NIST
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Half-year Report for NIST 2012 FMC Project
(From May to November, 2012)

Establish the "National Ballistics Evidence Search Engine (NBESE)" Based on 3D Topography Measurements on Correlation Cells

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1. Problems for Current Ballistics Identifications and the NIST Proposed Solution

2. Half-year Accomplishments (from May to November, 2012)

3. Future Work

1. Problems in ballistics identifications:

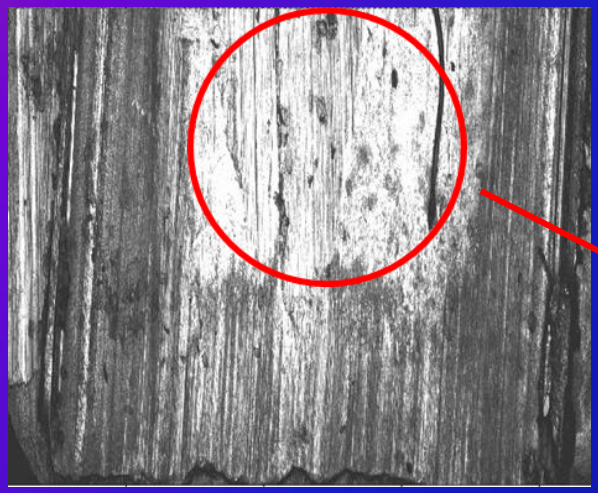
- Low correlation accuracy:
  - Use image comparisons, not topography measurements;
  - Use global area correlations including large “Invalid Correlation Areas”.
  - Poor traceability and lack of science-based error rate reports.
- Low correlation speed & poor system automation.
- Low interoperability: Use company-specific proprietary parameters and algorithms.

NIST-proposed solution: 3D topography measurements on correlation cells

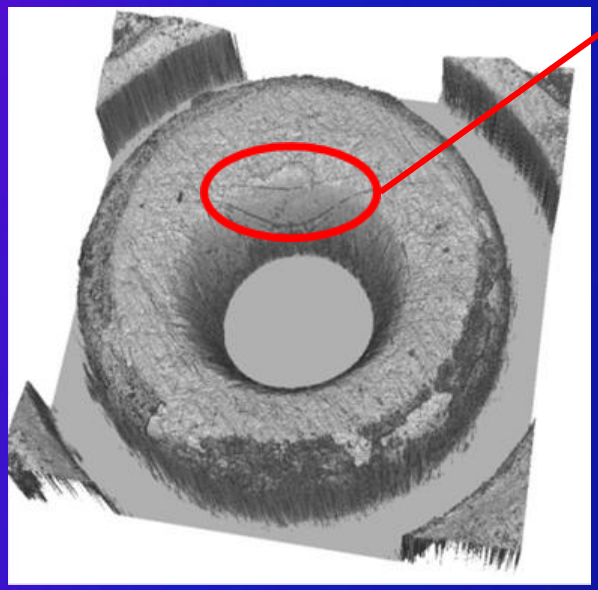
2. *Half-year Accomplishments*
(From May to November 2012)

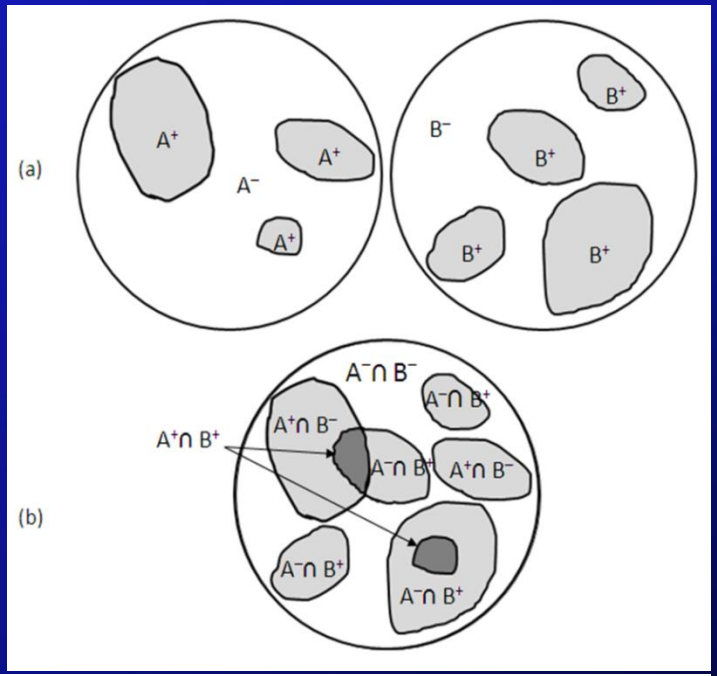
- Proposed “Correlation Cells” and “Congruent Matching Cells (CMC)” method for ballistics identifications;
- Completed the design for the proposed NBESE;
- Completed prototype programs for NBESE;
- Completed initial tests with excellent results;
- Designed an error rate report procedure;
- Investigating topography measurement instruments to be used for the NBESE.
- Publications and talks

