Automatic Online Signature Verification based only on FHE Features: an Oxymoron?

Marianela Parodi\(^1\)  Juan Carlos Gómez\(^1\)  Linda Alewijnse\(^2\)

\(^1\)Laboratory for System Dynamics and Signal Processing  
FCEIA, Universidad Nacional de Rosario and CIFASIS, ARGENTINA  
{parodi,gomez}@cifasis-conicet.gov.ar

\(^2\)Netherlands Forensic Institute  
The Hague, The Netherlands  
l.alewijnse@nfi.minvenj.nl

ICFHR 2014 - September 1-5, 2014 - Crete Island, Greece
Motivation
Why Online Features?

- Online acquisition devices have become very popular
- Dynamic signing behavior is more difficult to simulate/forge
Motivation
Why Features relevant to FHEs?

- Further understanding the signatures and the writer behavior.
- Features thoroughly investigated and accepted by FHEs.

To bridge the gap between the PR and FHEs communities
Motivation
Previous work on combination of Global and Time Functions Based features

- **Global Features**: are more simple and intuitive, and easier to compute and compare.

- **Time Functions Based features**: more complex and not so intuitive, but provide dynamic information of the signing process.

- **Different Combinations** of Global and Time Functions based features can be implemented.

Global features and Time Functions Based Features were shown to provide complementary information
Motivation

Automatic Signature verification based only on FHEs features?

- Constrain to use only FHE relevant features.
- Try Different Combinations of Global FHE and Time Functions based FHE features.

Global FHE features and Time Functions Based FHE Features could provide complementary information.

Using only FHE relevant features could suffice for the successful implementation of automatic signature verification systems.
Contributions

- **Exclusive use of FHE features** (both Global and Time Functions based ones).
- **Two Different Combinations** of Global FHE and Time Functions based FHE features.
  1. Global FHE Features used for **pre-classification followed by Random Forest classification** using Time Functions Based FHE features.
  2. **Decision Level Fusion** of two Random Forest classifiers using respectively Global FHE and Time Functions Based FHE features.
- **Evaluation on recent public signature database** → Western and Chinese signatures
- **Verification results quantified** by:
  - EER (Equal Error Rate)
  - Cost of the log-likelihood ratios $\hat{C}_{llr}$
FHE features

- **Global FHE features (GFHE):** Global features based on pen trajectories (time and space) are relevant to FHE. We choose the following ones:
  - Signature Total Time Duration: $T$
  - Pen-down Duration: $T_{pd}$

- **Time Functions FHE features (TFFHE):** the following time functions relevant to FHE are considered (same as in [1]):
  - velocity magnitude: $v_T$
  - velocity direction: $\theta$
  - curvature: $\rho$
  - first order derivative of pen pressure: $dp$

**TFFHE approximation using wavelets** → keep only the **approximation** coefficients in a wavelet decomposition.

Pre-classification Approach

GFHE Features

↓

Rough and quick representation
Distinctive characteristics
Detect some anomalies

TFFHE Features

↓

Detailed information

Pre-classification

- quickly recognize and classify gross forgeries
- speed up and simplify the verification process
Pre-classification Approach

Verification System Scheme

Decision rule

\[ \text{If } (g_{test} - \bar{g}_{train})^T \Sigma^{-1}_{train} (g_{test} - \bar{g}_{train}) > \alpha^2 \]

\[ \text{then } \text{signature} = \text{forgery} \]

\[ \text{else } \text{continue classification} \]
Pre-classification Approach

**Decision rule**

\[
(g_{\text{test}} - \bar{g}_{\text{train}})^T \Sigma_{\text{train}}^{-1} (g_{\text{test}} - \bar{g}_{\text{train}}) = \alpha^2
\]

**Hyperellipsoid:** 
\[
(g_{\text{test}} - \bar{g}_{\text{train}})^T \Sigma_{\text{train}}^{-1} (g_{\text{test}} - \bar{g}_{\text{train}}) = \alpha^2
\]
Pre-classification Approach

Parameter $\alpha$ is computed as:

$$\alpha^2 = \max_A \max_{A_i} \left\{ (g_{test} - \bar{g}_{train})^T \Sigma_{train}^{-1} (g_{test} - \bar{g}_{train}) \right\},$$

where

- $A$ is the set of all the authors in the Training Set,
- $A_i$ denotes the $i$-th author in the same set.
Decision Level Fusion Approach

Verification System Scheme

Decision rule

\[ P_{\text{fused}} = P_{\text{GFHE}}^{1-\beta} P_{\text{TFFHE}}^\beta \]

(weighted geometrical fusion of likelihood scores of individual classifiers, \( 0 < \beta < 1 \) user defined weighting parameter)
Evaluation Protocol
Signature Database

SigComp2011 Dataset[2] presented within ICDAR 2011:

- Publicly available Database
- Signatures acquired using a ballpoint pen on paper
- Natural writing process
- Two separate data sets:

  ![Dutch signatures](image1)
  ![Chinese signatures](image2)

[2] M. Liwicki et al., "Signature verification competition for online and offline skilled forgeries (Sig-Comp2011),"
ICDAR 2011.
Evaluation Protocol
Signature Database (cont.)

