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Fusion of Multibiometrics and Liveness Information for Automated Border Control

Dr Peter Wild
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Presentation based on
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Computational Vision Group @ University of Reading

### Team
- Prof J Ferryman
- 7 Postdocs
- 4 PhD Students

### Topics
- Iris Biometrics
- Multimodal Biometrics
- Counter-Spoofing
- 2D+3D Face Recognition
- Detection & Tracking
- Behaviour Recognition

### Funding
- FastPass, EU FP7
- IPATCH, EU FP7
- P5, EU FP7
- EDEN, EU FP7
- ARENA, EU FP7
- EFFISEC, EU FP7

Further info please visit: cvg.reading.ac.uk
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Fingerprint Recognition

- Unique, reliable recognition
- Most widely used biometric trait
- Cheaper than other biometric sensors (e.g. iris)
- Easy to integrate with other systems
- Used at border control
- Range of sensors: Optical, Solid state, Multispectral imaging, 3D

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Fingerprint Spoofing

Spoofing

Materials

- Fingerprint images
  - PlayDoh
  - Gelatin
  - Silicon
  - Cadaver fingers, etc.

Competitions

LivDet: Fingerprint Liveness Detection

- Since 2009, every 2 years
- Multiple sensors: optical & swipe
- Various materials

Direct attack at sensor-level

Replication of original fingerprint

Data to bypass the sensor

LivDet:

Fingerprint Liveness Detection

Since 2009, every 2 years

Multiple sensors:

- optical & swipe

Various materials

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Towards Anomaly Detection in Multibiometric Fusion

Problem
- Standard fusion sensitive to spoofing

Question
- How to make them more robust?

Intuition
- Detect and eliminate anomalies
- Modeling human surveillance operators

Solution
- Novel spoofing-resistant fusion method
- Improved security, while retaining accuracy
Related Work

- **Akhtar et al., BTAS'12**
  - Score-level fusion can be fooled by a single biometric

- **Rodrigues et al., BTAS'10**
  - Likelihood ratio (LLR) and fuzzy logic combining recognition scores and quality

- **Marasco et al., MCS'11**
  - Combining liveness detection with match scores modality-wise

- **Marasco et al., BTAS'12**
  - Bayesian Belief Network for combining match scores and liveness

- **Rattani et al., WIFS'13**
  - Learning-based fusion method
  - Quality, liveness and match scores are influenced by the sensor
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Median Filtering

- Fixed score rules:

\[ F_{\text{sum}}(\bar{s}) := \frac{1}{n} \sum_{i=1}^{n} s_i; \quad F_{\text{median}}(\bar{s}) := \text{med}_{i=1}^{n} s_i \]

- Median Filter:

\[ F_{mf}(\bar{s}) := \frac{1}{\sum_{i=1}^{n} M(\bar{s}, s_i)} \sum_{i=1}^{n} M(\bar{s}, s_i) s_i \]

\[ M(\bar{s}, s_i) := \begin{cases} 1, & \text{if } |s_i - \text{med}_{j=1}^{n} s_j| < \phi; \\ 0, & \text{else}. \end{cases} \]

- Median Filtering:

\[ F_{mf}^2(\bar{s}, \bar{l}) := \frac{1}{\sum_{i=1}^{n} M(\bar{s}, [s_i])} \sum_{i=1}^{n} M([s_i], [s_i]) \]

\[ M([s_i], [s_i]) := \begin{cases} 1, & \text{if } \|s_i - \text{med}_{j=1}^{n} s_j\| \leq \phi; \\ 0, & \text{else}. \end{cases} \]

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Experiments

Test Database:

- Liv’Det 2013 CrossMatch (2500 live, 2000 spoof images), multibiometric setup
- Right hand images for testing, left hand images for training

Tested Spoofing Attack:

- Impostor has access to $m = 0, 1, \ldots n$ out of $n$ presentable fingerprints ($m$-spoof)

System:

