References of firearms/toolmarks identification based on 3D surface metrology

Sensofar

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Adding an Objective Component to Routine Casework: Use of Confocal Microscopy for the Analysis of 9mm Caliber Bullets

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Abstract

The analysis of firearm and tool mark related to evidence has remained relatively unchanged for nearly a hundred years. Although the science behind these analyses has undergone rigorous testing and has been accepted in courts for many years, the science has recently been the subject of a great deal of scrutiny. In 2009, the National Academy of Sciences (NAS) report "Strengthening Forensic Science in the United States: A Path Forward" called to question the legitimacy of the comparative sciences. Specifically, the NAS report states that the science of firearm and tool mark analysis lacks empirical research, has not been validated, and suffers from bias and subjectivity. Extensive review of the literature has shown that the science has been validated and subjected to empirical research, but the need for adding an objective criterion exists, which will also help to minimize bias.

The Alabama Department of Forensic Sciences (ADFS) has procured a confocal microcope for the purpose of incorporating three-dimensional (3D) topographical analysis into routine casework. The purpose of employing such a technique would be to assist the examiner by complementing routine analysis with an independent objective analysis. This article will cover the research procedures conducted using confocal microscopy at the ADFS thus far.

Conclusions and Future research

This initial research conducted at ADFS suggests that confocal microscopy could serve as a viable technology for incorporating objective data into routine casework. The objective data collected by the confocal microscope further demonstrates the validity of the science of firearm and tool mark analysis.

Despite these indications, there are several items that still need to be addressed. The establishment of a cut-off value can only be determined after more data acquisition. Furthermore, this research has been limited to 9mm Luger caliber bullets and the need for expanding into other calibers is obvious. One area that needs to be addressed is how damage to bullets affects the results. This has been investigated on a limited basis at the ADFS and the preliminary results show that further research must be done.

One area that needs exploring is the possibility that the waviness left on a bullet is also unique to the barrel. The initial data analysis suggests that the waviness left on a bullet is a reflection of the vibrations between the barrel and the tools used in the manufacturing process. The author proposes that these vibrations are random in nature and could be compared along with the aforementioned roughness analysis as an additional metric of uniqueness. The need of more analysis is evident, but the author believes that using both roughness and waviness data would make the objective data collected by a confocal microscope more defensible.

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Identification of Bullets Fired from Consecutively Manufactured Double-Broached Ruger SR9c Barrels Utilizing Comparison Microscopy and Confocal Microscopy
AFTE Training Seminar 2016
Abstract Following the presentation, attendees will be aware of toolmarks produced by double-broached Ruger® barrels, the process of conducting a blind validation study, pattern matching error rates, methods for distinguishing between subclass and individual characteristics on test fired barrels, acquisition techniques for bullets using three-dimensional (3D) confocal microscopy, and correlation procedures used to evaluate 3D topographies from test fired bullets. Test fires were examined from 15 double-broached Ruger® pistol barrels. Twelve barrels were manufactured within a single production run of a broach (run 9mm PSB 650), 10 being consecutively manufactured (designated CM 0-CM 9) and 2 selected from further down the production run (designated CM 22 and CM 33). Three barrels/pistols were selected from the FBI FTU Reference Firearms Collection (RFC) and are designated D1893, D1925 and D1994. Each test set contained 12 fired bullets, including at least one matching pair from four or more production run barrels and one or more matching pairs from RFC pistols. Each test set also contained an instruction sheet and an answer worksheet which insured all 66 bullet comparisons were completed for each test set. This was a blind validation study because test sets were placed into a room where the test administer could not see participants pick-up/return the test sets, participating FTU examiners were not provided with any information in regard to the origin of bullets in the test sets (there where no "known's"), and the nature of the answer worksheet ensured the test administer could not tell which examiner completed the worksheet. Upon return of the test sets from examiners, a 3D topography of each individual land from every test bullet was acquired using a Sensofar® S neox confocal microscope which provided a total of 360 (5 tests, 12 bullets, 6 lands each) acquired 3D topographies for comparison analysis. The 3D topographies were analyzed with the application of a cross-correlation function (CCFMAX) which provided an objective numerical value that represents the similarity between two topographies. The numerical values were used to determine if there was significant and sufficient variation of individual characteristics between two test fires to correctly render a conclusion or if there were subclass characteristics present which would prevent a conclusion from being correctly rendered. Results from the examiners conclusions using traditional comparison microscopy were compared to results obtained using confocal microscopy combined with CCFMAX.
Conclusions This presentation will affect the forensic science community by supporting traditional means of pattern matching methods for identification and by beginning to establish/develop an objective nontraditional means to evaluate the rendering of an identification. Additionally, this presentation will serve as confirmation to the firearms/toolmarks theory of identification that the extent of sufficient agreement of individual characteristics occurring in toolmarks produced by the same tool exceeds the agreement which occurs in toolmarks produced by different tools. The presentation will also inform the forensics community to applications of an emerging technology within comparative based disciplines.
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Erich D. Smith and Jennifer Stephenson, MSFS, MS[1]

Comparing 6000 Consecutively Fired .40 S&W Bullets and Cartridge cases from a Sig Sauer P320 Pistol Utilizing Three-Dimensional Imaging and Objective Comparative Analysis

AFTE Training Seminar 2016

Abstract

Following the presentation, attendees will be aware of the acquisition techniques used by two types of three-dimensional instruments (Sensofar and Cadre Forensics) and one 2D+D instrument (Evofinder), the correlation procedures used to interpret the data collected from test fired bullets and cartridge cases, the application of the results as it relates to firearms identification, variations occurring throughout the sequence, and interpretation of the variations.

