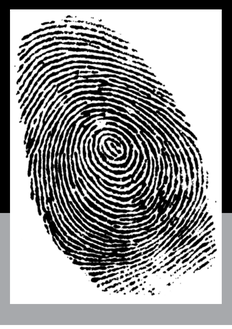
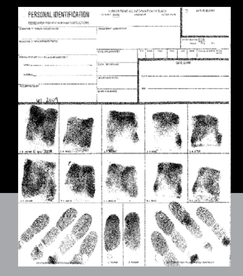


A Model Validation Scheme and Statistical Evaluation of a Fingerprint Search Program



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Introduction

In the midst of Daubert Hearings and challenges to meet the recommendations of the National Academy of Science's recent report on the forensic sciences, more emphasis is being placed on standardization and certifications. This applies to individual practitioners and methods they use. The accuracy of most instruments used in the lab must be certified by third parties and analytical instruments must be calibrated before use each day. This study presents a test protocol for fingerprint examiners to determine the accuracy and reproducibility of their own AFIS systems. This simple protocol tests software performance using known prints with known search outcomes. Accuracy and reproducibility that tested the AFIS search algorithm were

Learning Goals

Understand the rational of testing with known outcomes.
Develop a personal set of known test prints.
Determine the statistical performance of AFIS software.

Materials & Methods

Only the AFIS software was purchased, all other software was open source on a PC workstation running Microsoft's Windows XP operating system. Irfanview was used for graphics editing and batch file operations and Open Office.org Data spreadsheet application was used for data storage and mathematical calculations. Irfanview is a registered trademark of Irfan Siljan. Microsoft Windows XP is a registered trademark of the Microsoft Corporation and OpenOffice.org was produced by Oracle.

Software Operation

The AFIS software uses two categories of prints in its operations, the print being searched called the "Latent" or "Search Print" and the library of enrolled prints called the "Database." In the following experiments the latent print was always the test print being searched against the database. All tests were conducted using the scanned image with no additional image processing. Minutiae were extracted, recorded and searched according to the manufacturer's directions in the User's Manual. Once the minutiae were extracted and enrolled into the database the number and location of the minutiae remained unchanged for the search process.

Fingerprint Database Preparation

All prints in this study were inked prints that were applied to tenprint cards and scanned into lossless Tiff files at 600 dpi. Three databases were created:

1. A database containing only the duplicate of the latent search print.
2. A database of thirty tenprint cards of the same pair of hands contained 30 rolled and 30 slapped prints of the same finger, and 540 non-matching (False) prints.
3. A third database of individual prints that were the same prints found in the tenprint card database.

Latent Print Preparation

Using Irfanview graphics editor a single print from the tenprint card database was duplicated to be a latent search print. For example, the right hand index finger slapped print on card C61 (C61RIS) was one of the prints selected to be the latent search print. Because the identity of each latent search print was known, identification accuracy of true and false hits could be determined.

Results:

Expirement 1: AFIS Software Validation – Matching Duplicate Prints

This experiment tests the accuracy and reproducibility of the AFIS software's fundamental search algorithm. To minimize error caused by bad data, only a single print was enrolled in the database and its duplicate print was the latent search print. The expected outcome was a match on every search. The same search was repeated ten times resulting in ten matches. Two different sets of duplicate prints were searched in the same way resulting in matches in every case. The negative result of "No Match Found" indicating a software mistake was never encountered. Table 1 summarizes these results.

Table 1. **AFIS Software Validation – Matching Duplicate Prints**
Duplicate prints were chosen to be both the database and latent prints. Latent print C61RI is the right index rolled fingerprint from card 61 and C62LIS is the left index finger in the four finger slapped print group.

Print Name		Minutiae		Search Results	
Latent	Database	Latent	Database	Accuracy	Reproducibility
C61RIS	C61RISO	23	23	100% (30/30)	100% (30/30)
C62LIS	C62LISO	37	37	100% (30/30)	100% (30/30)

Table 2. **An example of original data is presented.**
Each search repetition is indicated by the number at the end of the latent print's filename.

Latent Print	Database Print	Finds Self	# Latent Minuti ae	1st on List
C62LISO	C62LIS1	Y	37-37	Y
C62LISO	C62LIS2	Y	37-37	Y
C62LISO	C62LIS3	Y	37-37	Y
C62LISO	C62LIS4	Y	37-37	Y
C62LISO	C62LIS5	Y	37-37	Y
C62LISO	C62LIS6	Y	37-37	Y
C62LISO	C62LIS7	Y	37-37	Y
C62LISO	C62LIS8	Y	37-37	Y
C62LISO	C62LIS9	Y	37-37	Y
C62LISO	C62LIS10	Y	37-37	Y

Conclusion AFIS Software Validation

The conclusion is that the software conducts minutiae extraction, database, enrollment, searches and comparisons accurately and reproducibly. This model of using known prints with known outcomes can be used by fingerprint examiners to test whether their own AFIS system is performing as expected. The following experiments shed light on search accuracy based on real-world prints.

