Scars, Marks and Tattoos (SMT): Automatic Matching & Retrieval

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Challenges in Forensic Science

• Increased expectations from forensic science
  – CSI effect: Jurors want to see physical evidence (fingerprints, DNA, etc.) to convict suspects
  – Detectives used to gather 4-5 pieces of evidence at crime scenes; now look at 50-400
  – sources

• Crime rate is falling but backlog is still increasing

• Throughput needs to be increased

• Need for better equipment, efficient techniques & strong theoretical & empirical proofs of effectiveness

Forensic Evidence

- Fingerprint
- Palmprint
- Face
- DNA
- Footprint
- Bite Mark
- Tattoo
- Tyreprint
Scars, Marks and Tattoos

- Skin imprints:
  - can be used to identify suspects/victims
- 2003 online Harris poll:
  - 16% of adults have at least one tattoo
Criminal History Records

Bertillon system
Suspect & Victim Identification

- Tattoos often imply gang membership, religions beliefs, previous conviction & military service
- Useful for victim and suspect identification

(a) and (b) body parts with tattoos found in a state park in Florida. Victim was identified based on tattoos within 12 hours (c) Teardrop criminal tattoo (person has killed someone or had a friend killed in prison); (d) Texas Syndicate (TS) gang tattoo
# ANSI/NIST Tattoo Classes

## ANSI/NIST ITL 1-2000 Tattoo Classes

<table>
<thead>
<tr>
<th>Class description</th>
<th>Class code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Forms and Features</td>
<td>HUMAN</td>
</tr>
<tr>
<td>Animals and Animal Features</td>
<td>ANIMAL</td>
</tr>
<tr>
<td>Plants</td>
<td>PLANT</td>
</tr>
<tr>
<td>Flags</td>
<td>FLAG</td>
</tr>
<tr>
<td>Objects</td>
<td>OBJECT</td>
</tr>
<tr>
<td>Abstractions</td>
<td>ABSTRACT</td>
</tr>
<tr>
<td>Insignias &amp; Symbols</td>
<td>SYMBOL</td>
</tr>
<tr>
<td>Other Images</td>
<td>OTHER</td>
</tr>
</tbody>
</table>

## ANSI/NIST ITL 1-2000 Animal Tattoo Subclasses

<table>
<thead>
<tr>
<th>Subclass</th>
<th>Subclass code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cats &amp; Cat Heads</td>
<td>CAT</td>
</tr>
<tr>
<td>Dogs &amp; Dog Heads</td>
<td>DOG</td>
</tr>
<tr>
<td>Other Domestic Animals</td>
<td>DOMESTIC</td>
</tr>
<tr>
<td>Vicious Animals (Lions, Tigers, etc.)</td>
<td>VICIOUS</td>
</tr>
<tr>
<td>Horses (Donkeys, Mules, etc.)</td>
<td>HORSE</td>
</tr>
<tr>
<td>Other Wild Animals</td>
<td>WILD</td>
</tr>
<tr>
<td>Snakes</td>
<td>SNAKE</td>
</tr>
<tr>
<td>Dragons</td>
<td>DRAGON</td>
</tr>
<tr>
<td>Birds (Cardinal, Hawk, etc.)</td>
<td>BIRD</td>
</tr>
<tr>
<td>Spiders, Bugs, and Insects</td>
<td>INSECT</td>
</tr>
<tr>
<td>Abstract Animals</td>
<td>ABSTRACT</td>
</tr>
<tr>
<td>Animal Parts</td>
<td>PARTS</td>
</tr>
<tr>
<td>Miscellaneous Animal Forms</td>
<td>MANIMAL</td>
</tr>
</tbody>
</table>
Tattoo Matching: Current Practice

- Find similar tattoos based on class labels
- ANSI/NIST labels are not precise: “Abstract” class
- Same tattoo image can have multiple labels

All these 12 tattoos belong to the FLAG category
Image-based Tattoo Matching

• Given a tattoo image query, find the top-N most visually similar images in the database

Query

Top-8 most similar tattoos for the query “star” tattoo
Image Similarity

Shape

Color

?
Tattoo-ID System

Enrollment
- Image
- Class

Manual Encoding

Feature Extraction

Database
- Feature Sets
- Class Label

Matching

Retrieval Results

User Feedback

Parameter Control

ARCHIVING

RETRIEVAL

Query Image

Feature Extraction

Class Label (Optional)

Feature Weight Learning
Michigan State Police Database

70,000 images
Image Preprocessing

- Manually crop & annotate

Skull
Fire
Weapon
Wording
Symbol

Symbol
Wording
Plant
Flag

Weapon
Object
Snake
Image Features

- Color: histogram and correlogram
- Shape: invariant moments
- Texture: edge direction coherence
SIFT Keypoint Matching

Numbers of matching points between (a) similar and (b) different images

(a) 370
(b) 64
Retrieval Experiment

- Duplicate tattoos used as queries
  - Query: 500 duplicates; Gallery: 11,000 images

- Rank-1 accuracy = 91.2%
- Rank-20 accuracy = 96.7%
## Retrieval Examples

### Query

<table>
<thead>
<tr>
<th>Query</th>
<th>Top-7 Retrieved Images with no. of matching keypoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Query #1</td>
<td><img src="image1" alt="Eagle Head" /></td>
</tr>
<tr>
<td>110</td>
<td>102</td>
</tr>
<tr>
<td>Query #2</td>
<td><img src="image8" alt="Tattoo" /></td>
</tr>
<tr>
<td>68</td>
<td>67</td>
</tr>
<tr>
<td>Query #3</td>
<td><img src="image15" alt="Tattoo" /></td>
</tr>
<tr>
<td>125</td>
<td>79</td>
</tr>
</tbody>
</table>
Difficult Queries

Rank 539

Rank 6684

Rank 4046

Rank 1419

Rank 1106

Rank 2432
Future Work

- Utilize ANSI/NIST labels
- Image enhancement
- Large body tattoos
- Automatic annotation
- Relevance feedback
- Database filtering
Degraded images (a,b,c,d) and ranks at which correct retrieval was found. Performance improves after enhancement (a’, b’, c’, d’).
Large Body Tattoos

- Tattoo may cover large area; query may cover only small portion
Automatic Annotation

- Use a training set to annotate tattoo database

Object
Symbol
Other
Wording

Object
Symbol
Other
Wording

Symbol
Other

Animal
Object
Star

Object
Symbol
Other

Human
Role

?
## Relevance Feedback

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Top-7 retrieved images</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>![Images 1]</td>
</tr>
<tr>
<td>2</td>
<td>![Images 2]</td>
</tr>
<tr>
<td>3</td>
<td>![Images 3]</td>
</tr>
<tr>
<td>4</td>
<td>![Images 4]</td>
</tr>
</tbody>
</table>

**Query**

![Query Image]
Database Filtering