B118 Toward a Novel, Fast, and Accurate 3D-Topography Imaging and Analysis System for Firearm Forensics

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After attending this presentation, attendees will be familiar with a novel 3D imaging and analysis system, the image acquisition technology, and the results of several cartridge casing matching experiments. This presentation will describe TopMatch-GS 3D, an accurate, fast, and low-cost 3D imaging and analysis system for cartridge casings.[1,2]

This presentation will impact the forensic science community by educating attendees on the latest generation of technology for 3D tool mark imaging and analysis. The use of a confidence score and interpretable match results will provide practitioners with a firm foundation on which to place identification results.

The work proposes that the 3D scanning system, TopMatch-GS 3D, is capable of acquiring high-resolution surface scans, visualizing these scans, and accurately comparing/matching pairs of casing scans. The study investigated if the matching algorithm is capable of recognizing known matches with high accuracy while keeping the rate of false positives to near zero.

The prototype TopMatch-GS 3D scanner incorporates the GelSight® retrographic sensor to measure 3D surface topography at a resolution of 1.4 microns per pixel.[3,4] The system was evaluated on a large data set containing casings from several hundred 9mm Luger® firearms, representing more than 20 firearm manufacturers and seven ammunition types. The firearms come from several crime laboratory reference collections and were not selected on their ability to produce strong tool marks. The casings represent the types of evidence and test-fires seen in a real-world setting. They contain milled, filed, granular, and striated marks as well as poorly marked casings. Data collection took place both in-house and at several collaborating California crime laboratories. Participants across these locations include trained firearms examiners, technicians, forensic science students, and university faculty.

The algorithm's match score is a function of the similarity between the casings' true breech-face impression and their aperture shear. For breech-face impression comparison, automatically identified distinctive features (corresponding to informative microscopic tool marks) are used to match and align two casings. By requiring spatial coherence of matched features, the methodology is able to strongly indicate when two casings were fired through the same firearm. In contrast to cross correlation-based methods, feature-based techniques compute the match score using only the portions of the surface identified as informative (i.e., the matching microscopic tool marks). The algorithm compares aperture shears by first extracting the linear shear profile and then aligning two profiles while accounting for baseline correction and warping.

The scoring function is a confidence score where each candidate match (pair of casings) is scored based on the likelihood that the two casings were fired through the same firearm. Unlike other systems, the TopMatch score reflects the true confidence of the match. The confidence score allows examiners to efficiently limit their search. In other words, examiners only need to consider candidate matches that score above a threshold.

The TopMatch system is able to match casings with high accuracy. True positives (known matches) have extremely high scores while true negatives (known non-matches) have low match scores. There are virtually no false positives (i.e., known non-matches mistakenly identified as a match).

The TopMatch-GS 3D imaging and analysis technology represents a promising new method for measuring and correlating the true 3D surface topography of cartridge casings. The results from several deployment studies and the large set of real-world casings demonstrate accurate matching results with an extremely low false positive rate (near zero as of the time of this writing).

References:

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2. Lilien, Brubaker, Duez, and Weller. "Progress Towards a Novel 3D-Topography Imaging and Analysis System for Firearm Identification, TopMatch-GS 3D" The Association of Firearm and Tool Mark Examiners (AFTE) Annual Training Seminar (Seattle), 2014.
3. Johnson and Adelson. "Retrographic Sensing for the Measurement of Surface Texture and Shape." Proc. of the IEEE Conf. on Computer Vision and Pattern Recognition (CVPR), 1070-1077, 2009.
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Firearm Forensics, Tool Mark Analysis, 3D Surface Topography