- Features: NIST *mindtct* (feature extraction) + *bozorth* (comparison)
- Spoofing: regularized LR - 27.65% ferrlive and 24.2% ferrfake

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Results I

<table>
<thead>
<tr>
<th>Method</th>
<th>(S)EER 0-spoof</th>
<th>(S)EER 1-spoof</th>
<th>(S)EER 2-spoof</th>
<th>(S)EER 3-spoof</th>
<th>(S)EER 4-spoof</th>
<th>d-Prime 0-spoof</th>
<th>d-Prime 1-spoof</th>
<th>d-Prime 2-spoof</th>
<th>d-Prime 3-spoof</th>
<th>d-Prime 4-spoof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum rule</td>
<td>0.14</td>
<td>1.91</td>
<td>3.42</td>
<td>5.83</td>
<td>7.52</td>
<td>2.48</td>
<td>2.40</td>
<td>2.27</td>
<td>2.10</td>
<td>1.94</td>
</tr>
<tr>
<td>Median rule</td>
<td>1.56</td>
<td>1.23</td>
<td>2.75</td>
<td>5.05</td>
<td>7.5</td>
<td>2.43</td>
<td>2.41</td>
<td>2.27</td>
<td>2.07</td>
<td>1.87</td>
</tr>
<tr>
<td>Median filter</td>
<td>1.24</td>
<td>1.29</td>
<td>2.89</td>
<td>5.60</td>
<td>7.76</td>
<td>2.55</td>
<td>2.52</td>
<td>2.34</td>
<td>2.12</td>
<td>1.93</td>
</tr>
<tr>
<td>1-Median filter + LR</td>
<td>1.69</td>
<td>1.78</td>
<td>1.78</td>
<td>1.78</td>
<td>1.78</td>
<td>2.89</td>
<td>2.89</td>
<td>2.89</td>
<td>2.89</td>
<td>2.89</td>
</tr>
</tbody>
</table>

- **How does a spoofing of m out of n fingers impact on fusion?**
  - Even a single spoofed finger severely shifts impostor score distribution.
  - Standard sum rule: every additional finger increases EER by an absolute value of 1.8-2.4%.
  - Even 4-finger spoofing does not necessarily imply success (EER in this case is 7.52% vs. 0.14% 0-spoof).

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Results II

- **How to avoid negative accuracy impact of scores from fake fingerprints?**
  - Median rule is more robust in spoofing (1.23% EER for 1-spoofs);
  - However, for the 0-spoof case, median rule rejects useful information.
Results III

- How to integrate spoofing countermeasures in fusion rules?
  - Idea: median has a breakdown point of 0.5 and is able to suppress a number of outliers
  - 1-median filtering (scores+liveness) is much more robust versus 3-spoof and 4-spoof attacks.
  - For (S)FARs greater than 10⁻³, corresponding GARs differ minimally, with stable EERs in 1.69-1.78% (d-Prime 2.89)

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Summary

Result 1
- Fingerprint Livdet 2013: If 1 or 2 out of 4 samples are spoofed, **median filtering outperforms sum rule**, while not using any ancillary information.

Result 2
- It is possible to define fusion rules (median filtering) integrating liveness scores such that **EERs remain stable over all spoofing attempts**.

Remaining Problem
- Median filtering comes at the cost of slightly **reduced 0-spoof performance**.

Further Tasks
- **Normalisation** (problematic in multimodal configuration).
Future Work and Remaining Challenges

Multimodal
- Increase difficulty to **spoof multiple traits**
- Decisions in the **absence of certain features**
- Extend to **multispectral** sensors 2D+3D

Quality
- Incorporation of **quality in decision process**
- Types of materials (material-**independence**)  
- Increase the **difficulty of replication process**

Optimisation
- **Optimised selection** of filter parameters
- Adaptive fusion schemes
- Normalisation issues

Evaluation
- **ABC-specific** dataset with realistic attacks
- FastPass Trial Start: Q1 2015 @ VIA
- Extension to multimodal biometrics

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Thank you for your attention!