A61 Shape Measurement Tools in Fingerprint Analysis: A Statistical Investigation of Distortion

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The goal of this presentation is to examine one of the concerns stated in the 2009 National Academy of Sciences Report (NAS), that of shape change (distortion) of a print as it is impressed on various substances with different mechanics of touch (i.e., pressure).

This presentation will impact the forensic science community by describing statistically the changes that occur when a print is impressed on different substances under varying pressures. This will allow for a quantifiable means to describe shape change of a fingerprint relative to these variables.

In the 2009 NAS report summary assessment on friction ridge analysis, it was stated that the impression left by a finger would invariably change each time due to degree of pressure used and impression medium touched. As per the NAS report, "None of these variabilities – of features across a population of fingers or of repeated impressions left by the same finger – has been characterized, quantified, or compared." It was the goal of this project to investigate the latter portion of this statement.

A well-developed method to study shape change is that of geometric morphometric analysis (GM). This involves the placement of landmark points on digital images. The data from the images is extracted and compared statistically, allowing for multivariate quantitative comparison.

Shape information can be visualized by plotting landmark positions in Procrustes superimposition. Procrustes distances can be used to summarize variations in populations, to express the degree of similarity of individual specimens, means of populations, or to search for matches between specimens.

The tools available for statistical analysis include Principal Component Analysis (PCA) with which the principal variations of shape can be plotted and visualized. This allows for determination of which shape aspect is responsible for the most variation and reveals patterns of covariance or related structure in data. Canonical Variates Analysis (CVA) can also be used to determine if shape information is distinguishable between different categories of data. CVA is a multi-axis discriminant function and it attempts to sort individuals into groups based on multivariate measurements.

It was the goal of this project to determine if these methods would translate to fingerprints describing changes in a print relative to pressure and substrate. A series of fingerprints were acquired from a volunteer who is also a fingerprint examiner. These prints were impressed on 10 print cards, computer paper, soft gloss photographic paper, and retabs. Each series was impressed with heavy pressure, normal pressure and light pressure. Ten prints were obtained in each series for a total of 114 prints of the same finger under the varying conditions of substrate and pressure.

The prints were then scanned on a flatbed scanner with a calibrated ruler in place and digital images created (1000dpi). Eighteen (18) landmarks were placed on the print and two on the scale for reference with tpsDig freeware. The landmarks were chosen at points of minutia that maximized the area of the entire print. The data was then extracted and the prints compared statistically with IMP freeware. Repeated measures were used to determine the variance, which was described by Root Mean Square (RMS) as the data was multivariate and not normally distributed.

Results indicated that there was a high degree of reproducibility of the prints at the varying substrates and pressures as the variance was very low at 0.000886 with an RMS of 0.029. PCA analysis determined that 56% of the variance in the prints can be seen in movement of the ridge structure in the fingertip portion of the print while the bottom portion remains almost stationary.

CVA plots of scores can separate specimens into groups (i.e. by pressure+ substrate). Cross-validation estimates of assignment tell how effectively the measurements are in performing this task of assigning specimens to groups. There was a high correct assignment to pressure based on substrate in all groups except the 10 print cards where the results were not pronounced, indicating that 10 print cards are relatively immune to pressure affects. Substrate differences were always detectable, an effect which increased with increasing pressure.

As per the NAS report, "Formal research could provide examiners with additional tools to support or refute distortion explanations." This study is a beginning attempt to understand affects of substrate and pressure on distortion of a fingerprint.

Forensic Science, Fingerprints, Geometric Morphometric Analysis

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