Evaluation of First Level Detail Occurrence in Fingerprints by Influences: Generational Distance, Sex, and Region

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Introduction

A prominent intelligence network utilized in forensic science is the Integrated Automated Fingerprint Identification System (IAFIS). IAFIS is a system where fingerprints are rapidly searched, collected, analyzed, and compared with reference material that is collated in national databases, for exclusion purposes, or directly with suspects. With an increasing database comes longer search times which is troubling as it hinders case development, case interpretation, and adjudication. The knowledge regarding the formation of the fingerprints can be utilized in the search method as the process is by nature heuristic. A more comprehensive understanding of friction ridge development can lead to informed searches through the application of pattern data. A comparison of established fingerprint statistics enables the analyst to generate a more accurate search for the fingerprint of interest within an ever-expanding database. For example, the Federal Bureau of Investigation manages the IAFIS system which now serves as a repository for 70 million criminal fingerprints, 31 million civil prints, and fingerprints from 73,000 known and suspected terrorists processed by the U.S. or by international law enforcement agencies [1]. A more efficient heuristic would enable the examiner to achieve a more effective search depth within the database. With such expansive size and further growth efficiency will be a necessary advancement for the fingerprint identification community.

As a solution, this study seeks to validate a small sample dataset for use as a population metric. This is achieved through the exploration of the probabilistic nature of occurrence for fingerprint patterns across generations. The implication would be that smaller local or regional databases could be utilized for the identification of individuals with an enhanced search heuristic. *A priori* information serves to be a viable asset for increasing search efficiency. Evaluation of both sex and geographical region may provide insight as to difference in fingerprint pattern occurrence frequency. Additionally, the study seeks to determine whether the published studies regarding the development of friction ridge skin can be statistically validated based using the occurrence frequency heuristic.

The following theories will be evaluated:
- The Folding Hypothesis
- Genetic Determination Hypothesis

These theories will be evaluated based upon several population studies. The conclusion that fingerprint development occurs through relationships between the fingers and not a random mechanism would reinforce the search heuristic developed by the study.

Experimental

Validation of Local Database

A local database consisting of 100 fingerprint sets was created from undergraduate students at West Virginia University. Two measurable fingerprint studies were utilized by comparison to the small local dataset collected within this study; the 1981 Royal Canadian Mounted Police (RCMP) study with 1.4 million fingerprints, and the 1993 FBI study with over 22 million fingerprints [2]. Both studies were compared to the 100 ten-print dataset for this study.

Studies Observed –The following studies were utilized for the evaluation of the factors of interest listed below.

Region of Study	Date	# Participants	Separated by Sex
Europe (Norway) [3]	1924	24,518	No
North America (RCMP) [2]	1981	1,400,000	No
North America (FBI) [2]	1993	22,264,713	Yes
Africa (Morocco) [4]	2002	2,000	Yes
Asia (South India) [5]	2009	1,000	Yes
North America (WVU)	2017	100	No

Factors of Interest

1. The study sought to determine whether the sex of an individual had any influence on the fingerprint patterns observed on their hands.
2. Region was evaluated to see if there was an influence of ethnicity on fingerprint patterns occurrence frequencies.

Analysis

The validation of the local dataset was completed through the linear correlation between the three studies.

The impact of sex on fingerprint pattern frequency was evaluated through a linear regression where p-values indicated level of significance.

The impact of ethnicity on fingerprint pattern frequency was evaluated through a linear regression where p-values indicated level of significance. Pairwise comparisons between each region was completed to determine if differences occurred between any region analyzed.

Dermatoglyphic Theory Evaluation

Statistical tests were completed to determine if genetic characters (sex, ethnicity) could provide insight or validity to presented theories.

