B109 The Impact of Bullet Caliber and Composition on the Statistical Distribution of Non-Match Scores Based on High-Resolution Topography Measurements

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Learning Overview: The goal of this presentation is to present the recently developed firearm identification method, based on high-resolution topographic data, for the comparison of fired bullets. Attendees will better understand the 3D profile-based (or pattern-matching) approach and the line-counting approach, as well as the systematic effects of different calibers and bullet compositions on the behavior of the statistical distribution of bullet similarity measures.

Impact on the Forensic Science Community: This presentation will impact the forensic science community by providing an understanding of the complementarity of the pattern-matching and line-counting perspectives for the analysis of bullet topographies. Additionally, this study will present the results that constitute an in-depth analysis of the systematic effects of bullet caliber and composition on the behavior of similarity measures.

High-resolution 3D acquisition technologies have been a catalyst for the development of quantitative analysis of toolmarks present on cartridge cases and bullets, with the aim of overcoming the limitations inherent in direct observation under a comparison microscope and reflectance (2D) image analysis. As most bullets have several regions of interest (Land Engraved Areas [LEAs]), a difficulty specific to the development of bullet comparison algorithms is the need to compare all available pairs of LEAs and then produce a score that quantifies the overall similarity of the two bullets being compared. It is therefore necessary to determine relevant similarity measures for LEA pairs and combine the resulting set of scores into a global similarity measure.

Over the past few years, a bullet comparison algorithm that considers the pattern-matching and line-counting approaches has been in development. Each LEA pair comparison produces four scores, two of which are profile-based (pattern matching), while the other two are based on line counting. The set of score values resulting from all LEA-to-LEA comparisons is used to determine the best phase between the two compared bullets. The Pattern Matching Score (PMS) is then defined as a combination of the best Cross-Correlation Function (CCF) and Absolute Normalized Difference (AND) values at this phase; similarly, the Line Counting Score (LCS) is defined as a combination of the best scores for peaks and valleys at this phase. The original analysis performed in 2018 using a dataset of 9mm copper-jacketed bullets enabled the definition of a False Match Rate (FMR) function on a 2D plot that shows both similarity scores for matches and non-matches.

To refine this study, 65 known match pairs were acquired using a 3D sensor based on a non-linear photometric stereo technique, for each of five calibers with conventional rifling: 9mm, .25 Auto, and .45 (copper-jacketed) and .22 and 357 (lead). All known match pairs were analyzed using a virtual comparison microscope prior to numerical analysis in order to define the subset of pairs that could actually be identified. The match and non-match statistical distributions of scores and the FMR function were for each dataset. This study found that the five non-match probability densities could be extrapolated with an exponential distribution where non-match data is missing and match data is available. A typical FMR value that discriminates between low and high levels of visual similarity was found to be 1/10,000 for each of the five calibers. Most visually matching pairs are found at FMR values lower than 1/10,000. A significant finding is the sensitivity of the non-match score distribution (and its corresponding FMR function) to the caliber and composition of the bullets. Research avenues are proposed to significantly reduce this variability, with promising preliminary results.

Firearm Identification, Bullet Topography Measurements, False Match Rate