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Applications of 3D measurements in the study of marks on cartridge cases

PhD project

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ESC|école des sciences criminelles

Unil
UNIL | Université de Lausanne

Problematic

- Ballistic Imaging (2008) / NRC Report (February 2009)

- Regarding firearms investigation some highlighted issues are summarized below:

  - The validity of the fundamental assumptions of uniqueness and reproducibility has not yet been fully demonstrated.

  - More researches would be needed to quantitatively characterize the probability of uniqueness.

  - There is a lack of objectivity during the identification process.

- This research tries to address some of these issues.

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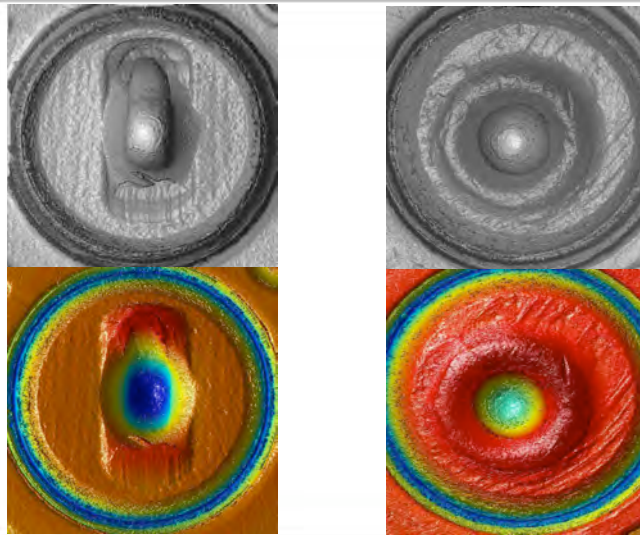

Aim of the PhD research

To quantify and to use the similarity between molded marks to help firearm experts making decisions regarding common origin of questioned cartridges cases.

➤ To do that an automatic comparison system based on 3D technology has been developed.

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Marks to be analyzed

Breech Face Mark

Firing Pin Mark

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3D measurement

Confocal detection profiler

μ surf of Nanofocus®

Resolution: 2 μ m

3D comparison

- Preprocessing of 3D measurement

  - Primer cup segmentation.
  - Firing pin mark and breech face mark separation.
  - Global shape suppression (to cut the biggest frequencies).

- Alignment of marks

  - ICP (Iterative Closes Point) – Firing pin marks.
  - Optimization algorithm – Breech face marks.

