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Determination of AFIS "sufficiency" in friction ridge examination

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ABSTRACT

Fingerprints have been used with considerable success over the past century in multiple civil government, law enforcement and criminal investigation applications. Since the 1970s, computer assisted systems (AFIS – Automated Fingerprint Identification System) have been increasingly used to automatically compare fingerprints and propose associations between multiple friction ridge impressions of known or unknown sources. AFIS were initially entirely subordinated to human examiners. Improvements in the matching algorithms and workload considerations have pushed agencies to implement completely automated processes, known as "Lights-out" modes, where AFIS's render unsupervised conclusions on the donors of the queries. Such fully automated process is common for tenprint-to-tenprint comparisons; however it is currently not being widely adopted for other types of comparisons, such as latent print-to-tenprint comparisons.

In this paper, we explore a statistical model that can be used to facilitate the latent print examination workflow by predicting whether any latent print should be searched in AFIS. In particular, we are interested in preventing poor quality latent prints to be searched in vain, and thus unnecessarily consume resources. Ultimately, we show that our model could be used to efficiently manage workflow and workload by categorizing latent prints as a function of the quality and quantity of information that can be observed on them, which enables examiners to select the most appropriate examination and quality assurance processes for each print.

1. Introduction

The skin of fingers, toes, palms and soles of human beings displays papillary ridges, also known as friction ridges. Impressions of friction ridge skin patterns of the finger left inadvertently on surfaces are commonly referred to as fingermarks (or latent prints in the U.S.), while finger impressions captured under controlled conditions are known as fingerprints (or control prints in the U.S.).

Fingerprints have been used with considerable success over the past century in multiple civil government, law enforcement and criminal investigation applications. Conceptually, the use of fingerprints in these contexts relies on the pairwise comparison of finger impressions in order to determine if they originate from the same person. Different situations will focus on pairwise comparisons between fingerprints only, fingermarks and fingerprints, or fingermarks only. For instance:

(1) The verification or determination of the identity of a given individual may be performed by comparing fingerprints taken from that individual and fingerprint records associated to individuals with known and undisputed identity (Tenprint to Tenprint comparisons – TP-to-TP);
(2) The determination of the identity of an offender may be performed by comparing fingermarks recovered on a crime scene and fingerprint records associated to individuals with known and undisputed identity (fingermark to Tenprint – LP-to-TP);
(3) Prints of newly arrested individuals may be compared to sets of fingermarks recovered on the scenes of previously unsolved crimes (Tenprint to fingermark comparisons – TP-to-LP), And multiple crime scenes or offences may be associated to each other by comparing fingermarks recovered at each one of them (fingermark to fingermark comparisons – LP-to-LP).

The pairwise comparison of finger impressions relies on the detection and comparison of different characteristics of the friction ridge skin pattern. These characteristics encompass elements, such as (a) the general pattern of the ridge flow; (b) the presence, spatial

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relationships and types of ridge events (also known as minutiae); and (c) the presence, shape, size, and (respective) location of the shape of ridge edges and pores [1].

Historically, comparisons and searches through reference fingerprint collections have been mostly performed manually by fingerprint examiners, who were responsible for forming conclusions on the commonality of the source of pairs of impressions. Since the 1970s, computer assisted systems (AFIS – Automated Fingerprint Identification System) have been increasingly used to perform TP-to-TP, LP-to-TP, TP-to-LP and LP-to-LP comparisons [2].

As with the manual process, fingerprint examiners were initially entirely responsible for forming conclusions based on candidates suggested by AFIS's. Improvements in the matching algorithms and workload considerations have pushed agencies to implement completely automated processes, known as "Lights-out" modes, where AFIS's render unsupervised conclusions on the donors of the queries.

"Lights-out" generally refers to the ability of the system to operate without human intervention. [2] The use of a fully automated process is common when comparing or searching high quality fingerprints (such as in TP-to-TP comparisons); however, it is currently not being widely adopted when comparing or searching fingermarks (such as in LP-TP). Indeed, comparisons involving only fingerprints rely on the extremely large quantity of good quality information present on both query and reference fingerprints. This amount and quality of information ensures the appropriateness of the candidates returned by the AFIS algorithm [3]; conversely, comparisons involving potentially degraded and distorted fingermarks are much more difficult to resolve automatically [4] and still generally require an examiner to carry out the examination process: latent print encoding, candidate print comparison and forming conclusion.