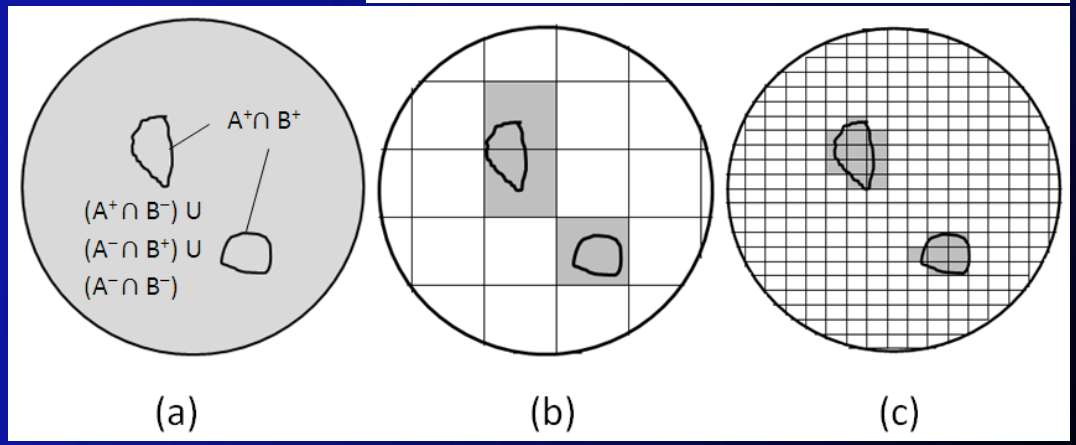
We proposed a new concept - "correlation cells" to identify "valid" and "invalid" correlation areas



Invalid correlation area

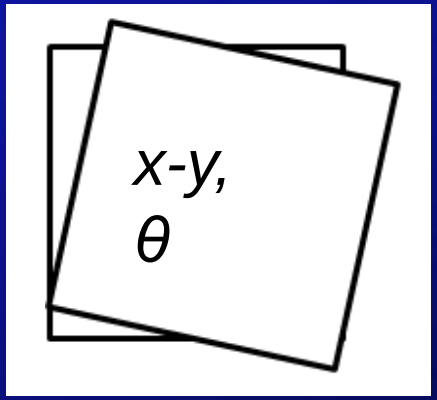


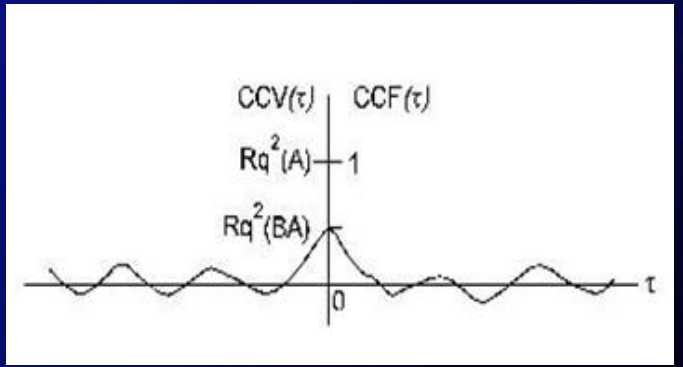




We proposed three identification parameters (with thresholds) for the correlated cell pairs:

- Registration position in *x-y*, (with a threshold, T_x, T_y)
- Registration angle θ, (with a threshold T_θ), and
- Correlation value CCF_{max} (with a threshold CCF_{low}).