- Error metric calculation after alignment

  - Quantify the similarities et/or differences between two marks.
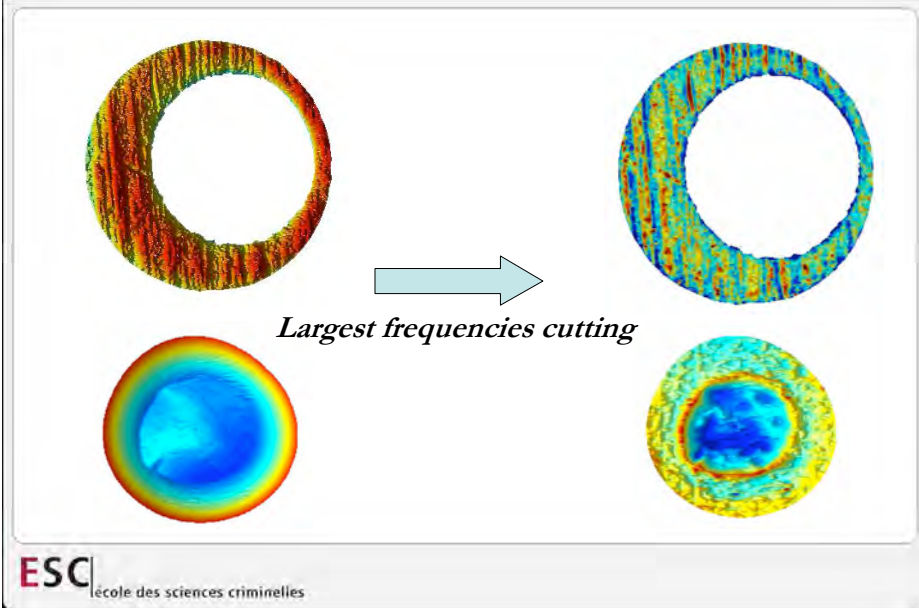
Primer Cup Cutting
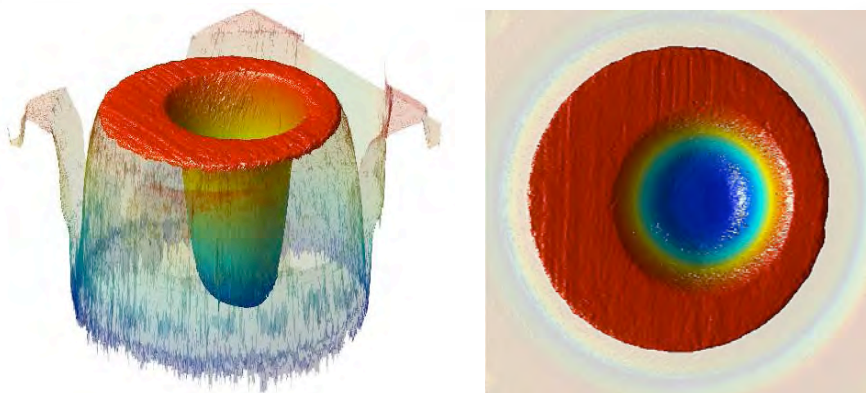
Automatic segmentation of the primer cup taking advantage of normal vectors
