Tests using CMC Method for Optical Image Correlations of Cartridge Cases Fired from Consecutively Manufactured Pistol Slides

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Disclaimer

Certain commercial equipment, instruments, or materials are identified in this report in order to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.

Contents:

1. Test Samples

The test samples are from a study by the Miami Dade Crime Laboratory. 40 cartridge cases fired from handguns with the 10 consecutively manufactured slides were correlated with one another. That includes 20 known cartridge cases (2 per slide) for references and 20 unknown cartridge cases for the validation test. There are a total of 780 pair combinations; comprising 63 known-matching (KM) and 717 known-non-matching (KNM). The topography images of these samples had been tested by NIST.

Test Samples (continued)

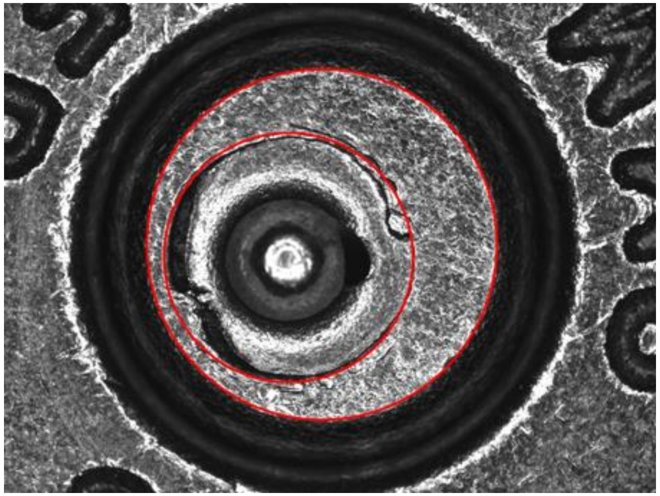
The optical intensity images of 40 cases were captured by Leica comparison microscope using top-ring light. In this experiment, we only measured and compared the breech face mark.

The other areas on the images were trimmed.

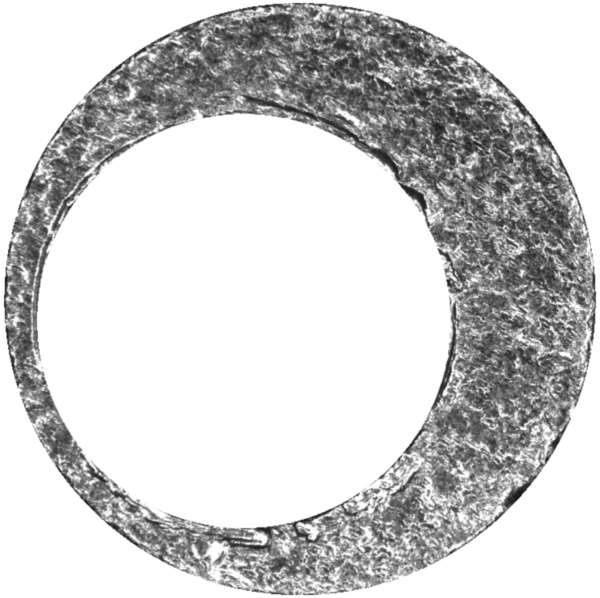
The final image size is (700 × 700) pixel with estimated pixel spacing 4.95 µm. A low-pass Gaussian filter (short cut-off is 26 µm) was applied to remove the high frequency components which is mainly noise.

Test Samples (continued)

