Liveness Detection Using An Intensity Based Approach in Fingerprint Scanners

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Outline

- Background for liveness detection
- Intensity-based approach
- Results of three different scanners
- Conclusion and future work
Background

- **Fingerprint scanners are susceptible to spoof attack by “fake” fingerprints**
  - Lifted latent fingerprints
  - Artificial fingers: gummy fingers, casts made from gelatin, play-doh etc
  - Worst case: dismembered fingers
- **Liveness detection**
  - An anti-spoofing method
  - Improves reliability and security of biometric system
- **Detection of perspiration pattern**
  - Time series images
  - Developed by our lab
- **Previous algorithms**
  - Ridge signal algorithm
  - Wavelet based algorithm
- **Motivation:** improve accuracy and speed
Human Visual Difference for Live and Non-Live Fingerprint Images

Live Image  Spoof Image  Cadaver Image

0 second  5th second
Features Extraction Based on Perspiration Pattern

- The basis of *static* features: live fingerprints looks “patchy” due to the perspiration pattern
- The basis of *dynamic* features: live fingers demonstrate a distinctive changing moisture pattern between 0 second and 5th second images
Ridge Signal Algorithm

- Capture time-series images over 5 seconds
- Map a 2-D fingerprint image to a 1-D signal representing the grey levels along the ridges
- 7 static and dynamic features are extracted
- Perform classification between live and non-live using BPNN
Wavelet Based Algorithm

- Perform wavelet transform on 0 and 5th second images
- Extract low frequency content using multiresolution analysis
- Extract high frequency content using wavelet packet analysis
- Perform classification using energy content of changing coefficients
Intensity Based Approach

- Motivation: improve speed with reasonable accuracy
- Approach: quantify grey level differences between live and non-live fingerprint images using histogram distribution statistics
- Advantages: simple, efficient and saving time
Intensity Based Approach - Examples

Live

Play-Doh
Intensity based Approach
-Examples (Cont.)

Gelatin

Cadaver
Intensity Based Approach - Steps

- Pre-process to remove noise and normalize
- Adaptively select interesting area
- Perform histogram distribution analysis for time-series images
- Extract static and dynamic features
- Generate and determine classification tree using training and validation dataset
- Test with final test dataset
Classification Tree

- Derives a sequence of if-then-else rules in order to assign a class label to the input data
- A data mining technique
- Commercial tools: CART, See 5, SPSS etc
- Free tool: Classification Tree in Excel

http://www.geocities.com/adotsaha/CTree/CtreeinExcel.html
Some Hints

- Different scanners have different histogram distributions
- Select appropriate features to different scanners
- Adaptively select area to avoid scars
- Some live fingerprints are very wet and change very little
- Some cadaver fingerprints change like a live finger, but their grey levels are different than live fingers
- Classification tree takes these situations into consideration
Fingerprint Sensors and Dataset

- **Fingerprint Sensors**
  - Capacitive DC: Precise Biometrics 100SC
  - Optical: Secugen FDU01
  - Electro-optical: Ethentica USB2500

- **Dataset**
  - Live: 58
  - Spoof: 50(Play-doh and gelatin)
  - Cadaver: 28
  - Training (4/9), validation(2/9) and test(1/3) set
Precise: Features Extraction

\[ H_{1\text{-before}} = A = \sum_{i=1}^{100} h1(i) \]

\[ \text{Ratio} = \frac{C}{B} = \frac{\sum_{i=246}^{256} h2(i)}{\left( \sum_{i=1}^{245} h2(i) + 0.1 \right)} \]

\[ \text{Dif}_{256} = D = \sum_{i=246}^{256} |h1(i) - h2(i)| \]
Precise: Features Extraction

Cadaver  Spoof  Live
Ratio

Cadaver  Spoof  Live
H1_before

Cadaver  Spoof  Live
Dif_256
Precise: Classification Tree and Results

Training Data

<table>
<thead>
<tr>
<th>True Class</th>
<th>Predicted Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>live</td>
<td>live</td>
</tr>
<tr>
<td></td>
<td>spoof</td>
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Validation Data

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Secugen: Features Extraction

\[ \text{Ratio} = \frac{B}{A} = \frac{\sum_{i=1}^{149} h(i)}{(\sum_{i=1}^{150} h(i) + 0.1)} \]

\[ \text{H1\_behind} = B = \sum_{i=150}^{254} h(i) \]

\[ \text{Dif\_256} = C = \sum_{i=255}^{256} |h(i) - h_2(i)| \]
Secugen: Features Comparison

- Cadaver
- Spoof
- Live

Ratio

H1_behind

Dif_256
Secugen: Classification Tree and Results

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</tbody>
</table>
Ethentica: Features Extraction

Dev = $\text{std}(h2(i))$

$P_{\text{before}} = \frac{A1}{A2} = \frac{\sum_{i=1}^{80} h1(i)}{\sum_{i=1}^{80} h2(i)}$

$D_{\text{if} \_0} = B = \sum_{i=1}^{10} |h1(i) - h2(i)|$

$D_{\text{if} \_256} = C = \sum_{i=200}^{250} |h1(i) - h2(i)|$
Ethentica: Features Comparison

![Graphs showing features comparison]

- Cadaver
- Spoof
- Live
- Dev
- Dif_256
- P_before
- Dif_0
Ethentica: Classification Tree and Results

Training Data

<table>
<thead>
<tr>
<th>True Class</th>
<th>Live</th>
<th>Spoof</th>
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<td>1</td>
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<td>Spoof</td>
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<td>33</td>
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Validation Data

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<td>12</td>
</tr>
<tr>
<td>Spoof</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td></td>
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Test Data

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<tr>
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<th>Spoof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>Spoof</td>
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<td>21</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>25</td>
</tr>
</tbody>
</table>

predicted Class

Support: 27%  Conf: 100%
Support: 11%  Conf: 100%
Support: 5%   Conf: 67%
Support: 2%   Conf: 100%
Support: 20%  Conf: 94%
Outcome Summary

- Success ratio: 84%~100%
- Grey level differences are specific to the type of spoof images we collected
Conclusion and Future Work

- **Intensity based approach**
  - Static and dynamic features are extracted to quantify gray level differences
- **Classification tree**
- **Simple, efficient and saving time**
- **Purely software based**
- **Anti-spoofing protection for fingerprint scanners**
- **Future work**
  - Consider other methods to defeat liveness algorithm
  - Study existence of perspiration pattern over larger number of subjects
Thank You Questions?