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

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# Outline

# 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** $\longrightarrow$ 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** $\rightarrow$ keep only the **approximation** coefficients in a wavelet decomposition.

[1] M. Parodi, J.C. Gómez, M. Liwicki, and L. Alewijnse, "Orthogonal function representation for online signature verification: which features should be looked at?", *IET Biometrics*, vol. 2, no. 4, pp. 137-150, 2013.

# Pre-classification Approach

**GFHE Features**

↓

Rough and quick representation

Distinctive characteristics

Detect some anomalies

**TFFHE Features**

↓

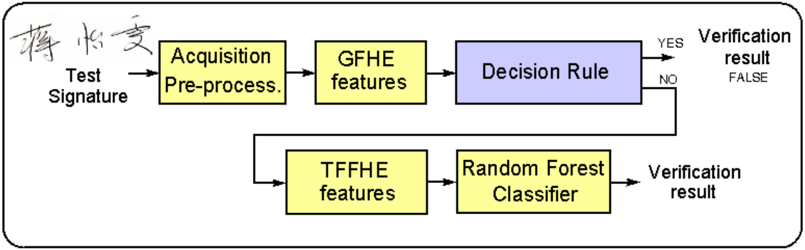
Detailed information

## Pre-classification

- quickly recognize and classify **gross forgeries**
- speed up and simplify the verification process

# Pre-classification Approach

## Verification System Scheme




**Decision rule**

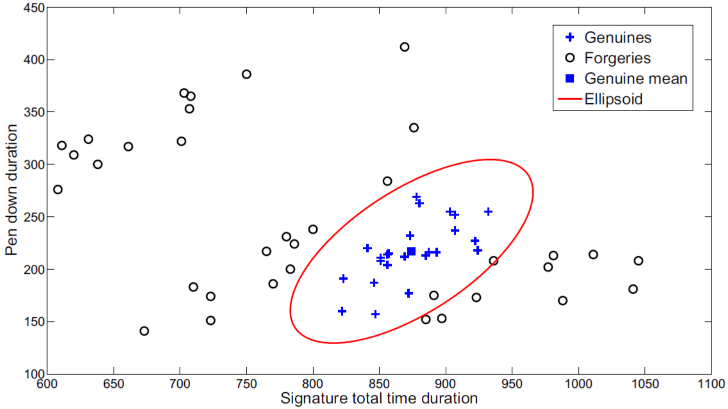
*If* $(\mathbf{g}_{test} - \bar{\mathbf{g}}_{train})^T \Sigma_{train}^{-1} (\mathbf{g}_{test} - \bar{\mathbf{g}}_{train}) > \alpha^2$

*then* signature = forgery

*else* continue classification

# Pre-classification Approach

## Decision rule




**Hyperellipsoid:** $(\mathbf{g}_{test} - \bar{\mathbf{g}}_{train})^T \Sigma_{train}^{-1} (\mathbf{g}_{test} - \bar{\mathbf{g}}_{train}) = \alpha^2$

# Pre-classification Approach

- Parameter $\alpha$ is computed as:

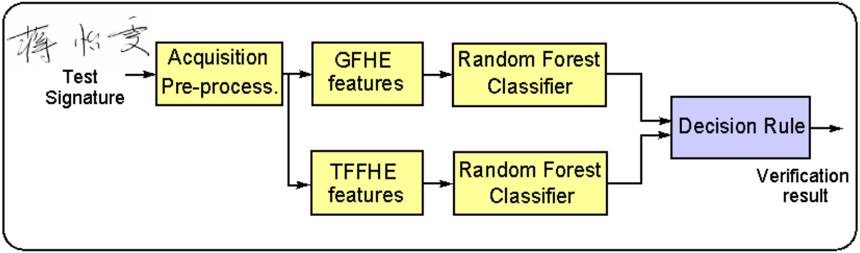
$$\alpha^2 = \max_{A} \max_{A_i} \left\{ (\mathbf{g}_{test} - \bar{\mathbf{g}}_{train})^T \Sigma_{train}^{-1} (\mathbf{g}_{test} - \bar{\mathbf{g}}_{train}) \right\},$$

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

$$P_{fused} = P_{GFHE}^{(1-\beta)} \, P_{TFFHE}^{\beta}$$

**(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

$\downarrow$

Natural writing process

- Two separate data sets:

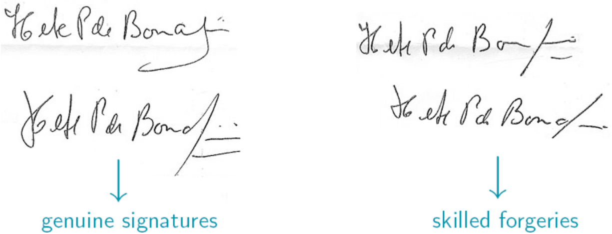
Dutch signatures

Chinese signatures

[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:




- Measured data:
  - pen coordinates $x$ and $y$
  - pen pressure $p$

# Evaluation Protocol
## Signature Database (cont.)

Datasets in the SigComp2011 Database are divided into two sets: **Training Set** and **Testing Set**

Dutch signatures

| Training Set | | |
|---|---|---|
| Authors | Genuines | Forgeries |
| 10 | 240 | 119 |
| Testing Set | | |
| Authors | Genuines | Forgeries |
| 54 | 1296 | 611 |

Chinese signatures

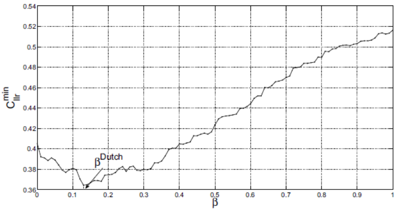
| Training Set | | |
|---|---|---|
| Authors | Genuines | Forgeries |
| 10 | 230 | 429 |
| Testing Set | | |
| Authors | Genuines | Forgeries |
| 10 | 219 | 461 |

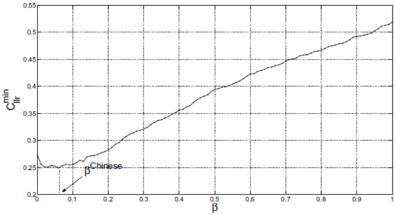
- **Training Set** $\longrightarrow$ optimization of the tuning parameters
- **Testing Set** $\longrightarrow$ independent testing purposes (**5-fold cross-validation**)

# 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

| | Dutch Dataset | | | Chinese Dataset | | |
|---|---|---|---|---|---|---|
| | EER | $\hat{C}_{llr}$ | $\hat{C}_{llr}^{min}$ | EER | $\hat{C}_{llr}$ | $\hat{C}_{llr}^{min}$ |
| **PC** | 4.42 | 0.222 | **0.178** | 5.98 | 0.265 | **0.211** |
| DLF | 8.12 | 0.335 | 0.298 | 7.63 | 0.299 | 0.251 |
| ASF [1] | 6.58 | 0.243 | 0.205 | 7.455 | 0.296 | 0.248 |

[1] M. Parodi, J.C. Gómez, M. Liwicki, and L. Alewijnse, "Orthogonal function representation for online signature verification: which features should be looked at?", *IET Biometrics*, vol. 2, no. 4, pp. 137-150, 2013.

# 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** $\longrightarrow$ 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.**

# Thanks a lot !!! Σε ευχαριστώ πολύ

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

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# 5-fold Cross Validation (Testing Dataset)