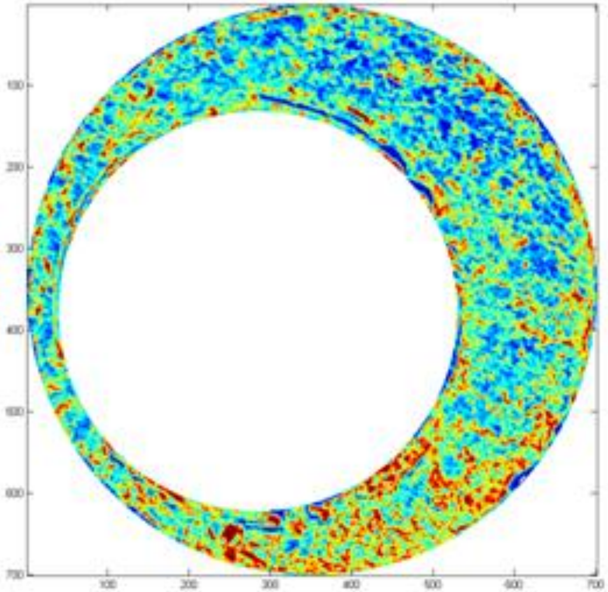
Fig. 1 Image Processing



(a) Breech Face Raw Data Image



(b) Trimmed Image



(c) The Image after the Gaussian Filter

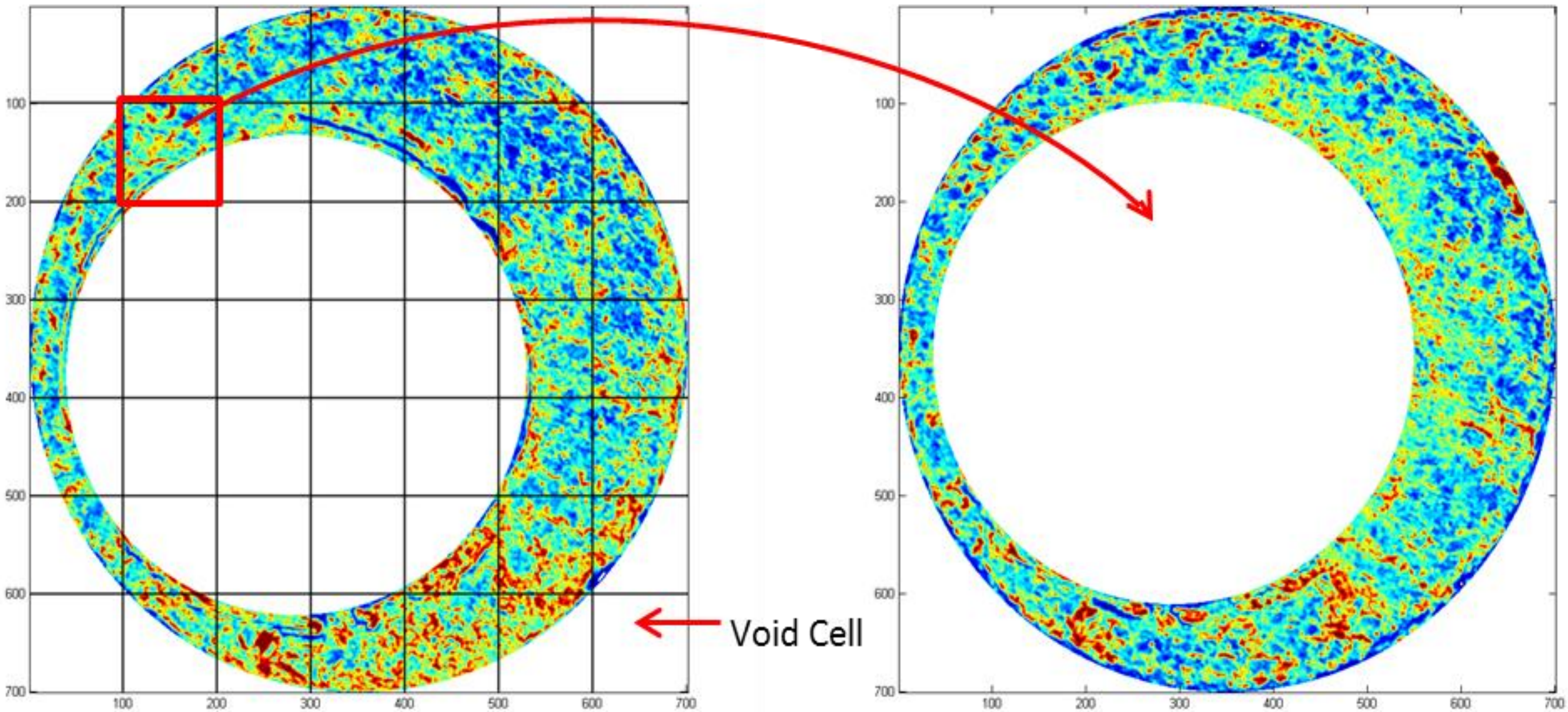
2. Implement of CMC Method

CMC Method

To reduce the effect of correlation from the invalid correlation area, the CMC method divides the image data into correlation cells. In this experiment, the cell size is set as (100 × 100) pixel or (0.49 × 0.49) mm^2. The resulted number of cells is (7 × 7).

For a pair of images A and B, every valid cell divided from A is correlate to every rotated image B. The rotation range is ±30° with 3° increments. Each correlation cell in image A scans the whole area of each rotated reference image B to find the best matching position. Once the procedure is completed, the similarity metrics consisting of the CCF_{max} value, the registration angle θ and the translation distances in x and y are recorded.

Implementation of CMC Method, cont.



Case-A Case-B

Fig.2 Correlation scheme using the CMC method

Fast CMC Method

Cell correlations against the whole reference image are time consuming. To shorten exam time, a fast correlation method was proposed. In most modern handguns, the barrel, bullet, cartridge case and slide are concentric (see Fig. 3). Thus the matching patterns from a pair of matching cases will appear in the same relative position in each breech face image.

