



*Initial Tests and Analysis of the NIST
Proposed Congruent Matching Cells
(CMC) Method using Fired Cartridge
Cases from Consecutively Manufactured
Pistol Slides*

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Disclaimer

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Motivation

Test the Congruent Matching Cells (CMC) method proposed by NIST for the FMC2012 project entitled “Establish the National Ballistics Evidence Search Engine (NBESE) Based on 3D Topography Measurements on Correlation Cells.”

Material

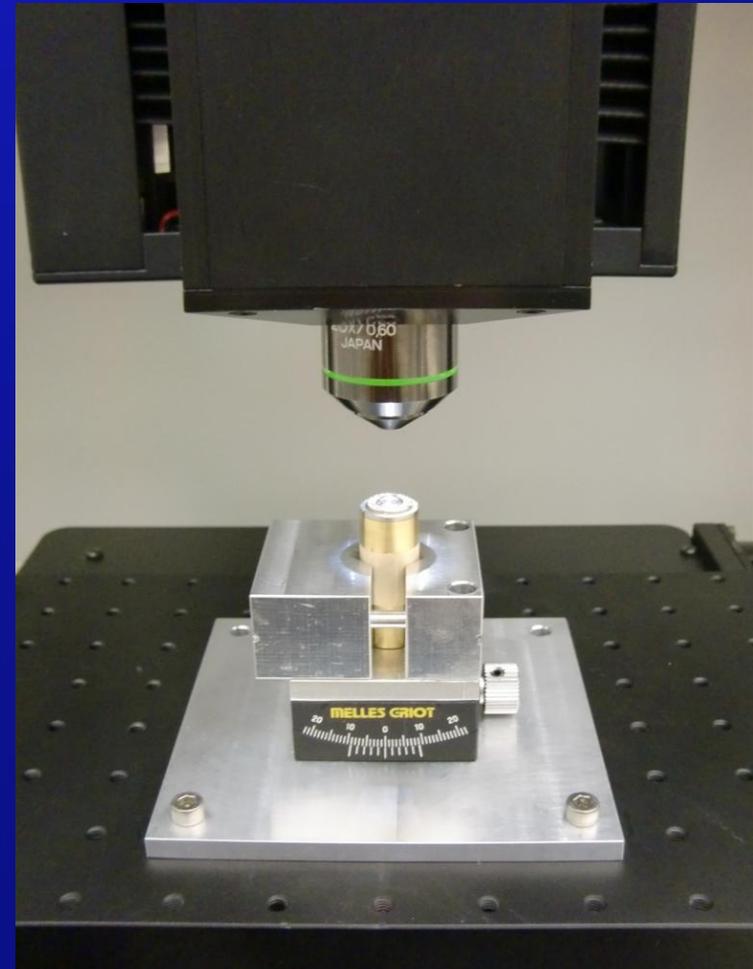
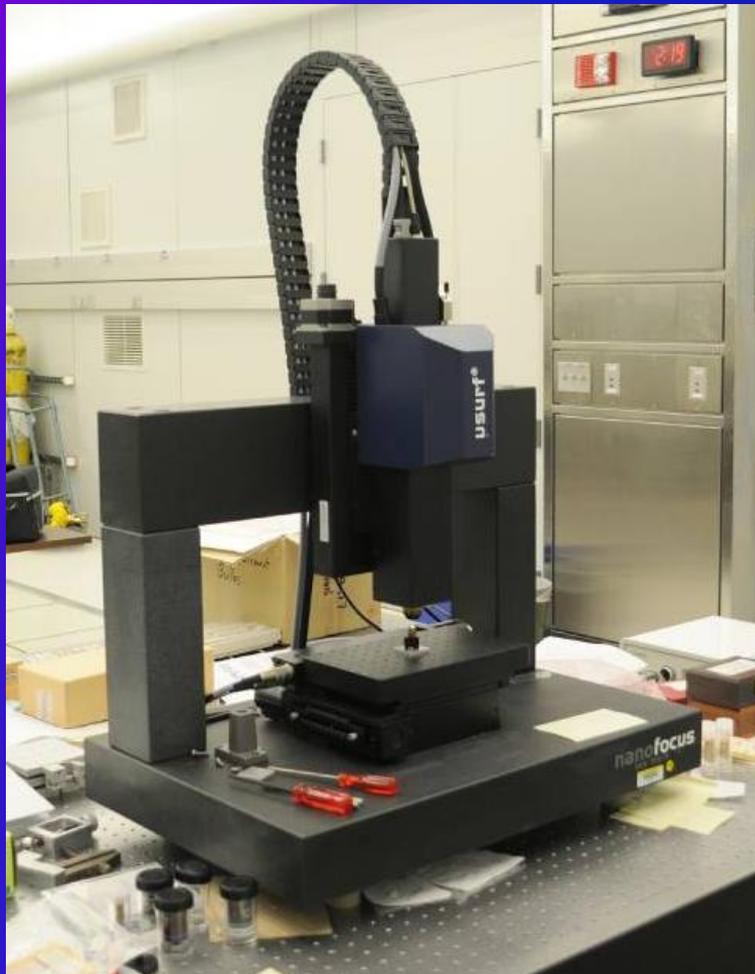
Thomas Fadul from the Miami Dade Crime Laboratory initiated a consecutively manufactured slide study.

