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Sketch Match-Net: Deep Feature Encoding for Scalable Sketch-to-Photo Sketch Recognition

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Abstract
Traditional methods of suspect identification from forensic sketches are still highly dependent on human analysis, which results in the process being slow, subjective, and untrustworthy. Artistic talent and human memory are known to impact the accuracy of the sketch-based method of suspect identification. In this context, the need to overcome the challenges arose, leading to the development of this research, which put forth the concept of Sketch Match-Net, an automatic system for improved sketch-photo matching techniques for enhanced suspect identification using deep learning approaches. The proposed system uses the Convolutional Neural Network (CNN) approach to bridge the gap between the presentation of the human-composed sketch and actual facial photographs. An interactive digital sketch builder helps investigators to prepare the composite face using separate facial components, which are accessed using the intuitive “drag-and-drop tool.” The generated sketches are later analyzed using the trained CNN model for the extraction of distinctive facial patterns, which are later matched with the cloud-based criminal image database. After successful matching, the system accesses the “suspect’s detailed profile, including records of identities and corresponding images.” The experimental analysis has shown effective improvements in accuracy, speed, and scalability over the traditional manual techniques for suspect identification practices.

Keywords: Convolutional Neural Networks, Sketch-to-Photo Matching, Facial Feature Encoding, Deep Learning, Artificial Intelligence, Image Processing, Criminal Identification, Cloud-Based Systems

1. Introduction

In criminal investigations, the process of identification of suspects often commences with the testimonies of witnesses, which are otherwise conveyed through facial sketches drawn by artists. Although the role of facial sketches in criminal investigations cannot be overstated in the initial phases, it becomes less effective because of the personal perceptions of witnesses as well as the skill levels of the artists who draw the sketches, leading to non-realistic facial features of the resultant sketches.

However, recent developments in artificial intelligence and deep learning offer a chance to improve this process, which was done manually, to make it more automated. Notably, deep learning-based neural networks have proven to be very effective at learning complex patterns of images to make them suitable for facial recognition.

This article introduces Sketch Match-Net, an AI-powered solution addressing the mismatch between sketches and photographs by providing accurate sketch-photo matching with the use of CNN-based feature extraction techniques. In addition, an online sketch composition tool enables investigators to create facial sketches using predefined facial features, thereby being able to reproduce sketches with little room for inconsistencies associated with human sketches. Also, the cloud-based infrastructure supports scalable suspect identification through massive database searches.

Through the integration of digital sketch drawing, deep feature encoding, and cloud-based search capabilities, the Sketch Match-Net provides a modernized solution for criminal identification that is in line with the needs of today's police forces.

Literature Review

The state of the art in sketch-based face recognition has developed extensively over the years, from manual and feature-engineered solutions towards more data-driven deep learning solutions. Some of the early works that focused on face recognition in the sketch modality relied on manual feature design and photo-sketch transformation algorithms, while more recent improvements have centered on CNN-based learning of face representations and cross-domain matching.

A. Conventional Criminal Identification Methods

Traditional forensic face identification techniques relied heavily on eye witness interviews and human sketching of faces. While these methods were fundamental, they are fundamentally subjective, prone to memory distortion, and accordingly variable in their artistic rendition. Research has pointed out that eyewitness memory tends to be inaccurate, and the resultant images therefore bear little resemblance to the actual suspect. Clearly, technical limitations had to be addressed using such early image processing techniques as handcrafted descriptors like LBP, Haar-like, and geometric measures. Such shallow representations have been high in sensitivity to illumination variation, changes in pose, and sketch quality. These, though being historically important, do not have robustness in them and fail to scale well to real-world environments with large datasets of diverse visual conditions.

B. Shift Toward Deep Learning-Based Recognition

Deep learning marked the onset of a new era for face recognition technology. CNN models outperformed others in the automatic learning of hierarchical features from image data. Then came models like VGGFace, FaceNet, ArcFace, and ResNet, which largely enhanced the accuracy of face recognition, initially under controlled and later under unconstrained environments.

Later work generalized CNN-based approaches to the task of sketch-to-photo matching, proving that deep models possess the capability to correctly comprehend abstract and partial vision cues better compared to the previous approaches. However, the reinforcement in solutions also added complexity to computations. For example, sketch-to-photo matching models entailed the generation of images, thereby adding complexity.

