Forensic Sketch Recognition:
Matching Forensic Sketches to Mugshot Images

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With: Anil Jain, and Zhifeng Li
Forensic Sketches

- Forensic sketches are drawn by a police artist based on verbal description provided by witness/victim
- Useful when no surveillance video or other biometric data available
- FR engines do not perform well in matching sketch to photo
- FR capabilities need to be enhanced to identify these high value targets
Identifying Criminals using a Sketch

Current Method

- Disseminate sketch to media outlets and law enforcement agencies
- Wait for someone to recognize culprit
- **Pro**: Resulted in many arrests to date
- **Con**: Relies on someone who can recognize the person after seeing the sketch

Don’t know him

I know that guy!!!
**Identifying Criminals using a Sketch**

**Automated Method**

- Match sketch against state and federal mugshot databases
- Consider top ~100 matches as suspects
- **Pro:** Can consider entire criminal population, no need to wait for a tip
- **Con:** False positives can cause incorrect leads

*That’s him!*
Goal of Sketch Matching Research

- Increase the impact of forensic sketches
- Little research effort has been spent on this problem despite:
  - Representing the most heinous crimes that occur
  - Being able to leverage existing mugshot and DMV databases
Two Difficulties in Sketch Matching

- **Inaccurate Sketches:**
  - Sketches are drawn from human memory
  - May cause inaccurate description of the suspect
    - i.e. the sketch may not even look like the same person

- **Different image modalities:**
  - Cannot directly compare a sketch to a photograph
    - Though accurate, the sketch has a different “appearance”
Types of Sketches in FR Research

- Two types of sketches in FR research:
  - Viewed sketches
    - Drawn while looking at a photo of the person
    - Not practical
    - Good for finding solution to the different image modalities difficulty
  - Forensic sketches
    - Drawn from eye witness description
    - Real-world scenario
Method for Matching Forensic Sketches to Mugshot Photos

**TRAINING**

- Training set of sketch/photo correspondences
- Break each image into set of overlapping patches
- HOG or MLBP feature extraction for each patch
- Group patch vectors into slices
- Learn discriminant projection for each slice

\[
\begin{bmatrix}
\Phi(1) \\
\Phi(2) \\
\vdots \\
\Phi(N)
\end{bmatrix}
= \begin{bmatrix}
\Psi_1 \\
\Psi_2 \\
\vdots \\
\Psi_N
\end{bmatrix}
\]

**MATCHING**

- Feature extraction and group into slices
- Discriminant projection

\[
\begin{bmatrix}
\Phi_s(1) \\
\Phi_s(2) \\
\vdots \\
\Phi_s(N)
\end{bmatrix}
= \begin{bmatrix}
\Psi_1^T \\
\Psi_2^T \\
\vdots \\
\Psi_N^T
\end{bmatrix}
\begin{bmatrix}
\Phi_s(1) \\
\Phi_s(2) \\
\vdots \\
\Phi_s(N)
\end{bmatrix}
= \varphi_s
\]

\[
\begin{bmatrix}
\Phi_p(1) \\
\Phi_p(2) \\
\vdots \\
\Phi_p(N)
\end{bmatrix}
= \begin{bmatrix}
\Psi_1^T \\
\Psi_2^T \\
\vdots \\
\Psi_N^T
\end{bmatrix}
\begin{bmatrix}
\Phi_p(1) \\
\Phi_p(2) \\
\vdots \\
\Phi_p(N)
\end{bmatrix}
= \varphi_p^i
\]

for \( i = 1 \cdots n \) do
\[
d(i) = \|\varphi_s - \varphi_p^i\|_2
\]
end for

Identity = \min (d)
Experiments

- Sketch database:
  - 159 total pairs of mated sketches and photos:
    - 73 images from forensic sketch artist Lois Gibson
    - 43 images from forensic sketch artist Karen Taylor
    - 39 forensic sketches from the Michigan State Police Department
    - 4 forensic sketches from the Pinellas County Sheriff’s

- Matched against an additional 10,000 mugshot images provided by the MSP

- Two leading commercial face recognition systems:
  - FaceVACS (Cognitec)
  - FaceIT (L1)

Forensic Sketch Matching

- Sketches divided into two categories:
  - Good sketches
    - Sketches that look mostly similar to the subject
  - Poor sketches
    - Sketches that do not resemble the subject
Demographic Information

- Using ancillary demographic information, matching performance can be increased by filtering the results.
- Such information would be available in real scenario.

