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Supporting fingerprint identification assessments using a skin stretch model — A preliminary study

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ABSTRACT

To support fingerprint expert opinion, this research proposes an approach that combines subjective human analysis (as currently applied by fingerprint practitioners) with a statistical test of the result. This approach relies on the hypothesis that there are limits to the distortion caused by skin stretch. Such limits can be modelled by applying a multivariate normal probability density function to the distances and angle formed by a marked ridge characteristic and the two closest neighbouring minutiae.

This study presents a model tested on 5 donors in total. The "expected range" of distortion in a within-source comparison using 10 minutiae was determined and compared to between-source comparisons. The expected range of log probability densities for within-source comparisons marked with 10 minutiae was determined to be from −33.4 to −60.0, with all between-source data falling outside this range, between −83 and −305.

These results suggest that the proposed generated metric could be a powerful tool for the assessment of fingerprint expert opinion in operational casework.

1. Introduction

Fingerprint identification, as currently practiced by examiners, is a subjective evidence form in which a fingerprint examiner, based on their training and experience, is required to provide an expert opinion on a comparison of minutiae to determine whether a fingermark was created by a certain person as opposed to some other person. For the majority of the 20th Century, such testimonies have been very rarely challenged. However, in the wake of the Daubert decision by the Supreme Court in the USA, concerning expert evidence admissibility [1] and the 2009 report of the US National Academy of Sciences (NAS) [2], there have been a number of questions raised regarding the scientific validity of forensic fingerprint identification [3–8][1]. It has been recently argued that the criticisms are largely due to the absence of a scientifically sound probabilistic framework for fingerprint evidential assessment agreed upon by the forensic science community [9]. It is beyond the scope of this article to discuss the research into probabilistic frameworks for fingerprint identification as this study does not seek to evaluate the strength of the evidence or to provide a likelihood ratio. The reader is directed towards the recent review by Neumann [10]. This study proposes a tool to assist practitioners in the testing of their subjective comparative assessment in operational casework.

In the practice of fingerprint examination, one general protocol aimed at minimizing the risk of errors and providing a measure of quality assurance is broadly accepted: ACE-V (analysis, comparison, evaluation and verification) [11–13]. As stated by Neumann et al. [14]: "*Without doubt, forensic fingerprint examination has an extremely low rate of misidentification and has demonstrated a tremendous contribution to criminal investigations. Nevertheless, the inherent subjectivity and lack of transparency of the decision-making at each stage of the ACE-V process exposes it to constant challenges and criticisms*". Their recent 2-year study involving 146 fingerprint examiners and trainees showed a lack of standardisation with

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[1] On Page 88, Ref. [7] specifically quotes "There are also nascent efforts to begin to move the field from a purely subjective method toward an objective method—although there is still a considerable way to go to achieve this important goal."

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respect to many aspects of friction ridge skin examination, including factors such as distortion, degradation, and influence of background and development techniques [14]. This is unfortunate as these factors are often used to explain the differences observed between the fingermark and the control fingerprint. It is suggested that an additional level of confidence in the experts' decision could be provided by an impartial measure of distortion.

Research has recently been undertaken by Kalka and Hicklin [15] to visualise, characterise and even correct distortion once it has been identified by the practitioner. This study, however, seeks to determine the range of distortion that can be expected from marks made by the same finger (within-source comparisons) and to use this information as a tool to assist the expert with their decision. The model used in this study requires the examiner to perform a comparison as currently undertaken by fingerprint practitioners, thus maintaining the current expert analysis component, but where positional data sets for the marked minutiae are subsequently extracted and subjected to statistical analysis using a multivariate normal probability density function.

The underlying hypothesis is that

friction ridge skin has a stretch limitation and, therefore, corresponding minutiae between a mark and the control fingerprint left by the same finger will vary in their relative positions but within limits.

In other words, the variations in positions of minutiae from within-source comparisons should fall within a threshold range. Proximal minutiae should not change their relative positions beyond a determinable amount. By extracting the positions of the minutiae marked by the expert, it is possible to then test the variations in positions to assess whether the comparison made by the expert falls within this range, supporting the hypothesis of a within-source comparison, or falls outside this range, supporting the hypothesis that the fingermarks came from different sources (between-source comparison).