A total of 6000 cartridges were consecutively fired for this study over a period of two weeks. Of the 6000 cartridges, 342 were collected for analysis. Cartridge sets of 1-10, 91-100, 491-500 and 991-1000 were collected and inter-compared for each 1000 cartridge interval. In addition to the multiple test fire sets, every 50th cartridge was collected. No parts of the pistol were cleaned until after cartridge 6000 was fired. The first test was used as reference sample for comparative analysis against all the subsequent test fires. Prior to the three-dimensional image acquisition, the bullets and cartridge cases were laser etched with a unique identifier and cleaned with acetone. Images of land impressions on the bullets were acquired using confocal microscopy and analyzed with the application of a cross-correlation function. Both the cross-correlation and bidirectional reflectance distribution functions provided objective numerical values representing the similarity between two samples topography. The numerical values were used to determine if there was significant variation of individual characteristics over the sequence of test fires and whether or not the variations would prevent a result of identification from being rendered. The bullets and cartridge cases were also examined by several firearms/toolmarks examiners to determine if they were still identifiable by traditional means. Photographs of the pistols barrel and breech face were taken prior to firing and at every 1000 round interval. These photographs serve as an additional indication of variation of individual characteristics over the sequence of test fires due to wear. The photographs also indicated the extend of buildup of brass, lead, and other residues over the lifetime of the pistol without cleaning.

Conclusions

This presentation will affect the forensics science community by establishing/developing an objective means to evaluate an identification and serve as confirmation to the firearms/toolmarks theory of identification that the extent of sufficient agreement of individual characteristics occurring in toolmarks produced by the same tool exceeds that agreement which occurs in toolmarks produced by different tools. The presentation will also inform the forensic community to applications of emerging technologies within comparative based disciplines.

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Cristina Cadevall, PhD[1,2]

New Automated Composite Comparison Score for Bullet Analysis Using High Resolution Optical 3D Surface Metrology

AFTE Training Seminar 2016

Abstract

It is a general goal in the firearm and tool mark analysis sciences to provide quantifiable, objective information to assist the examiner with routine casework. Three-dimensional measurements of bullet

surfaces enable quantifiable mathematical comparisons between any two surfaces, which can supplement traditional comparison microscopes or 3D virtual microscopy, which provide qualitative information. We have defined a methodology for the firearms examiners to extract Individual Characteristics (IC) surfaces from accurate topographic measurements of bullet land surfaces. With this step they filter out class characteristics and select the region of interest. Resulting IC surfaces are saved and used for automated batch analysis making it possible to reduce the processing time for comparisons and to provide easy to interpret scores. We obtain a comparison score for a pair of IC surfaces using cross-correlation of mean profiles. We have found out that known non-matches (KNM) pairs have low comparison values but not all known-matches (KM) pairs have high comparison values. If we would use only this value there is a risk of false negatives. We have analyzed different ways to combine comparison scores of all pairs of IC surfaces from two bullets and have created a composite comparison score that shows a very good degree of discrimination between KNM and KM bullets. Thus we can calculate a safer single value for comparison between two bullets and we can define thresholds to obtain a list of probable matches between bullets.
Results and Conclusions We run a blind test using the James Hamby study (download from NIST Research Ballistics Toolmarks Database) and correctly identify 100% of unknowns with no false positives. Extraction of IC surfaces for 35 bullets takes 2 hours for a trained examiner, about 3 minutes per bullet. Automatic comparison of 15 unknown bullets against the 20 known bullets (10,800 pairs of IC surfaces), takes about 4 seconds, without human intervention. The new composite comparison score for bullet analysis makes it possible to automatically process large batches of bullets for comparison and provide the examiners with a list of probable bullet matches by applying filtering criteria on comparison scores.
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Other references

John Song[1]
Proposed "NIST Ballistics Identification System (NBIS)" Based on 3D Topography Measurements on Correlation Cells*
AFTE Journal - Volume 45 Number 2 - Spring 2013
Abstract The National Institute of Standards and Technology (NIST) has proposed a "NIST Ballistics Identification System (NBIS)" to facilitate accurate ballistics identifications and fast evidence searches [1]. The NBIS will use three-dimensional (3D) topography measurements for ballistics identification and evidence searches. The 3D topographies will be subdivided into arrays of correlation cells in order to help identify "valid correlation areas" and eliminate "invalid correlation areas" from the matching and identification procedure. "Synchronous processing" is proposed for correlating dozens or even hundreds of cell pairs at the same time. Based on the concept of correlation cells, a "Contiguous Matching Cells (CMC)" method using three identification parameters of the paired correlation cells

(cross correlation function maximum CCFmax, spatial registration position in x-y and registration angle θ) is proposed for high accuracy ballistics identifications. Based on the proposed CMC method, a "National Ballistics Evidence Search Engine (NBESE)" is also proposed for fast and accurate ballistics evidence searches.