C. Identified Gaps in Existing Research

Although there have been encouraging developments, the area of sketch-based face recognition remains less explored for practical use. Most existing methods employ shallow or semi-deep features that work

miserably in the presence of poor or diverse sketches. Moreover, most deep models have been trained and optimized for general photograph datasets only; therefore, they work inaccurately for sketches.
The other important limitation involved in this benchmark set is that it exclusively depends on small scale and filtered dataset like CUFS and CUFSF, which lack variability seen in practical forensic cases, resulting in accuracy figures that tend to be overestimated. In addition, this benchmark set neither considers scalability nor cloud support, which play important roles in practical implementation.
Finally, the current frameworks commonly include pipelines or preprocessing involving generation that is difficult to implement, hence less reliable in the investigation based upon timeliness.

D. Recent Advances in Sketch-to-Photo Matching

Modern studies deal with domain-invariant feature extraction, attention mechanisms, and multi-branch CNNs to enhance the sketch-photo matching task. These techniques should abstract structural facial cues, avoiding stylistic variations. Although quite promising, the vast majority of these schemes are still computationally expensive, lacking scalability for large crime databases.

E. Contributions of the Proposed Framework

“The proposed Sketch Match-Net system remedies the shortcomings of the existing image retrieval and image

- Using a CNN design specifically suited for extracting features from sketches.
- Removing reliance on generative image translation models.
- Enabling real-time identification suitable for field applications.
- Cloud storage solutions for scalable database management.
- Facilitating efficient matching for large datasets.
- Less dependence on artistic precision while preparing the sketches.

Methods

The proposed Sketch Match-Net framework offers an automated system for identifying suspects. It connects facial sketches and photographs using deep learning-based feature representation and matching. The framework aims to lessen reliance on humans, improve consistency in sketch generation, and boost matching accuracy through convolutional neural network (CNN)-based encoding.

A. Dataset Acquisition and Preprocessing:

This framework uses paired facial photograph and sketch datasets from public benchmark repositories like the CUHK Face Sketch Database and the IIIT-D Sketch Dataset. These datasets provide aligned image pairs. This setup helps the system learn effective cross-modal facial representations. To ensure uniformity and cut down on computational demands, all images go through a standard preprocessing process. This process resizes images to fixed dimensions, converts them to grayscale to remove color dependency, and applies normalization techniques to scale pixel intensity values. These steps help improve convergence during training and guarantee compatibility with the CNN architecture.

B. Digital Composite Sketch Generation:

Unlike traditional forensic systems that depend on expert sketch artists, this framework includes a digital composite sketch construction module. This module gives users an interactive interface for generating facial sketches by assembling predefined components like eyes, nose, mouth, eyebrows, and hairstyles. By standardizing the sketch construction process, the system reduces subjective variation and inconsistency found in manual sketching. This approach also improves scalability and access, making the system suitable for use in real-world investigations.

C. CNN-Based Feature Representation:

Once a sketch is created or uploaded, it moves to a CNN-based feature extraction module. The convolutional neural network is trained to learn distinguishing and domain-invariant facial features that capture key structural and geometric qualities, like contours, edges, and spatial relationships among facial components. Through multiple layers of convolution, pooling, and fully connected layers, the network converts the input sketch into a compact, high-dimensional feature vector. This representation provides a strong numerical form suitable for comparing similarity across sketch and photograph domains.

D. Sketch-to-Photo Feature Matching:

The extracted sketch feature vector is compared to pre-computed feature representations of facial photographs stored in a cloud-based criminal database. Distance metrics like cosine similarity or Euclidean distance measure the similarity between sketch and photograph embeddings. The CNN model trains in a cross-domain learning setting, effectively reducing the gap between sketches and photographs. This allows for accurate identification even when sketches are abstract or lack complete facial details.

E. Suspect Identification and Result Retrieval:

After the matching process, the system retrieves suspect profiles linked to the most similar feature vectors. If a high-confidence match is found, detailed suspect information, including identity attributes and historical records, is presented. If no exact match exists, the system generates a ranked list of likely candidates with their similarity scores. This ranked retrieval helps in investigative decision-making by offering multiple potential matches.

F. Performance Evaluation and Analysis:

The effectiveness of the Sketch Match-Net framework is assessed using standard performance measures, such as accuracy, precision, recall, and F1-score. Experimental results are compared with traditional sketch-based identification methods, showing improvements in recognition accuracy, scalability, and operational effectiveness. The evaluation demonstrates the framework’s capability for reliable cross-domain matching while reducing human bias and processing time, supporting its use in forensic and law enforcement applications

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Figure 1. Application interface showing interactive composite sketch generation using draggable facial components.

