecting and positioning additional face elements until the entire face sketch is created. After the user has positioned all the necessary facial features, they click the "Save" button to finalize the face sketch. Once the save button is clicked, the system converts the entire canvas into an image using the html2canvas library. This library captures the content on the canvas and converts it into a downloadable PNG image. After the conversion, the user is provided with the option to download the face sketch as a PNG image, which can be saved and shared. This process ensures that users can easily create customized face sketches and download them for further use. The flow concludes when the face sketch is saved and downloaded, completing the entire process from start to finish.

The Fig. 3 illustrates the process flow of a facial recognition system designed to match sketches with a database for identifying suspects. The process begins by opening the face recognition module, where the user determines the type of sketch to be processed. If the sketch is hand-drawn, the user selects the appropriate image manually. Alternatively, if the sketch is created using an application, it is directly uploaded to the system. Once the sketch is ready, it is uploaded onto the server, where it undergoes a matching process against a database of stored facial data. After the matching is complete, the system displays the similarity results, highlighting the degree of resemblance between the sketch and the database entries. If a match is identified, the system proceeds to display additional details about the suspect. Finally, the metadata related to the identified suspect can be shared, enabling further communication or investigative actions. This flow is particularly relevant for law enforcement and security applications, where accurate identification based on sketches is crucial for solving cases and ensuring public safety.

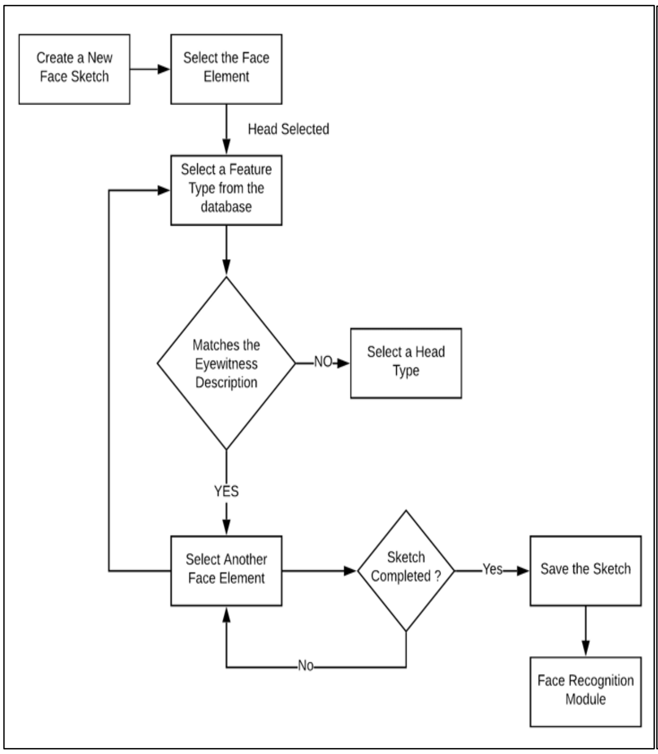

Fig. 2. Flow Chart for Creating a Face sketch

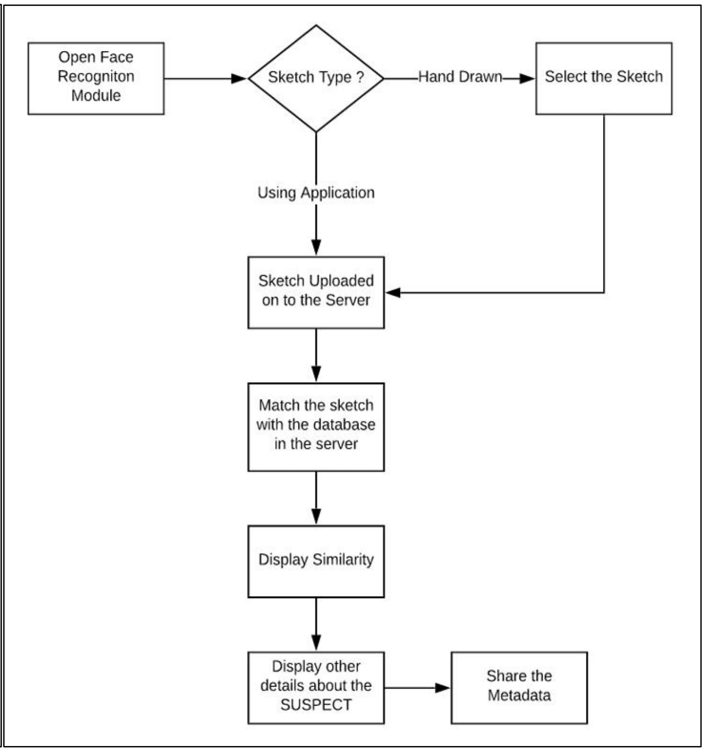

Fig. 3. Flow Chart for Recognizing a sketch

IV. RESULT AND ANALYSIS

The system enable user to create faces sketches using facial tools by drag and drop interface and allows users to upload this sketch or existing sketch for recognition of suspect. These results indicate its effectiveness for use in Forensic departments. The following are the snapshots of result.

