A103 Statistical Firearm Correlation Analysis

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After attending this presentation, attendees will learn about the mathematical techniques of auto- and cross-correlation as applied to images from tool marks, more specifically with the markings left on shell casings as they are ejected from a weapon. The correlations will be followed by a statistical analysis that can aid a forensic examiner in comparative analysis. This analysis will enable a quantitative score with confidence intervals when comparing images of tool marks.

This presentation will impact the forensic science community by demonstrating mathematical techniques to make quantifiable statements regarding the confidence of comparative analysis.

Cross-correlation is a mathematical technique that compares the similarity of two sets of data and is often used in pattern recognition algorithms. The cross-correlation is calculated by shifting one data set with respect to another, multiplying the two data sets and summing the result. The technique is insensitive to amplitude and background and is invariant under translation. Because of these features, the cross-correlation is a powerful technique that can be used to quantify the similarity of two samples. Once the similarity of the evidence is quantified, the data can be presented at court using statistics. Quantifiable comparative analysis will strengthen the evidence presented at trial because the evidence is not solely dependent on the opinion of the forensic examiner, but based on quantifiable statistical techniques. Ultimately a national database of shell casings and bullet rifling could be developed and searches made to find and make linkage between forensic evidence found at a crime scene and previously collected data.

A firearms examiner examined and recorded all of the data used in this experiment. First, the examiner observes a shell casing under 40x magnification and notices unique markings that can be exploited using cross-correlation. Several images of this area are recorded of this shell casing and of shell casings from a different weapon of the same make and model. Using a Graphical User Interface (GUI) developed in MatLab, the examiner selects the region of interest in the image. The region of interest is then cut out of the image and the color information is converted to grayscale. The grayscale image is then normalized with a zero mean. Typically, the examiner can accurately align the horizontal striations to the pixels in the image when the photograph is made; however, if any rotations are needed, they can be accomplished by the software. Since the striations are aligned horizontally, average pixel intensity is calculated for each row in the selected area. This reduces the dimension of the problem to 1-D; the average pixel brightness across the striations. A normalized cross-correlation can be calculated in order to compare the similarity of the striations. Normalization is a crucial step in comparing cross-correlations because it provides a means of calibrating one "yardstick" versus another — otherwise the comparisons would be meaningless. A useful method for normalizing the cross-correlation is to divide the cross-correlation by the square-root of the auto-correlations. The auto/cross-correlation between photos of the same shell casing should be nearly one; whereas the shell casings from different firearms are expected to have cross-correlations significantly less than one. A statistical significance can be determined by comparing the means of the correlations of the same shell casings versus the correlations of the different shell casings use a z-score and a student's t distribution, since there are few images to compare. The null hypothesis is the difference in the means of the correlations. A p-value can be calculated based on the means, standard deviations, and number of samples. The null hypothesis that the two data sets have the same means can then be either accepted or rejected based on a predetermined significance level.

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Cross-Correlation, Firearms, Comparative Analysis