- Forgeries in the Database are skilled forgeries:
  - Genuine signatures
  - Skilled forgeries

- Measured data:
  - Pen coordinates $x$ and $y$
  - Pen pressure $p$
Datasets in the SigComp2011 Database are divided into two sets: **Training Set** and **Testing Set**

<table>
<thead>
<tr>
<th></th>
<th>Dutch signatures</th>
<th>Chinese signatures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Training Set</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authors</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Genuines</td>
<td>240</td>
<td>230</td>
</tr>
<tr>
<td>Forgeries</td>
<td>119</td>
<td>429</td>
</tr>
<tr>
<td><strong>Testing Set</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authors</td>
<td>54</td>
<td>10</td>
</tr>
<tr>
<td>Genuines</td>
<td>1296</td>
<td>219</td>
</tr>
<tr>
<td>Forgeries</td>
<td>611</td>
<td>461</td>
</tr>
</tbody>
</table>

- **Training Set** $\rightarrow$ optimization of the tuning parameters
- **Testing Set** $\rightarrow$ independent testing purposes

*(5-fold cross-validation)*
Evaluation Protocol
Optimization of the tuning parameters

Optimization of the tuning parameters is performed over the Training Set

- **Pre-classification Approach:** $\alpha$
- **Decision Level Fusion Approach:**
  - $\beta^{Dutch} = 0.13$
  - $\beta^{Chinese} = 0.06$
Evaluation Protocol
Design parameters

- **Both Approaches:**
  - normalized length of the resampled time functions (= 256)
  - resolution level of the wavelet approximation (= 3)
  - number of trees in the RF classifier (= 500)
  - randomly selected splitting variables in the RF classifier (= $\sqrt{P}$, being $P$ the feature vector dimension)
Verification Results

<table>
<thead>
<tr>
<th></th>
<th>Dutch Dataset</th>
<th></th>
<th>Chinese Dataset</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EER</td>
<td>$\hat{C}_{llr}$</td>
<td>$\hat{C}_{llr}^{min}$</td>
<td>EER</td>
</tr>
<tr>
<td><strong>PC</strong></td>
<td>4.42</td>
<td>0.222</td>
<td><strong>0.178</strong></td>
<td>5.98</td>
</tr>
<tr>
<td><strong>DLF</strong></td>
<td>8.12</td>
<td>0.335</td>
<td><strong>0.298</strong></td>
<td>7.63</td>
</tr>
<tr>
<td><strong>ASF [1]</strong></td>
<td>6.58</td>
<td>0.243</td>
<td><strong>0.205</strong></td>
<td>7.455</td>
</tr>
</tbody>
</table>

Conclusions

- **Exclusive use of FHE features** (both GFHE and TFFHE ones).
- **Two Different Combinations** of GFHE and TFFHE features.
  1. GFHE Features used for **pre-classification followed by Random Forest classification** using TFFHE features.
  2. **Decision Level Fusion** of two Random Forest classifiers using respectively GFHE and TFFHE features.
- Evaluation on recent public signature database → Western and Chinese signatures
- Verification results are comparable to the state-of-the-art.

Automatic online signature verification based only on FHE features is **not an oxymoron**.
Automatic Online Signature Verification based only on FHE Features: an Oxymoron?

Marianela Parodi\textsuperscript{1} \hspace{1cm} Juan Carlos Gómez\textsuperscript{1} \hspace{1cm} Linda Alewijnse\textsuperscript{2}

\textsuperscript{1}Laboratory for System Dynamics and Signal Processing  
FCEIA, Universidad Nacional de Rosario and CIFASIS, ARGENTINA  
\{parodi,gomez\}@cifasis-conicet.gov.ar

\textsuperscript{2}Netherlands Forensic Institute  
The Hague, The Netherlands  
l.alewijnse@nfi.minvenj.nl

ICFHR 2014 - September 1-5, 2014 - Crete Island, Greece
5-fold Cross Validation (Testing Dataset)