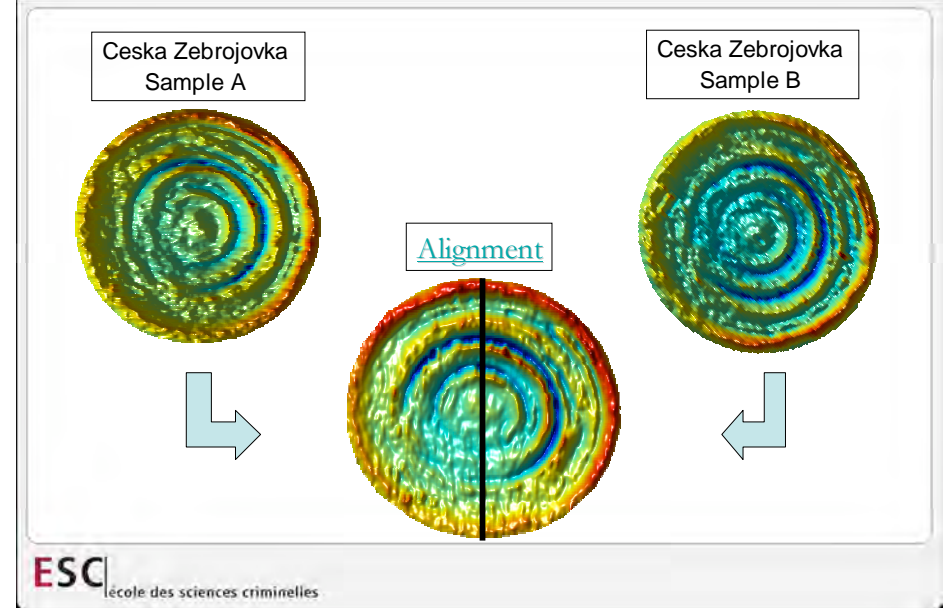
Marks separation
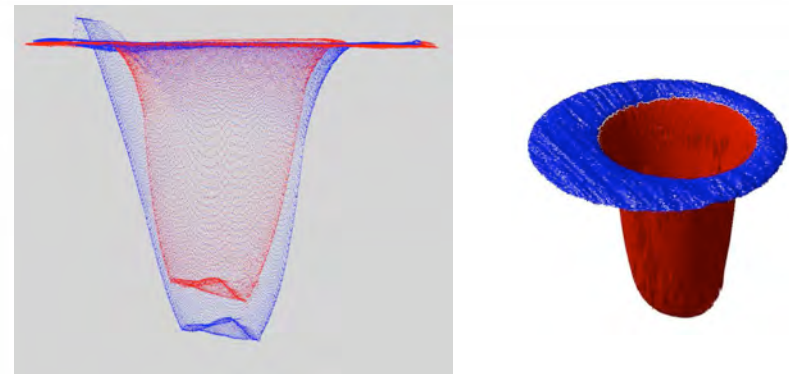
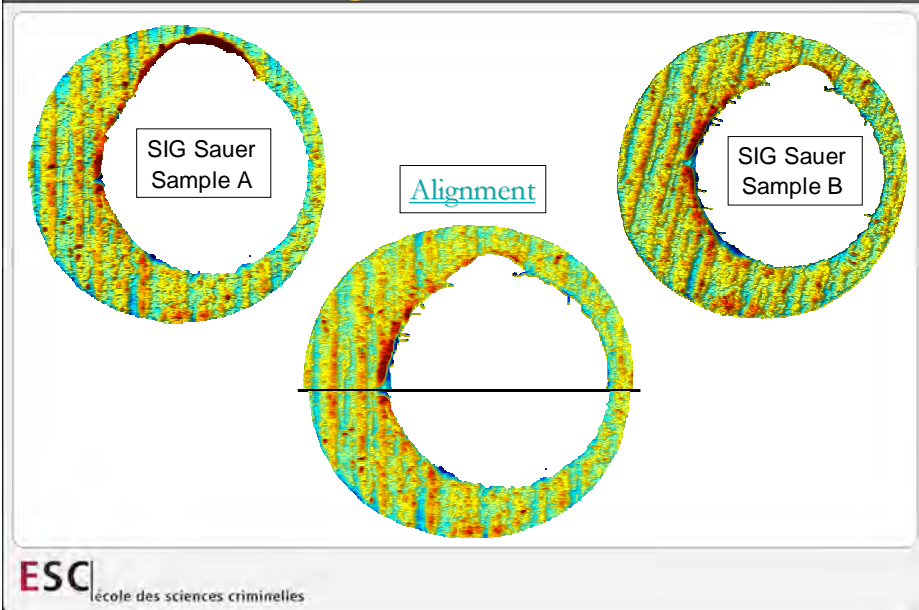Automatic separation of the marks taking advantage of normal vectors
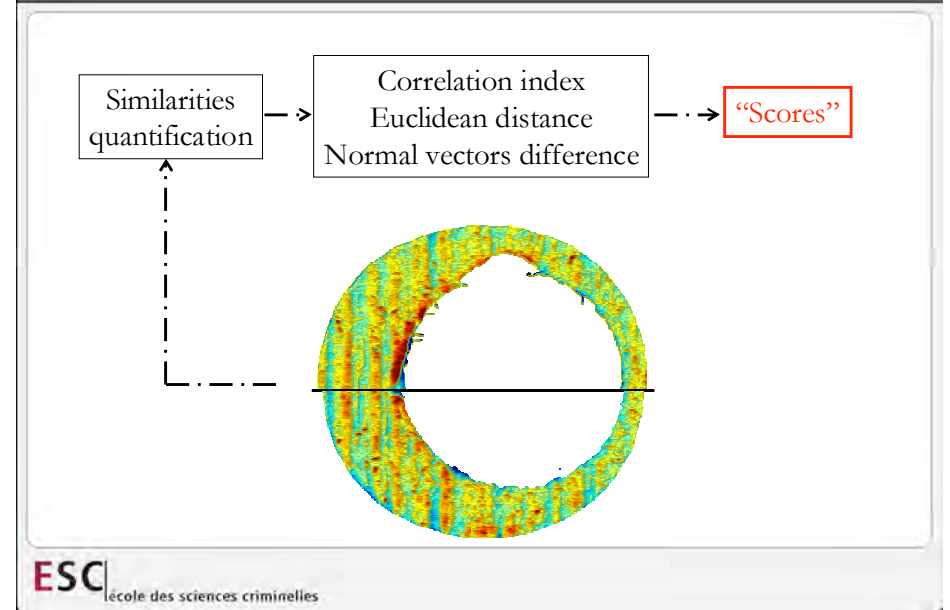
Global shape suppression

