A Score-level Fusion Fingerprint Indexing Approach based on Minutiae Vicinity and Minutia Cylinder-Code

Guoqiang Li
Norwegian Biometric Laboratory,
Gjøvik University College,
Norway
Outline

- Fingerprint indexing
- State of art on feature extraction
- Proposed Score-level fusion approach
- Experimental Results
- Conclusion
Fingerprint indexing

- Fingerprint indexing is a technique to reduce the number of candidate identities to be considered by the verification algorithm.

The basic structure of Fingerprint indexing:

1. **Enrolment**
   - Feature extraction
   - Index table
   - Database

2. **Retrieval**
   - Feature extraction
   - A list of comparison scores sorted by descending order
   - A short list of candidates
State of the art in feature extraction

- **Global features:**
  - Orientation field

- **Local features:**

- **Other features:**

  [Liu et al. 2012]
  [Jiang et al. 2006]
  [Li et al. 2006]
State of the art in feature extraction

Three features are based on the geometry of the triangle;
Six features are extracted from the ridges associated with three minutiae.

[Ross and Mukherjee. 2007]
State of the art in feature extraction

Minutia Cylinder-Code (MCC)

2D local structure

3D local structure

Computing a numerical value for each cube.

[Cappelli et al. 2011]
Proposed feature extraction

Each triangle is represented by a 9-D feature vector:

- 4 geometric features:

\[
\begin{align*}
  f_1 &= \cos(\max(\alpha_1, \alpha_2, \alpha_3)) \\
  f_2 &= \sqrt{\ell \ast (\ell - l_1) \ast (\ell - l_2) \ast (\ell - l_3)} \\
  \text{where } \ell &= \frac{l_1 + l_2 + l_3}{2}, \\
  f_3 &= \frac{4(l_1 + l_2 + l_3)\sqrt{(l_1 + l_2 + l_3)}}{\sqrt{(l_1 + l_2 - l_3)(l_1 + l_3 - l_2)(l_2 + l_3 - l_1)}} \\
  f_4 &= \frac{\max(l_1, l_2, l_3)}{\min(l_1, l_2, l_3)}
\end{align*}
\]
Proposed feature extraction

- 3 features based on the minutia direction info:
  
  \[
  f_5 = \text{abs}(d_1 - d_2), \quad f_6 = \text{abs}(d_2 - d_3), \quad f_7 = \text{abs}(d_3 - d_1)
  \]

- 1 feature is the average value of ridge curvatures from three minutiae:
  
  \[
  f_8 = (r_1 + r_2 + r_3)/3
  \]

- 1 feature is based on the ridge density around the location of the minutia neighbors:
  
  \[
  f_9 = (c_1 + c_2 + c_3)/3
  \]

[Tomasz and Wieclaw, 2011]
Proposed a score-level fusion method

- Design a new indexing method using this feature vector;
- A score-level fusion approach by by combing the Minutiae Vicinity (MV) indexing method with the minutiae cylinder-code (MCC) indexing method;

Structure of proposed approach
Minutiae Vicinity based indexing method

1. Training set
2. Feature extraction
3. A set of feature vectors
4. 9-D feature vector from training set
5. K-means algorithm

Each feature vector:

\[
\begin{align*}
C_1 & \quad 0 \\
C_2 & \quad 0 \rightarrow 1 \\
C_3 & \quad 0 \\
& \quad \vdots \quad \vdots \\
C_K & \quad 0 \\
\end{align*}
\]
Proposed a score-level fusion method

MV-Index space will be represented by a matrix $M$ whose size is $R \times K$, where $R$ is the number of subjects enrolled in the database, $K$ is the number of clusters.