Expirement 2: Search Performance

Just as the above experiment tested the accuracy and reproducibility of the software's fundamental search algorithm, the following experiments explore how accuracy and reproducibility are affected by different types of data.

Different Prints of the Same Finger – Tenprint Card Database

Because AFIS databases contain both matching and non-matching prints, the following experiments are an indicator of search performance. There were thirty tenprint cards all of the same pair of hands, each card containing a rolled and a slapped print of the same finger. Along with 540 False prints the database contained 30 rolled, 29 slapped and the duplicate prints that were all True candidates matching the latent print. The expected search result is a list of tenprint cards in which each card contains two candidate prints. However, the AFIS software is limited to choosing the best match and disregards multiple potential candidates on the same card. Therefore, only a single match per card is selected as a possible matching candidate print. This software constraint automatically cuts the number of potential matching candidates in half.

Table 3. **Summary of Tenprint Cards Containing Possible Candidates Matching the Latent Print.**
A print in the tenprint database was selected to be the latent print and was cropped from the tenprint card for each trial. Each search was repeated five times and the results are summarized. The accuracy of all trials together is 89.75%.

Latent Print	Minutiae	Duplicate Print List Position	Candidate List Summary (T / F)
C61RIS(1)	22	12	26 / 4
C61RIS(2)	28	8	27 /3
C61RIS(3)	26	16	29 / 1

Table 4. **An Example Listing of Original Data Is Presented.**
C61RI S is the right hand index finger from the slapped four finger grouping. For each trial search it was newly cropped from ten-print card C61 and entered into the database as a new latent. These are example data from one of the experiments

Exp. 1 Dataset C Original Slapped Datasheet 1 Summary
Filename: Dataset C Original

Date 09/14/10 **Group** C **Similarity Setting**

Latent Test Print C61RI S **Minutiae** 22

Card #	Comparison Value	Self	Single Same Finger	4 Print Slap Group	FALSE Candidates
C80	9744			X	
C79	8685			X	
C64	8682			X	
C73	8253			X	
C67	8163			X	
C85	8116			X	
C71	8078			X	
C75	7262			X	
C77	7247			X	
C65	6800			X	
C84	6686			X	
C61	6116	X		X	
C82	5757			X	
C88	5374			X	
C74	5028			X	
C69	4793			X	
C62	4611			X	
C86	4600			X	
C81	3413			X	
C76	3259			X	
C63	2880			X	
C89	2860		X		
C78	2483			X	
C70	2360			X	
C66	1827			X	
C83	1558				Left Index Rolled
C68	1219			X	
C90	747				Left Index Rolled
C87	317				Left Index Rolled
C72	203				Left Index Rolled

Number of hits: 30

Part B. Single Print Database

In this experiment, a new latent print database was populated with the same prints that were in the tenprint card database, but as individual prints. The major difference between the tenprint card search and this experiment is that each fingerprint is matched individually and overcomes the single candidate per card limitation seen in the experiments with the tenprint card database. Because this AFIS software allows only 500 individual entries, the single print database was reduced to 25 cards instead of the 30 cards used in preceding experiments. Additionally, only the first 30 candidates on the candidate list were considered for accuracy tests. The accuracy of all trials together was 100%.

Table 5. **A Summary of Search Performance Using a Database of Individual Fingerprints.**

Latent Print	Minutiae	Duplicate Print List Position	Candidate List Summary (T / F)	
C61RIS(1)	25	6	30 True	0 False
C61RIS(2)	34	4	30 True	0 False
C61RIS(3)	27	3	30 True	0 False

Routine searches include both tenprint and individual data. Although both approaches produce a high percentage of True prints, searching individual prints is more accurate,

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Figure 6. **List of Possible Candidates Matching the Latent Print in the Individual Print Database (Example Data).**

FILENAME: /Joshi/Single Print Search Data/C61RIS v Single Print db.xls
Latent Search Print: C61RIS (2), 34 Minutiae
Database: Single Prints