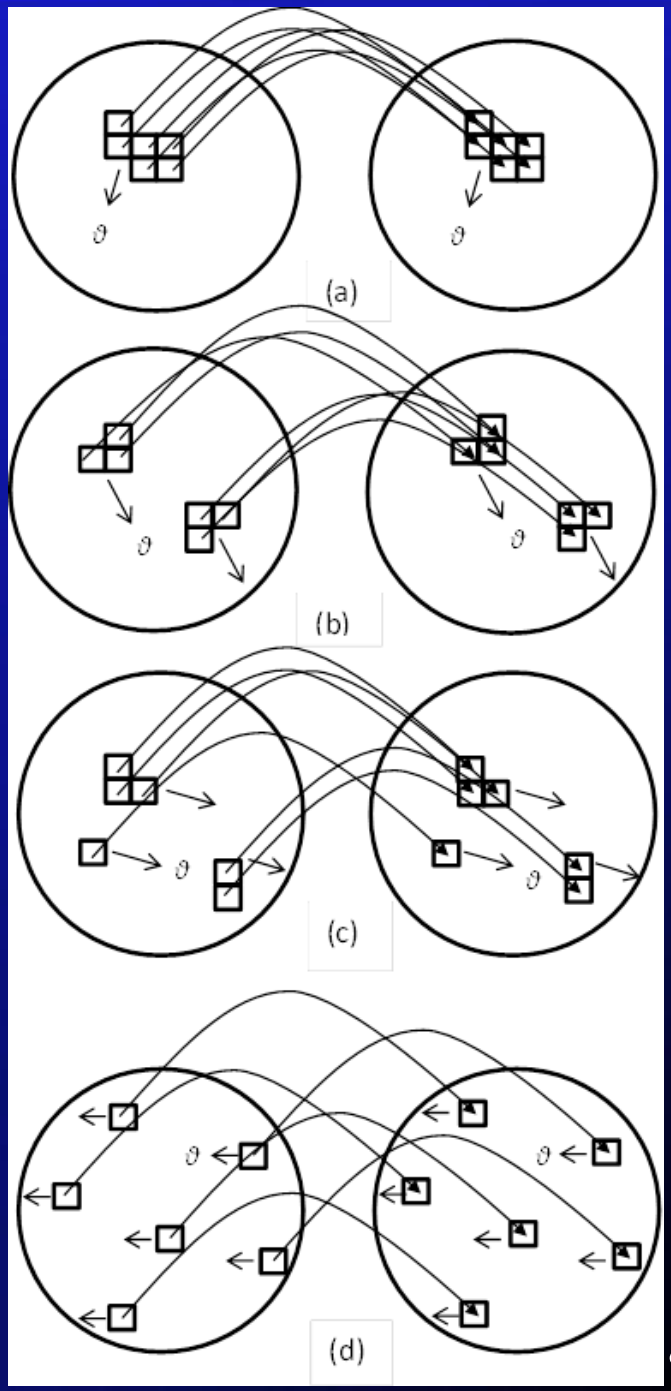




Proposed a new method - "Congruent Matching Cells" (CMC) for ballistics identifications

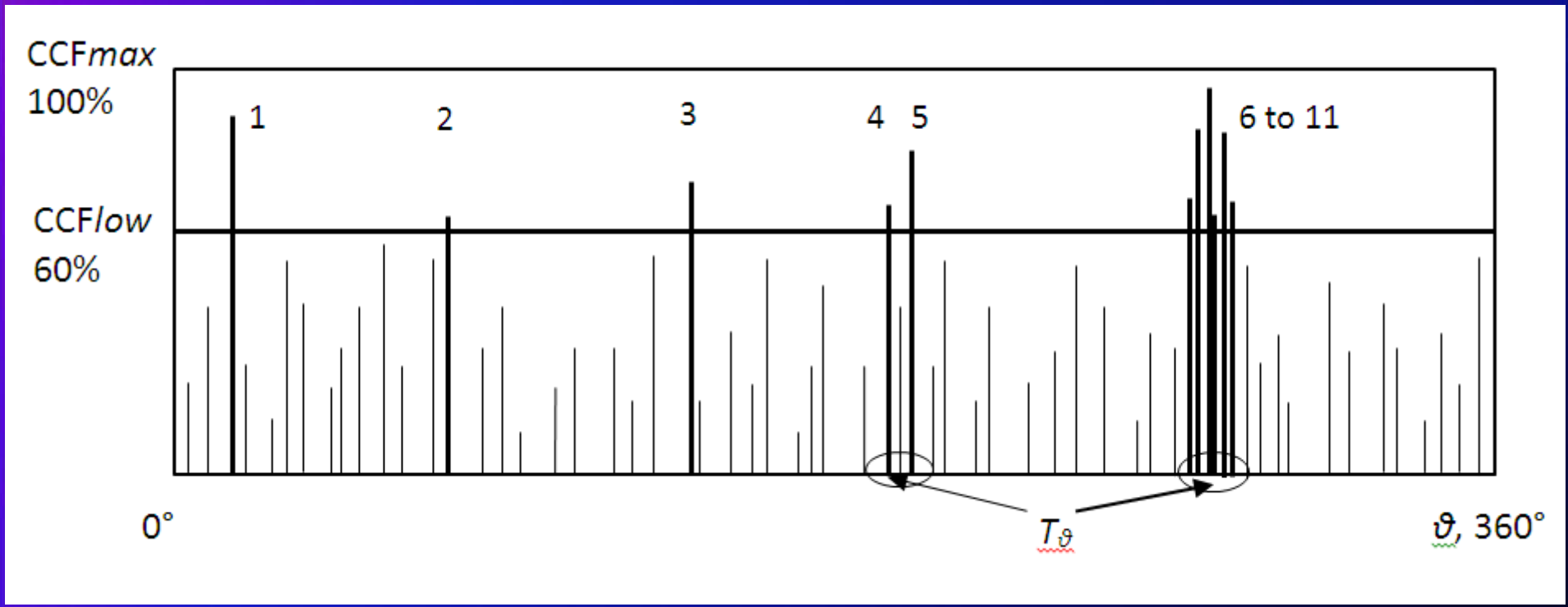
- Three identification parameters to identify CMC

- A Numerical Identification Criterion *"C"*
(Assume $C \geq 6$ → Match, to be tested)



Drafted a design with three steps for the proposed NBESE :

