Latent Orientation Field Estimation via Convolutional Neural Network (ConvNet)

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State of the Art AFIS

Rank-1 identification rates:
• Plain to plain matching = 99.3% (NIST FpVTE 2012)
• Latent to rolled matching = 67.2% (NIST ELFT 2012)
Importance of Orientation Field (OF)

1) ridge structure enhancement
2) segmentation
3) classification/indexing
4) matching

....
Latent OF Estimation

Orientation patch dictionary (patch size = 160X160)

Ridge structure dictionary (patch size = 64X64 & 32X32)

Feng et al., Orientation field estimation for latent fingerprint enhancement. *TPAMI*, 2013.
Latent OF Estimation

The initial orientation field is not reliable
While ridge structure dictionary works better, it can be further improved by using larger patch size. But large patch size will significantly increase dictionary size.

Dictionaries learnt from high quality fingerprints do not generalize to varying quality well!!
Convolutional Neural Network (ConvNet)

- ConvNet can learn feature representations, given a large number of image examples

A latent patch

Pose orientation field estimation as a classification problem

Representative orientation patterns
Framework for OF Estimation

1 million orientation patches from NIST SD4 used for learning

128 orientation pattern classes
Framework for OF Estimation

1.28M patches (10K/class) selected from 6K fingerprints in NIST SD14 for training

1 million orientation patches from NIST SD4 used for learning

128 orientation pattern classes

ConvNet
Framework for OF Estimation

1.28M patches (10K/class) selected from 6K fingerprints in NIST SD14 for training

A cropped input latent

Preprocessed latent

Latent patches

ConvNet

1 million orientation patches from NIST SD4 used for learning

128 orientation pattern classes
Framework for OF Estimation

A cropped input latent → Preprocessed latent → Latent patches

ConvNet

1.28M patches (10K/class) selected from 6K fingerprints in NIST SD14 for training

1 million orientation patches from NIST SD4 used for learning

128 orientation pattern classes

Estimated orientation field
1) ReLU activation function \( f(x) = \max(0, x) \) is used at the convolutional layers and the fully connected layer.
2) Dropout regularization for the fully connected layer: 50% neurons are randomly selected with their output set as 0.
3) \( N \)-way softmax is used at output layer.
Experimental Setup

• Database for evaluation
  – NIST SD27 (258 latents and their rolled mates)

• Evaluation
  – Accuracy of estimated OF
    • Compared to manually marked orientation field
  – Identification performance
    • Matching enhanced latents against 100K reference prints including mated rolled prints in NIST SD27
Latent Orientation Field Comparison

Original latent | Orientation patch dictionary | Ridge structure dictionary | Proposed method

Feng et al., Orientation field estimation for latent fingerprint enhancement. *TPAMI*, 2013.
Latent Orientation Field Comparison

Original latent  Orientation patch dictionary  Ridge structure dictionary  Proposed method

Feng et al., Orientation field estimation for latent fingerprint enhancement. *TPAMI*, 2013.
# Orientation Field Estimation Accuracy

Average estimation error (in degrees) of different orientation field estimation

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>All</th>
<th>Good</th>
<th>Bad</th>
<th>Ugly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manually marked pose</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RidgeDic [2]</td>
<td>19.35</td>
<td>15.34</td>
<td>20.70</td>
<td>22.68</td>
</tr>
<tr>
<td>Proposed</td>
<td>13.51</td>
<td>10.76</td>
<td>13.41</td>
<td>16.00</td>
</tr>
</tbody>
</table>

Identification Experiments

Database
- Latent database: NIST SD27
- Background database: 100,000 reference prints including mates

Matcher:
- A state of the art latent matcher

Input
- Original latent
- Enhanced by [2]
- Enhanced by proposed OF and fixed frequency

7.36% rank-1 improvement after fusion
Successful Example

Original latent (Failed to match)

Enhanced by ridge structure dictionary (Rank 61)

Enhanced by proposed (Rank 1)
Failed Example

- Original latent (Rank 4)
- Enhanced by ridge structure dictionary (Rank 528)
- Enhanced by proposed (Failed to match)

Adaptive ridge frequency

Fixed ridge frequency
Conclusion and Future Work

• Proposed orientation field estimation method via convolutional neural network
• Improved the rank-1 performance of a COTS matcher by 7.36% on NIST SD27
• Future work:
  – Effect of No. of orientation pattern classes
  – Noise level added to the training patches
  – Estimate ridge frequency field using ConvNet
Thanks