Near-Infrared Illumination Add-On for Mobile Hand-Vein Acquisition

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1 Vascular Biometrics

2 Mobile Hand-Vein Scanner Add-On

3 Mobile Hand-Vein Data Set

4 Experiments and Results

5 Conclusion and Future Work
Outline

1. Vascular Biometrics

2. Mobile Hand-Vein Scanner Add-On

3. Mobile Hand-Vein Data Set

4. Experiments and Results

5. Conclusion and Future Work
The network of blood vessels under the skin of the hand and fingers form a unique structure for every individual. Therefore, blood vessel characteristics are suitable for biometric applications. Similar to fingerprints, images of the blood vessels can be used for authentication.
Advantages

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

- Comparatively large capturing devices
- 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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The basic components of a hand-vein scanner are:

- **NIR sensitive image sensor:**  → Modified Nexus 5 from Eigen Imaging\(^1\)

- **NIR illumination:**  → Self-developed mobile NIR illumination add-on

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1. https://www.eigenimaging.com/
NIR Illumination Add-On: Technical Details

- Housing: 3D-printed components
- Arduino Nano control board\(^2\)
  - Bluetooth module for communication with smartphone
  - 16 channel LED driver IC
- LED Ring where all 16 NIR LEDs (850 nm) can be controlled individually
- NIR pass-through filter with 780 nm cut-off frequency
- Developed Smartphone application allows brightness control and capturing of images and videos
- Currently powered over USB

\(^2\)https://store.arduino.cc/arduino-nano/

Figure: Nexus 5 smartphone with NIR illumination add-on (back)
**Image capture:**
- Illumination can be controlled by user
- User can operate the smartphone with one hand and acquire with the other one

**Video capture (Challenge Response):**
- Challenge Response (CR) authentication using the 16 NIR LEDs to prevent presentation and replay attacks
- Challenge: Random number generated for each acquisition
- Response: Blinking sequence during video acquisition corresponding to random number
- Detection: Blinking sequence is extracted from the video and compared to random number
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Mobile Hand-Vein Data Set

Statistical data:

- 2 sessions: Outdoor and indoor
- 31 subjects (18 outdoor, 28 indoor, 15 in both)
- 5 images/videos per hand per view (dorsal, palmar)

- No hand support was used during acquisition
- Realistic scenario with rotation, tilting, scaling, illumination changes
- Will be publicly available as part of PROTECT Multimodal DB\(^3\) [1]

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\(^3\)http://projectprotect.et

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Experiments I

Experiment 1: Recognition performance of database (images):
- Palmar and dorsal images are analysed independently
- Analysis of session 1 (outdoor) and 2 (indoor)
- Comparison of session 1 against session 2

Experiment 2: Detection of CR sequence (videos):
- Palmar and dorsal images are analysed independently
- 65 videos of 13 different users
- Videos of 3 seconds length containing a 8-bit CR sequence
Experiments II

Used recognition schemes:

- Vein pattern based feature extraction methods (binarization)
  - Maximum Curvature (MC) [2]
  - Principal Curvature (PC) [3]
  - Gabor Filter (GF) [4]
- Key-point based methods
  - SIFT [5]
  - Modified version of Deformation-Tolerant Feature-Point Matching (DTFPM) [6]

Used performance indicators:

- EER (FMR = FNMR)
- FMR100 (the lowest FNMR for FMR = 1%)
- FMR1000 (the lowest FNMR for FMR = 0.1%)
- ZeroFMR (the lowest FNMR for FMR = 0%)
- HD (Hamming Distance)
### Results: Recognition Performance of Database I

#### Dorsal

<table>
<thead>
<tr>
<th></th>
<th>EER</th>
<th>FMR100</th>
<th>FMR1000</th>
<th>ZeroFMR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outdoor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC</td>
<td>4.13 (±1.11)</td>
<td>6.79</td>
<td>10.54</td>
<td>12.50</td>
</tr>
<tr>
<td>PC</td>
<td>10.71 (±1.72)</td>
<td>15.54</td>
<td>18.39</td>
<td>18.75</td>
</tr>
<tr>
<td>GF</td>
<td>28.08 (±2.50)</td>
<td>68.39</td>
<td>74.64</td>
<td>75.89</td>
</tr>
<tr>
<td>SIFT</td>
<td>10.63 (±1.72)</td>
<td>17.50</td>
<td>27.68</td>
<td>28.57</td>
</tr>
<tr>
<td>DTFPM</td>
<td>7.33 (±1.45)</td>
<td>13.04</td>
<td>16.61</td>
<td>17.32</td>
</tr>
<tr>
<td><strong>Indoor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC</td>
<td>5.69 (±1.77)</td>
<td>9.44</td>
<td>23.06</td>
<td>23.06</td>
</tr>
<tr>
<td>PC</td>
<td>8.97 (±2.17)</td>
<td>13.61</td>
<td>16.94</td>
<td>16.94</td>
</tr>
<tr>
<td>GF</td>
<td>36.37 (±3.66)</td>
<td>81.39</td>
<td>85.83</td>
<td>85.83</td>
</tr>
<tr>
<td>SIFT</td>
<td>14.17 (±2.65)</td>
<td>31.11</td>
<td>37.22</td>
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</tr>
<tr>
<td>DTFPM</td>
<td>12.00 (±2.47)</td>
<td>23.33</td>
<td>28.33</td>
<td>28.33</td>
</tr>
<tr>
<td><strong>Outdoor vs. Indoor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC</td>
<td>24.30 (±2.49)</td>
<td>56.13</td>
<td>69.87</td>
<td>69.87</td>
</tr>
<tr>
<td>PC</td>
<td>28.48 (±2.62)</td>
<td>54.13</td>
<td>68.00</td>
<td>68.00</td>
</tr>
<tr>
<td>GF</td>
<td>42.24 (±2.87)</td>
<td>96.67</td>
<td>99.20</td>
<td>99.20</td>
</tr>
<tr>
<td>SIFT</td>
<td>41.12 (±2.86)</td>
<td>88.80</td>
<td>94.40</td>
<td>94.40</td>
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<tr>
<td>DTFPM</td>
<td>30.22 (±2.67)</td>
<td>65.87</td>
<td>74.53</td>
<td>74.53</td>
</tr>
</tbody>
</table>