Fig. 4 illustrates the home screen of the application, featuring two primary options: Upload Sketch, which allows users to upload an existing sketch for recognition, and Create Sketch, enabling users to construct a new facial sketch using the drag-and-drop interface.

Fig. 4. Home screen page

Fig. 5 depicts the Create Sketch Screen, where users can assemble facial features such as eyes, nose, mouth, hair, head, eyebrows and moustache using an intuitive drag-and-drop interface to construct a suspect's sketch.

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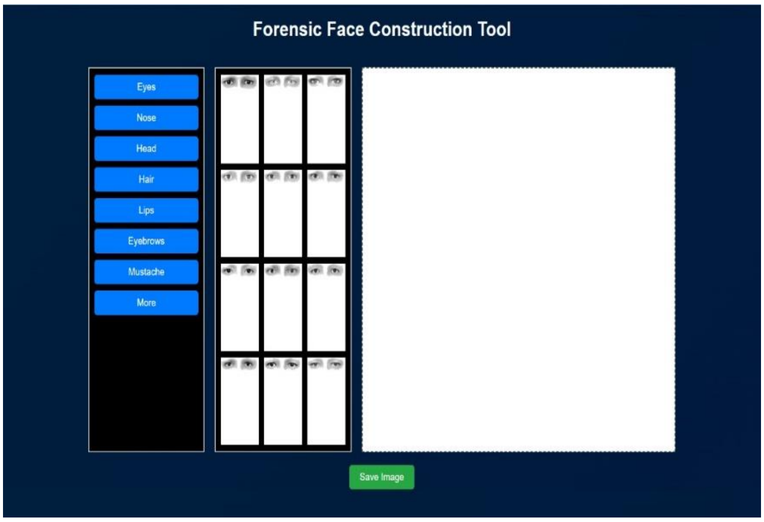

Fig. 5. Face construction page

Fig. 6 illustrates the Step-by-Step Facial Feature Placement on Canvas, where users can drag and position individual facial elements, such as eyes, nose, and mouth, onto the canvas. Each feature can be resized and adjusted for accurate alignment. This process allows users to build a complete and precise facial sketch by adding one element at a time.

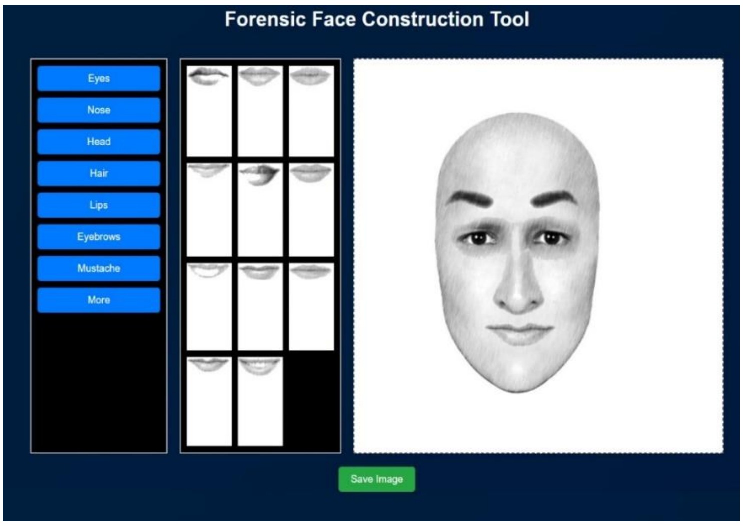

Fig. 6. Face construction by dragging facial elements

Figure. 7 shows the process when the user clicks the "Save Image" button. The system saves the facial sketch displayed on the canvas in PNG format. This ensures the sketch is securely stored with proper formatting for future use.