Results

Validation of Local Database Comprising 100 Individuals

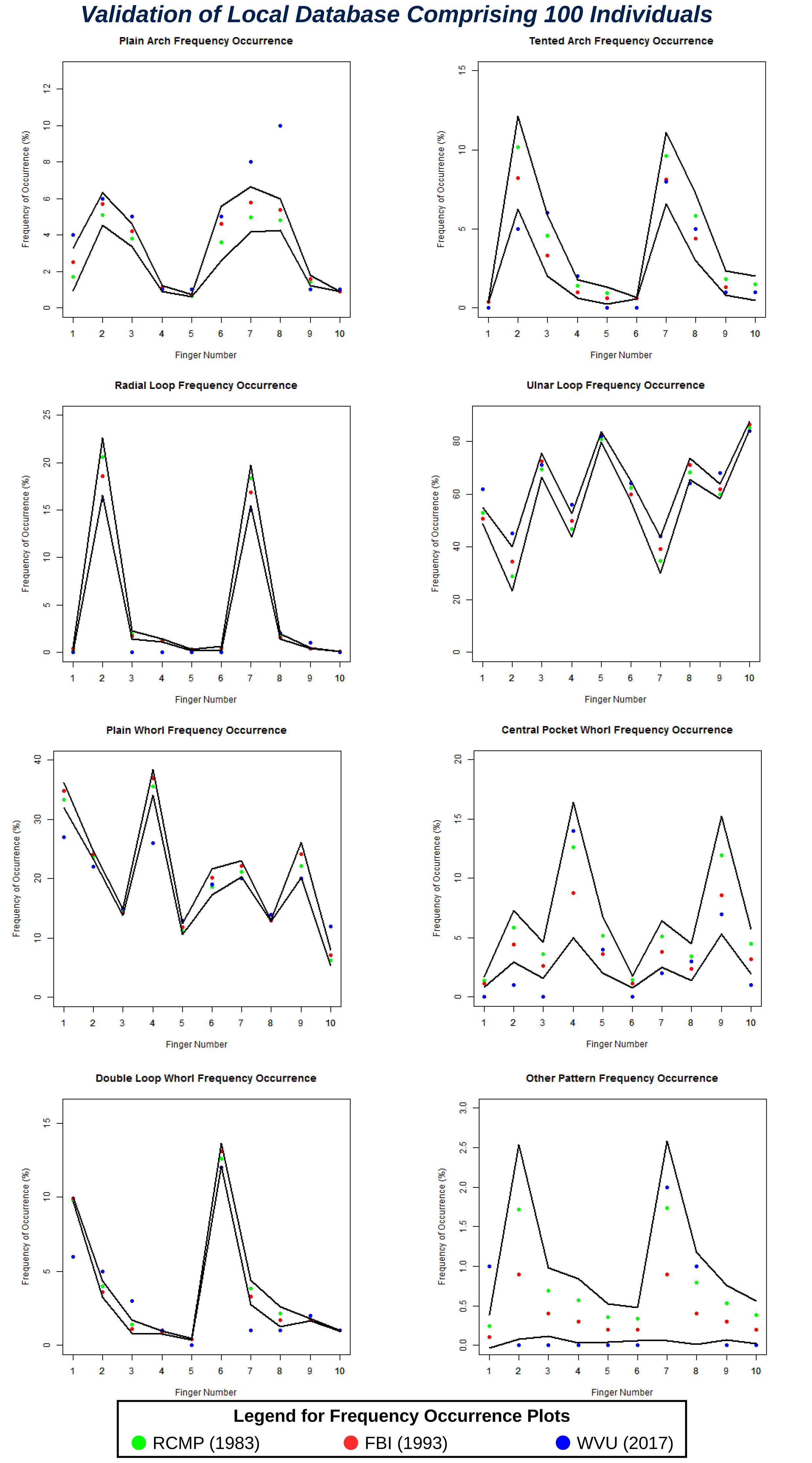
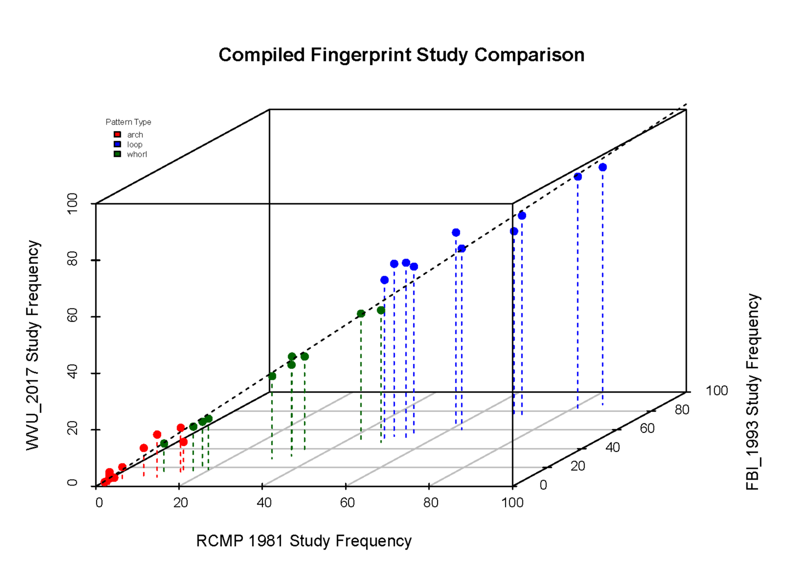


