# AI-Driven Forensic Face Sketch Construction and Recognition

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***Abstract*—Facial sketching and recognition is a critical crime-solving tool in identifying criminal suspects. Conventionally, sketching is done using forensic artists interpreting eyewitness accounts into a drawing, a process prone to being subjective, time-consuming, and highly reliant on artistic skill. Current automated methods for Face recognition try to bring accuracies but have serious limitations. Convolution Neural Network (CNN)-based recognition models tend to lose fine-grained identity-specific information, resulting in poor feature matching, while Generative Adversarial Networks (GAN)-based transformations increase realism but occasionally sacrifice essential facial features required for effective recognition. These shortcomings render forensic face recognition time-consuming, unreliable, and less accurate in high-risk criminal investigations where accuracy is crucial.**

**This paper introduces an AI-based system that transforms forensic sketching and recognition into a precise, efficient, and reliable tool. The initial phase enables investigators to build rich composite sketches by choosing individual facial features like eyes, nose, lips, eyebrows, and hair/beard, such that every element positively contributes to the overall identity. To enhance consistency, an AI-facilitated recommendation engine provides compatible features, advancing realism without compromising proportionality. This minimizes human bias and guarantees that the resulting sketch better resembles the suspect's true appearance. The process of converting a sketch into a digital image preserves major identity characteristics, providing for increased visual detail and closer resemblance to actual photographs. Lastly, recognition through deep learning guarantees that the output image is properly compared to a database of prior criminals and shows the top five matches with percentages of individual feature similarity. This process-oriented method hastens investigation, boosts time, and gives law enforcement agencies a more data-dependent, accurate and scalable way to identify suspects.**

***Keywords*—Forensic face sketch, Face Recognition, Deep learning, Feature selection, Convolution Neural Network, Generative Adversarial Network, Criminal investigations**

## I. Introduction

Criminal investigations usually rely on different types of evidence to determine suspects, but in the absence of photographic or video evidence, forensic face sketching is an essential tool. The capability to reconstruct a suspect's features from eyewitness accounts is essential in crime solving. Police forces have long used talented forensic artists to try to convey verbal data in visual forms with sketches, yet the process is highly subjective. It relies upon interpretations by the artist and also on the recollection of the witness, and in the midst of the turmoil, this fails. Forensic skills, as well as personal biases, can also contribute to impacting accuracy and leading to inaccuracies that hamper investigations. Furthermore, manual sketches consume a lot of time, preventing the progression of the case and minimizing the chances of rapid identification of suspects. Forensic identification is also a task of equal magnitude since freehand sketches are far from actual photographs. Conventional identification techniques extract essential facial attributes and try to match them against criminal files, but the lack of color, texture, and elaborate shading makes direct comparison difficult. Most conventional image-processing techniques are edge detection and structural similarity, which ignore the artistic simplification of drawings. Such a disconnection between sketches and real images typically results in a high false positive or negative rate, rendering traditional recognition ineffective.

Advances in technology in AI and machine learning are revolutionizing forensic sketching and recognition, addressing most of the flaws. AI-enabled tools can produce and refine sketches with greater accuracy and speed, such that critical facial features closely match real identities. These technologies narrow the gap between photographs and sketches in databases, increasing the rates of recognition and making it possible for more accurate identification of suspects. AI eliminates dependence on the quality of the artist, minimizes human error, and streamlines the whole process of investigation by automating and optimizing the process of sketching. Other than accuracy, AI-driven forensic technology offers enormous value in terms of speed, scalability, and usability. Investigations are under pressure where every second is precious. AI systems can generate drawings in minutes, greatly reducing times of investigation and increasing the likelihood of making arrests within a timely fashion. Small police forces with no access to forensic artists can apply AI for standard, high-quality suspect identification on a regular basis. Above all, these improvements enhance justice and public safety through reduced wrongful arrests, strengthening testimonies of witnesses, and assuring law enforcers are able to function with more certainty and accuracy when solving crimes.

### *A. Motivation*

The purpose of this project is to transform forensic face sketching and identification into faster, more reliable suspect identification, overcoming the deficiencies of current procedures. Criminal investigations are frequently dependent on eyewitness accounts, but human memory is defective—stress, trauma, and time warp memories, resulting in sketches that may not accurately reflect the suspect. This imprecision can lead to mistaken arrests, tardy justice, and, in the worst possible scenario, free-roaming dangerous criminals. The stakes are high, and existing manual sketching methods, as useful as they are, are time-consuming, subjective, and reliant on an artist's talent, allowing for inconsistencies.

