Handwriting evidence evaluation based on the shape of characters

MSSFHA, Gaithersburg, MD
4-5 June 2013
Research goal

Comparison

Findings

Training & experience

Assessment

Quantitative data

Conclusion
Analysis of shape

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Fourier descriptors

Each curve is described by a series of harmonics

\[ R(\theta) = R_n + \sum_{m=1}^{n} [a_m \cos(m\theta)] + \sum_{m=1}^{n} [b_m \sin(m\theta)] \]

Each harmonic is described by two parameters

\[ A_n = \sqrt{a_n^2 + b_n^2} \quad \text{amplitude} \]
\[ P_n = \arctan \left( \frac{a_n}{b_n} \right) \quad \text{phase} \]
Fourier descriptors

Original contour

Harmonic 1  
(Ampl₁, Phase₁)  
1 leaf

Harmonic 2  
(Ampl₂, Phase₂)  
2 leaves

Harmonic 3  
(Ampl₃, Phase₃)  
3 leaves

Harmonic 4  
(Ampl₄, Phase₄)  
4 leaves

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Fourier descriptors

Original contour

0 to 1
0 to 2
0 to 3
0 to 4
> Sampling

- 13 writers
- 4 letters: a, d, o, q
- 2325 loops
Assessment model

> Methodology based on a model of Aitken and Lucy (2004)
> Consideration of the correlation between variables
> Consideration of the dependence of the within-writer variability on the writer
> Two-level model
LR: evaluative framework

\[
LR = \frac{P(E|H_1)}{P(E|H_2)} = \frac{P(\text{findings} | \text{the suspect wrote the questioned text})}{P(\text{findings} | \text{the suspect did not write the questioned text})}
\]

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LR: evaluative framework

\[ E = y_1, y_2 \quad y_i \sim N(\theta_i, W_i) \]

- \( y_1 \): characters of the threatening text
- \( y_2 \): characters of the reference material

\[ LR = \frac{f(y_1, y_2 | H_1)}{f(y_1, y_2 | H_2)} \]

> the LR value depends on the draw of characters
> multiple draws of a given number of characters
LR: evaluative framework

Let $H_1$ be true

The reference material comes from the writer of the questioned text

![Histogram showing frequency distribution of LLR values](image)

**Quest.**

**Ref.**
LR: evaluative framework

> Let $H_2$ be true

The reference material comes from another writer

![Histogram of LLR (log-likelihood ratio)](image)

- Quest.
- Ref.
LR: investigative framework
LR: investigative framework

> Coefficient B₂ of:
  60 males (1566 letters \( d \)),
  20 females (4260 letters \( d \))

> Given measurements on questioned characters:

\[
LR = \frac{f(y|H_1)}{f(y|H_2)}
\]

H1: the author is a male
H2: the author is a female
LR: investigative framework

- 5 values of B2 of a writer are taken from the male population
- The LR is computed
- This operation is repeated 10'000 times

<table>
<thead>
<tr>
<th>LR apportionments</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&lt;10^{-3}$</td>
<td>45</td>
<td>54</td>
</tr>
<tr>
<td>$10^{-3} - 10^{-2}$</td>
<td>1329</td>
<td>5559</td>
</tr>
<tr>
<td>$10^{-2} - 10^{-1}$</td>
<td>2103</td>
<td>2487</td>
</tr>
<tr>
<td>1 – 10</td>
<td>1758</td>
<td>615</td>
</tr>
<tr>
<td>$10 - 10^2$</td>
<td>2493</td>
<td>615</td>
</tr>
<tr>
<td>$10^2 - 10^3$</td>
<td>1446</td>
<td>328</td>
</tr>
<tr>
<td>$10^3 - 10^4$</td>
<td>535</td>
<td>233</td>
</tr>
<tr>
<td>$&gt;10^4$</td>
<td>291</td>
<td>109</td>
</tr>
</tbody>
</table>

$LR = 125$

$\frac{328}{1446 + 328} \rightarrow 18\%$
Conclusion

> The model supports the correct hypothesis
> The model provides a quantitative tool
> Measurements should be treated carefully in investigative scenarios
> The procedure is automated
Perspectives

> Three-level model
> Open curves
> Comparison of simulated handwritings
> Application of the model to other fields
Thank you for your attention!