Liveness Detection

- Detect vitality from biometrics signature
- Targeted to **sensor level** attacks

![Diagram of liveness detection system](image)
Iris Liveness Detection

- **Training**
  - Collection of real and fake iris images
  - Photo attacks:

Iris Liveness Detection

Training

- Collection of real and fake images
- Contact lens attacks:

Artificial Intelligence Approach

- Let an intelligent agent perceive what are the characteristics that make a biometrics real or fake
- Pattern recognition

Deep learning

- Features
  - Low-level learnt features
  - Mid-level learnt features
  - High-level learnt features
- Classifier
Specialized Deep Learning


Our Approach

Learn by comparing **local features**

Set of \( n \) reference real and fake patches:

\[
L = \{ r(x_{L1}), r(x_{L2}), \ldots, r(x_{Ln}) \}
\]

\[
F = \{ r(x_{F1}), r(x_{F2}), \ldots, r(x_{Fn}) \}
\]

Matching problem:

Given a query image

Extract \( p \) patches \( Q = \{ r(Q_1), r(Q_2), \ldots, r(Q_p) \} \)

Real if \( \sum_{j=1}^{p} D(L, Q_j) \geq \sum_{j=1}^{p} D(F, Q_j) \)

Fake otherwise
## Architecture

<table>
<thead>
<tr>
<th>Layer Description</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>32x32 gray level image</td>
<td></td>
</tr>
<tr>
<td>5x5 conv. filters, stride 1, 1 → 64 feat. maps</td>
<td>64x28x28</td>
</tr>
<tr>
<td>batch normalization</td>
<td>64x28x28</td>
</tr>
<tr>
<td>rectifier linear unit</td>
<td>64x28x28</td>
</tr>
<tr>
<td>3x3 conv. filters, stride 2, padding 1, 64 → 64 feat. maps</td>
<td>64x14x14</td>
</tr>
<tr>
<td>3x3 conv. filters, stride 1, 64 → 128 feat. maps</td>
<td>64x12x12</td>
</tr>
<tr>
<td>batch normalization</td>
<td>64x12x12</td>
</tr>
<tr>
<td>rectifier linear unit</td>
<td>64x12x12</td>
</tr>
<tr>
<td>3x3 conv. filters, stride 2, padding 1, 128 → 128 feat. maps</td>
<td>128x6x6</td>
</tr>
<tr>
<td>3x3 conv. filters, stride 1, 128 → 256 feat. maps</td>
<td>256x4x4</td>
</tr>
<tr>
<td>batch normalization</td>
<td>256x4x4</td>
</tr>
<tr>
<td>rectifier linear unit</td>
<td>256x4x4</td>
</tr>
<tr>
<td>3x3 conv. filters, stride 2, padding 1, 256 → 256 feat. maps</td>
<td>256x2x2</td>
</tr>
<tr>
<td><strong>fully connected layer 4x256 → 256</strong></td>
<td>256</td>
</tr>
<tr>
<td>dropout p = 0.4</td>
<td>256</td>
</tr>
<tr>
<td>rectifier linear unit</td>
<td>256</td>
</tr>
<tr>
<td><strong>fully connected layer 256 → 256</strong></td>
<td>256</td>
</tr>
<tr>
<td><strong>softmax</strong></td>
<td>256</td>
</tr>
</tbody>
</table>
Metric Learning

- Increase **number of examples**
  - patch based representation
  - examples arranged in **triplets**

\[
c(x_i, x_j^+, x_k^-) = \left| d(r(x_i), r(x_j^+)) - d(r(x_i), r(x_k^-)) + 1 \right|_+
\]
\[
c(x_i, x_j^+) = d(r(x_i), r(x_j^+))
\]

\[
L = \sum_{i,j,k} \left\{ c(x_i, x_j^+, x_k^-) + \beta c(x_i, x_j^+) \right\} + \lambda \|\theta\|_2
\]

Validation: Classification error leads to **underfitting**

- **Criterion**: how many patches closer to the respective reference set?
- **Stop**: when the number of violating triplets does not decrease for five epochs.
## Results

- **Average Classification Error %**

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Triplet Net</th>
<th>SID</th>
<th>CNN</th>
<th>Dense SIFT</th>
<th>DAISY</th>
<th>LCPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iris-2013-Warsaw</td>
<td>0.0</td>
<td>0.0</td>
<td>0.2</td>
<td>0.5</td>
<td>0.9</td>
<td>7.1</td>
</tr>
<tr>
<td>Cogent</td>
<td>5.5</td>
<td>6.2</td>
<td>-</td>
<td>13.9</td>
<td>17.2</td>
<td>11.0</td>
</tr>
<tr>
<td>Vista</td>
<td>0.7</td>
<td>3.5</td>
<td>-</td>
<td>2.5</td>
<td>8.8</td>
<td>3.1</td>
</tr>
</tbody>
</table>

- **Computational time: 0.2ms + 1ms (GPU)**

- **Average between**
  - Attack Presentation Classification Error Rate (APCER)
  - Bona Fide Presentation Classification Error Rate (BPCER)
T-SNE Representation
Visualization

Accuracy wrt the number of patches to evaluate a test iris image

In red, patches classified as Fake (sliding window)
Conclusions

› We proposed a software system for Iris liveness detection

› We overcome the scarcity of examples by:
  › Patch based representation
    › Full scale image analysis
  › Metric learning
    › Examples arranged in a multitude of triplets

› State of the art or better performance