<table>
<thead>
<tr>
<th></th>
<th>Forensic Sketches</th>
<th>Mugshot Gallery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian</td>
<td>58.49%</td>
<td>46.43%</td>
</tr>
<tr>
<td>African American</td>
<td>31.45%</td>
<td>46.93%</td>
</tr>
<tr>
<td>Other</td>
<td>10.06%</td>
<td>6.64%</td>
</tr>
<tr>
<td>Male</td>
<td>91.19%</td>
<td>84.33%</td>
</tr>
<tr>
<td>Female</td>
<td>8.81%</td>
<td>15.52%</td>
</tr>
<tr>
<td>Unknown</td>
<td>0.00%</td>
<td>0.03%</td>
</tr>
</tbody>
</table>
Understanding the results

• In biometrics, success of an algorithm often quantified as the **average rank**

• **For example, an average Rank-\(x\) accuracy of 90% means:**
  • 90% of the time, the top \(x\) matches contain the correct subject
  • Often this is used with Rank-1 (i.e. the percentage of time the top match is correct)

• In Sketch Recognition:
  • The Rank-50 accuracy more important than Rank-1 accuracy
  • This is because the top 50 (or so) returned matches will be considered by investigators
Good vs Poor

Accuracy vs Rank

- LFDA - Good
- LFDA - Poor
- FaceVACS - Good
- FaceVACS - Poor

Range: Rank 0 to 70
Demographic Filtering
Effect of Increasing the Gallery Size
## Forensic Sketch Matching

### Without Race/Gender Filtering

<table>
<thead>
<tr>
<th>Method</th>
<th>Rank-1 Accuracy (%)</th>
<th>Rank-10 Accuracy (%)</th>
<th>Rank-50 Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FaceVACS</td>
<td>2.04</td>
<td>4.08</td>
<td>8.16</td>
</tr>
<tr>
<td>LFDA</td>
<td>16.33</td>
<td>22.45</td>
<td>32.65</td>
</tr>
</tbody>
</table>

### With Race/Gender Filtering

<table>
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<th>Rank-10 Accuracy (%)</th>
<th>Rank-50 Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FaceVACS</td>
<td>2.04</td>
<td>8.16</td>
<td>26.53</td>
</tr>
<tr>
<td>LFDA</td>
<td>18.37</td>
<td>26.53</td>
<td>44.90</td>
</tr>
</tbody>
</table>
Most failed matches were due to poorly drawn sketches with little resemblance to the true photo:

- This mugshot was returned as the top match: it looks very similar to the subject.
- This is the true photograph. It does not look as similar.
Our framework allows individual facial components to be emphasized.

For example, if a witness believes he is more confident in his description of eyes then a higher weight can be assigned to eyes.

This is not common in standard face recognition: the internal features are always more salient.
How sketch artists can improve sketch recognition?

- Make sketches as realistic looking as possible

This sketch is not very accurate, but it looks realistic. This will improve the matching accuracy.

This sketch is actually rather accurate, but it is not realistic (i.e. it is out of proportion). This lowers the matching accuracy.
How sketch artists can improve sketch recognition?

- Understand (and record) which facial components the victim feels are the most accurate.

If the victim was able to convey this information, then our system would be able to increase the importance of the eyes and nose.

<table>
<thead>
<tr>
<th>Method</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFDA</td>
<td>1</td>
</tr>
<tr>
<td>FaceVACS</td>
<td>2</td>
</tr>
<tr>
<td>Eyes</td>
<td>5</td>
</tr>
<tr>
<td>Nose</td>
<td>2</td>
</tr>
<tr>
<td>Mouth</td>
<td>823</td>
</tr>
<tr>
<td>Chin</td>
<td>24</td>
</tr>
<tr>
<td>Internal</td>
<td>1</td>
</tr>
<tr>
<td>External</td>
<td>6</td>
</tr>
</tbody>
</table>

The eyes and nose are quite precise. The mouth and chin are not.
Help us!
We need more mated sketches and photos
  i.e., we need sketches, and the mugshot photographs of any subjects later identified
This is very important for the success of our algorithm
In the scientific field of Pattern Recognition, we need data (in this case mated sketches and photos) to **learn** how to recognize a person from their sketch
Please let me know if you can help:
  Brendan Klare  klarebre@msu.edu
We have already benefited from data from the FBI, Michigan State Police, and the PCSO.
A sketch recognition system has been prototyped and tested on real forensic sketches.

Our system shows substantial improvement over commercial face matchers.

Further research is being conducted to improve the accuracy of the system; e.g., use of SMT (scars, marks and tattoos).

A major bottleneck in our success is a lack of data (mated sketches and photos) to train and test our algorithm.