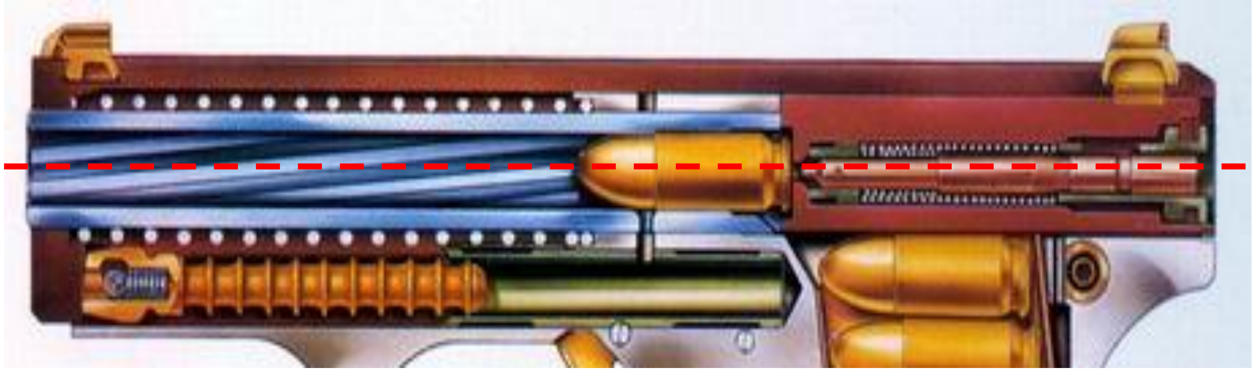


Fig.3 Barrel, breech face (cartridge cases) and slide are concentric

Fast CMC Method

Fast CMC Method

With this feature, the whole reference area from image B could be reduced to a small "reference area" (see the red dotted areas in Fig. 4 right) which is little bigger than the cell from image A. The central position of the reference area is the same as the corresponding cell position of the image A (cell A2 in Fig. 4 left). The reference area keeps stationary, and independent of image B's rotation during the correlation process. The correlation speed can now be increased ten times.

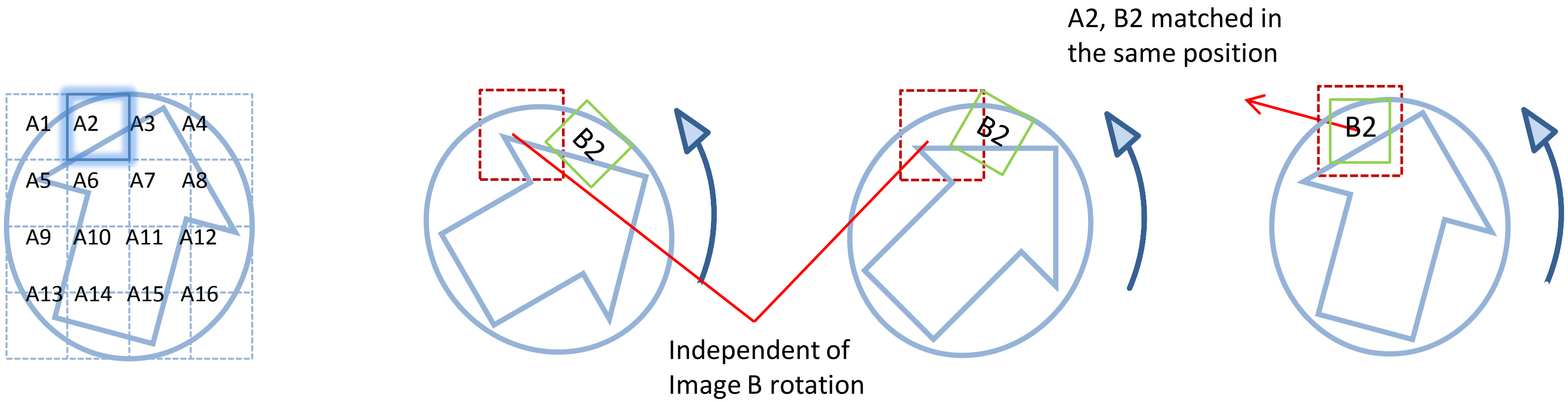


Fig.4 Correlation scheme using the quick CMC method

Determination of the CMC Numbers

The 20 known cartridge cases were correlated first and statistically analyzed. Excluding those cell pairs that do not contain sufficient data points, the correlations were implemented for 266 cell pairs of 10 KM correlations and 4794 cell pairs of 180 KNM correlations. The CCF_{max} distribution histograms for all cell pairs are shown in fig. 5. To allow the most KM and KNM cell to participate in the determination of the CMC numbers, the CCF_{low} = 25% was selected.