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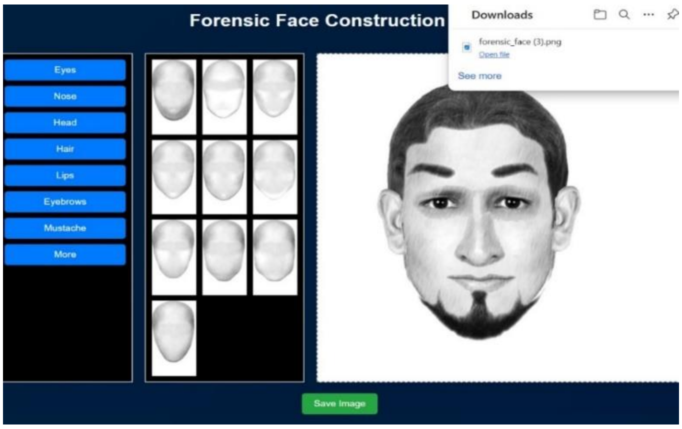


Fig. 7. Saving sketch after constructing

Fig. 8 illustrates the result screen for the created sketch recognition process. It displays the suspect's matched image from the criminal database alongside relevant details, providing law enforcement with a clear and efficient identification output.

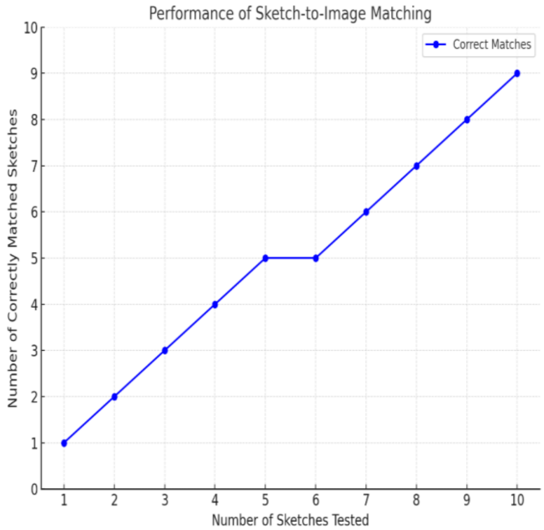
Fig. 8. Recognition of constructed sketch

Fig. 9 illustrates the result screen for the existing pencil sketch. It displays the suspect's matched image from the criminal database alongside relevant details, providing law enforcement with a clear and efficient identification output.

Fig. 9. Recognition of available or existing sketch

Analysis of the results illustrated in Fig. 10 which shows the performance of a sketch-to-image matching system, depicting the relationship between the number of sketches tested and the number of correctly matched sketches. The graph displays a linear progression of correctly matched sketches, indicating a direct correlation between the two variables.

Fig. 11 illustrates a comparative analysis of two methodologies—Structural Similarity Index Measure (SSIM) and Face Encoding—in the context of facial recognition across four performance metrics: Accuracy, Robustness, Scalability, and Facial Feature Focus. The graph highlights the percentage performance for each metric, providing insights into the effectiveness of these approaches.



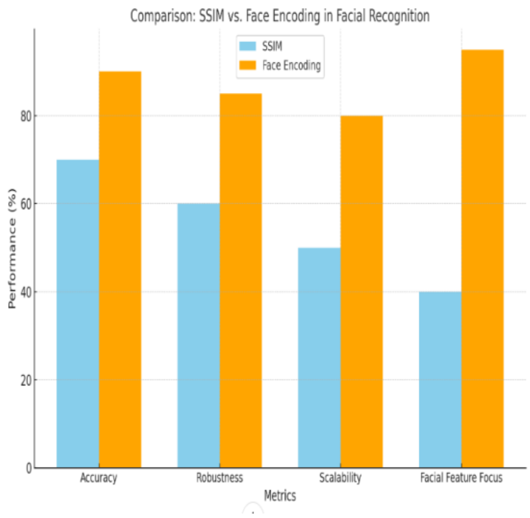


Fig. 10. SSIM vs. Face Encoding in Facial Recognition

Fig. 11. Performance of Sketch-to-Image Matching

In Fig. 10, The x-axis represents the number of sketches tested, ranging from 1 to 10, while the y-axis denotes the number of correctly matched sketches. Each data point, represented by a blue dot, marks the outcome of the matching process for the corresponding number of sketches.

In Fig 11, The x-axis represents metrics while y-axis represents percentage of performance.

V. CONCLUSION

The Face Sketch Construction and Recognition for Forensic project provides a robust and efficient platform to assist law enforcement in identifying suspects without relying on professional forensic artists. By enabling the creation of accurate face sketches through intuitive drag-and-drop tools and integrating advanced facial recognition algorithms, the system bridges the gap between artistic sketching and modern technology. With its ability to preprocess sketches, extract facial features, and match them against a database of known individuals using machine learning models, the platform ensures high precision and speed. This innovative solution significantly enhances investigative capabilities, offering a time-saving and scalable method for criminal identification, ultimately contributing to improved public safety and justice delivery.

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