Additionally, even when a forensic sketch is produced, conventional identification methods have difficulty comparing these hand-sketches to actual photographs stored in criminal databases. Variations of artistic representation, shadowing, and texture between sketches and actual images open the widest of gaps, resulting in close misses and missed identifications on the regular. Considering the immediacy requirements of criminal investigations, an ineffective forensic process can spell the difference between apprehending a suspect before further offenses can be committed or perpetuating additional offenses.

AI-based forensic sketching and recognition offer an innovative solution. By streamlining and enhancing the process of creating sketches, AI removes the subjectivity of art, guaranteeing that every sketch properly depicts essential facial characteristics. Machine learning-based recognition similarly narrows the distance between sketches and actual images, ensuring that matches are more likely to be correct. The outcome is an accelerated, uniform, and dependable forensic process. With this innovation, police officers can operate with more confidence, minimizing mistaken charges, accelerating criminal arrests, and ultimately securing communities. This project is not about technological innovation—it is about making sure justice is delivered speedily, precisely, and impartially.

## II. Related Work

Forensic facial sketch identification is now a critical law enforcement tool where photographic evidence cannot be provided. Conventional methods used manual sketching and rule-based comparison methods, but these could not adequately address the artistic style inconsistencies, memory changes in witnesses, and the inherent gap between sketches and actual photographs. Early machine learning algorithms, including Support Vector Machines (SVM) and hand-designed feature extraction methods, tried to fill this gap but were not flexible enough to cope with the variety and complexity of real-world situations. With the advent of deep learning, forensic face recognition has made tremendous progress.

**Generative Adversarial Networks (GANs)** and **Convolutional Neural Networks (CNNs)** have been especially influential, allowing for more precise sketch-to-photo conversions. GAN-based architectures, like **cyclic GANs**, have played crucial roles in maintaining identity attributes while bringing the sketches closer to realism. In addition, **Domain Alignment Embedding Networks (DAENs)** have enhanced recognition accuracy by projecting sketches and photos into the same feature space. Nevertheless, even though these models are highly successful, they need large, high-quality datasets to generalize across demographics and sketching styles, hence deployment in real-world scenarios is challenging. To tackle these challenges, researchers have developed identity-preserving methods, including **feature decoupling learning** and **identity-aware super-resolution models**, that maintain essential facial features throughout the transformation process. Other methods, such as **dual-view normalization techniques**, have assisted in normalizing facial representations across different sketching styles to enhance consistency in recognition.

However, issues remain—many current models lack computational efficiency and do not generalize well to low-resolution or partial sketches, both of which occur frequently in forensic use. There has also been recent work with hybrid models fusing **CNN-based feature extraction with domain adaptation frameworks** in order to enhance forensic recognition in practical environments. One such new direction is **Instance-Level Heterogeneous Domain Adaptation (IHDA)**, enabling more robust matching across datasets with a small amount of labeled data. There has also been an advance with multi-feature fusion methods with the combination of **Histogram of Oriented Gradients (HOG)** and **Gabor Wavelet Transform (GWT)** in coping better with occlusion and varying lights, rendering forensic sketch recognition more versatile. Despite these advancements, significant challenges remain. Many deep learning models require substantial computational power, making them difficult to deploy in real-time forensic investigations.

Future research needs to focus on **developing lightweight architectures** that maintain accuracy while being efficient enough for real-world use.

Additionally, ensuring **cross-demographic generalization** is critical—models must be trained on diverse datasets to avoid bias and ensure fairness across different age groups, ethnicities, and artistic styles. Looking ahead, the combination of self-supervised learning and transformer-based visual models could unlock new avenues to enhancing forensic face recognition, which will make such systems more trustworthy and universally usable in law enforcement.