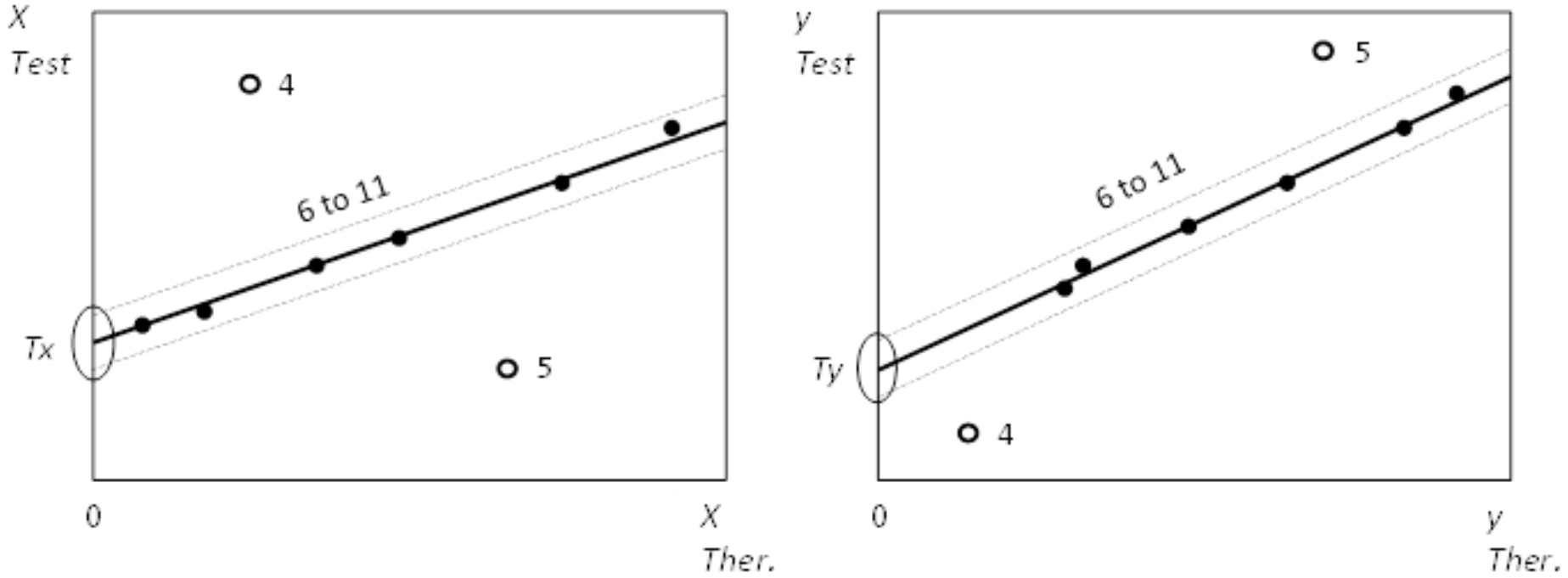
The first and second step: CCF_{max} and θ searches



CCF_{low} is the threshold for CCF_{max}; T_θ is the threshold for registration angle θ.

Drafted a design with three steps for the proposed NBESE :