Reference samples

A example of MV-Index space

Each subject will be represented by a $K$-dimension binary string.
Proposed a score-level fusion method

Retrieval in minutiae vicinity (MV) based index Space

Feature extraction

A set of feature vectors

Each feature vector

$C_1, C_2, C_3, \ldots, C_K$

0 1 0 0 0 \ldots 0 1
1 1 0 1 0 \ldots 0 1
\vdots
0 1 1 1 0 \ldots 1 0
\vdots
1 0 0 1 0 \ldots 1 0

3
56
\ldots
0
\vdots
2
Performance measures

From ISO/IEC 19795-1

**Pre-selection error**: error that occurs when the corresponding enrolment template is not in the preselected subset of candidates when a sample from the same biometric characteristic on the same user is given;

**Penetration rate**: measure of the average number of pre-selected templates as a fraction of the total number of templates;

- **Database**: Enrolled 1,000 subjects
  - The number of candidates: 10
    - Penetration rate: 10/1,000 = 1%
    - If 5 probes are outside of the candidates list, pre-selection error: 5/100 = 5%;
    - If 10 probes are outside of the candidates list, pre-selection error: 10/100 = 10%;
  - The number of candidates: 50
    - Penetration rate: 50/1,000 = 5%
    - If 1 probes are outside of the candidates, pre-selection error: 1/100 = 1%;

- **Each probe sample**: 100 probe samples

Low penetration rate, and low pre-selection error
Experimental results


<table>
<thead>
<tr>
<th>Pre-selection Error Rate(%)</th>
<th>20</th>
<th>15</th>
<th>10</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Ross et al. 2007]</td>
<td>40.04</td>
<td>43.03</td>
<td>45.97</td>
<td>48.75</td>
</tr>
<tr>
<td>MV-Index</td>
<td>12</td>
<td>17.38</td>
<td>26</td>
<td>48.5</td>
</tr>
<tr>
<td>MCC-Index</td>
<td>&lt;1</td>
<td>2.94</td>
<td>7</td>
<td>16.5</td>
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<tr>
<td>MV-MCC fusion</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>1.19</td>
<td>8.9</td>
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</tbody>
</table>


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<thead>
<tr>
<th>Pre-selection Error Rate(%)</th>
<th>20</th>
<th>15</th>
<th>10</th>
<th>5</th>
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</thead>
<tbody>
<tr>
<td>[Ross et al. 2007]</td>
<td>40.79</td>
<td>43.61</td>
<td>46.45</td>
<td>49.34</td>
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<td>MV-Index</td>
<td>10</td>
<td>18.25</td>
<td>32.33</td>
<td>45.75</td>
</tr>
<tr>
<td>MCC-Index</td>
<td>1.8</td>
<td>4.93</td>
<td>15</td>
<td>29.5</td>
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<tr>
<td>MV-MCC fusion</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>2.4</td>
<td>9.75</td>
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Database preparation
Experimental results

Performance evaluation of MV-MCC fusion, MCC-index, MV-Index on database FVC_2004_DB1_a.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Subjects' number</th>
<th>Samples' number</th>
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</thead>
<tbody>
<tr>
<td>Training set</td>
<td></td>
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</tr>
<tr>
<td>FVC_2002_DB2_a</td>
<td>100</td>
<td>800</td>
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<td>Test set</td>
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<tr>
<td>FVC_2004_DB1_a</td>
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<td>References</td>
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<td>100</td>
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<tr>
<td>Probes</td>
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<td>700</td>
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<td>FVC_2004_DB2_a</td>
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<td>References</td>
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<tr>
<td>Probes</td>
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<td>1540</td>
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<tr>
<td>FVC_2004_DB3_a</td>
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<tr>
<td>FVC_2006_DB3_a</td>
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Experimental results

Performance evaluation of MV-MCC fusion, MCC-index, MV-Index on database FVC_2004_DB2_a.
Conclusion

- Extracted a feature vector including 9 components based on the minutiae vicinity;
- Developed a new indexing method using this feature vector;
- Proposed a scole-level fusion approach by combing this new method with minutia cylinder-code (MCC) indexing method;

- Future works:
  - Improve the performance of indexing method based on the minutiae vicinity;
  - Consider to set-up the fusion on feature level;
References


THANKS FOR YOUR ATTENTION!