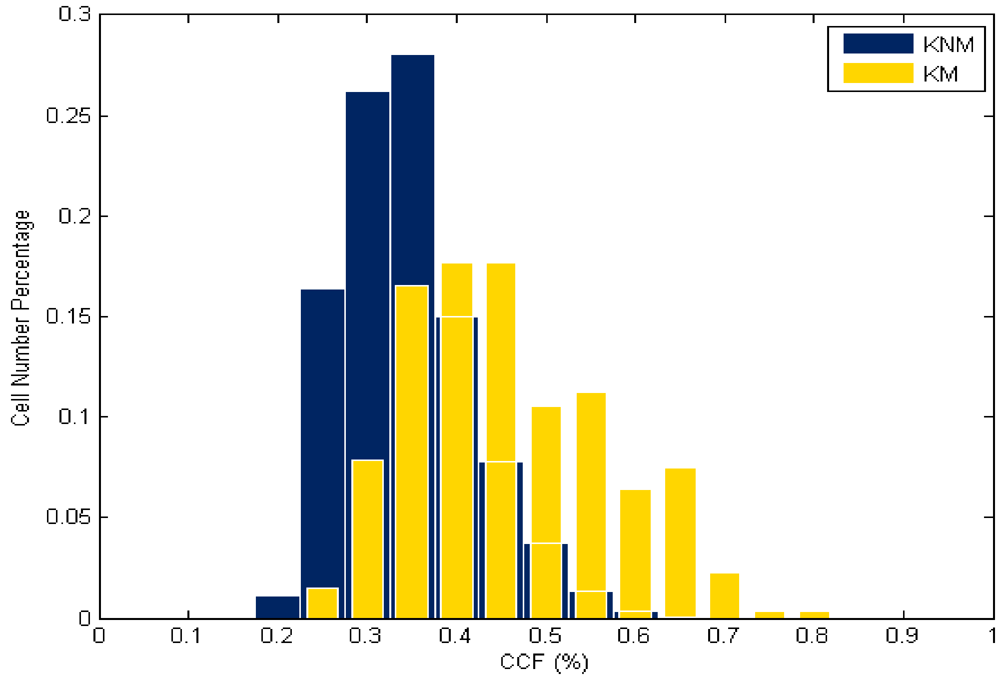


Fig. 5 Correlation scheme using the quick CMC method

Determination of the CMC Numbers

Based on the CMC definition, if all the three identification parameters of the correlated cell pairs CCF_{max}, θ and x, y show positive results with three thresholds (CCF_{low}, T_{θ} and $T_{x,y}$), these correlated cell pairs are considered congruent matching cell pairs.

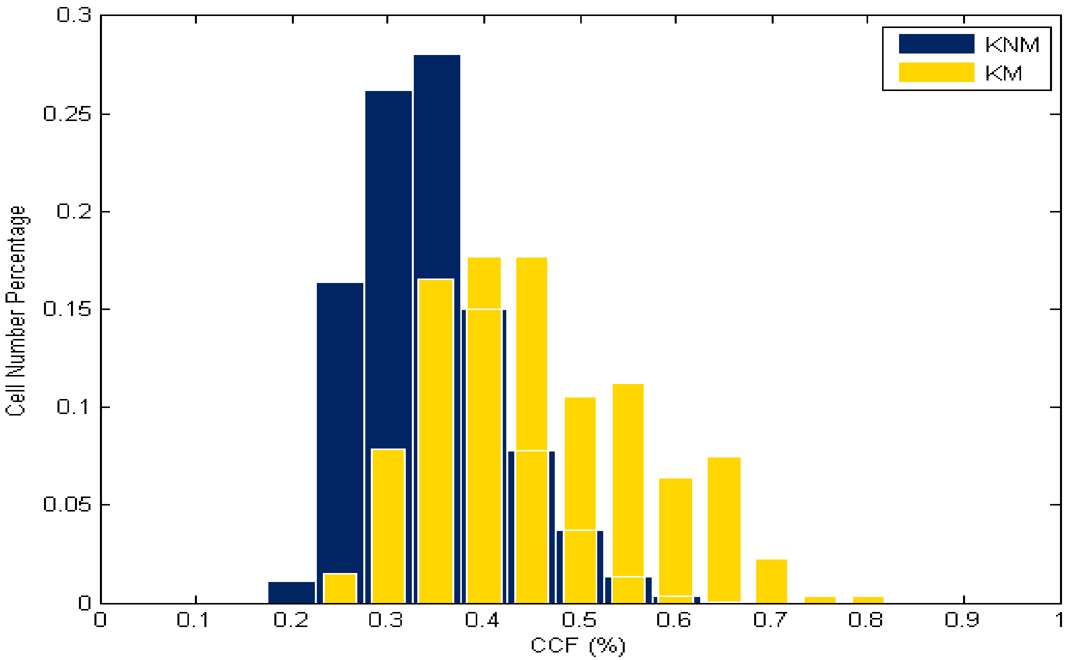


Fig. 5 Correlation scheme using the quick CMC method

3. Analysis of Correlation Results

Based on the CMC definition, a program was made which can search the difference between the <u>min CMC number of KM group</u> and the <u>max CMC number of KNM group</u> in all different T_{θ} and $T_{x,y}$ combination with a given CCF_{low} value.

Analysis of Correlation Results

For the 20 known cartridge cases, Fig. 6 shows the distribution of the CMC differences for the selected 190 correlations with CCF_{low} = 25%. The CMC difference achieves the maximum as shown in the area of white frame (see Fig. 6). By selecting the thresholds in this area (T_{θ} = 3°, $T_{x,y}$ = 25 pixel), Fig. 7 shows the CMC distribution based on these thresholds.

The KM and KNM distributions are well separated. The maximum CMC number of the 180 KNM correlations is 5, and the minimum CMC number for the 10 KM correlations is 12. There is a gap of 6 CMCs, which indicates no misidentification or missed identification.