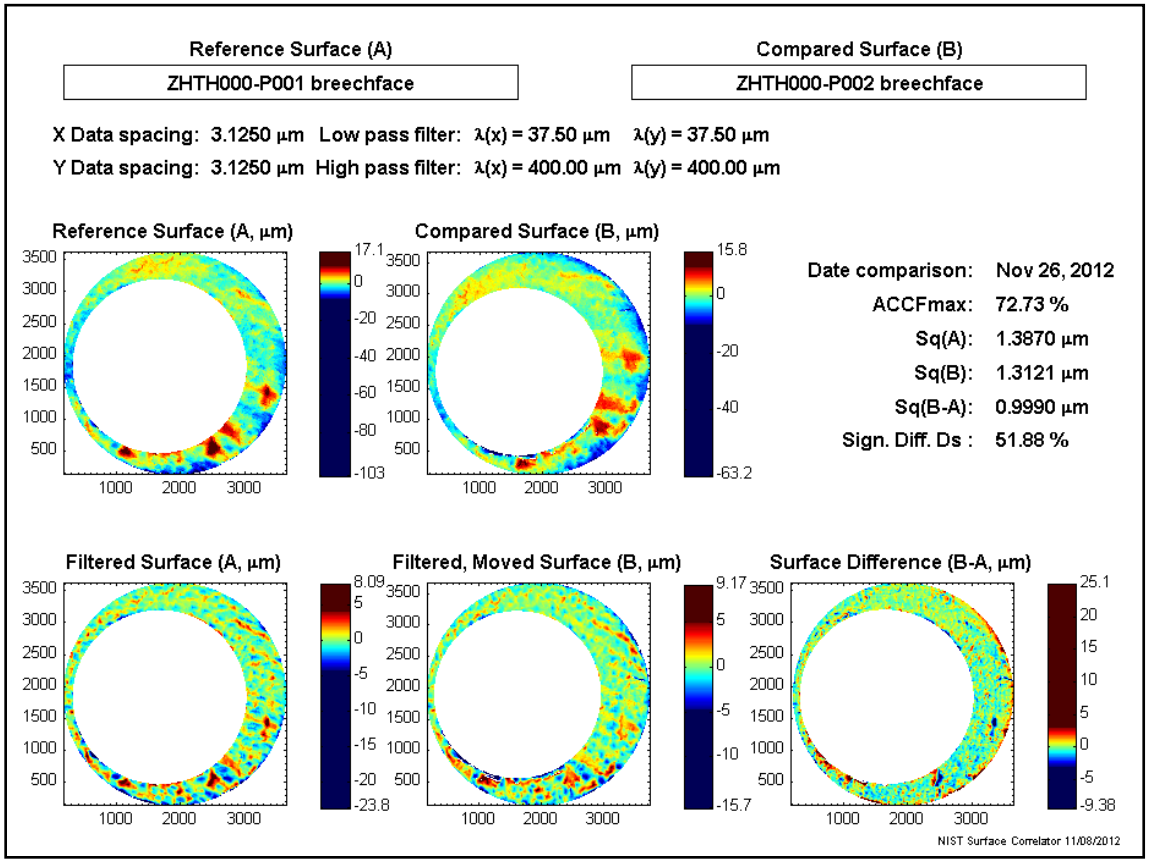
The third step: x-y searches

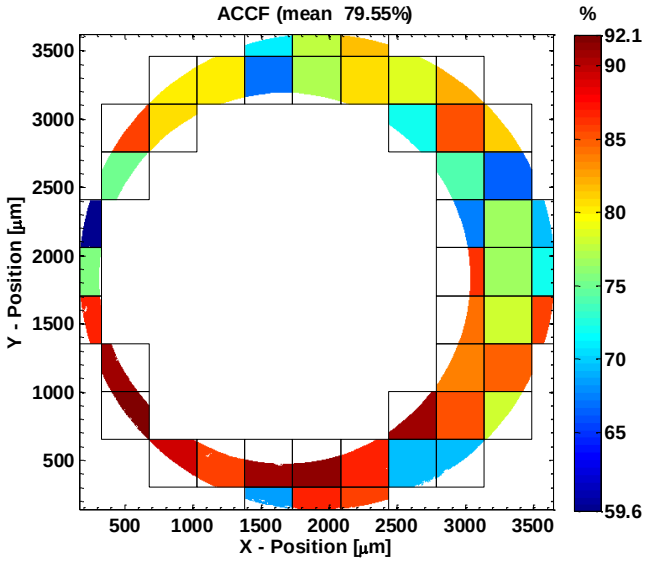


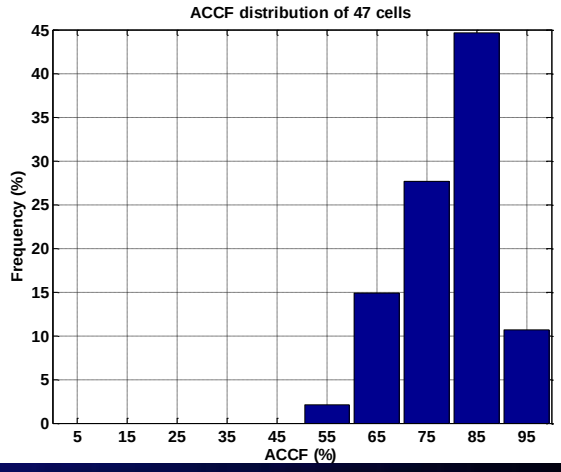
T_x and T_y are thresholds or searching windows for *x-y* searches.

Conclusion: CMC = 6 → Match.