The decision to search a given fingermark in an AFIS is currently based on the determination that the fingermark bears *sufficient* quantitative and qualitative information, such that the AFIS algorithm will be able to find its correct source if that source is in the AFIS database. This determination is very similar to the determination of suitability performed by fingerprint examiners during the initial stage of the manual examination of fingermarks (sometimes known as the Analysis stage of the Analysis, Comparison, Evaluation and Verification process – ACE-V) [1].

In both examination processes (manual and AFIS), the analysis stage is essentially designed to identify and potentially filter out fingermarks of low quality. On the one hand, the analysis stage acts as a quality assurance step aimed at reducing the risk of errors in the subsequent stages of the examination process: (a) a low quality fingermark may never be compared/searched at all, thus the reporting of an erroneous conclusion can be avoided; (b) if it is compared/searched, the determination that the fingermark is of low quality may result in requiring additional quality assurance steps to ensure the appropriateness of the resulting conclusions. On the other hand, the analysis stage can also act as a workload management tool. This stage could be used to identify or filter out low quality fingermarks, which examination/search may require significant amount of time, and which may not provide fruitful results.

In the context of AFIS, entering and searching fingermarks of sub-par quality has the following consequences:

(1) Correct sources may not be identified even if they are in the database. Thus, computational and human resources are wasted during the processing of fingermarks and review of candidate lists;
(2) The candidate lists returned by the system are more likely to contain close non-matching prints when low quality and partial marks are searched. Therefore, resources must be spent in the quality assurance process to differentiate between inconclusive, or exclusions and appropriate identification conclusions;
(3) Low quality fingermarks are stored as unmatched fingermarks and searched against every new fingerprint record or fingermark entered into the system. This process is known as reverse searches. The presence of sub-par fingermarks in the reverse searches database results in the waste of computational and human resources to process the reverse searches and review the sub-par fingermarks allowed to appear in the candidate list for each new entry of a set of reference prints.

The level of *sufficiency* of given impressions is determined by examiners based on their training, experience and several other factors discussed in recent research reports [5,6]. These research projects demonstrated significant variability between fingerprint examiners when determining the level of *sufficiency* of given impressions in the manual examination process: some impressions may be deemed suitable for comparison by some examiners, while they may not be deemed usable by others (see Fig. 1 (compiled from Figs. 23 and 24 in [5])). There is no reason to believe that this variability is not also present in the AFIS context.

This project was designed to study the feasibility of an objective measure for the determination of the *sufficiency* of fingermarks in the AFIS context with the view to:

(1) Reduce the variability between different examiners when assessing the quantitative and qualitative information present on fingermarks;
(2) Inform AFIS users of the pertinence of searching and storing any given fingermark, thus preventing sub-par fingermarks from congesting the system;
(3) Automatically determine the type of processing required for any given fingermark, thus increasing the efficiency of the overall forensic workflow and utilization of human/system resources by, for example, (a) enabling lights-out searches for higher quality marks; (b) using auto-encoding for medium quality marks; (c) queuing only lower quality marks for manual processing.
(4) Use the intrinsic qualitative and quantitative information present on the mark to adapt the type of quality assurance process required when reviewing candidate lists and forming conclusions.

Overall, this project aims at developing a proof-of-concept model for predicting the usefulness of searching any fingermark (i.e., it's *sufficiency* in the AFIS context), based on different intrinsic measures of quantity and quality, on the size of the AFIS database against which it will be searched, and on the length of the candidates list returned by the system (as defined by the user). Our proof-of-concept currently relies on the manual annotation of fingerprints by fingerprint examiners, as human detection of minutiae still outperforms automatic detection on poor quality fingerprint images. However, we plan to extend our work to automatic detection in the near future to propose a fully deployable system that will provide the full range of benefits in term of workflow and workload management, and objectivity.

2. Materials and method

During this project, a proof-of-concept model was created to predict the pertinence of searching any given fingermark (i.e., its level of *sufficiency* in the AFIS context) based on a series of intrinsic independent variables for that mark.