Largest frequencies cutting

Firing pin alignment

Ceska Zebrojovka Sample A

Ceska Zebrojovka Sample B

Alignment

Breech face alignment

SIG Sauer Sample A

SIG Sauer Sample B

Alignment

Scores

Similarities quantification → Correlation index, Euclidean distance, Normal vectors difference --> "Scores"

Results Interpretation

Likelihood ratio (LR)

- The LR is a value that represent the ratio between the probability to observe the comparison results under two different hypothesis:

  - H_1 : The cartridge cases are fired by the same firearm
  - H_2 : The cartridge cases are fired by different* firearms

- If LR > 1
  - → The comparison results provide support for H_1 compared to H_2

- If LR is between 0 and 1
  - → The comparison results provide support for H_2 compared to H_1

* With the same class characteristics

Results Interpretation

- To assess a Likelihood Ratio, at first we have to create :

  - **Within distribution**

    - Results of comparisons between cartridge cases fired by the same firearms ➔ Probability to observe a result under H_1.

  - **Between distribution**

    - Results of comparisons between cartridge cases fired by different* firearms ➔ Probability to observe a result under H_2.

  - Evaluate the results of a new comparison (questioned vs. test fires) under the two hypothesis using these two distributions.

Within vs. Between
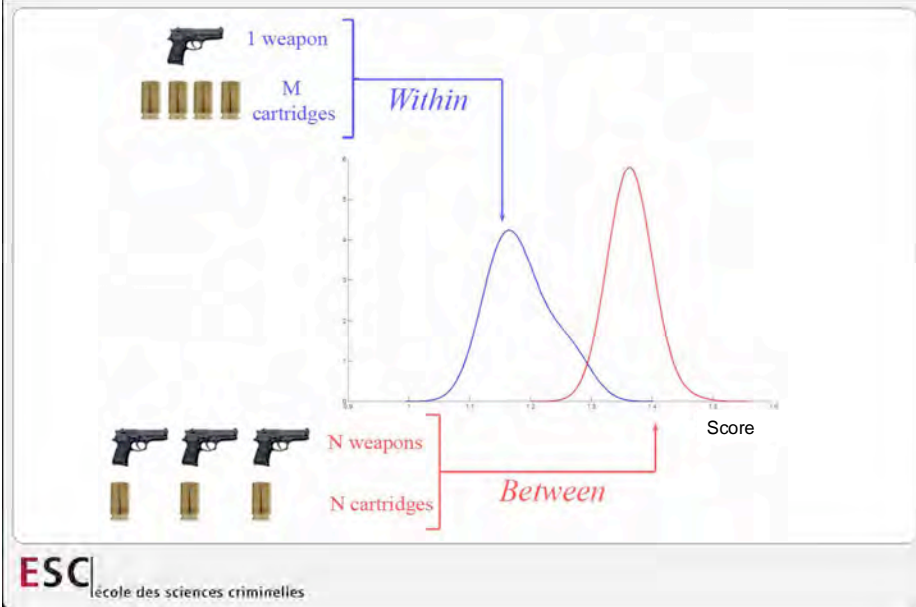
LR extrapolation – One dimension
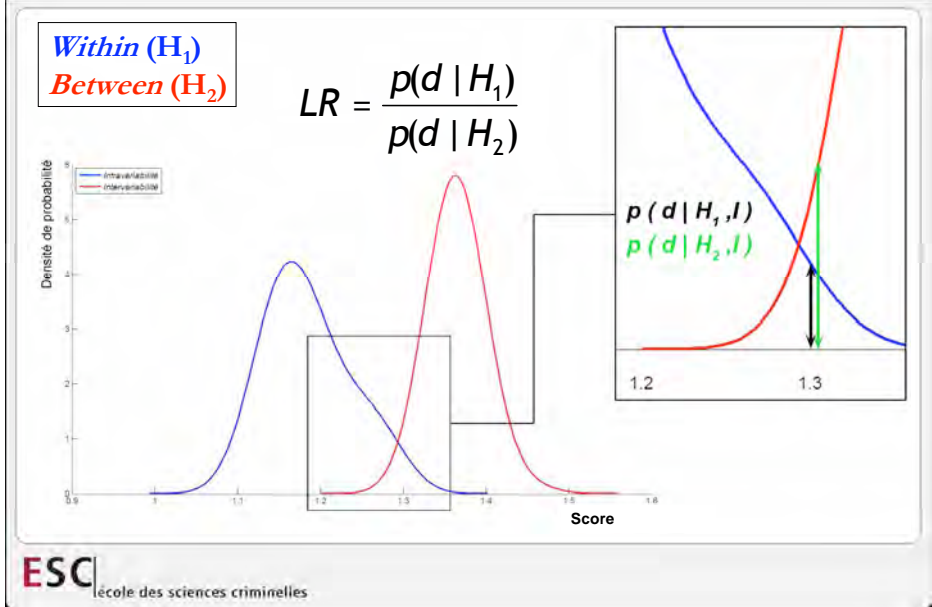
Within (H_1)
Between (H_2)
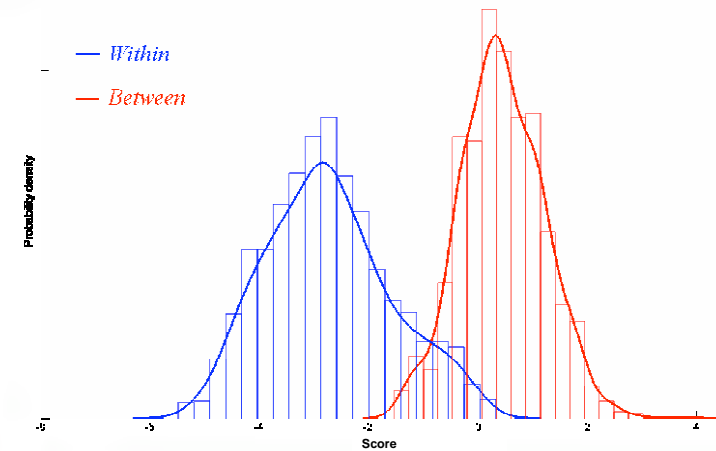
$$LR = \frac{p(d \mid H_1)}{p(d \mid H_2)}$$
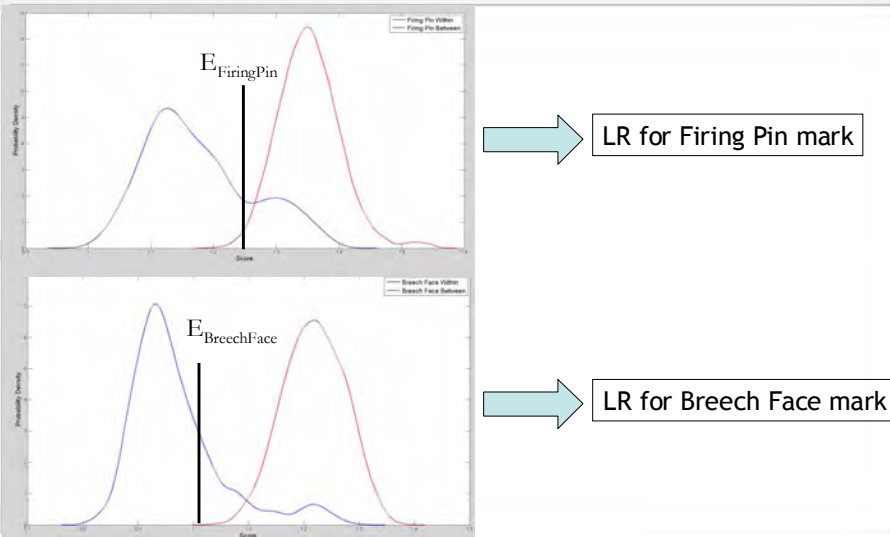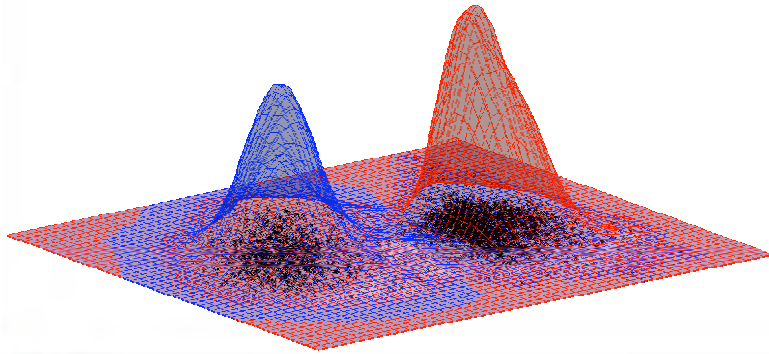
More than one score