Completed three prototype programs using "Correlation Cells" and "CMC" method

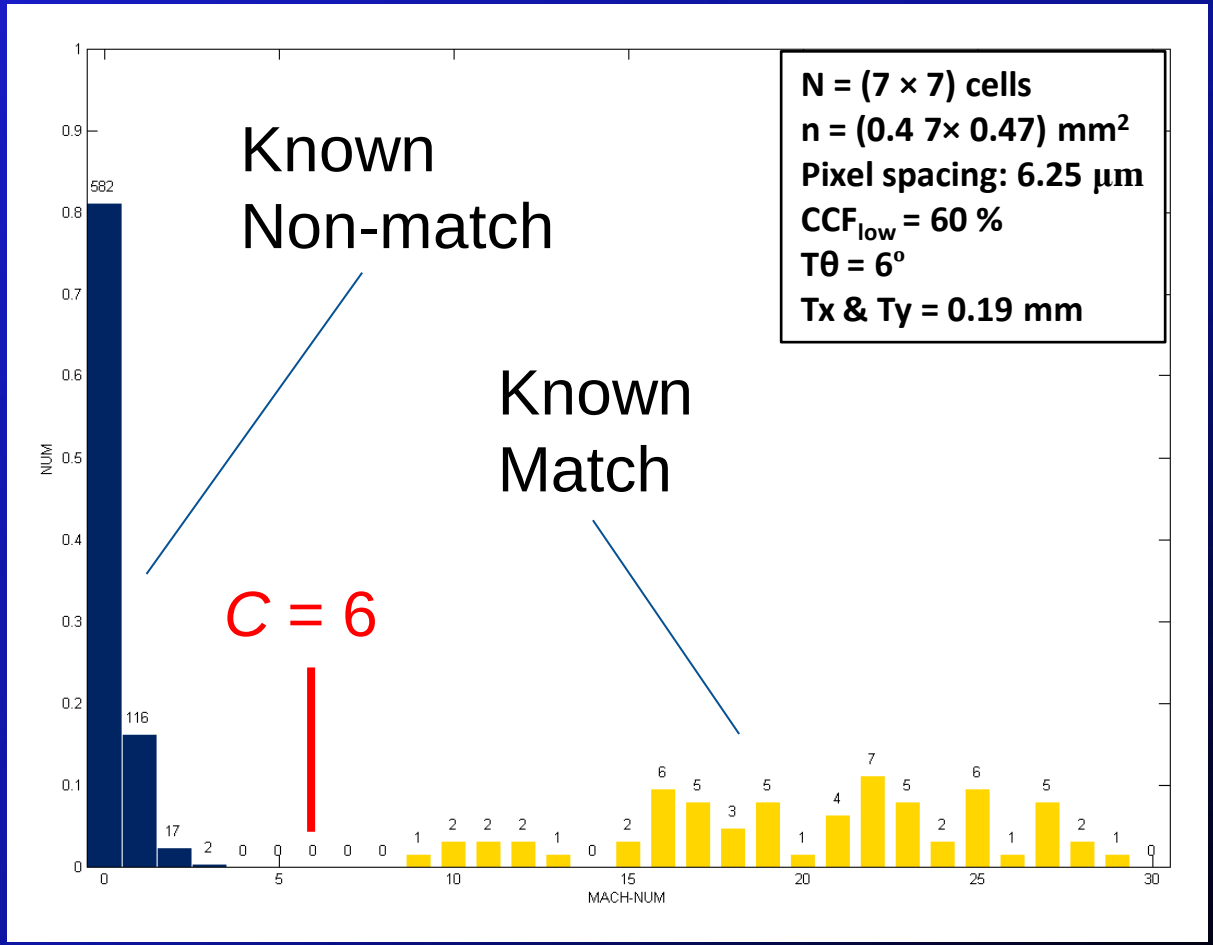






Completed initial tests using the CMC method with excellent correlation results

- 40 cartridge cases fired from guns with 10 consecutively manufactured pistol slides.
- A total of 780 correlations with 63 KM and 717 KNM correlations.
- No false pos. & neg. identifications, with $C = 6$ looks OK.
- To be improved.



Designed an error rate report procedure

Both the false positive and false negative error E_1 and E_2 are determined by the cell number *N*, the numerical identification criterion *C* (assuming *C* = 6), and the combined false identification probability P_1 and P_2. For example:

False positive error rate E_1 can be calculated:

- $$E_1 = \sum_{g=C}^{g=N} E_{1(g)} = E_{1(g=C)} + E_{1(g=C+1)} + \cdots + E_{1(g=N)}$$

$$= 1 - (E_{1(g=0)} + E_{1(g=1)} + \cdots + E_{1(g=C-1)}).$$

$$E_{1(g)} = C_N^g \cdot (P_1)^g \cdot (1 - P_1)^{N-g}.$$

Investigating topography measurement instruments to be used for the NBESE

- Developed Technical Specifications:
  - About (10 × 10 × 1) mm^3 *x-y-z* range with 1 µm horizontal and 0.01 µm vertical resolution.
  - High speed, ability to measure steep slopes to about 45°.
  - Lateral and vertical resolution optimized for accuracy and discrimination capability vs. speed vs. expense.
- Investigating optical microscopy methods, including confocal, coherent scanning interferometry, and focus variation.
- Assembled a set of samples for testing profile accuracy, steep slope capability, resolution, and discrimination capability between matching and nonmatching pairs of surfaces.

Publications and talks

- A NIST Provisional Patent was filed on Match 13, 2012;
- Submitted two journal papers, passed NIST review for publication;
- Four invited talks and presentations at U.S. and international conferences.

3. Future work

- Develop and verify the numerical identification criterion *C* for proposed Congruent Matching Cells (CMC) method.
- Optimize correlation parameters including cell size *n*, cell number *N*, and the thresholds CCF_{low}, T_θ, T_x, T_y.
- Automate the correlation system using "synchronous processing" for correlation cells.
- Conduct verification tests using image signatures.
- Hardware development for the proposed NBESE.
- Use the developed NBESE for national ballistics database searches.

Technical superiority of the NIST-invented NBIS and NBESE to current commercial systems

Comparisons in	Commercial Systems	NIST-Invented NBIS and NBESE
Fundamental principle	Based on image comparison	Based on 3D-topo. measurements
Scientific support	Without error rate report	With error rate report
Identification criterion	Use proprietary correlation scores	Use NIST invented CMC method
Correlation accuracy	Low accuracy correlate whole area	High accuracy use correlation cells
Correlation speed	Low speed correlate whole area	High speed synchronous process
System automation	Need manual trimming	Objective and fully automated system
Interoperability between systems	Use proprietary algorithms & parameters	Use CMC method with interoperability

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Questions?