40 cartridge cases fired from guns with 10 consecutively manufactured pistol slides are correlated:

- 20 known cartridge cases were fired from the 10 slides (2 per slide).
- 15 unknown casings and 5 more persistence casings

Instrument

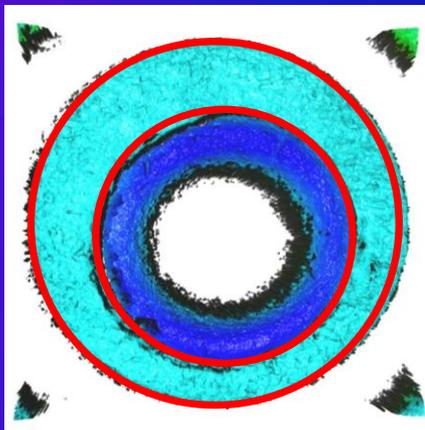
Nipkow Disk Confocal Microscope



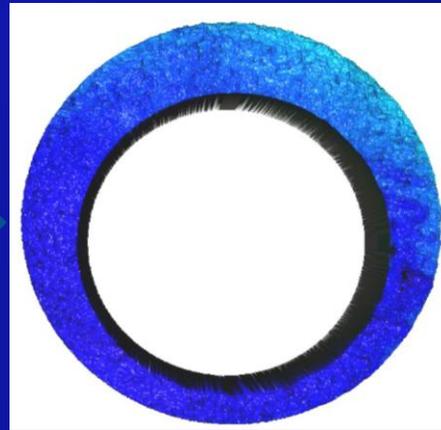
Data collection and preprocessing

Parameters for data collection:

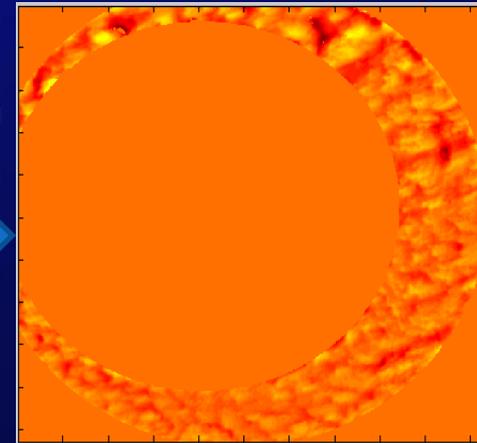
- Z direction step size: $0.2 \mu\text{m}$
- Lateral Resolution: $3.125 \mu\text{m}$
- Measured Dimension: $4.8 \text{ mm} \times 4.8 \text{ mm}$



Trim



Gaussian filter



Previous test and results using CCF method

Approach: Cross Correlation Function CCF

Index	Filename	Casing ID	Known	Unknown	Persistence
1	ZHTH-P01	Known Slide 1 A	2	24	
2	ZHTH-P02	Known Slide 1 B	1	24	
3	ZHTH-P03	Known Slide 2 A	4	23,29	
4	ZHTH-P04	Known Slide 2 B	3	23,29	
5	ZHTH-P05	Known Slide 3 A	6	21,35	40
6	ZHTH-P06	Known Slide 3 B	5	21,35	40
7	ZHTH-P07	Known Slide 4 A	8	22	
8	ZHTH-P08	Known Slide 4 B	7	22	
9	ZHTH-P09	Known Slide 5 A	10	25	37
10	ZHTH-P10	Known Slide 5 B	9	25	37
11	ZHTH-P11	Known Slide 6 A	12	26	38
12	ZHTH-P12	Known Slide 6 B	11	26	38
13	ZHTH-P13	Known Slide 7 A	14	34	39
14	ZHTH-P14	Known Slide 7 B	13	34	39
15	ZHTH-P15	Known Slide 8 A	16	30,31,33	
16	ZHTH-P16	Known Slide 8 B	15	30,31,33	
17	ZHTH-P17	Known Slide 9 A	18	27	
18	ZHTH-P18	Known Slide 9 B	17	27	
19	ZHTH-P19	Known Slide 10 A	20	28	36
20	ZHTH-P20	Known Slide 10 B	19	28	36
21	ZHTH-P21	UnKnown Casing A		5,6,35,40	Slide 3
22	ZHTH-P22	UnKnown Casing B		7,8	Slide 4
23	ZHTH-P23	UnKnown Casing C		3,4,29	Slide 2
24	ZHTH-P24	UnKnown Casing F		1,2	Slide 1
25	ZHTH-P25	UnKnown Casing H		9,10,37	Slide 5
26	ZHTH-P26	UnKnown Casing I		11,12,38,	Slide 6
27	ZHTH-P27	UnKnown Casing K		17,18	Slide 9
28	ZHTH-P28	UnKnown Casing L		19,20,36	Slide 10
29	ZHTH-P29	UnKnown Casing M		3,4,23	Slide 2
30	ZHTH-P30	UnKnown Casing P		15,16,31,33	Slide 8
31	ZHTH-P31	UnKnown Casing Q		15,16,30,33	Slide 8
32	ZHTH-P32	UnKnown Casing R		13,14,34,39	Slide 7?
33	ZHTH-P33	UnKnown Casing X		15,16,30,31	Slide 8
34	ZHTH-P34	UnKnown Casing Y		13,14,32,39	Slide 7
35	ZHTH-P35	UnKnown Casing Z		5,6,21,40	Slide 3
36	ZHTH-P36	UnKnown Persistence Casing E		19,20,28	Slide 10
37	ZHTH-P37	UnKnown Persistence Casing N		9,10,25	Slide 5
38	ZHTH-P38	UnKnown Persistence Casing O		11,12,26	Slide 6
39	ZHTH-P39	UnKnown Persistence Casing S		13,14,32,34	Slide 7
40	ZHTH-P40	UnKnown Persistence Casing T		5,6,21,35	Slide 3

Previous test results

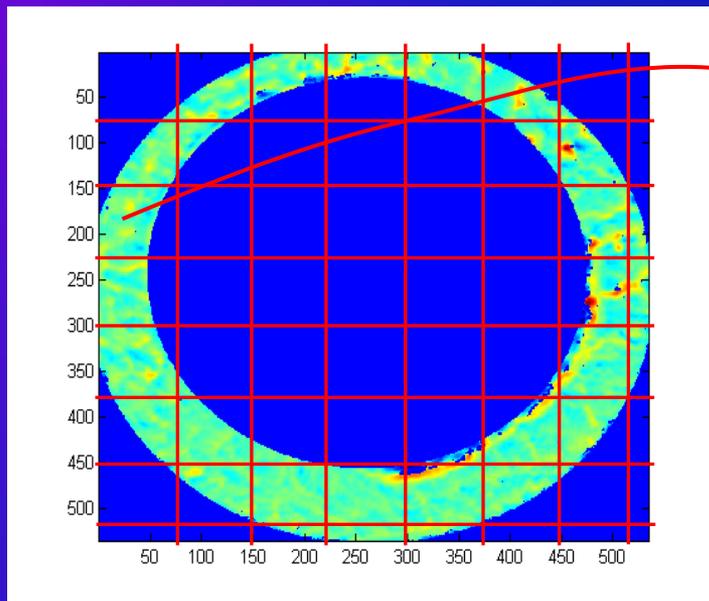
All ten pairs of KM cases are correctly identified each other. 19 out of the 20 unknown casings were correctly identified back to the slide they came from.

