AI-Based Forensic Sketch Drawing and Recognition Systems: A Comprehensive Survey

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Abstract

Forensic sketch-based identification is a crucial technique in criminal investigations, especially in situations where photographic or video evidence of suspects is unavailable. Traditionally, forensic sketches are manually drawn by skilled artists based on eyewitness descriptions. However, this process is inherently subjective, time-consuming, and prone to inaccuracies due to human memory limitations and interpretation biases. These challenges significantly reduce the reliability and efficiency of sketch-based suspect identification in real-world scenarios.

With the rapid advancement of artificial intelligence, computer vision, and deep learning, automated forensic sketch generation and recognition systems have emerged as powerful alternatives. These systems aim to bridge the modality gap between sketches and photographs by learning robust feature representations that can effectively match sketches with real facial images. Techniques such as Convolutional Neural Networks, transfer learning models like ResNet and VGG16, and advanced frameworks such as Generative Adversarial Networks have significantly improved the accuracy and efficiency of sketch-to-photo recognition.

This survey presents a comprehensive analysis of AI-based forensic sketch drawing and recognition systems by reviewing multiple research contributions in this domain. It evaluates methodologies, datasets, system architectures, and performance metrics used in existing approaches. It also highlights key challenges, including dataset limitations, sketch variability, computational complexity, and ethical concerns such as bias and privacy. Furthermore, a unified

and scalable system architecture is proposed to enhance real-time applicability and improve recognition accuracy in practical forensic environments.

Keywords

Forensic Sketch Recognition, Deep Learning, Artificial Intelligence, Convolutional Neural Networks, VGG16, ResNet, GAN, Face Recognition, Sketch-to-Photo Matching, Computer Vision

I. INTRODUCTION

Forensic identification plays a fundamental role in modern law enforcement by enabling authorities to identify suspects involved in criminal activities. In many real-world cases, especially those lacking surveillance footage or photographic evidence, eyewitness descriptions serve as the primary source of information. These descriptions are typically translated into visual representations in the form of forensic sketches by trained artists. While this traditional approach has been widely used for decades, it suffers from several limitations, including subjectivity, inconsistency, and dependency on the skill and interpretation of the artist.

Human memory is inherently unreliable and influenced by various psychological factors such as stress, perception, and cognitive bias. As a result, eyewitness descriptions may be incomplete, distorted, or inaccurate. This leads to sketches that do not accurately represent the suspect's appearance. Additionally, different artists may produce different sketches based on the same description, introducing further variability.

One of the primary challenges in forensic sketch recognition is the modality gap between sketches and photographs. Sketches lack color, texture, and fine details present in real images, making it difficult for traditional face recognition systems to match them accurately. With advancements in artificial intelligence, deep learning models such as Convolutional Neural Networks have demonstrated strong capabilities in extracting discriminative features, enabling effective sketch-to-photo matching.

Transfer learning using pre-trained models such as VGG16 and ResNet has further improved performance by reducing training time and enhancing generalization. Additionally, Generative Adversarial Networks have been introduced to convert sketches into photorealistic images, thereby reducing the modality gap and improving matching accuracy.

II. LITERATURE SURVEY

Significant research has been conducted to improve forensic sketch recognition using artificial intelligence techniques. Early approaches relied on handcrafted features such as Local Binary Patterns and Histogram of Oriented Gradients. However, these methods were limited in handling cross-domain variations.

Recent approaches utilize deep learning models, particularly CNNs, to extract robust feature representations. One study proposed a CNN-based system trained on CUFS and CUFSF datasets, achieving improved recognition accuracy. Another work introduced an automated sketch creation system using a drag-and-drop interface combined with deep learning models.

Further research developed a complete pipeline including preprocessing, feature extraction, and similarity matching. Another approach incorporated facial landmark detection to enhance recognition performance. Real-time systems using VGG16 architecture achieved high accuracy levels, while GAN-based methods improved sketch-to-photo conversion.

III. DATASETS AND PERFORMANCE METRICS

The effectiveness of forensic sketch recognition systems largely depends on the datasets used for training and evaluation. Commonly used datasets include CUFS and CUFSF, which contain paired sketch and photo images. These datasets provide a standard evaluation platform but are limited in diversity and size.

Some systems also use custom datasets collected from criminal records or generated using composite sketch tools. However, lack of standardization makes comparison difficult.

Performance metrics include accuracy, precision, recall, and F1-score. Accuracy measures overall performance, while precision and recall provide detailed insights. In forensic applications, recall is particularly important to ensure no suspect is missed. The F1-score balances both precision and recall for comprehensive evaluation.

IV. COMPARATIVE ANALYSIS

Comparative analysis shows that deep learning-based systems outperform traditional methods. CNN models provide better feature extraction, while transfer learning improves generalization. VGG16-based systems achieve high accuracy, and GAN-based methods reduce the modality gap.

However, there is a trade-off between accuracy and computational complexity.

High-performance systems often require more processing power, which may limit real-time deployment.

V. CHALLENGES

Despite advancements, several challenges remain. The modality gap between sketches and photographs continues to affect accuracy. Limited dataset availability restricts performance. Variations in sketch quality and drawing styles introduce inconsistencies.

Additionally, deep learning models require high computational resources, making real-time implementation challenging. Ethical concerns such as bias and privacy also need to be addressed.

VI. PROPOSED SYSTEM ARCHITECTURE

The proposed system integrates multiple modules to improve forensic sketch recognition. It begins with an input module that accepts sketches or eyewitness descriptions. A preprocessing module standardizes the input by removing noise and normalizing features.

A CNN-based feature extraction module, using architectures such as VGG16 or ResNet, generates feature embeddings. These embeddings are compared with a criminal database using similarity measures such as cosine similarity.

An optional GAN-based module can be integrated to enhance sketch quality by converting it into a photorealistic image before feature extraction. The system supports real-time processing and scalable database integration.

VII. ADVANTAGES

The proposed system reduces dependency on manual sketch artists and improves identification speed. It provides high accuracy through deep learning techniques and supports scalability for large databases. Real-time processing capability makes it suitable for practical law enforcement use.

VIII. FUTURE WORK

Future research can focus on integrating GANs for improved image quality and incorporating multimodal inputs such as text and voice. Cloud-based deployment can enhance scalability and accessibility.

Further improvements include reducing bias in AI models and integrating the system with surveillance technologies such as CCTV for real-time monitoring.

IX. CONCLUSION

This survey highlights the importance of AI-based forensic sketch recognition systems in modern criminal investigations. Deep learning techniques have significantly improved sketch-to-photo matching accuracy. Despite existing challenges, the proposed system provides a scalable and effective solution. Continued research will further enhance system performance and reliability.

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