**Table:** Recognition performance results for the dorsal subset.
**Figure:** DET plot for session 1 (left) and session 2 (right) of the dorsal view.
## Results: Recognition Performance of Database III

### Palmar

<table>
<thead>
<tr>
<th></th>
<th>EER</th>
<th>FMR100</th>
<th>FMR1000</th>
<th>ZeroFMR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outdoor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC</td>
<td>7.52 (±1.47)</td>
<td>10.54</td>
<td>13.04</td>
<td>13.39</td>
</tr>
<tr>
<td>PC</td>
<td>13.88 (±1.93)</td>
<td>23.75</td>
<td>31.07</td>
<td>34.64</td>
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<tr>
<td>GF</td>
<td>32.52 (±2.61)</td>
<td>85.71</td>
<td>90.71</td>
<td>93.93</td>
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<tr>
<td>SIFT</td>
<td>11.90 (±1.80)</td>
<td>21.43</td>
<td>34.11</td>
<td>39.82</td>
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<tr>
<td>DTFPM</td>
<td>7.67 (±1.48)</td>
<td>12.14</td>
<td>16.79</td>
<td>21.96</td>
</tr>
<tr>
<td><strong>Indoor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC</td>
<td>7.78 (±2.04)</td>
<td>15.28</td>
<td>22.78</td>
<td>22.78</td>
</tr>
<tr>
<td>PC</td>
<td>14.52 (±2.68)</td>
<td>21.94</td>
<td>24.17</td>
<td>24.17</td>
</tr>
<tr>
<td>GF</td>
<td>33.93 (±3.60)</td>
<td>82.22</td>
<td>89.17</td>
<td>89.17</td>
</tr>
<tr>
<td>SIFT</td>
<td>14.21 (±2.66)</td>
<td>30.28</td>
<td>43.61</td>
<td>43.61</td>
</tr>
<tr>
<td>DTFPM</td>
<td>12.14 (±2.49)</td>
<td>22.50</td>
<td>26.67</td>
<td>26.67</td>
</tr>
<tr>
<td><strong>Outdoor vs. Indoor</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC</td>
<td>27.73 (±2.60)</td>
<td>56.00</td>
<td>65.47</td>
<td>65.47</td>
</tr>
<tr>
<td>PC</td>
<td>34.27 (±2.76)</td>
<td>62.80</td>
<td>75.33</td>
<td>75.33</td>
</tr>
<tr>
<td>GF</td>
<td>42.24 (±2.87)</td>
<td>98.53</td>
<td>99.87</td>
<td>99.87</td>
</tr>
<tr>
<td>SIFT</td>
<td>41.38 (±2.86)</td>
<td>86.00</td>
<td>95.87</td>
<td>95.87</td>
</tr>
<tr>
<td>DTFPM</td>
<td>34.07 (±2.76)</td>
<td>76.67</td>
<td>85.07</td>
<td>85.07</td>
</tr>
</tbody>
</table>

**Table:** Recognition performance results for the palmar subset.
Results: Recognition Performance of Database IV

Figure: DET plot for session 1 (left) and session 2 (right) of the palmar view.

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Table: Detection accuracy (ACC) and mean Hamming Distance for non-matches (Mean HD NM) for CR sequence detection. For $ACC = 1$ there are no non-matches, the HD can not be calculated (indicated by a –).
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Conclusion and Future Work I

Contribution:

- We proposed an illumination add-on turning a smartphone with NIR sensitive camera in a mobile hand vein scanner device.
- Established real-world hand vein dataset with indoor and outdoor data.
  - Will be made available to the public in the future.
- Evaluated recognition performance using well-established vein recognition schemes.
- Proposed a Challenge Response protocol in order to prevent replay and presentation attacks.
Conclusion

- Outdoor session exhibits a better recognition performance than the indoor session
- Inter-session comparison performs significantly worse than the single sessions
- Detection of CR sequence achieves competitive results
- Many challenges due to unconstrained conditions
Future Work

- Improvements on hardware to improve acquisition quality
- Multi-sample fusion of different video-frames
- Evolve DTFPM as a non-planar-rotation tolerant hand vein scheme
- Use other smartphone sensors to deal with challenges due to unrestricted positioning
Thank you!

Q & A


Modified version of DTFPM:

Removed deformation correction due to finger form

Figure: Normalization of descriptor area in DTFPM [6]