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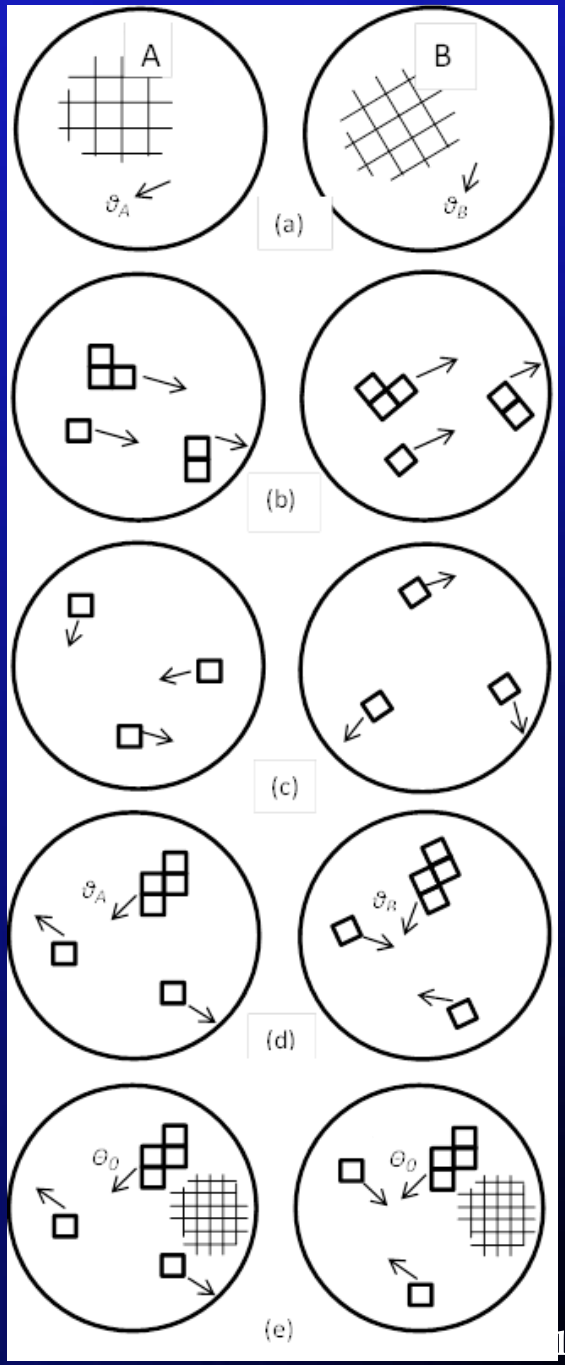
What is New -

Prototype "NIST Ballistics Identification System (NBIS)"

a) Divide A and B for cell correlation;
b) CMC ≥ 6, Matching;
c) CMC ≤ 0, 1, Non-matching;
d) CMC = 2 to 5, No-conclusion;
e) Align A and B; divide to small cells for accurate correlations.

This project was funded by OLES of NIST in 2012, and is currently in development.

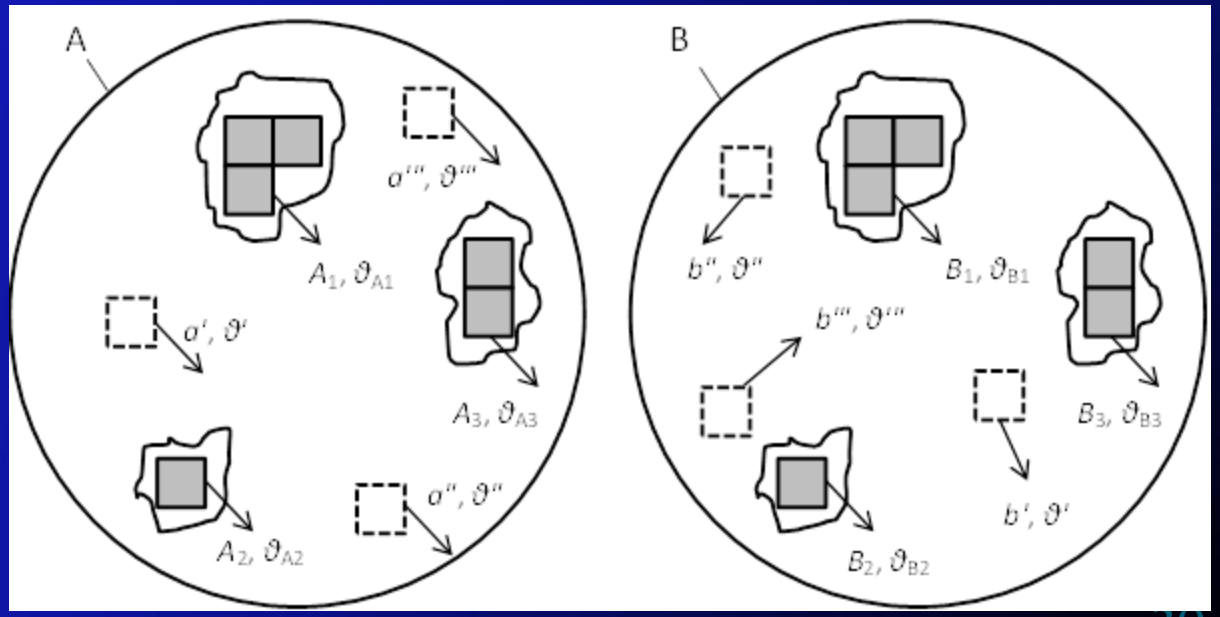


The "Congruent Matching Cells (CMC)"

The Congruent Matching Cells (CMC) are defined by

1) $A_1A_2A_3\ldots \cong B_1B_2B_3\ldots$ congruent *x-y* positions;
2) $\vartheta_1 = \vartheta_2 = \vartheta_3 \ldots$ same registration angle;
3) $CCF_{max} \geq CCF_{low}$, high correlation value.

(CCF_{low} is the low control limit to be determined.)



Why topography, not imaging?