Correct Candidate = T
Incorrect Candidate = F

Search Rank	Candidate Name	Print Type Rolled / Slapp	Candidate True / False		Search Rank	Candidate Name	Print Type Rolled / Slapp	Candidate True / False
1	C65RI	R	T		31	C75RIS	S	T
2	C71RIS	S	T		32	C73RI	R	T
3	C67RIS	S	T		33	C83RIS	S	T
4	C61RIS*	S*	T		34	C62RI	R	T
5	C79RIS	S	T		35	C69RIS	S	T
6	C73RIS	S	T		36	C66RI	R	T
7	C78RI	R	T		37	C88RIS	S	T
8	C82RIS	S	T		38	C84RIS	S	T
9	C75RI	R	T		39	C85RI	R	T
10	C77RIS	S	T		40	C81RI	R	T
11	C62RIS	S	T		41	C77RI	R	T
12	C80RIS	S	T		42	C83RI	R	T
13	C66RIS	S	T		43	C75LT	R	F
14	C70RIS	S	T		44	C70LI	R	F
15	C74RIS	S	T		45	C64LI	R	F
16	C81RIS	S	T		46	C81LT	R	F
17	C74RI	R	T		47	C71RI	R	T
18	C79RI	R	T		48	C80LT	R	F
19	C76RIS	S	T		49	C66LI	R	F
20	C84RI	R	T		50	C71LIS	S	F
21	C64RIS	S	T		51	C62LI	R	F
22	C82RI	R	T		52	C74LTS	S	F
23	C61RI	R	T		53	C64RI	R	T
24	C63RI	R	T		54	C81LI	R	F
25	C63RIS	S	T		55	C70LTS	S	F
26	C72RI	R	T		56	C83LI	R	F
27	C65RIS	S	T		57	C72RIS	S	T
28	C85RIS	S	T		58	C86LTS	S	F
29	C90RI	R	T		59	C85LIS	S	F
30	C76RIS	S	T		60	C81LTS	S	F

Experiment 3. Other Types of Latent Image Preparation that Affect Search Results

The location of the cropped edges of the latent print image may affect the number of extractable minutiae. As seen in the preceding experiments, individual prints are assessed differently based on how they were presented to the AFIS software. Does how the print is cropped also affect the number of minutia that are extracted? Of the two types of image trimming, the first, that removes only white space that is void of any ridge structure had no apparent effect on extractable minutiae. In Figure 7 white space on the left edge was repeatedly trimmed and searched without changing the number of minutiae. However, when the image in Figure 8 was trimmed inward from the bottom right-hand corner removing ridges below the knuckle a different number of minutiae were extracted than when the ridges were present. As the area below the knuckle produced no minutiae in the original print, and because the area below the knuckle is routinely blocked out, the reason why its presence, or absence, effects minutiae count is obscure. This and other types of data presentation are subjects of ongoing investigation

Figure 7. **Areas In Which Image Trimming Had No Effect on Minutiae Extraction.**

Figure 8. **Areas in Which Image Trimming Changed the Number of Minutiae Extracted.**

Discussion

The usefulness of an AFIS program is rated by its ability to produce True candidate prints that match the latent search print. This AFIS passed that test. Searching duplicate prints verified the search algorithm was accurate and reproducible and when limiting the length of the candidate list to best thirty matches candidate lists of 90% accuracy for tenprint card searches and 100% accuracy for individual print searches were produced. But search results also revealed that how print images were processed affected search results.

Although the screening capability of this AFSI software worked with high accuracy and reproducibility, the selected candidates were not always the best selection possible and duplicate prints were rarely the best match. These results depart from theoretical expectation and suggest the software assesses the same print differently depending how it is presented to the AFIS software.

Two observations suggest the AFIS software handles individual prints on tenprint cards differently than when the same print is presented as a single latent print. The first observation is that both the tenprint card database and the latent print database are limited to a total of 500 entries each. In this study 600 individual prints were present in the tenprint card database suggesting individual prints on tenprint cards are not recognized as individual prints. The second observation is when a matching print in the tenprint card database is identified, it has a different number of minutiae than its duplicate print in the latent print database. Consequently, the card with the latent's duplicate print was usually not the first card on the matching candidate list.

Searching against the database of individual fingerprints was more accurate than searching against the database of tenprint cards because this AFIS software is limited to listing only a single hit per card even when two True prints existed. Never were both True prints identified on the same card, or was the same tenprint card listed a second time with the other True print identified as a possible matching candidate. It seems the software was written to report only the best possible match and ignore all other possible candidates on that card.

In this study prints were presented for minutiae extraction and enrollment into the database without modification. And the Owner's Manual is specific that angular rotation was not important. However, modified how prints are cropped from the tenprint card, or trimmed before being presented to the AFIS software appears to have an effect on search accuracy. Reasons for these differences are being investigated.

Although examiners are primarily interested matching a print in their current case, knowing how the AFIS software handles data and understanding its limitations is becoming more important when trying to answer questions about the accuracy and reproducibility of their tools and conclusions.