Unknown Casing R was deemed non-matching.

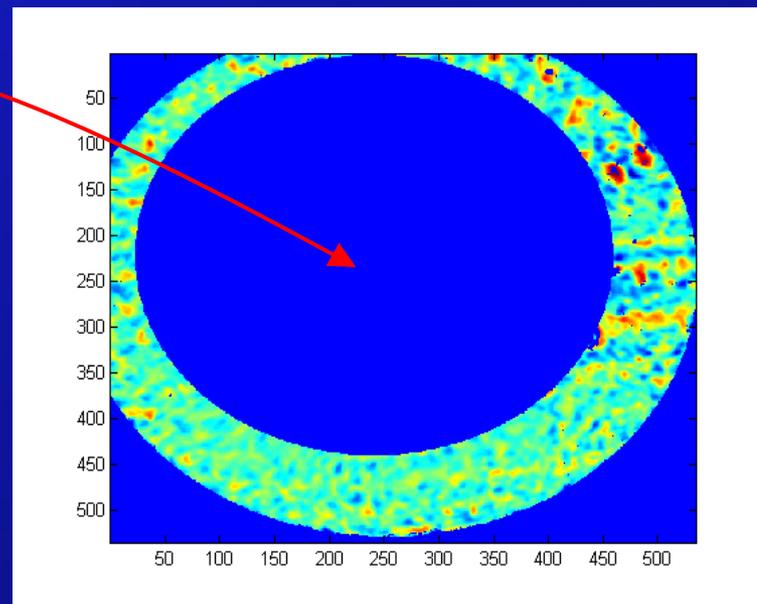
<u>Correlation</u>	<u>CCF%</u>
Unknown Casing R \leftrightarrow Known Casing 7A	0.5389 (Missed)
Unknown Casing R \leftrightarrow Known Casing 7B	0.5448 (Missed)
Unknown Casing R \leftrightarrow Unknown Casing Y	0.5972 (Missed)
Unknown Casing R \leftrightarrow Unknown Persistence Casing S	0.7125 (Identified)

Persistence Casing S was able to link Unknown Casing R back to the correct slide.

Initial tests using the Congruent Matching Cells (CMC) method: Correlation scheme



A



B

Cell size: 75 pixel x 75 pixel (0.47 x 0.47) mm²

Total cell number: 7 x 7 or 6 x 6

Rotate image B, find the best matched patch with each cell in A

Rotation range: 30°

X- and Y- displacement search range: whole image

Control set correlation results

Data input: 20 known matching breech face images (10 pairs)

Total comparisons: 190 ($20 \times 19/2$)