In order to do this, the positional data (distances and angles between minutiae) were modelled using a multivariate normal probability density function. This translated into a calculation of joint probability densities of all minutiae occurring in the observed configuration given that the compared mark and print came from the same source.

The aim of this study was to find the range of tolerance for within-source comparisons by intentionally inducing distortion into fingermark images known to have originated from the same source and determining the range of resulting probability densities.

2. Material and methods

2.1. Image collection

An initial set of images was collected during a pilot study [16]. These images were collected by placing the finger to be examined on a prism taking advantage of Frustrated Total Internal Reflection [17], and photographing the contact area of the friction ridge skin. These images were processed before data extraction to overcome foreshortening caused by the arrangement of the camera, lens and prism. The additional images required for the extended study were collected using a Futronic FS60 Ten Print Scanner and Futronic Scan Demo Software v.21 with no additional image processing. Each image was loaded into a program developed for this study, called TouchBase, which allowed for visualisation, comparison and analysis of the images.

For both the pilot and extended studies, both within-source and between-source comparisons were undertaken. Within-source comparisons are performed between fingermarks that are known to originate from the same person and finger, while between-source comparisons are performed between fingermarks that are known to originate from different fingers. Within-source images were collected by first collecting an "undistorted" reference image of a finger, followed by the collection of multiple images of the same finger with induced distortion. This distortion was induced by placing the finger onto the scanning surface with as little distortion as possible and then either rotating or displacing the finger while maintaining contact with the scanner surface to stretch the skin and cause distortion. Each donor was asked to donate 190 images, 19 per finger, which were broken down as follows:

1. A single undistorted reference image.
2. Five images with a progressive clockwise rotation of the finger. The first of these five was at 0°, providing an undistorted image. The following four images were collected by rotating the finger to approximately 11°, 22°, 33° and 44°, respectively.
3. Five images with a progressive counter-clockwise rotation. As with the clockwise images, the first of these five was with 0° rotation, providing an undistorted image. The following four images were collected by rotating the finger to approximately −11°, −22°, −33° and −44°, respectively.
4. Two images as part of a downwards shift. The first was taken without displacement and the second collected by pushing the finger downwards without slipping.
5. Two images as part of a left shift. The first was taken without displacement and the second collected by pushing the finger left without slipping.
6. Two images as part of a right shift. The first was taken without displacement and the second collected by pushing the finger right without slipping.
7. Two images as part of an upwards shift. The first was taken without displacement and the second collected by pushing the finger upwards without slipping.

Each of the images was then compared to the initial undistorted image, resulting in 18 within-source comparisons per finger. The degrees of rotation were taken with 0 being in the centre of the bottom of the scanner and 11° as having the finger rotated 11° to the left. These angles of rotation were chosen as it was found that this represented the maximum range of rotation achievable with a 'realistic' force before the finger slipped on the scanner surface. This process has been summarised in Table 1.

Between-source comparisons were obtained by searching the donor's marks against reference fingerprint holdings of the Australian Federal Police (AFP) on the National Automated Fingerprint Identification System (NAFIS) and selecting a number of nominated non-matching candidates. NAFIS search marks and prints nominated as candidates had all "corresponding" minutiae marked by the NAFIS. Images from the NAFIS were obtained by extracting the mark and print images from a screen capture of the NAFIS comparison screen scaled to 1000 DPI. All images acquired using the prism and NAFIS were also scaled to 1000 DPI before data extraction. Due to restrictions placed on the use of the available NAFIS database, between-source comparisons could only be conducted using search prints from the one donor used in the pilot study [16].

The images collected for the pilot study were re-examined in the extended study along with an additional 4 donors, resulting in a total of 5 donors providing 950 images and 9000 data points.

2.2. Data extraction

While the pilot study considered a varying number of nominated minutiae, the study presented here focussed on the assessment of comparisons using 10 minutiae only. This number of minutiae was selected because it provided statistically useable