Analysis of Correlation Results

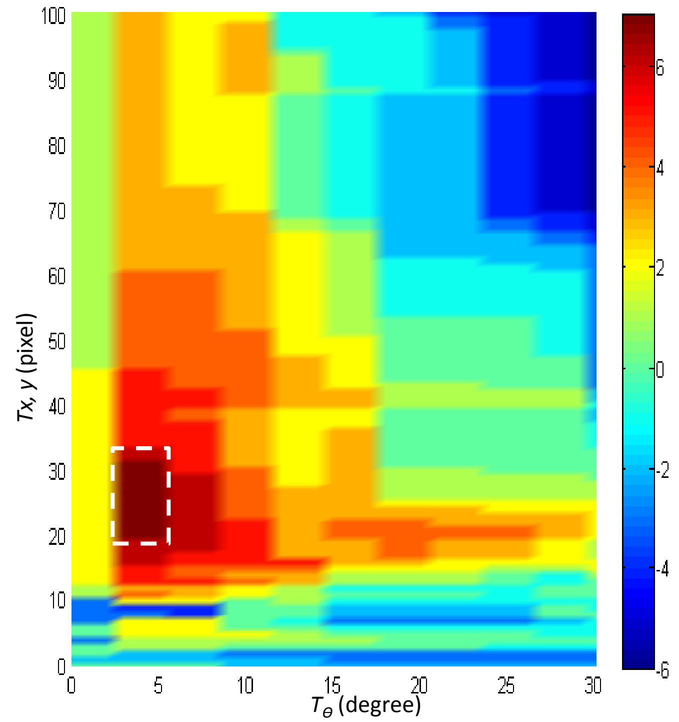


Fig. 6 Difference of KM Minimum and KNM Maximum
(190 correlations; CCF_{low} = 25%)

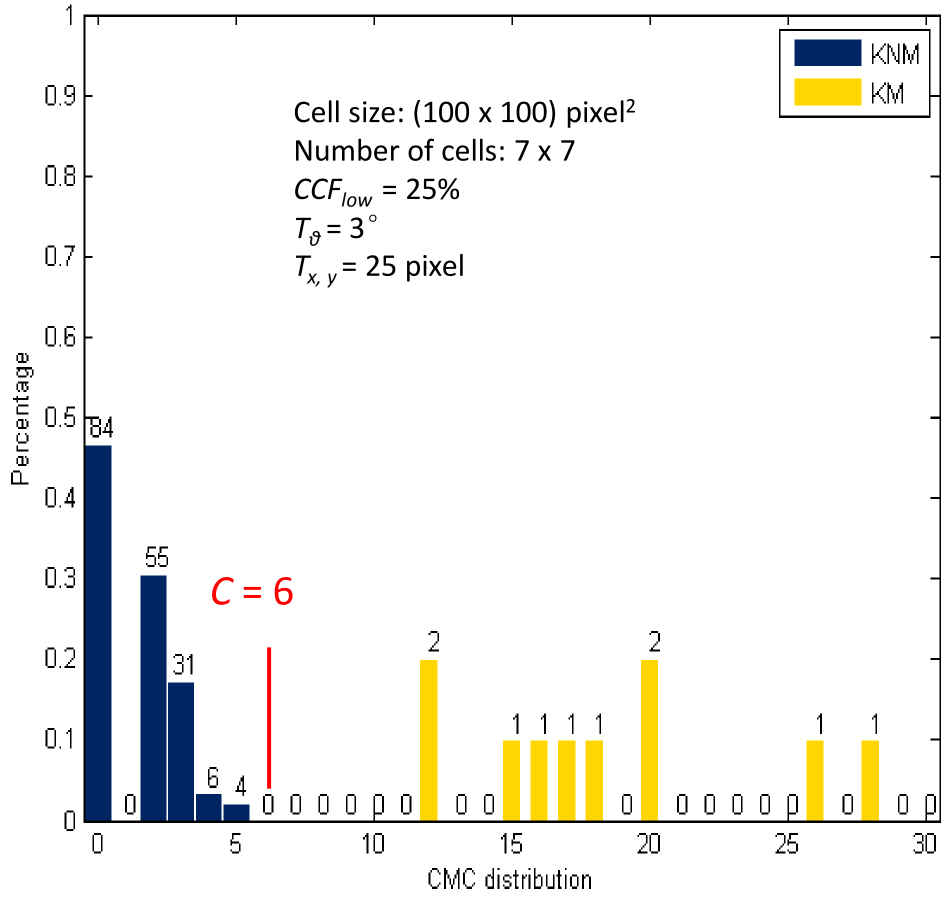


Fig. 7 CMC Distribution
(190 correlations; top-ring light)

Analysis of Correlation Results

- **The same processing was now conducted on all of the 40 cartridge cases. The difference distribution of 63 KM and the 717 KNM is shown in Fig. 8. The max difference is -1. It means there has been a misidentification or missed identification.**
- **The max CMC difference area of 780 correlations (see Fig. 8) is the same as the max CMC difference area of 190 correlations (see Fig. 6). By using the same thresholds, the CMC distribution of 780 correlations is showed in Fig. 9. In this result, the distribution of KNM doesn't have an obvious change.**

Analysis of Correlation Results

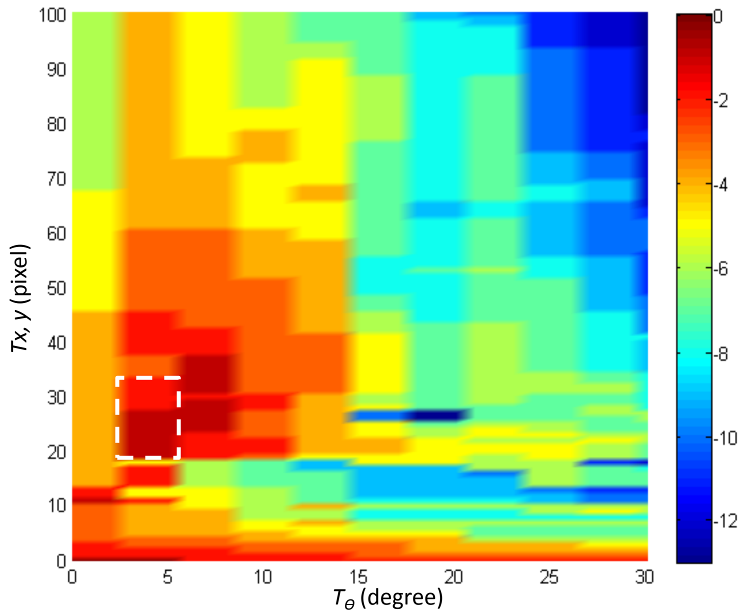


Fig. 8 Difference of KM Minimum and KNM Maximum
(780 correlations; CCF_{low} = 25%)