- If we have more than one score to describe one comparison? It could be the case when we have scores coming from the firing pin mark and scores from the breech face mark.

Monovariate distribution (KDE)

1D - Probability density function

Monovariate distribution (KDE)

$E_{FiringPin}$ → LR for Firing Pin mark

$E_{BreechFace}$ → LR for Breech Face mark

More than one score

- If we have more than one score to describe one comparison? It could be the case when we have scores coming from the firing pin mark and scores from the breech face mark.

  - PCA (Principal Component Analysis) is performed:

    - Reduce the number of dimensions keeping the more discriminative.
    - Fusion between firing pin scores and breech face scores.
    - Reduction until two dimensions.
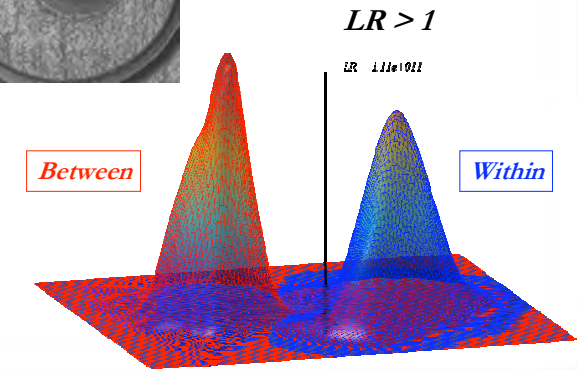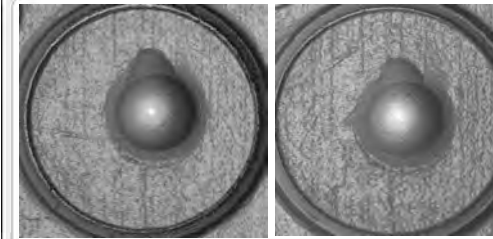   - Bivariate distributions (estimated by kernel density estimations or normal distributions).

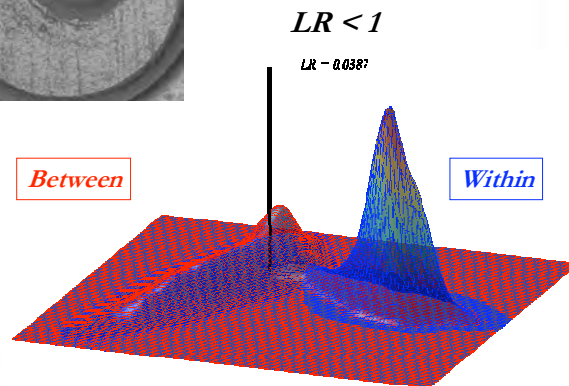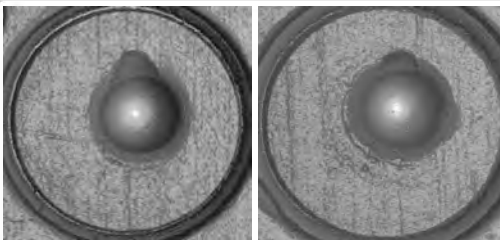## Bivariate distribution (KDE)

2D - Probability density function

■ Within
■ Between
· Data - Within
· Data - Between

LR extrapolation – Two dimensions

LR > 1

LR 1.11e1011

Between   Within

LR extrapolation – Two dimensions

LR < 1

LR = 0.0387
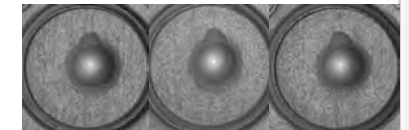
Between   Within

Results on SIG pistols

- Test have been performed with SIG Sauer 9 mm Luger pistols
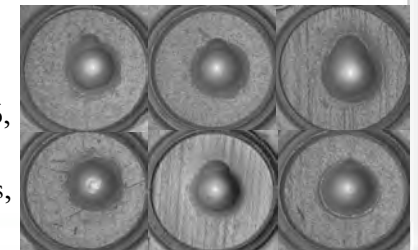
  - Within distribution