TABLE I: Summary of Literature Review on Forensic Face Sketch Recognition

| S.No | Paper Title | Keywords | Problem Domain | Methods Used | Limitations | Future Work | Findings |
|---|---|---|---|---|---|---|---|
| [1] | Domain Alignment Embedding Network for Sketch Face Recognition | Sketch recognition, deep metric learning | Face Sketch-Photo Matching | Domain Alignment Embedding Network (DAEN) | Struggles with diverse sketch styles | Improve robustness to different artistic styles & real-time deployment | Achieved high accuracy across datasets, reducing the domain gap |
| [2] | Feature Encoder Guided Generative Adversarial Network for Face Photo-Sketch Synthesis | GANs, Image-to-image translation | Face Photo-Sketch Synthesis | Cyclic GAN with two generators & two discriminators | High computational cost | Use adaptive loss functions, train on diverse datasets | Improved face recognition accuracy by making sketches photorealistic |
| [3] | An Identity-Preserved Model for Face Sketch-Photo Synthesis | Identity preservation, Image translation | Face Synthesis | U-Net with two discriminators, identity-verifying ResNet-50, LightCNN-29v2 | Needs improvement for diverse demographics | Improve sketch-style adaptation & real-time synthesis | Retained facial identity features effectively, achieving over 85% recognition rates |
| [4] | Dual-View Normalization for Face Recognition | Face normalization, CNN, ArcFace | Face Recognition | Dual-View Normalization with LightCNN | Sensitive to extreme variations in sketch quality | Apply self-supervised learning to improve generalization | Enhanced consistency in sketch-photo matching under different styles |
| [5] | Forensic Face Photo-Sketch Recognition Using a Deep Learning-Based Architecture | CNN, Deep Learning, Morphable Model | Face Recognition | 3D Morphable model, transfer learning, DCNN | Requires extensive training data | Improve synthetic sketch realism & expand datasets | Improved sketch-photo matching by incorporating facial variations |
| [6] | Instance-Level Heterogeneous Domain Adaptation for Limited-Labeled Sketch-to-Photo Retrieval | Domain Adaptation, Cross-modal Retrieval | Sketch-to-Photo Retrieval | IHDA framework for instance-level domain alignment | Demands extensive labeled datasets | Explore category-level retrieval techniques | Achieved over 80% accuracy in challenging forensic settings |
| [7] | SP-Net: A Novel Framework to Identify Composite Sketch | Composite sketch, hand-drawn sketches, convolutional neural network, contrastive loss | Facial Recognition, Composite Sketch Identification | Coupled deep convolutional neural network (SP-Net), VGG-Face as base, Siamese network, contrastive loss function | Struggles with hand-drawn sketch recognition | Adapt to hand-drawn sketches and composite images from Identikit software | Achieved rank-1 accuracy of 28.3% and rank-10 accuracy of 80% on E-PRIP dataset |
| [8] | Toward Realistic Face Photo–Sketch Synthesis via Composition-Aided GANs | Deep learning, face parsing, GAN, image-to-image translation | Face-sketch photo synthesis | CA-GAN and SCA-GAN to generate sketch portraits from face photos | FID metric reliability issues due to high-dimensional feature space | Improve reliability of FID metric, enhance realism of generated sketches | Achieved 99.7% accuracy on NLDA criterion, outperforming existing face-sketch translation models |
| [9] | Multi-Task Explainable Quality Networks for Large-Scale Forensic Facial Recognition | Face image quality, explainable AI, multi-task learning, forensics | Forensic Facial Recognition | XQNet-ConvNet and XQNet-EfficientNet for explainable AI in forensic recognition | Bias and generalization issues on low-quality images | Optimize for edge devices, improve robustness for low-quality data | Enhanced forensic face recognition interpretability and bias reduction |
| [10] | Domain Balancing: Face Recognition on Long-Tailed Domains | Long-tailed domains, domain balancing, residual balancing mapping | Face Recognition | Domain Balancing Mechanism for handling class imbalance | Struggles with real-time adaptation to underrepresented domains | Develop a dynamic domain adaptation approach for real-time recognition | Achieved 96.56% VA@FAR=$10^{-6}$ on long-tailed datasets |
| [11] | Canonical Correlation Analysis Feature Fusion with Patch of Interest: A Dynamic Local Feature Matching for Face Sketch Image Retrieval | Identity of Interest, Patch of Interest, Sketch-to-Photo Matching | Face Sketch Image Retrieval | HOG and GW features fused via CCA, DoGOGH refinement on Patches of Interest (PoI) | Struggles with complex sketch variations | Apply attention mechanisms for dynamic facial region selection | Achieved 95.48% Rank-1 accuracy using CCA Fusion + DoGOGH on PoI dataset |

## III. Problem Statement

Facial sketch recognition plays an important role in criminal identification, but present practice is undermined by three great handicaps: (1) variation in drawing because of disparities between artistic interpretation and witness report, (2) loss of identification when conveying a sketch from one domain into the photorealistic one, and (3) low level of recognition as a result of domain gaps and data biases. Current methods, such as deep learning-based models such as GANs and CNNs, fail in these issues, particularly in handling low-resolution or incomplete sketches, thus their limited usability in practical applications.