Ballistics signatures are
2D Profiles,

$Z = F(x)$ or

3D Topographies

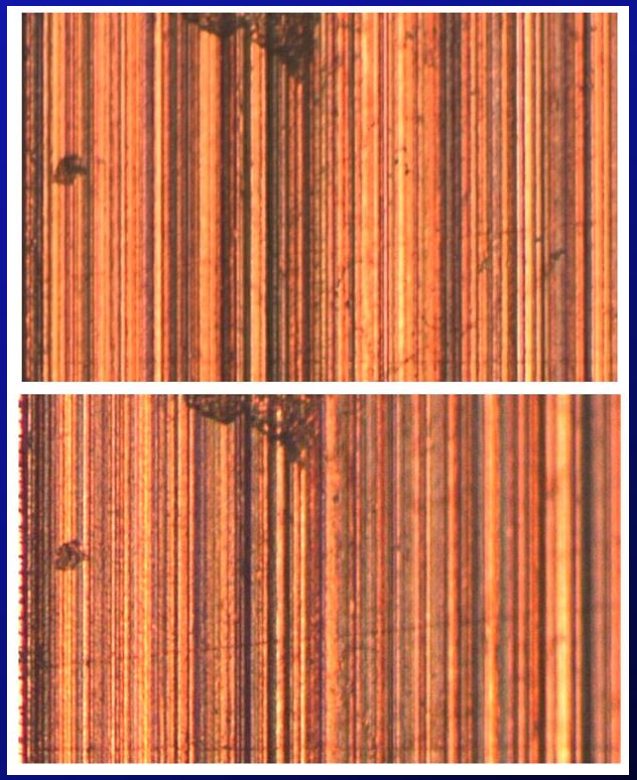
$Z = F(x, y)$

Optical image

- lighting conditions,
- surface properties…

$I = \Phi(x, y) \neq Z = F(x, y)$

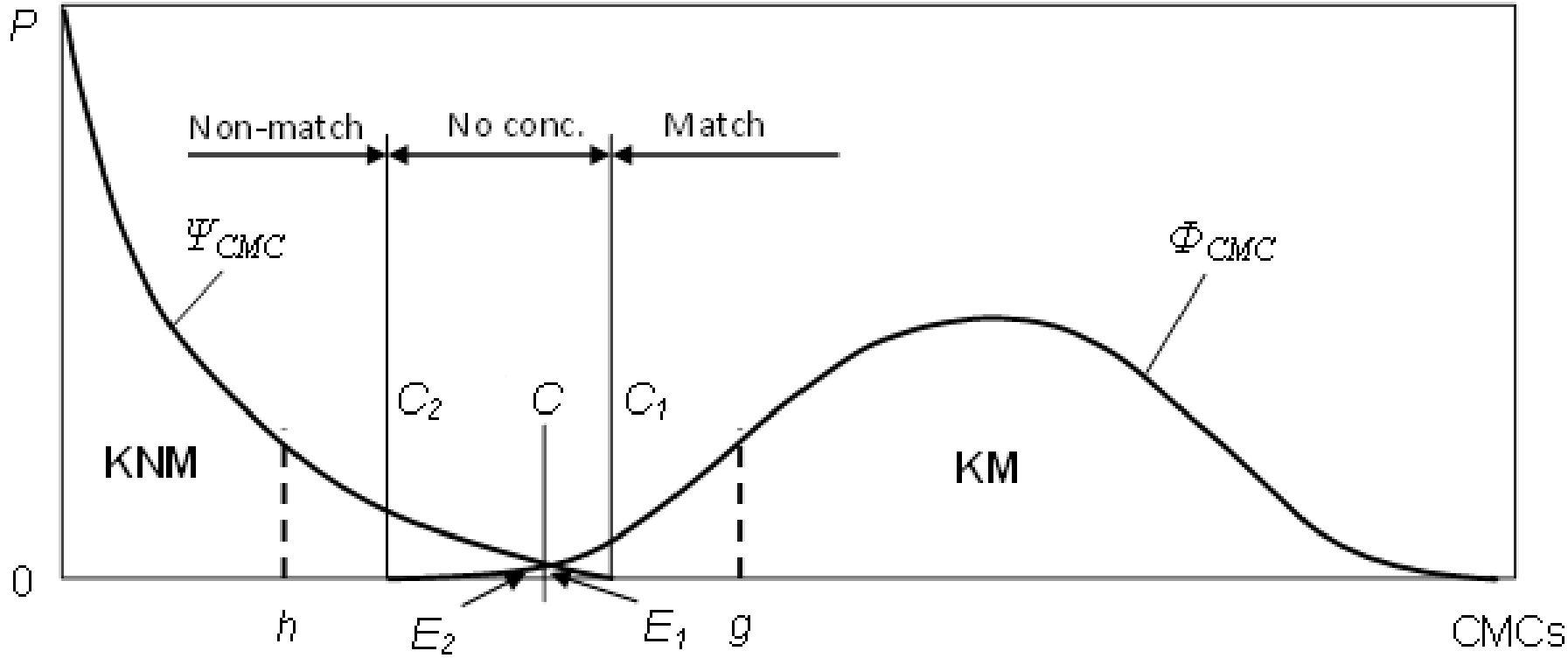
"Match" or "Non-Match"?



(*By T.B. Renegar of NIST*)

Optical image ≠ Ballistics signature

How to determine numerical criterion “C”



Assumed CMC distribution for paired KM and KNM topographies. The CMC distribution for KNM topographies Ψ_{CMC} may be close to a logarithmic distribution.