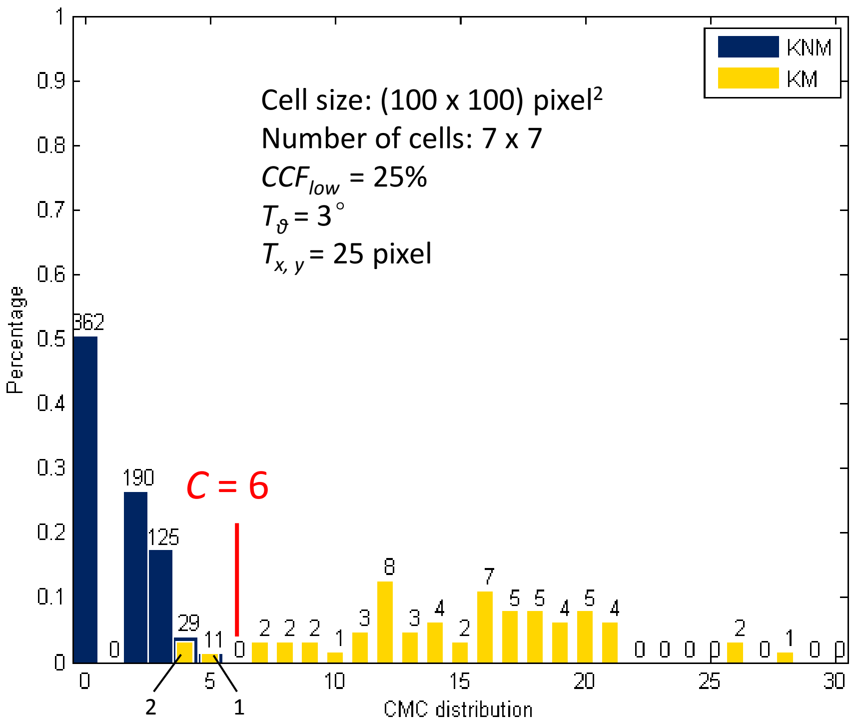
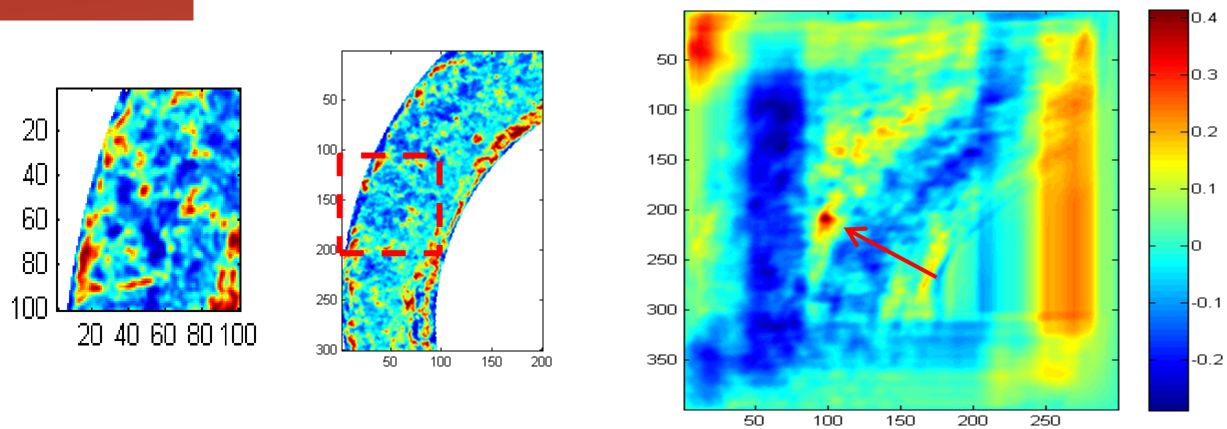


Fig. 9 CMC Distribution
(780 correlations; top-ring light)

4. Correlation Analysis by Angle

To further analyze the “misidentification” and the “CMC close to 6” results, the correlation processing of a typical pair of matching cells is shown in Fig. 10.



(a) Cell-A **(b) Cell-B** **(c) CCF distribution**

Fig. 10 Correlation Processing of KM Cell Correlation

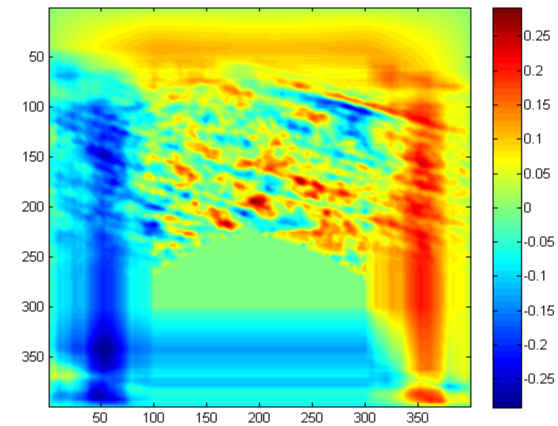
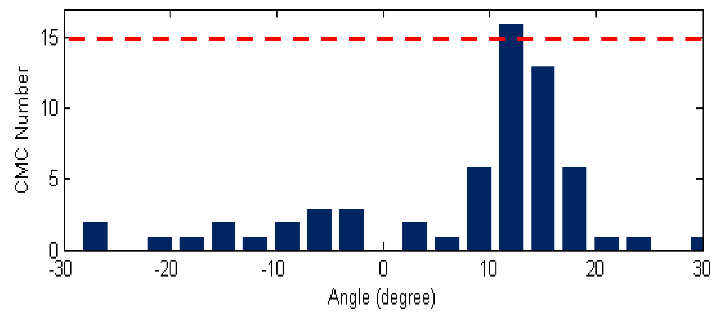
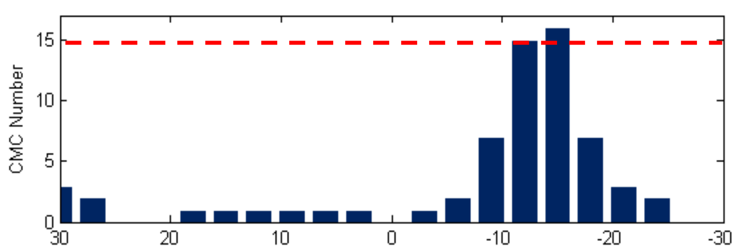


Fig. 11 CCF Distribution of KNM Cell Correlation

Correlation Analysis by Angle (continued)