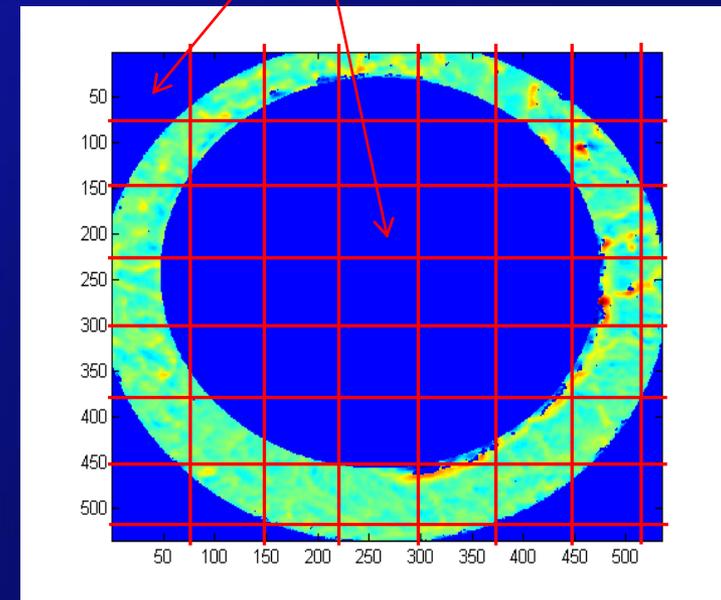
Matching comparisons: 10

Nonmatching comparisons: 180

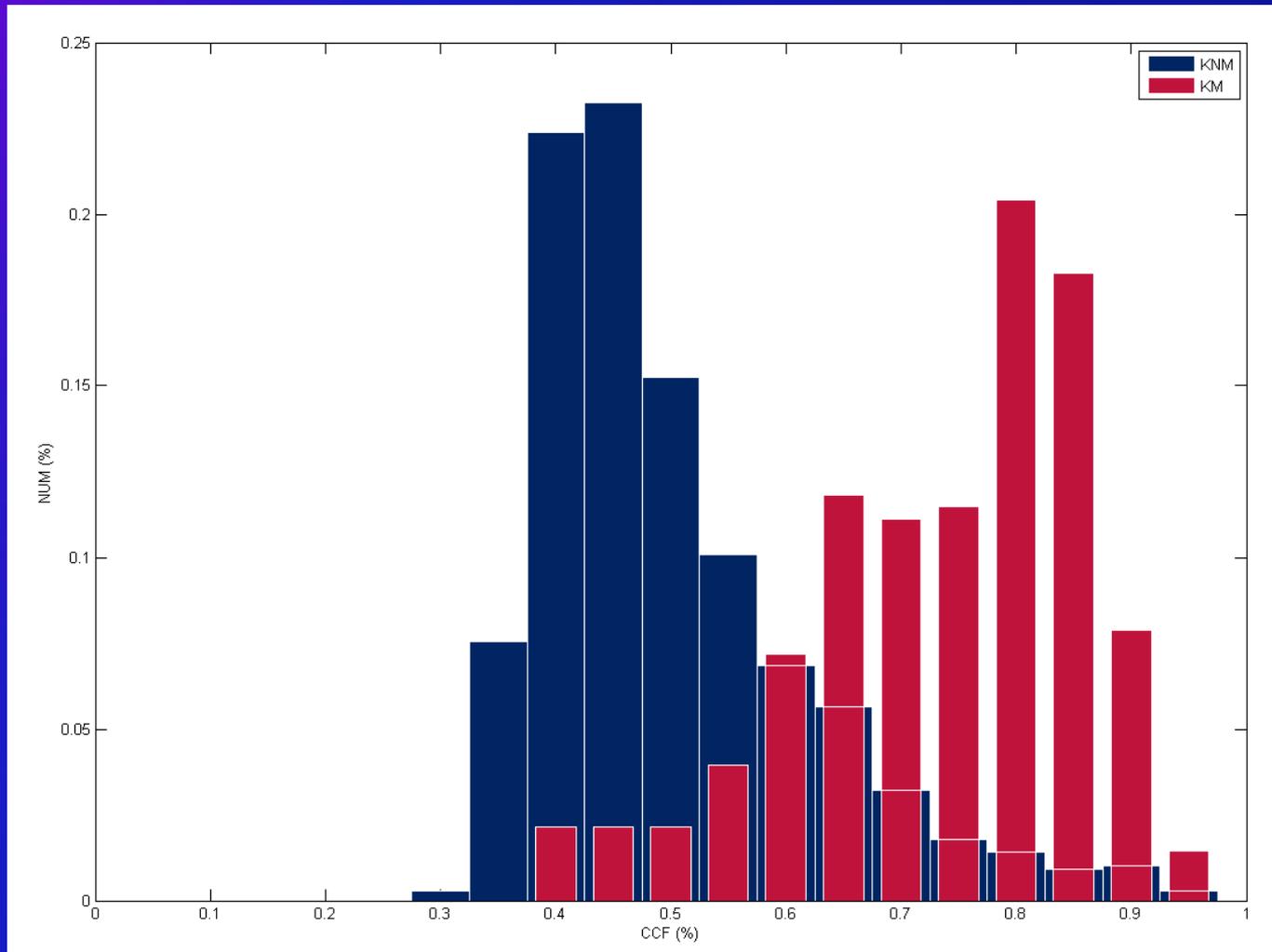
Removing those cells that do not include sufficient valid data points, valid correlation cell numbers are:

- 279 cells in total for 10 matching comparisons
- 4737 cells in total for 180 matching comparisons