    - 2 weapons
    - Just one presented – similar results

  - Between distribution

    - 84 weapons model SIG P226, P228 and SIG Pro.
   - Weapons used by policemen's, during training period.

Tippett Plot

- For each comparison used to build the within (H_1) and between (H_2) distributions one LR is calculated. The result is two sets of LRs.

- These distributions are illustrated using a Tippett plot that shows one minus the cumulative distribution for respectively the LRs computed under H_1 and H_2.

- The Tippet plot allow also to show the rates of misleading evidence.

  - RMED: rate of _LR < 1_ if the cartridge cases are fired by the _same_ weapons.
  - RMEP: rate of _LR > 1_ if the cartridge cases are fired by _two_ weapons.
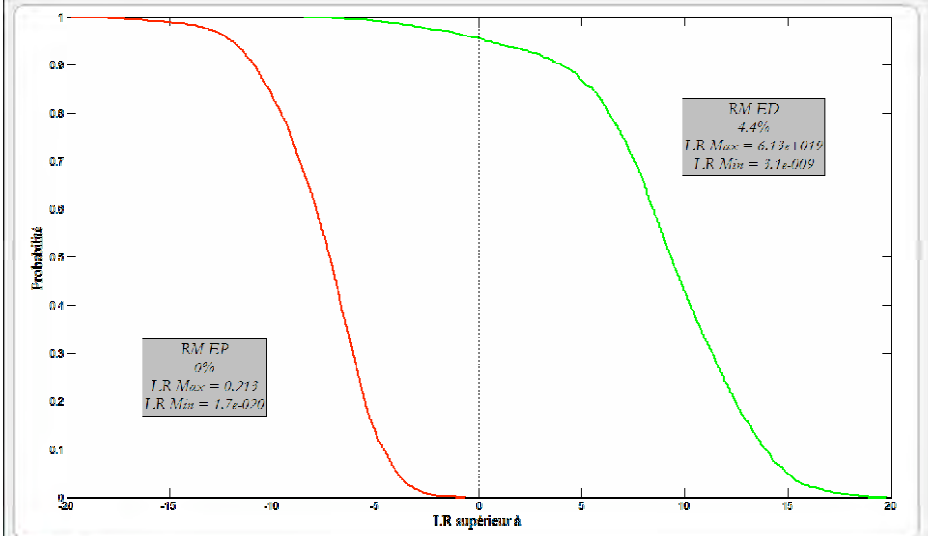
Tippett Plot - Weapon A - Firing pin
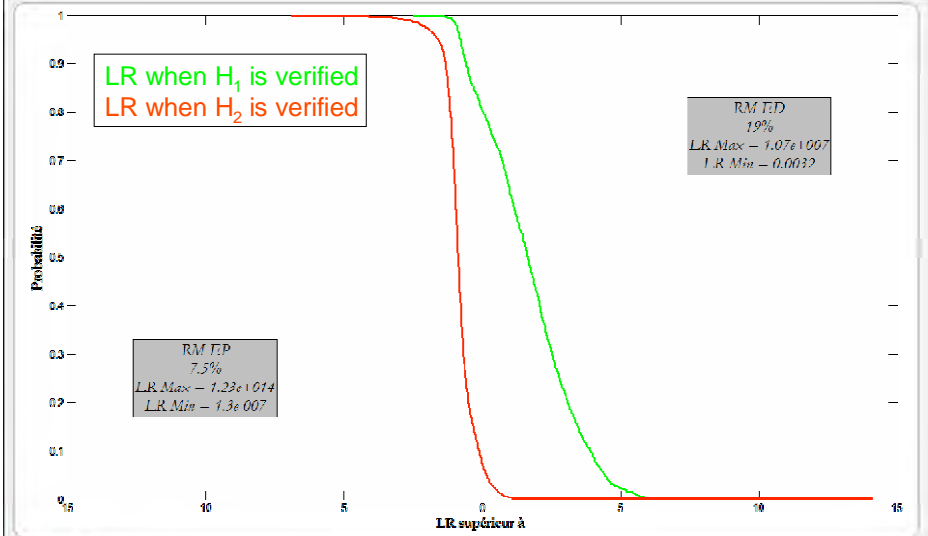
Tippett Plot - Weapon A - Breech Face
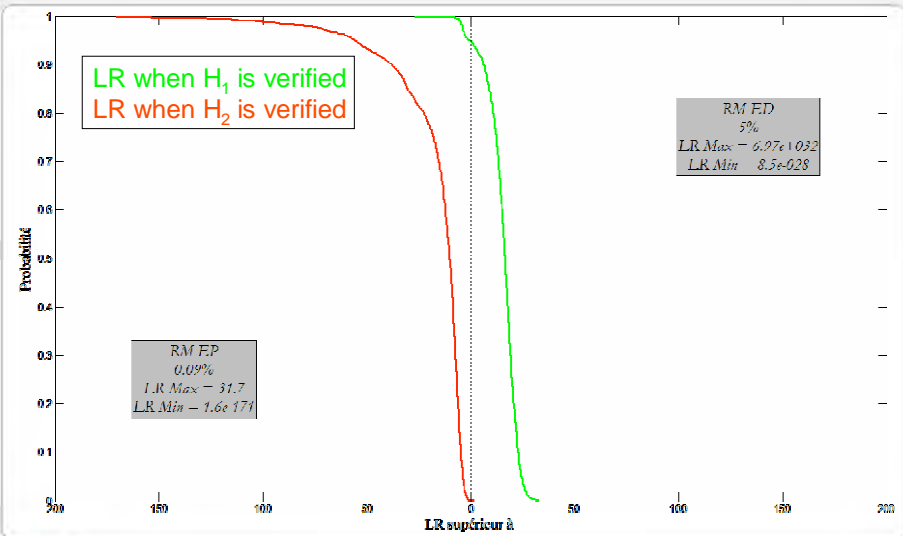
Tippett Plot - Weapon A - Fusion