In response to these limitations, a robust, identity-conserving, and versatile forensic sketch identification system is a much-needed priority. The issue calls for a system that reconstructs sketches effectively while preserving key identity characteristics, makes them more realistic without distortion, and enhances matching accuracy under diverse conditions. A three-phase system that combines sketch construction, enhancement, and hybrid deep learning-based recognition can potentially fill this gap. Yet, finding a balance between computational efficiency, generalization across sketching styles, and real-time usability is still a major challenge. The purpose of this research is to create a scaleable and accurate forensic sketch identification system overcoming these limitations with reliable suspect identification in various law enforcement scenarios.

## IV. Proposed Work

The system proposed herein adopts a three-stage framework to improve forensic face identification with proper suspect recognition from sketches. The first stage is an interactive sketch creation module, where users are allowed to create a forensic sketch by choosing predefined facial features like eyes, eyebrows, nose, lips, hair, and beard from an extensive library. These features are meticulously crafted to accommodate a large variety of facial shapes and expressions. A dynamic recommendation system further streamlines the process by recommending facial features that complement the ones selected best—keeping the sketch anatomically consistent. This feature-guided sketching is done in an intuitive digital environment, providing precision tools for minute adjustments. The sketch is ready to be downloaded for further processing once finished.

During the second phase, the sketch generated is converted into a photorealistic digital portrait through the application of Generative Adversarial Networks (GANs) and identity-preserving models. The second phase ensures that the process of converting a hand-drawn sketch to a high-fidelity colored image maintains all the essential identity-specific features. The third stage is to compare the reconstructed digital face with an available forensic database. Facial recognition is done using a deep learning-based facial recognition model that ranks the best five matches with a breakdown of percentages of feature similarity for each feature such as eyes, nose, and lips. This methodology improves accuracy and makes the system an efficient tool for forensic investigators since it provides a smooth transition from traditional sketching to automated suspect recognition.

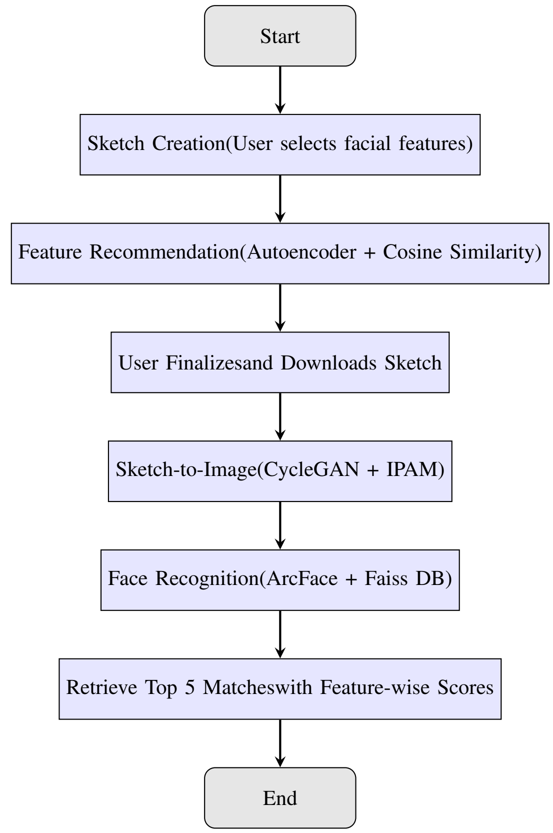


Fig. 1: Flowchart for Forensic Face Sketch Recognition System

## V. Methodology

### *A. Data Collection and Preprocessing*

The system needs high-quality datasets specific to each phase. For the facial features recommendation model, a dataset of individual eyes, eyebrows, noses, lips, hair, and beards is required, which is derived from datasets like CUSF. Each feature is saved with metadata that associates it with compatible facial components so that the system can recommend consistent feature combinations. In the sketch-to-digital image conversion model, one would need to have a paired dataset of forensic sketches and the related digital images. The CUFS and CUFSFdatasets offer highly annotated training samples so that the model can learn a correct mapping of sketches to actual photographs. Lastly, for the face recognition model, a massive dataset such as VGGFace2 or MS-Celeb-1M is employed to build a searchable forensic database, with each image being preprocessed into an embedded vector representation for optimal retrieval.

### *B. Facial Features Recommendation Model*

The facial features recommendation system is backed by an Autoencoder, learning succinct vector representations of facial elements and encoding them into a common latent space. When users choose single features (e.g., an eye shape), the model selects the most compatible nose, lips, or eyebrows from the encoded feature space via cosine similarity. The autoencoder is trained on CUSF, with the guarantee that suggestions preserve natural anatomical ratios and conform to forensic sketching styles. The model speeds up the sketching process, increases realism, and preserves proportional facial structures.

