Longitudinal Finger Rotation Problems and Effects in Finger-Vein Recognition

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Overview

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2. The Problem of Longitudinal Finger Rotation
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The networks of blood vessel under the skin of the finger are unique.

Therefore, finger-vein characteristics are suitable for biometric applications.

Similar to fingerprints also images of the blood vessels can be used for authentication.
Biometric finger vein recognition system

Figure: Basic components of a biometric recognition system
Recognition performance strongly depends on quality of acquired images.

Acquisition effected by internal

- NIR light source
- camera module
- sensor configuration
- ...

and external factors

- environmental conditions (temperature, humidity, ...)
- finger misplacements (including longitudinal finger rotation)
- ...

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Advantages

- Resistant to forgery as vein structures are inside the finger and only visible in infrared light
- Liveness detection is possible
- No abrasion as with fingerprints
- Insensitive to finger surface conditions
Disadvantages

- Comparatively large capturing device
- Images have in general lower contrast and lower quality than fingerprint images
- Vein structures are influenced by temperature and physical activity
- Vein structure may be influenced by certain diseases or injuries
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Figure: Finger longitudinal axis rotation principle: a schematic finger cross section showing five veins (blue dots) rotated from -10° to -30° (top row) and 10° to 30° (bottom row) in 10° steps. The projection of the vein pattern is different according to the rotation angle following a non-linear transformation.
Figure: Finger rotation example using an off-the-shelf commercial scanner
PLUSVein-Finger Rotation Data Set I

- Up to now only palmar (and one dorsal) data sets
- Evaluation of longitudinal finger rotation not possible
- New finger-vein data set providing images all around the finger (360°-view)
- Acquired using our custom build sensor

**Figure:** Example images of the data set acquired from 0° to 180° in 60° steps
Figure: Left: Principle of the multi-perspective finger vein scanner, right: the scanner itself (originally published in [1], © 2018 IEEE)
Statistical data

- 63 subjects (27 female, 36 men)
- 11 nations (Austria, Brazil, China, Ethiopia, Germany, Hungary, Iran, Italy, Russia, Slovenia, USA), but mainly white Europeans (73%)
- Age: 18 (limited by national law) to 79 years
- Further acquisitions planned (33 additional subjects for PROTECT Multimodal DB [2], another session at PLUS planned)
- Containing the same subjects as the PLUSVein-FV3 Data Set [3], a data set that provides palmar and dorsal finger vein images acquired using two different sensors (laser/LED transillumination → poster session).
PLUSVein-Finger Rotation Data Set IV

Total data set

- 252 unique fingers (63 different subjects, 4 fingers per subject)
- 5 samples per finger
- 1,260 images per view
- Step-size: 1°
- 361 different views (0° + 360°)
- 454,860 images in total.

Used sub-set for this paper

- Range of ±90° around palmar view (0°)
- Step-size: 1°
- 181 different views
- 228,060 images in total.
Figure: Examples of finger vein images and extracted MC features acquired at different longitudinal rotation angles. Left: -30°, middle: 0° (palmar view), right: 30°.
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Systematic robustness analysis of several finger vein recognition schemes against longitudinal rotation.

- Palmar perspective = reference view
- Used range: ±90°, step size 1°
- Cross-comparison of the rotated perspectives to the reference view
- Analysed the change of the recognition performance
Used recognition schemes:

- Vein pattern based feature extraction methods (binarization)
  - Maximum Curvature (MC) [4]
  - Principal Curvature (PC) [5]
  - Gabor Filter (GF) [6]
- Key-point based methods
  - SIFT [7]
  - Deformation-tolerant feature-point matching (DTFPM) [8]

Except for DTFPM, all methods are widely used and publicly available implementations exist.

DTFPM has been fully re-implemented and will be available at 
http://www.wavelab.at/sources/Prommegger18b/
Experiments III

Performance indicator:

- EER (FMR = FNMR)
- FMR1000 (the lowest FNMR for FMR = 0.1%)
- ZeroFMR (the lowest FNMR for FMR = 0%)
- Relative performance degradation (RPD):

\[ RPD = \frac{EER_{current} - EER_{reference}}{EER_{reference}} \]  

Baseline performance results (palmar view, 0°) for the different recognition schemes:

<table>
<thead>
<tr>
<th></th>
<th>PC</th>
<th>MC</th>
<th>DTFPM</th>
<th>SIFT</th>
<th>GF</th>
</tr>
</thead>
<tbody>
<tr>
<td>EER [%]</td>
<td>0.48</td>
<td>0.59</td>
<td>1.15</td>
<td>1.53</td>
<td>3.14</td>
</tr>
<tr>
<td>FMR1000 [%]</td>
<td>0.79</td>
<td>0.83</td>
<td>2.54</td>
<td>4.88</td>
<td>5.40</td>
</tr>
<tr>
<td>ZeroFMR[%]</td>
<td>1.51</td>
<td>1.31</td>
<td>3.93</td>
<td>6.43</td>
<td>7.82</td>
</tr>
</tbody>
</table>
Figure: Trend of the EER across the different rotation angles, left: -90° to 90°, right: -25° to 25°.
Figure: Trend of the relative performance degradation (RPD) across the different rotation angles, left: -90° to 90°, right: -25° to 25°.
Figure: Trend of performance indicators across the different rotation angles from -90° to 90°, left: FMR1000, right: ZeroFMR in %.
EER at specific rotation angles [%]:

<table>
<thead>
<tr>
<th></th>
<th>±0°</th>
<th>±5°</th>
<th>±10°</th>
<th>±15°</th>
<th>±20°</th>
<th>±25°</th>
<th>±30°</th>
<th>±45°</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>0.48</td>
<td>0.60</td>
<td>1.04</td>
<td>1.96</td>
<td>5.38</td>
<td>13.43</td>
<td>27.14</td>
<td>46.50</td>
</tr>
<tr>
<td>MC</td>
<td>0.59</td>
<td>0.62</td>
<td>1.07</td>
<td>2.92</td>
<td>8.88</td>
<td>22.34</td>
<td>37.91</td>
<td>46.82</td>
</tr>
<tr>
<td>DTFPM</td>
<td>1.15</td>
<td>1.07</td>
<td>1.53</td>
<td>2.03</td>
<td>2.91</td>
<td>4.49</td>
<td>6.97</td>
<td>19.26</td>
</tr>
<tr>
<td>SIFT</td>
<td>1.53</td>
<td>1.53</td>
<td>2.49</td>
<td>3.90</td>
<td>5.59</td>
<td>8.53</td>
<td>12.61</td>
<td>30.15</td>
</tr>
<tr>
<td>GF</td>
<td>3.14</td>
<td>3.62</td>
<td>5.36</td>
<td>11.03</td>
<td>22.70</td>
<td>37.86</td>
<td>46.06</td>
<td>50.46</td>
</tr>
</tbody>
</table>

- Up to ±10° PC and MC perform best
- Starting with ±15° DTFPM outperforms all other schemes
- Starting with ±20° SIFT outperforms all vein pattern based schemes
Relative performance degradation at specific rotation angles [%]:

<table>
<thead>
<tr>
<th>Method</th>
<th>±0°</th>
<th>±5°</th>
<th>±10°</th>
<th>±15°</th>
<th>±20°</th>
<th>±25°</th>
<th>±30°</th>
<th>±45°</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>0%</td>
<td>26%</td>
<td>119%</td>
<td>312%</td>
<td>1031%</td>
<td>2727%</td>
<td>5610%</td>
<td>9684%</td>
</tr>
<tr>
<td>MC</td>
<td>0%</td>
<td>7%</td>
<td>83%</td>
<td>399%</td>
<td>1416%</td>
<td>3715%</td>
<td>6373%</td>
<td>7894%</td>
</tr>
<tr>
<td>DTFPM</td>
<td>0%</td>
<td>0%</td>
<td>33%</td>
<td>76%</td>
<td>153%</td>
<td>290%</td>
<td>505%</td>
<td>1573%</td>
</tr>
<tr>
<td>SIFT</td>
<td>0%</td>
<td>0%</td>
<td>63%</td>
<td>155%</td>
<td>266%</td>
<td>459%</td>
<td>726%</td>
<td>1876%</td>
</tr>
<tr>
<td>GF</td>
<td>0%</td>
<td>15%</td>
<td>71%</td>
<td>252%</td>
<td>624%</td>
<td>1107%</td>
<td>1369%</td>
<td>1509%</td>
</tr>
</tbody>
</table>

- DTFPM performs best (designed to be so)
- Values need to be read carefully (calculated to baseline result, baseline result different for every method)
Rotation angle at which a certain relative performance degradation is hit:

<table>
<thead>
<tr>
<th></th>
<th>10%</th>
<th>25%</th>
<th>50%</th>
<th>100%</th>
<th>200%</th>
<th>300%</th>
<th>400%</th>
<th>500%</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>±1°</td>
<td>±3°</td>
<td>±5°</td>
<td>±8°</td>
<td>±12°</td>
<td>±13°</td>
<td>±15°</td>
<td>±16°</td>
</tr>
<tr>
<td>MC</td>
<td>±5°</td>
<td>±6°</td>
<td>±8°</td>
<td>±11°</td>
<td>±14°</td>
<td>±13°</td>
<td>±14°</td>
<td>±15°</td>
</tr>
<tr>
<td>DTFPM</td>
<td>±7°</td>
<td>±8°</td>
<td>±11°</td>
<td>±14°</td>
<td>±19°</td>
<td>±23°</td>
<td>±26°</td>
<td>±28°</td>
</tr>
<tr>
<td>SIFT</td>
<td>±4°</td>
<td>±4°</td>
<td>±8°</td>
<td>±12°</td>
<td>±16°</td>
<td>±20°</td>
<td>±23°</td>
<td>±25°</td>
</tr>
<tr>
<td>GF</td>
<td>±4°</td>
<td>±5°</td>
<td>±7°</td>
<td>±9°</td>
<td>±12°</td>
<td>±14°</td>
<td>±16°</td>
<td>±17°</td>
</tr>
</tbody>
</table>

- Key-point based methods perform better than vein pattern based methods
- All vein pattern based methods show the same trend
Conclusion and Future Work I

Contribution:

- Designed a custom rotating multi-perspective finger vein scanner device
- Established the first multi-perspective finger vein data set (360°-view)
  - Will be made available to the public in the future
- Systematic robustness analysis of several finger vein recognition schemes against longitudinal finger rotation
- Publicly available implementation of DTFPM
Conclusion

- Up to $\pm 10^\circ$ all schemes can handle longitudinal rotation.
- Key-point based algorithms (DTFPM, SIFT) are more tolerant against this kind of deformation.
- Above $\pm 30^\circ$ a reliable recognition is not possible at all.

An implementation of all recognition schemes, the scores and detailed results will be available at:
http://wavelab.at/sources/Prommegger18b
Future Work

- Verify to which extend longitudinal rotation can be corrected
  - by using the known rotation angle (PLUSVein-Finger Rotation Data Set)
  - by detecting/estimating the angle (e.g. like Chen et al. [9])
- Try to find new algorithms to reduce the effect of longitudinal finger rotation.
Thank you!

Q & A
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