Conclusions

- An automatic comparator system based on 3D technology has been developed.

  - The promising potential of 3D technology have been demonstrated.
  - These results have been obtained using the same ammunition (Geco SX). Several difficulties were met when different ammunitions are employed (not shown here).

- A bivariate model to calculate Likelihood ratios has been set up

  - Allow to evaluate the amount of similarities (or differences) between two marks.
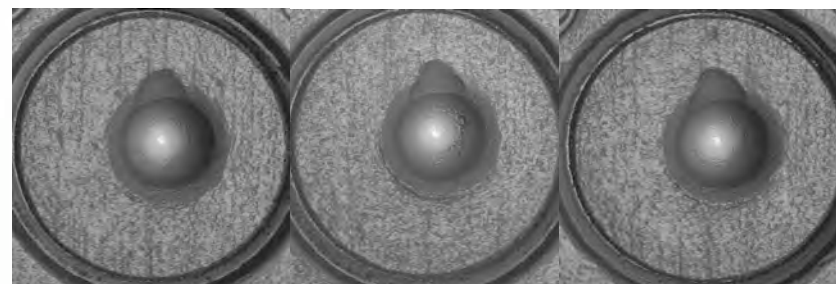 - Allow to take in account the marks separately or together.

Conclusions

- The most important points coming out from this research are the followings :

  - This is an objective and repeatable procedure to evaluate similarities between moulded marks.

  - It allows the quantification of relevant error rates (RMED, RMEP) and a quantification of "inconclusive" cases (low LRs).

  - Regarding the criticism raised by the NRC report on strengthening forensic science in the United States (2009). This research represents a move towards transparency and objectivity.

- The operational constraints of this approach will be explored in collaboration with the Netherlands Forensic Institute (2010-2011).

THANK YOU
for your patience

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for your patience

Within – Same weapon

Between – Different weapons