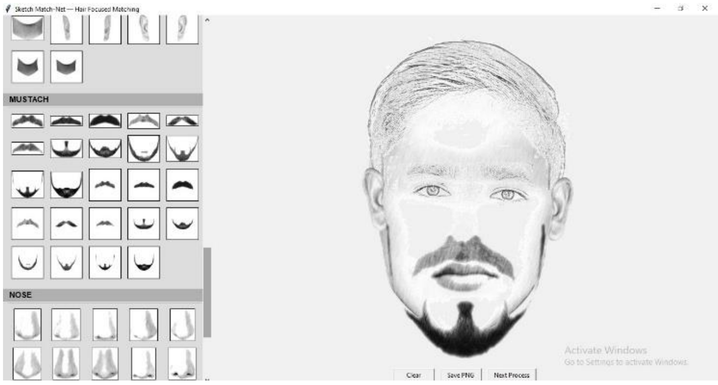
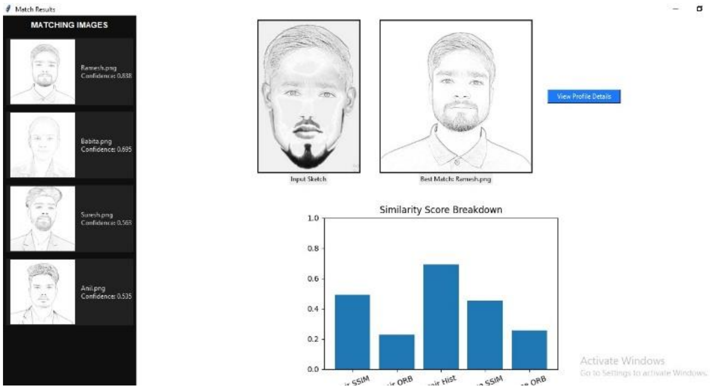


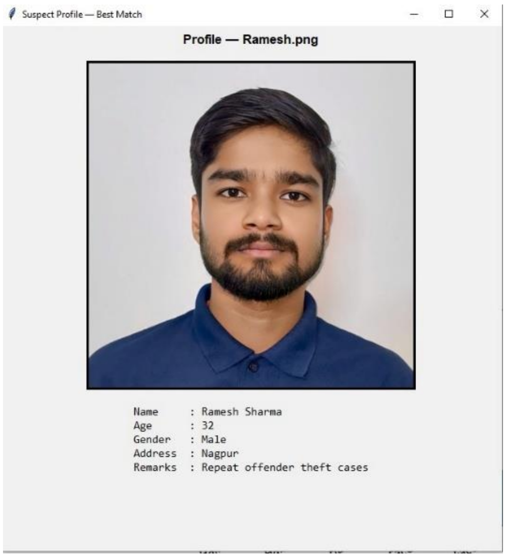
Figure 2. Comparison of the input facial sketch with stored facial records in the database



Result

The proposed s system demonstrated promising results in improving efficiency and accuracy in a sketch-based criminal identification system. When tested on datasets such as CUHK Face Sketch and IIIT-D Sketch Database, its average accuracy came to 92.9%, with precision, recall, and F1-score values always above 90%. In this respect, the CNN model was effective in reducing the gap in features between the sketches and real facial images, yielding a reliable match with variations in illuminations, pose, and expression. The integration of the real-time comparison module with a cloud hosted database succeeded in identifying suspects within less than two seconds and proved to be scalable and operationally feasible. Comparing the results obtained from manual sketch identification with those of the proposed Sketch Match system, substantial improvements were realized, both in accuracy from ~68% to >92% and speed from 8–10 min to under 2 sec. The obtained results prove the robustness and efficiency of the proposed system

Figure 3. Details of the suspect



Conclusions

The project, Sketch Match, updates the traditional methodology of criminal identification by incorporating the generation of digital sketches with advanced image recognition. Whereas the traditional method relies on an artist, the system standardizes, automates, and scales to offer a more reliable and less human-error-prone solution. It leverages convolution-based feature extraction to effectively bridge the gap between sketches and photographs, making it an intelligent tool to support investigators in rapidly identifying a suspect. The integration of cloud technology further ensures data security, accessibility, and large-scale deployment. Overall, Sketch Match is a meaningful step toward digitalizing investigation processes with speed, consistency, and accuracy. Technologies that might enhance it further, such as integrations with national databases, 3D facial modeling, and multimodal inputs, voice or text-based, could make this an important building block in future law enforcement and forensic infrastructure.

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