Matching Forensic Sketches and Mug Shots to Apprehend Criminals

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Emerging face recognition technology can use forensic sketches to help identify criminal suspects.

Dating back to the late 1800s, law enforcement agencies have used forensic sketches to help identify unknown culprits. A forensic sketch is a drawing by a specially trained artist of a suspect's face that is based solely on a verbal description by a witness or victim. Figure 1a shows a modern example of one such sketch of Jack the Ripper, the famous serial killer who terrorized London's Whitechapel district in 1888. Forensic sketches are a valuable tool for visually representing a subject when no other medium exists for capturing his or her face—for example, a surveillance camera.

Even to this day, forensic artists routinely generate sketches to help authorities apprehend criminals—it's not uncommon to see a forensic sketch in a newspaper or on the nightly news. In fact, the method for using forensic sketches has remained unchanged for decades: disseminate the sketch to relevant law enforcement agencies and media outlets with the hope that an officer or citizen will recognize the individual portrayed.

However, this approach is both expensive and time-consuming. Given the often egregious nature of crimes committed by culprits depicted in forensic sketches—including murder, terrorism, sexual assault, and armed robbery—failing to quickly capture them can have severe consequences. Improving forensic sketch recognition would greatly increase public safety.

Under the broad umbrella of biometric recognition, a new paradigm has emerged for identifying suspects using forensic sketches. A sketch can be converted to a digital image and then automatically matched against mug shots (arrestee photos) and other face images in a database—for example, drivers' license photos—to help make an identification. This automated approach, enabled by progress in computer vision and machine learning algorithms, offers a valuable resource to authorities seeking to accurately and quickly capture dangerous criminals.

AUTOMATIC FACE RECOGNITION

During the past decade, the accuracy of automatic face recognition systems increased dramatically, as benchmarked in a series of assessments by the National Institute of Standards and Technology (P.J. Phillips, "Improving Face Recognition Technology," *Computer*, Mar. 2011, pp. 84-86). However, these systems are highly sensitive to variations in facial pose and expression as well as environmental factors such as ambient illumination.

Face images acquired from mug shots and ID cards such as drivers' licenses and passports are generally well suited for automatic face recognition because the acquisition conditions and subject's cooperation minimize pose, expression, and lighting variations. This has prompted approximately half of all US department of motor vehicle (DMV) agencies to implement face recognition technology. While the primary use of face recognition by DMVs is to prevent the issuance of multiple drivers' licenses to the same person (deduplication), legislation in many states also permits law enforcement agencies to access the DMV face database.

Between DMV and mug shot databases, law enforcement agencies often have access to digital images of a large percentage of their jurisdiction's population. Unfortunately, commercial off-the-shelf (COTS) face recognition systems that have high

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levels of success matching two face photos perform poorly in matching forensic sketches to mug shots.

IMPROVING SKETCH RECOGNITION

Matching a hand-drawn sketch to a photograph is difficult because

- a subject's facial appearance may change between the time the photo was taken and the sketch is made, and
- incomplete and inconsistent witness descriptions can result in inaccurate facial depictions.

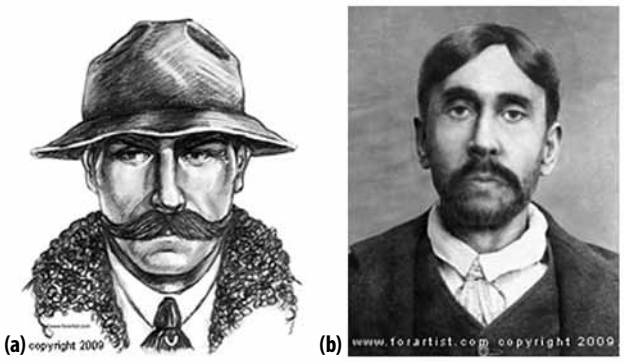

Figure 1. Applying sketch recognition technology to a 120-year-old series of crimes. (a) Example of a forensic sketch of serial killer Jack the Ripper based on a witness account. (b) Age-regressed mug shot of a perpetrator who committed similar murders in New York in the early 1900s. Source: www.forartist.com.