Invalid cells for correlation

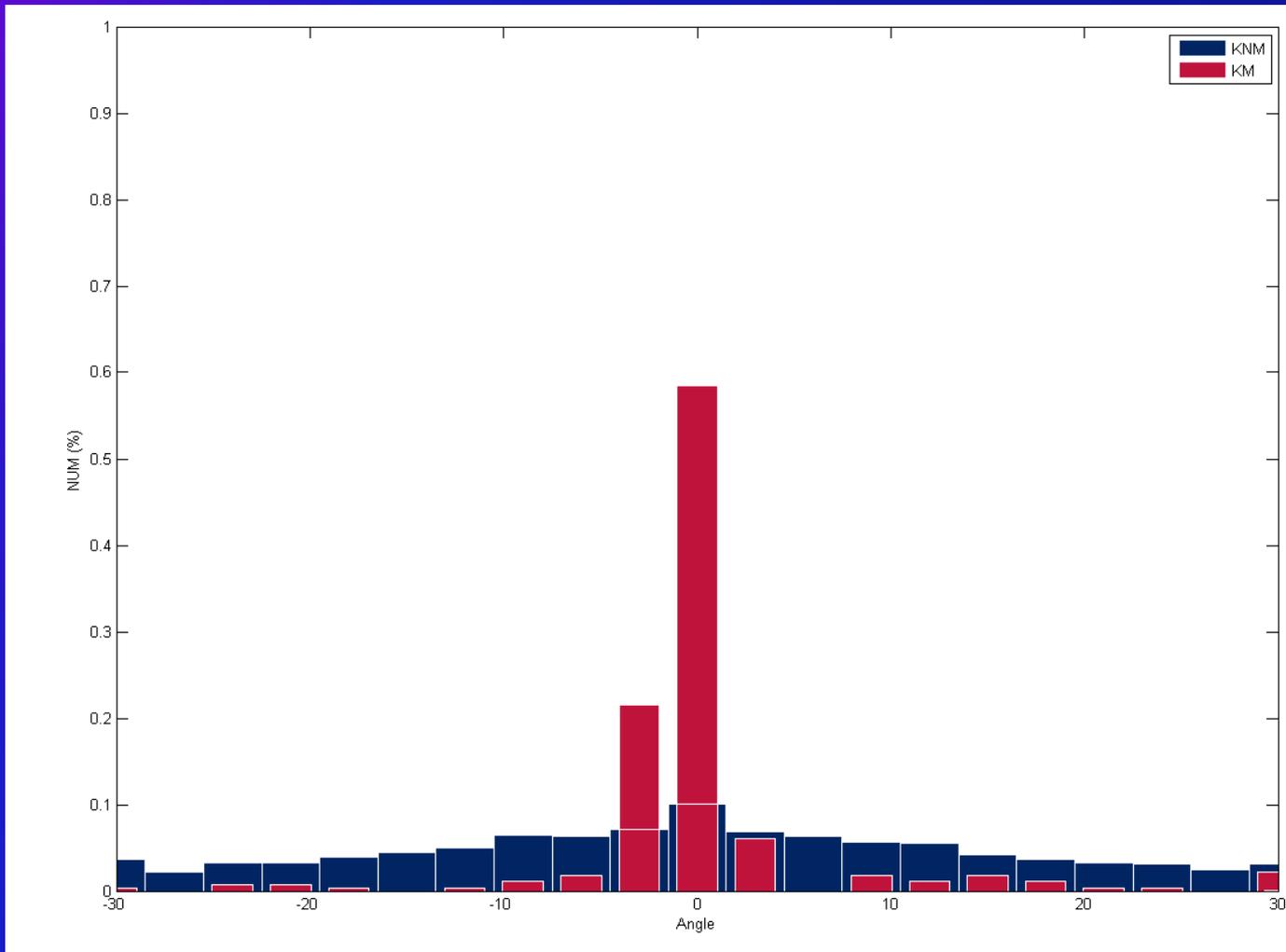


Distribution of CCF value of the correlated cell pairs



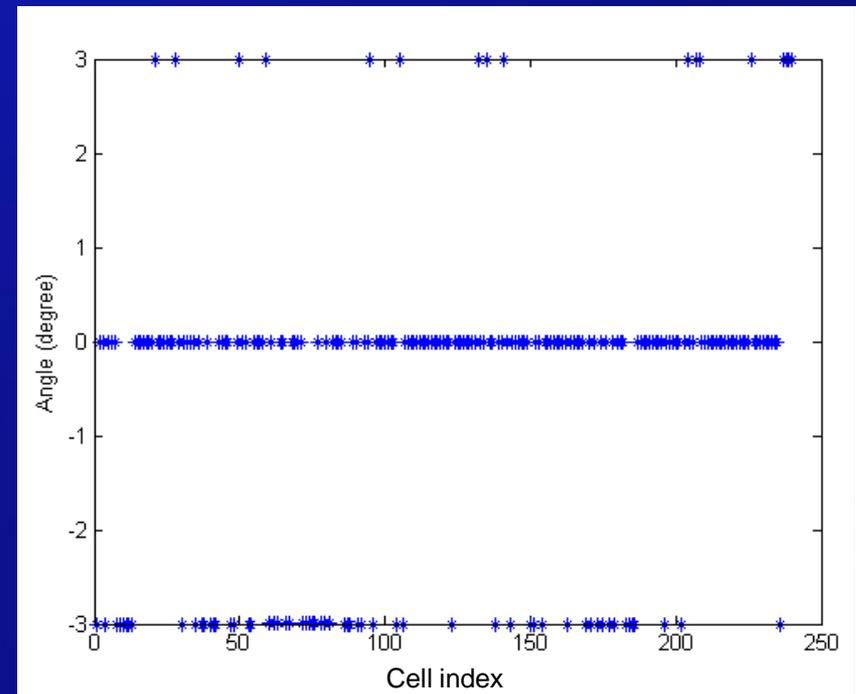
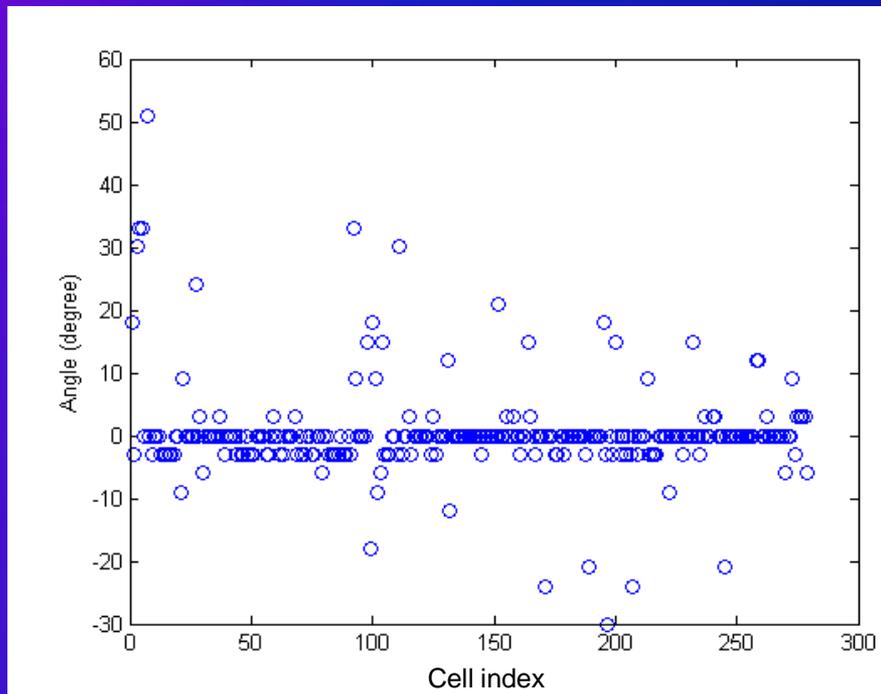
Statistical distribution after normalization

Angle



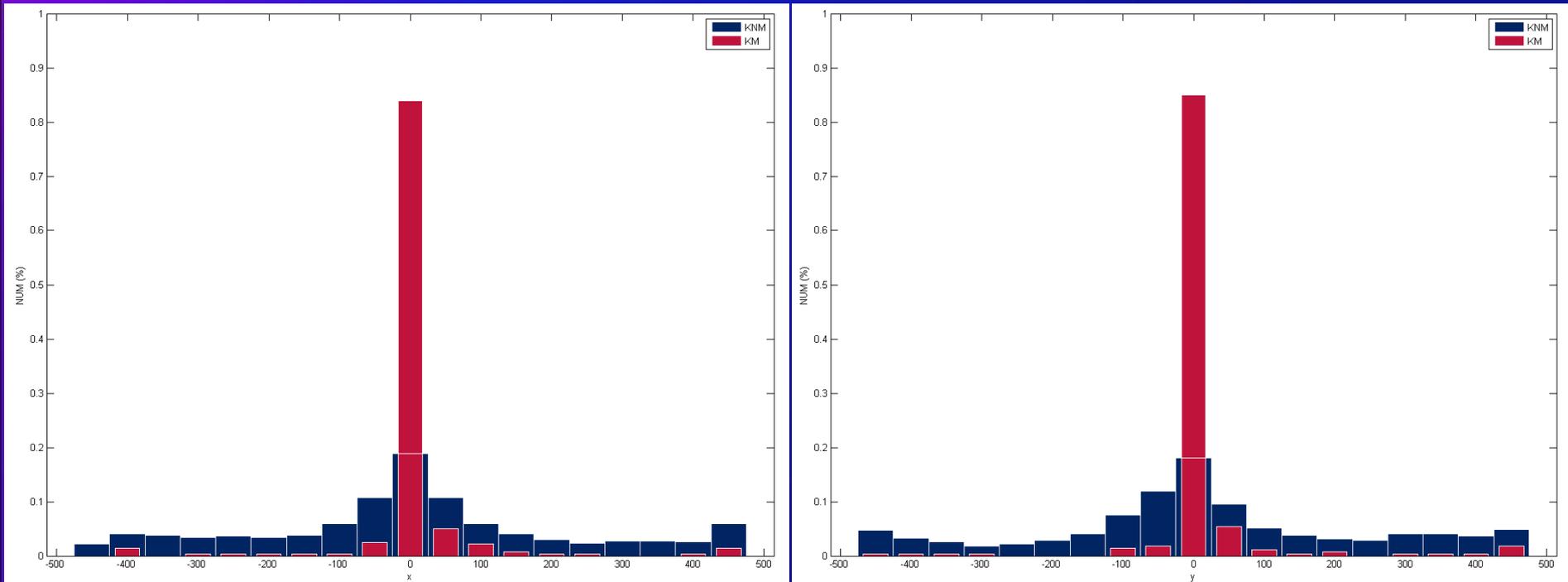
Statistical distribution after normalization