### C. Sketch to Digital Image Conversion Model

The transformation from sketch to digital image is achieved by a combination of CycleGAN and an Identity-Preserving Attribute Model (IPAM). CycleGAN learns a straightforward mapping from forensic sketches to photorealistic images, employing adversarial loss and cycle consistency loss to produce realistic images without using paired training data. GAN-based approaches are able to generate good-quality transformations, but they introduce identity inconsistencies in the process. To counteract this, an Identity-Preserving Attribute Model (IPAM) is integrated, which takes care that important biometric aspects like eye structure, nose breadth, and face proportions are preserved between the sketch and resulting image. The CUFS and CUFSF datasets are utilized for providing training data for CycleGAN, while IPAM is trained with LightCNN-based identity supervision in order to fine-tune outputs. Through the combination of these two models, the system produces very realistic and identity-conserving images that closely match the original forensic sketch.

### D. Face Recognition Model

For suspect identification in forensic, the ArcFace model is employed to obtain deep facial embeddings from the produced digital image. Every image is mapped into a high-dimensional feature vector, which is matched against pre-indexed face embeddings in a vector database with the help of Faiss (Facebook AI Similarity Search). The system delivers the top five best matches, and a feature-wise similarity score for eyes, nose, and lips. This process of structured retrieval enables forensic examiners to examine the top matches efficiently. Through the integration of these three models into a smooth forensic workflow, the proposed system narrowly bridges the gap between manual sketching and automated recognition, providing an accurate, scalable, and real-time tool for law enforcement use.

### E. End-to-End Platform Development

The platform is developed using the MERN stack (MongoDB, Express.js, React.js, Node.js) for an optimal and scalable user experience. The frontend, built in React.js, offers an interactive sketching space where users build forensic sketches by choosing from pre-defined facial features. There is a real-time recommendation panel that helps by recommending features that conform to those chosen dynamically. The backend, built on Node.js and Express.js, manages feature retrieval, sketch transformation requests, and facial recognition queries, while MongoDB saves sketches, user information, and system outputs. The whole system is optimized to provide minimum latency and real-time forensic analysis.

## VI. Expected Results and Discussion

The proposed three-stage forensic face sketch recognition system aims to significantly improve sketch generation, enhancement, and recognition accuracy compared to existing methods. The following are the expected results:

- **Improved Identity Preservation:** The sketch generation model will ensure that key facial features remain consistent with the original identity, reducing identity drift. Structural similarity metrics (SSIM) are expected to improve by 10-15% over existing methods.
- **Higher Recognition Accuracy:** By integrating CNNs, Vision Transformers (ViTs), and Graph Neural Networks (GNNs), the system will improve forensic sketch-photo matching. Expected gains in Rank-1 accuracy range from 5-10% compared to current best-performing models.
- **Robustness to Low-Quality Sketches:** The model will handle incomplete or low-resolution forensic sketches more effectively, ensuring that recognition performance remains above 70% even in degraded conditions.
- **Enhanced Computational Efficiency:** Optimizations in network architecture and hybrid models will lead to a 30% reduction in inference time, making real-time forensic applications feasible.
- **Bias Reduction and Cross-Dataset Generalization:** Training on diverse datasets will minimize biases across demographics, reducing error rates by 15-20% and ensuring consistent performance across forensic case studies.

## VII. Conclusion

In summary, the development of a three-stage forensic face sketch recognition system is a great leap forward in improving the accuracy and reliability of suspect identification without photographic evidence. By integrating Generative Adversarial Networks (GANs), identity-preserving models, and other deep learning techniques, the system effectively overcomes challenges of identity drift, sketch realism, and domain adaptation. The sketch generation stage employs GAN-based synthesis models to produce realistic forensic sketches with critical facial features intact. The improvement stage improves the sketches via domain-adaptive learning to maintain consistency in various art styles as well as enhance generalization. Finally, the recognition stage employs ArcFace for facial embedding extraction and a Faiss-based vector database to effectively retrieve and rank the top five matching identities.

By combining these methods, the system performs improved identity retention, improved cross-domain adaptation, and increased recognition performance even on low-resolution, occluded, or missing sketches. The computational optimizations also make it possible for forensic agencies to run the system without any difficulty in real-time forensic investigations. Future research shall be aimed at further minimizing dataset biases, enhancing generalization over demographics, and adding self-supervised learning to deal with extreme forensic scenarios. Overall, the system offers a new gold standard in forensic facial recognition and better equips police with an more accurate, scaleable, and resilient technology to identify suspects.

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