Improving forensic sketch recognition requires a feature extractor and matcher specifically designed for this task. At Michigan State University, we recently developed such a system, which demonstrated a four times improvement in accuracy over a leading COTS face recognition system (B. Klare, Z. Li, and A.K. Jain, "Matching Forensic Sketches to Mug Shot Photos," *IEEE Trans. Pattern Analysis and Machine Intelligence*, Mar. 2011, pp. 639-646).

As Figure 2 shows, our system first partitions sketch and face images into N slices. It then computes scale-invariant feature transform (SIFT) and multiscale local binary pattern (MLBP) descriptors for each slice, which remain stable between sketches and photos. Next, it uses local-feature-based discriminant analysis (LFDA) to extract the most salient features for each slice. Finally, the system measures the similarity between feature vectors to match sketches with photos.

The LFDA system's accuracy is further improved using subjects' demographic information such as race, gender, age, and height. This information is generally stored in DMV and face databases and often available from witness accounts.

Despite the significant improvement in matching accuracy achieved by our automatic sketch recognition system, the difficult nature of matching sketches and photos requires human verification. The routine procedure in forensic face recognition, similar to that for latent fingerprint matching, is for a forensic examiner to vet the top N retrieved matches ($N < 100$) to determine whether a true match exists. Thus, for a given sketch, our system narrows down possible matches from a face database containing thousands of images to around 100 likely subjects for further human investigation.

Figure 3 shows three successful matches our LFDA system made between a forensic sketch and a mug

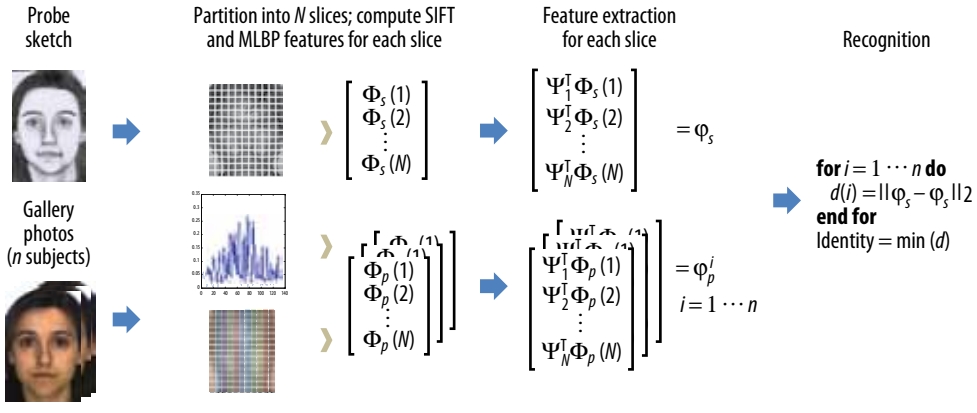

Figure 2. Automatic forensic sketch recognition system. The system, which uses local-feature-based discriminant analysis (LFDA) to match sketches and gallery photos, demonstrated a four times improvement in accuracy over a commercial off-the-shelf (COTS) face recognition system.

Method	Rank	Method	Rank	Method	Rank
LFDA	1	LFDA	1	LFDA	1
COTS	320	COTS	299	COTS	2,131

Figure 3. Examples of three successful matches the LFDA system made between a forensic sketch (top row) and a mug shot (bottom row) from a database of 10,000 face images. In each case, the COTS face recognition system failed to retrieve the correct photo within the top 100 matches.

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Automatic sketch recognition can be used in other ways to assist criminal investigations. For example, as Figure 4 shows, forensic artists can draw high-quality sketches of suspects captured in low-resolution surveillance video, and investigators can then use the system to match these sketches to mug shots in their database.

Investigators also could use the system to match forensic sketches to mug shots subjected to manipulation such as age progression and regression. For example, Figure 1b shows an age-regressed mug shot of a perpetrator who committed murders in New York in the early 1900s and had facial features resembling the forensic sketch of Jack the Ripper.

Law enforcement's need for a system that matches sketches to photos has prompted continued research to increase automatic face recognition accuracy. With a prototype automatic sketch recognition system soon to be deployed in the field, this technology will improve a process that has helped identify suspects for well over a century.

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Figure 4. Images from a recent Los Angeles Police Department investigation in which forensic artists generated high-quality sketches from low-quality video. The first two suspects were then identified from the sketches. Source: www.lacrimestoppers.org/wanteds.aspx.