For all 279 valid cells in ten pairs of KM comparisons, 240 ($\approx 86\%$) cells are left after iteratively removing those outside the 3σ range. They are in the range of $\pm 3^\circ$

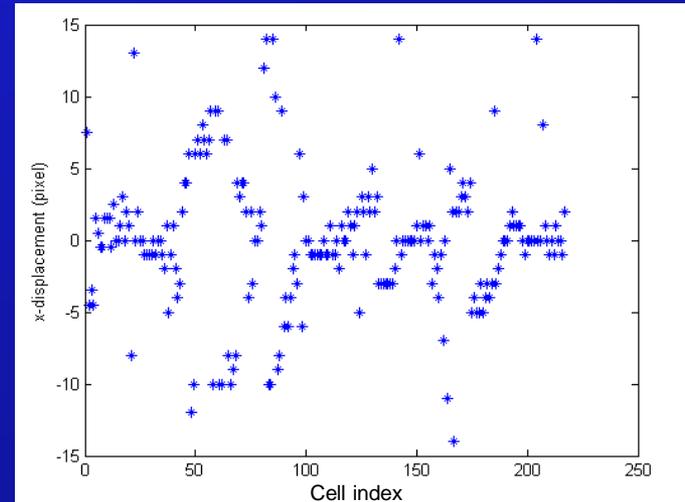
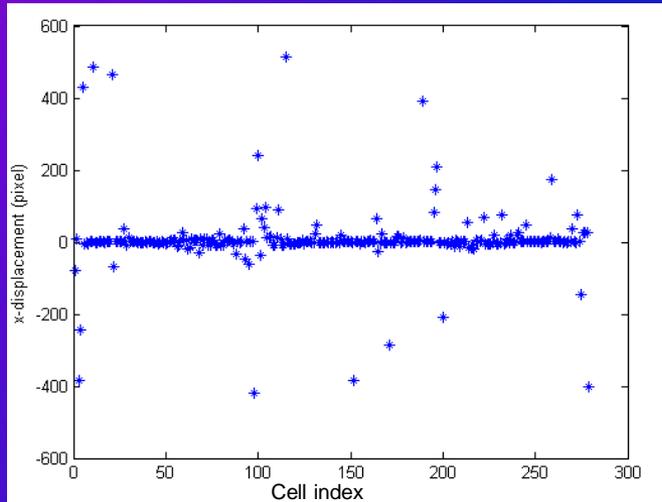


Statistical distribution after normalization

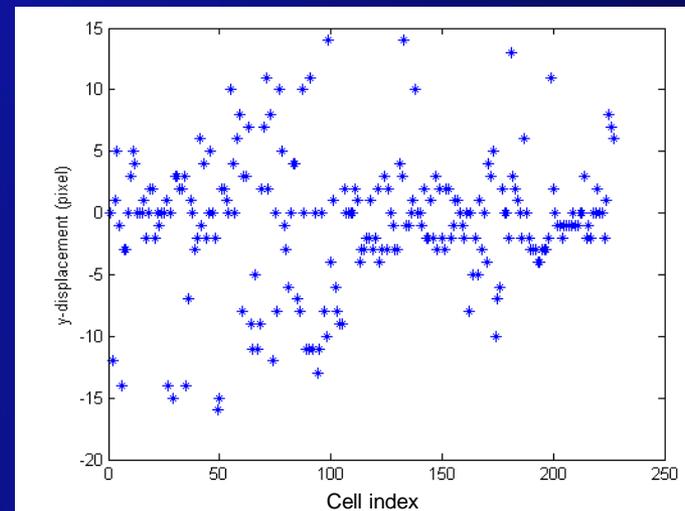
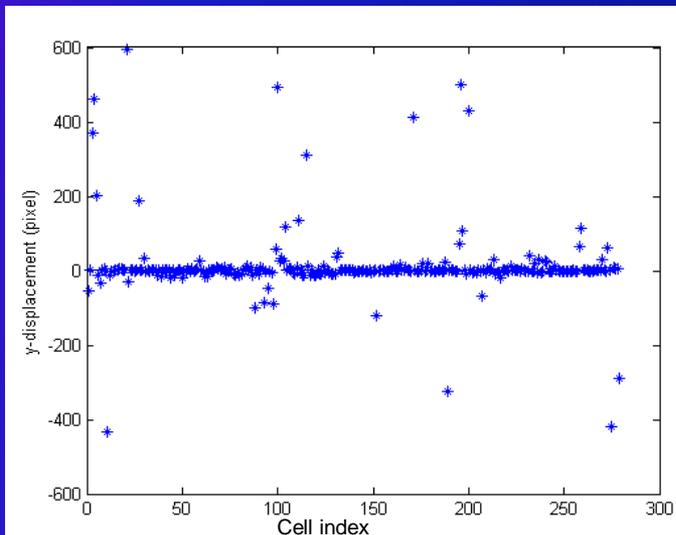
X-Y Displacement



