Comparison and Interpretation of Impressed Marks Left by a Firearm on Cartridge Cases

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Objective

• To bring an *objective measure of the weight* associated with comparison results between impressed marks (breech face and firing pin) on cartridge cases.

Likelihood Ratio (LR)
3D measurement

Confocal detection profiler
μscan of Nanofocus®
Resolution: 2 μm
Primer Cup Cutting

Automatic segmentation of the primer cup taking advantage of normal vectors
Marks separation

Automatic separation of the marks taking advantage of normal vectors
Firing pin alignment using ICP

Firing pin N°1

Firing pin N°2
Firing pin alignment using ICP

Ceska Zebrojovka
Sample A

Ceska Zebrojovka
Sample B

Alignment
Breech face alignment

SIG Sauer Sample A

Alignment

SIG Sauer Sample B
Similarity metrics (scores)

- Correlation index
- Euclidean distance
- Normal vectors difference

3 Scores
A → B

A → B

3x Scores
BFM

3x Scores
FPM
Towards a likelihood ratio (LR)

The LR represents the ratio between the probability to observe the comparison results ($E$) under two different hypothesis: $H_1$: The cartridge cases are fired by the same firearm versus $H_2$: The cartridge cases are fired by different* firearms

$$LR = \frac{\Pr(E|H_1,I)}{\Pr(E|H_2,I)}$$

*With the same class characteristics

**Within distribution:** Results of comparisons between cartridge cases fired by the same firearms

**Between distribution:** Results of comparisons between cartridge cases fired by different* firearms

Evaluate the results ($E$) of a comparison as a ratio of the likelihoods under both propositions invoking the **within** and the **between** distributions.
Reduction to two dimensions by PCA

within + between using 3 scores

within + between using 3 scores

within + between using 6 scores (3xFPM + 3xBFM)
Bi-dimensional case

Within \( (H_1) \)

Between \( (H_2) \)

\[
LR = \frac{p(PC_1, PC_2 | H_1)}{p(PC_1, PC_2 | H_2)}
\]
## Samples used initially

<table>
<thead>
<tr>
<th>Firearms</th>
<th>Manufacturer</th>
<th>Model</th>
<th>Ammunition Type</th>
<th>Quantity of cartridge cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Within N°1 (firearm W1)</td>
<td>SIG Sauer</td>
<td>P228</td>
<td>Geco Sintro 9 mm Luger</td>
<td>60 from one firearm</td>
</tr>
<tr>
<td>Within N°2 (firearm W2)</td>
<td>SIG Sauer</td>
<td>P226</td>
<td>Geco Sintro 9 mm Luger</td>
<td>60 from one firearm</td>
</tr>
<tr>
<td>Between</td>
<td>SIG Sauer</td>
<td>P226 (42), P228 (14), and Sig Pro (23)</td>
<td>Geco Sintro 9 mm Luger</td>
<td>79 from 79 firearms</td>
</tr>
</tbody>
</table>
Overall performances (P228)

- RMED
  - 4.4%
  - LR Max = 3.92e+019
  - LR Min = 3.5e-009

- RMEP
  - 0%
  - LR Max = 0.224
  - LR Min = 3.3e-020
Overall performances (P226)

- **RMED**: 0.26%
  - LR Max = 2.11e+022
  - LR Min = 0.043

- **RMEP**: 0.09%
  - LR Max = 13.2
  - LR Min = 1.4e-017

Graph shows cumulative probability against Log10(LR) range from -20 to 0.
Methodology for an operational application

**Questioned cartridge case**

**Suspected firearms**

**Within**

**Between**
Towards an operational application

- **Ammunition influence**: Is it possible to make abstraction of the type of ammunition?

- **Faster establishment of the within distribution**: Can we use a limited number of samples to establish the within distribution?

- **Generalization of the between distribution**: Has the between distribution to be re-established for each case?
Additional data to test the different options

• **Within** distribution
  
  • Firearm W1 (SIG Sauer P228)
    - 60 Geco, 60 Geco SX, 60 Winchester, 60 Fiocchi
  
  • Firearm W2 (SIG Sauer P226)
    - 60 Geco, 60 Geco SX, 60 Winchester, 60 Fiocchi

  \[ 8x\text{ Within of 1770 comparisons} \]

• **Between** distribution
  
  • 79 firearms (SIG Sauer P226,P228,Pro)
    - 79 Geco, 79 Geco SX, 79 Winchester, 79 Fiocchi

  \[ 4x\text{ Between of 3081 comparisons} \]
Effect of Ammunition

Examples: Geco vs Geco SX and Winchester vs Geco SX
Generalization of the *between* distribution

- Comparison between the LRs calculated using the *between* distribution established with one ammunition (A) and with four ammunition types (A+B+C+D).

![Graphical representation of LRs comparison](image)
Generalization of the between distribution

High correlation supports the use of a "general between distribution"
Generalization of the between distribution

Low correlation leads to an under- or – overestimation of the LRs
Conclusions

• This system offers an **objective measure of the weight of evidence** (LR). It is characterized by low rates of misleading evidence (RMED and RMEP).

• The LRs that it provides are **very indicative** of the true state.

• From an **operational perspective**:
  • The *within* distribution can be established using a limited number of samples (**7 cases**) without adverse consequences (stable RMEP and RMED).
  • If available, the *between* distribution has to be established using **the same type of ammunition**.