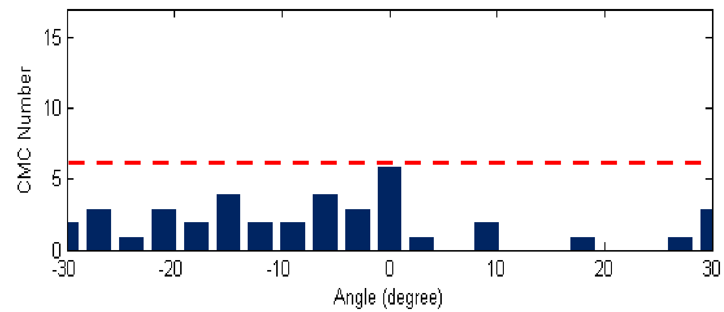


(a) Forward Comparison (A vs. B)

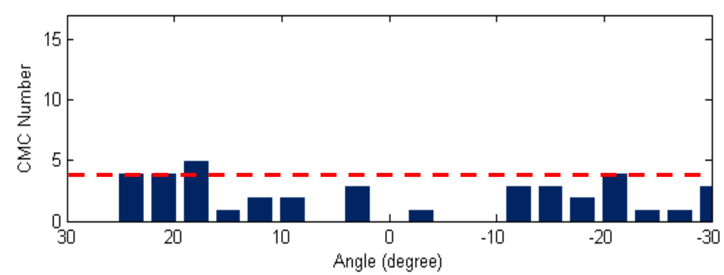


(b) Reverse Comparison (B vs. A)

Fig. 12 CMC Distribution of a Typical KM by Angle



(a) Forward Comparison (A vs. B)



(b) Reverse Comparison (B vs. A)

Fig. 13 CMC Distribution of a Typical KNM by Angle

Correlation Analysis by Angle

We propose two methods to increase the accuracy:

1) Using "High CMC Number" replace the max CMC number to find the matched angle. In KM correlations, if existing angles which CMC number is a little less than the maximum (less 1 or 2), these angles are usually close to the peak angle. But in KNM correlations, these angles are usually randomly distribute in the whole range.

Correlation Analysis by Angle

2. Combining forward and reverse correlations (A vs. B, then B vs. A). According to the analysis, some random factors could make KNM correlations show a high CMC number in some angles. Making a "reverse" correlation means making two correlations with different parameters (cell size, cell direction) in same angle (see Fig. 14 below).

Fig. 14 Forward and Reverse Correlations

Result of Correlation Analysis by Angle

Based on the lower result of a pair of correlations (forward and reverse correlations) with the original CMC method, and using the assisted analysis results then an optimized result with no misidentification or missed identification is shown in Fig. 15 following.

Result of Correlation Analysis by Angle

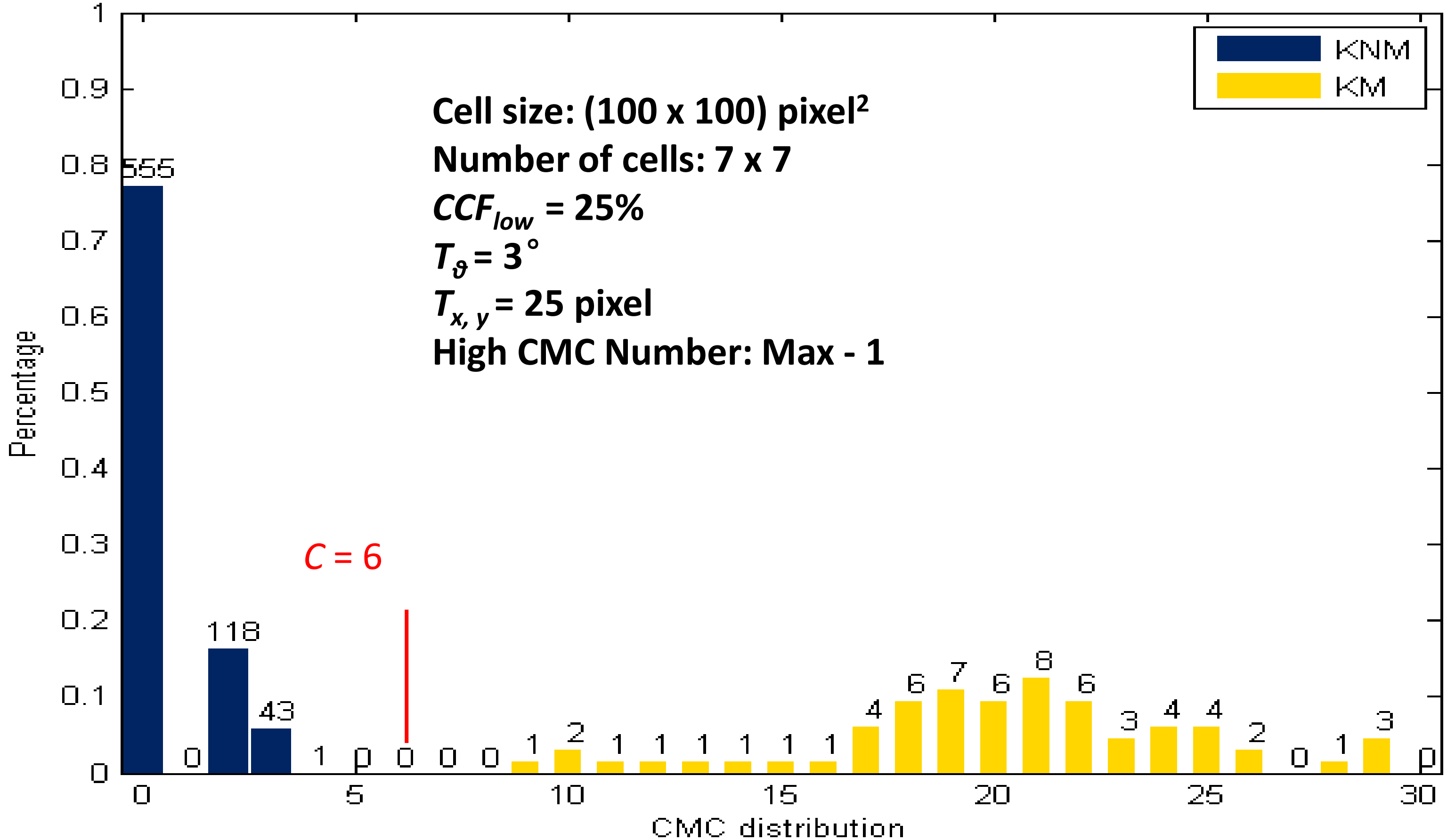
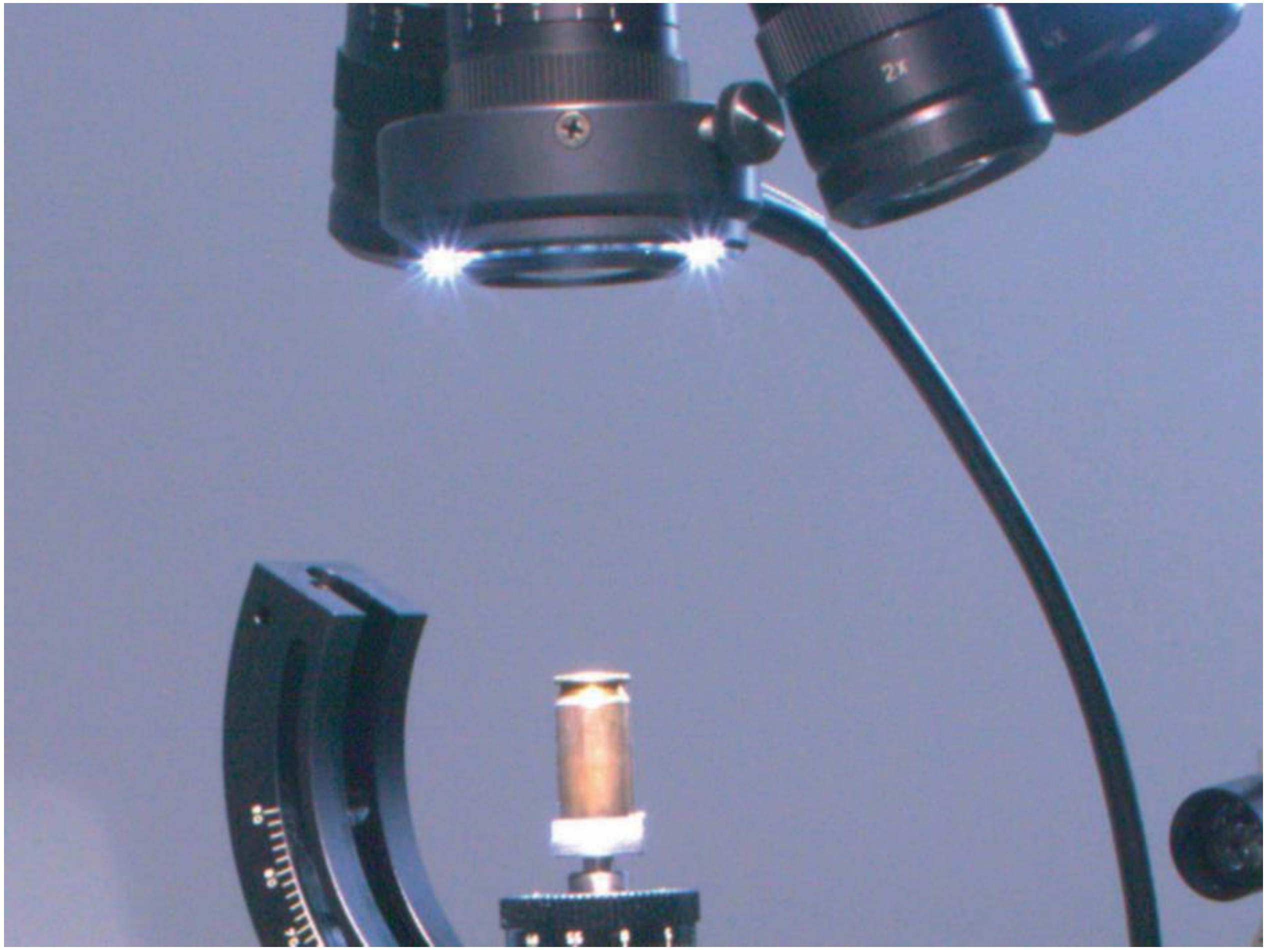