For X-displacement, 217 of total 279 results (77.8%) distribute in range of ± 15 pixel



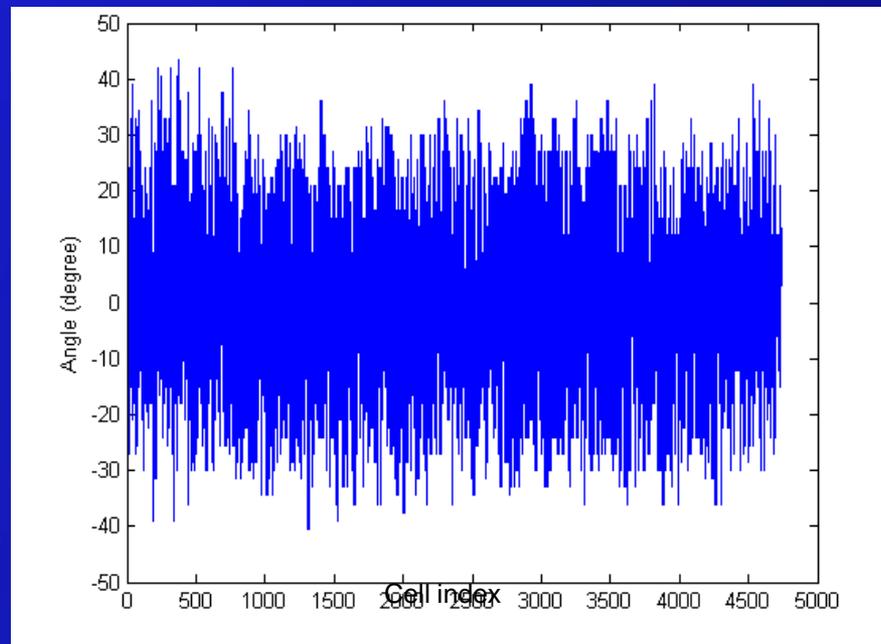
For Y-displacement, 227 of total 279 results (81.4%) distribute in range of ± 16 pixel



Non-matching

Only 12% of these cells have their angle distributed in the range of $\pm 3^\circ$
(compared with cells in matching set: 86%)

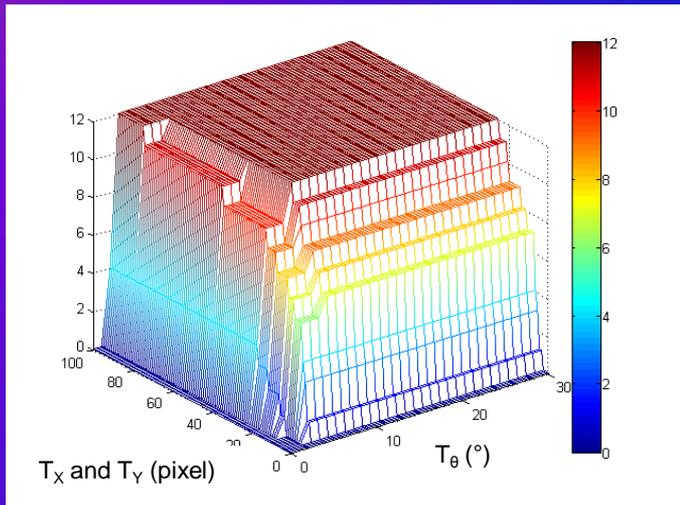
12.6 % and 12.2 % have their x- and y-displacement distributed in the range of ± 15 pixel respectively
(compared with cells in matching set: 78% and 81%)



Distribution of rotation angle

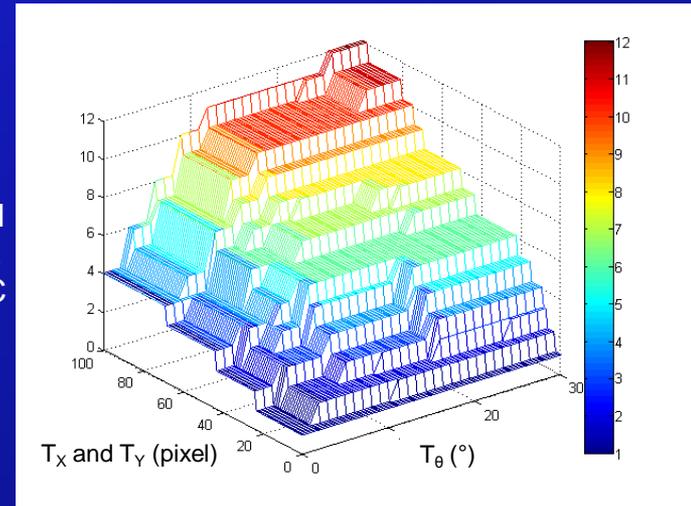
Selection of threshold parameters

KM
Min.
CMC



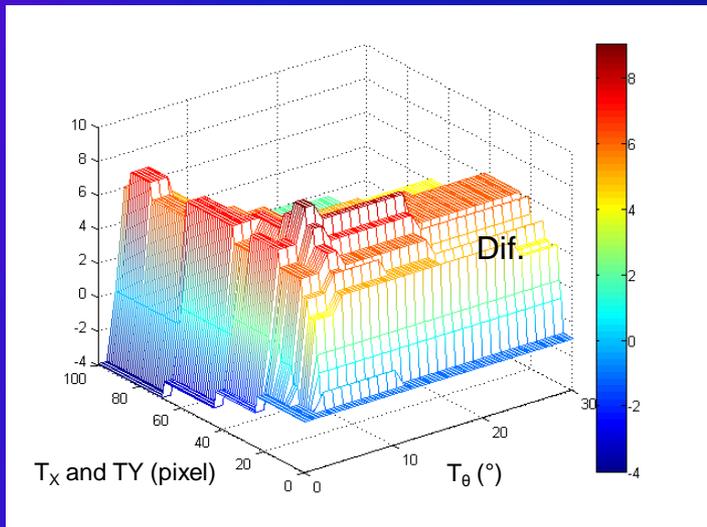
KM Samples' Minimum CMC ($CCF_{low} = 50\%$)