The proposed NBIS and NBESE can be used for correlations of both geometrical topographies and optical intensity images, and can be potentially applied for all case scenarios of fired bullets, cartridge cases and toolmarks. All the parameters and algorithms will be in the public domain and subject to open tests. An error rate reporting procedure will be developed that can greatly add to the scientific support for the firearm and toolmark identification specialty, and give confidence to the trier of fact in court proceedings. Both the NBIS and NBESE will be engineered to employ publicly available software and database file protocols, and provide published search algorithms and statistical models. In this way interoperability between different ballistics identification systems using this invention can be more easily achieved. This interoperability will make the NBIS and NBESE suitable for ballistics identifications and evidence searches with large national databases, such as those of the National Integrated Ballistic Information Network (NIBIN) in the United States, as well as national databases in the European Network of Forensic Science Institutes (ENFSI).

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John Song[1]

Proposed "Congruent Matching Cells (CMC)" Method for Ballistic Identification and Error Rate Estimation

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Abstract

The 3D measurement and correlation on "correlation cells" were proposed at the National Institute of Standards and Technology (NIST) for establishing the NIST Ballistics Identification System (NBIS) [1]. Based on the concept of correlation cells, a Congruent Matching Cells (CMC) method is proposed for accurate ballistic identification and error rate estimation using three sets characteristic parameters of the paired correlation cells: cross correlation function maximum CCFmax, spatial registration positions in x-y and registration phase angle θ. The proposed CMC method can be used for correlation of both geometrical topographies and optical images. The "congruent matching" method can be potentially applied for all case scenarios of fired cartridge cases, fired bullets, and toolmarks. The CMC parameters and algorithms are in the public domain and subject to open tests. High-speed correlations are ensured by "synchronous processing" of multiple correlation cell pairs at the same time. Based on the CMC method, an error rate procedure is proposed for establishing a statistical foundation to support nationwide ballistics identifications in forensic science, and to provide an error rate report for court proceedings in a manner similar to the method used for reporting the Coincidental (Random) Match Probability (CMP) in forensic identification of DNA evidences.

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Topography measurements and applications in ballistics and tool mark identifications

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Abstract

The application of surface topography measurement methods to the field of firearm and toolmark analysis is fairly new. The field has been boosted by the development of a number of competing optical methods, which has improved the speed and accuracy of surface topography acquisitions. We describe here some of these measurement methods as well as several analytical methods for assessing similarities and differences among pairs of surfaces. We also provide a few examples of research results to identify cartridge cases originating from the same firearm or tool marks produced by the same tool. Physical standards and issues of traceability are also discussed.

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Proposed Congruent Matching Profile Segments (CMPS) Method for Bullet Signature Correlations

AFTE Training Seminar 2016

Abstract

A Congruent Matching Profile Segments (CMPS) method is proposed at NIST for bullet signature correlation and error rate estimation. The captured 3D topographies on the land engraved areas (LEA) are processed by striation edge detection. The resulting 3D striation signatures are compressed into 2D profiles for representing the individual characteristics of bullet LEAs.

The CMPS method is based on the principle of discretization. Each compressed profile of the LEA is divided into profile segments for accurate correlation using four identification parameters: the cross correlation function, the twist angle, the index number of correlated LEA, and the series number of correlated profile segments at each LEA.

For any correlated profile segments pair, if the four identification parameters are within the range of thresholds, it is considered as a CMPS. For any correlated bullet image pair, if the CMPS number is large enough, say, CMPS ≥ 6, it can be concluded that this image pair is from the same source.

A set of test bullets fired from 10 consecutively manufactured gun barrels including 10 pairs of KM bullets for training and 15 unknown bullets for tests. The total correlations include 46 known-matching (KM) and 549 known non-matching (KNM) comparisons with a total of 595 image pairs correlated by the CMPS method. Each pairwise bullet image correlation consists of 6x6 land comparisons. Two methods are used for calculating the CMPS scores. In both cases, there is a significant separation between CMPS scores of KNM and KM distributions, which means no false identification of false exclusion occurred.

Conclusions

Based on the principle of discretization, the CMPS method is proposed for bullet signature correlation using four identification parameters. Initial tests have shown that the CMPS method doesn't show any false identification and false exclusion. The CMPS method also enables an approach to estimating error rates based on statistical fitting of CMPS distribution models, and statistical analysis of the total number o the profile segments N, the number of Congruent Matching Profile Segments CMPS, and the statistical distribution of the identification parameters.

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