Fig. 15 Optimized CMC Distribution
(780 correlations; top-ring light)

Side-light using controllable ring-light



Leica FS M with LED Ring-Lights **Leica Microsystems**

5. Side Light Test and Result

Examiners typically use a side light when they are reviewing comparisons. The side light adds surface contrasts that in turn give a better sense of depth and texture of the primer surface.*

We made an initial test using the CMC method for side light images. Images from all 40 cases were captured using side light. The correlations gave much better results than ring light (see Fig. 16).

(* National Research Council of the National Academies, Ballistic Imaging:182)

Side Light Test and Result

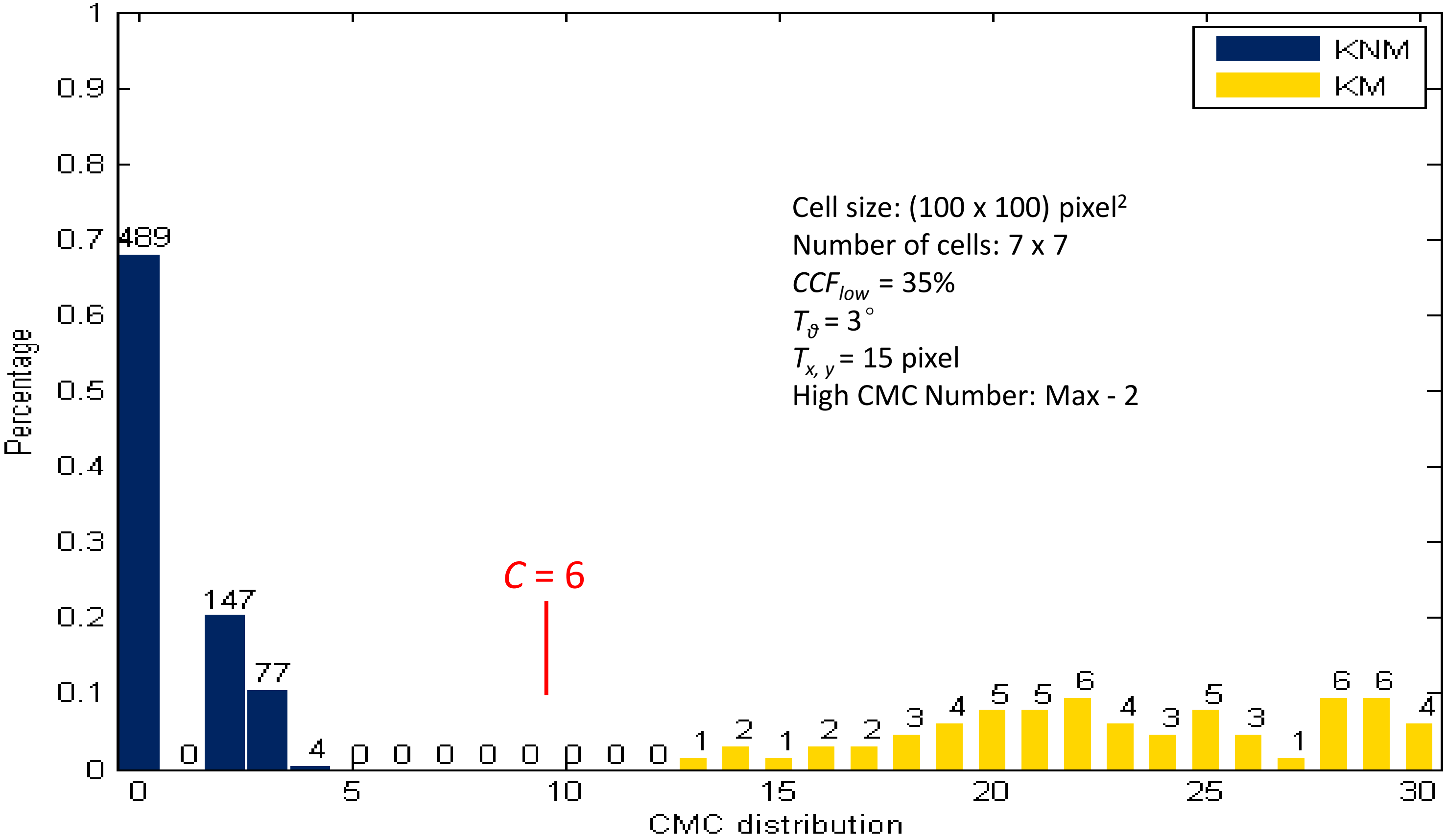


Fig. 16 Optimized CMC Distribution
(780 correlations; 3 o'clock side light)

Comparison of results, top ring light vs. side-light

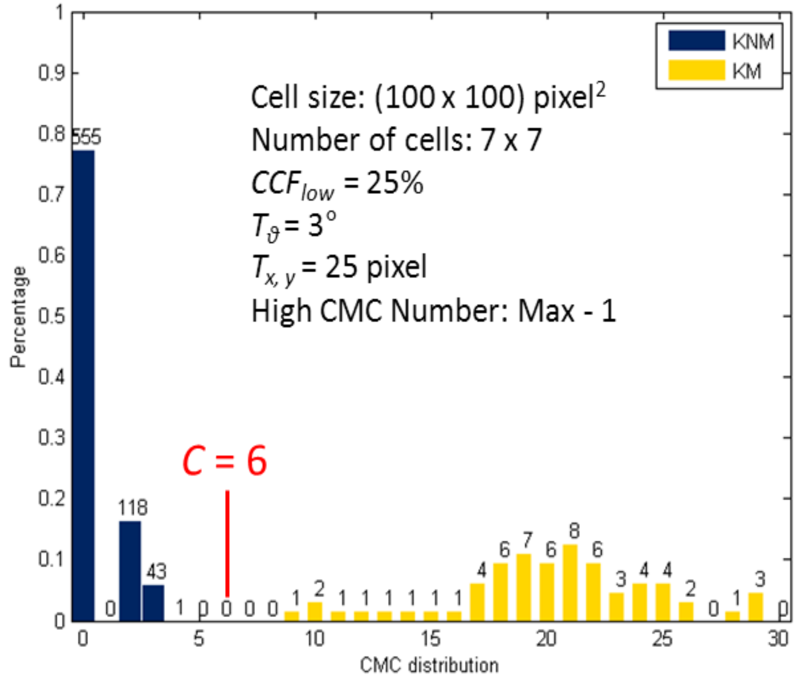


Fig. 15 Optimized CMC Distribution (780 correlations; top-ring light)

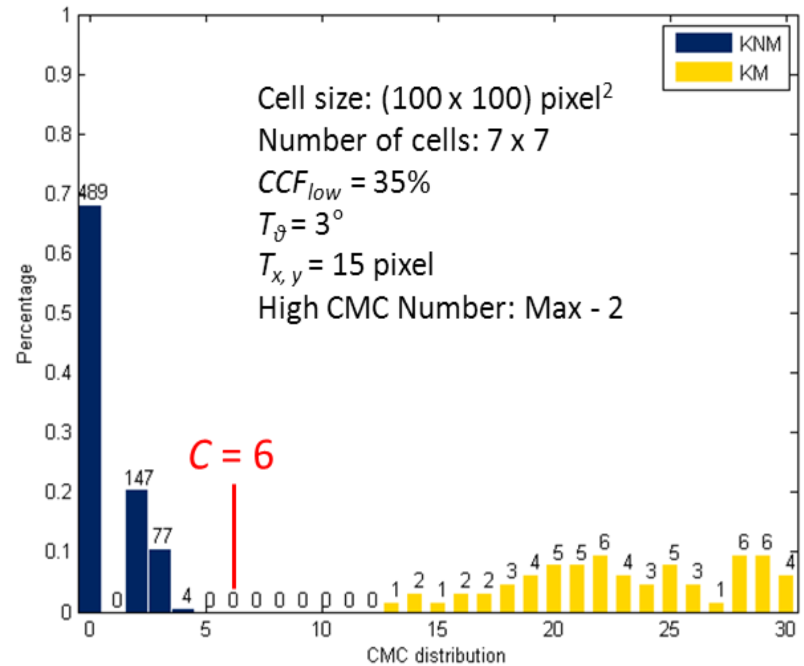


Fig. 16 Optimized CMC Distribution (780 correlations; 3 o'clock side light)

6. Conclusions and Future Work

The CMC method and the proposed numerical identification criterion ($C \geq 6$) for ballistic identification were proven effective in three-dimensional topography images of cartridge case by NIST. Results were obtained without any false positive or false negative identification.

In the optical images of the same 40 samples test, one case was "Falsely excluded" using the original CMC method. This might indicate that topography data is still better suited for ballistics identification than optical images.

Conclusions and Future Work

However, the proposed assisted analysis method based on features of CMC can effectively enhance this identification accuracy. The correlation results show a significant separation between the KM and KNM distributions without any false positive or false negative identification. As an assisted technology, initial tests show promise.

Additionally, these improvements can also used for topography comparisons and identification.

Conclusions and Future Work

In the initial test, the side light images demonstrate better results than ring light, and close to topography correlation results.

However the side light approach lacks a unified illumination standard that may limit the side light applications in search systems. In our future work, more lighting variables will be tested and analyzed.

Conclusions and Future Work

In our future plans, more impression “signatures” on cartridge case will be tested, including firing pin and ejector marks, using derivatives of the CMC method.

We are also finalizing an error rate reporting method for ballistics identification based on the CMC method.

Thanks for your attention!
Questions?

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