KNM
Max.
CMC

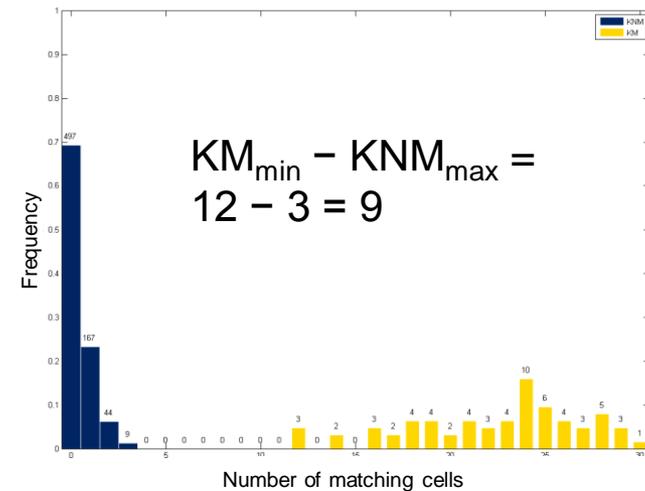


KNM Samples' Maximum CMC ($CCF_{low} = 50\%$)

Difference
(KM
Min.
-
KNM
Max
CMC)



Difference of KM Minimum and KNM Maximum



CMC Distribution

Test results for all 40 casings

Thresholds selected at

CCF: 60%;

Angle: 6 ;

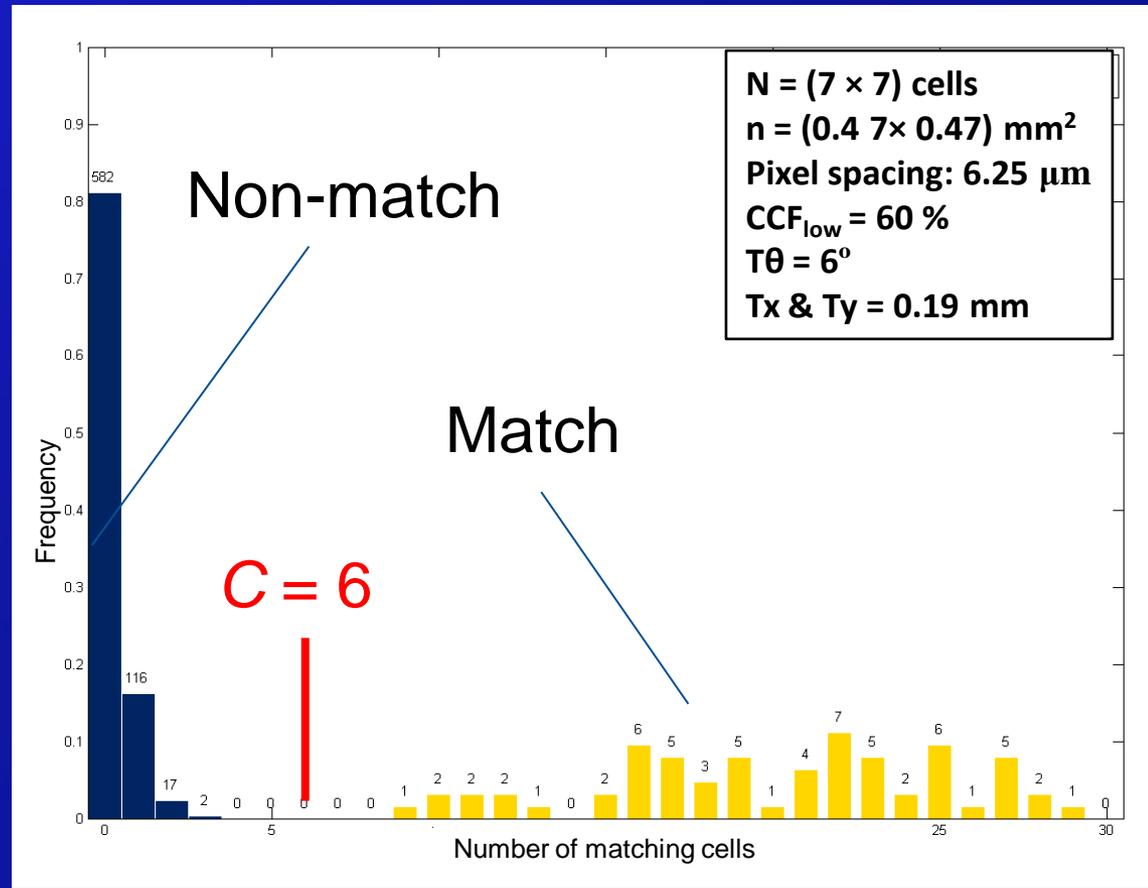
x- and y-displacement: 30 pixel

63 comparisons in total between two actually matched casings, no missed identification

24	----->	1, 2
23, 29	----->	3, 4
21, 35, 40	----->	5, 6
22	----->	7, 8
25, 37	----->	9, 10
26, 38	----->	11, 12
32, 34, 39	----->	13, 14
30, 31, 33	----->	15, 16
27	----->	17, 18
28, 36	----->	19, 20

Distribution of matched cell number

- A total of 780 correlations with 63 KM and 717 KNM correlations.
- No false pos. & neg. identifications, with $C = 6$.
- To be improved.



Conclusion and Discussion

1. The use of the CMC method represents the highest identification accuracy for the same set of cartridge cases that we have tested thus far.
2. Optimizing parameter such as cell size, image processing procedure, parameter thresholds CCF_{low} , T_{ϑ} , T_x , T_y for the proposed CMC method improves the separation between the distributions for the matching and non-matching set of data.
3. The preliminarily recommendation of the CMC criterion: “C = 6” Minimum number of 6 valid cells for a positive match.

Acknowledgements

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