Fig 1. Fingerprint pattern frequencies from RCMP, FBI, and WVU studies for each finger shown by different pattern type. A 95% confidence interval is shown by the black lines. First level detail analyzed are the following: arches (a-b), loops (c-d), and whorls (e-h).

Evaluation of First Level Detail Across Generations



Fit Line for 3D Plot:
$WVU_i = 0.5175\, RCMP_i + 0.5041\, FBI_i – 0.2661$

- Observable linear trend among all studies
- Linear trend indicates consistency of pattern occurrence frequency across generations (1981, 1993, 2017)
- Trend is conserved across all patterns and fingers

Fig 2. Fingerprint pattern frequencies from RCMP, FBI, and WVU studies for each finger shown by different pattern type. Each study is representative of a different generation.

Influence of Sex on Fingerprint Pattern Occurrence

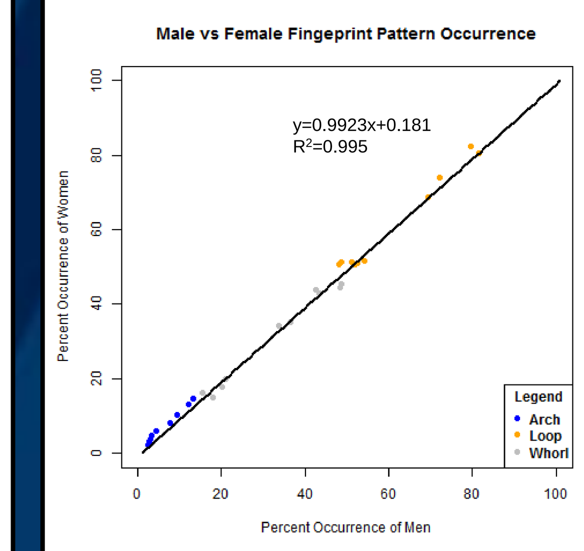


Fig 3. Comparison of fingerprint pattern frequencies between sexes for each finger shown by different pattern type.

Linear Regression Table for Influence of Sex
Dependent Variable: Fingerprint Pattern Frequency

Independent Variable	Difference	P-Value
Male vs Female	0.014 (2.037)	0.995
y-intercept	3.967778 (1.402873)	
R-squared	0.9952	

Note: Value in parenthesis is Std. Error

- Male vs female comparison is linear
- Points highly correlated with value of 0.9923
- Linear regression analysis of male vs female pattern occurrence determined exceptionally high p-value (0.995) which shows no statistically significant difference between male and female occurrence

Influence of Region on Fingerprint Pattern Occurrence

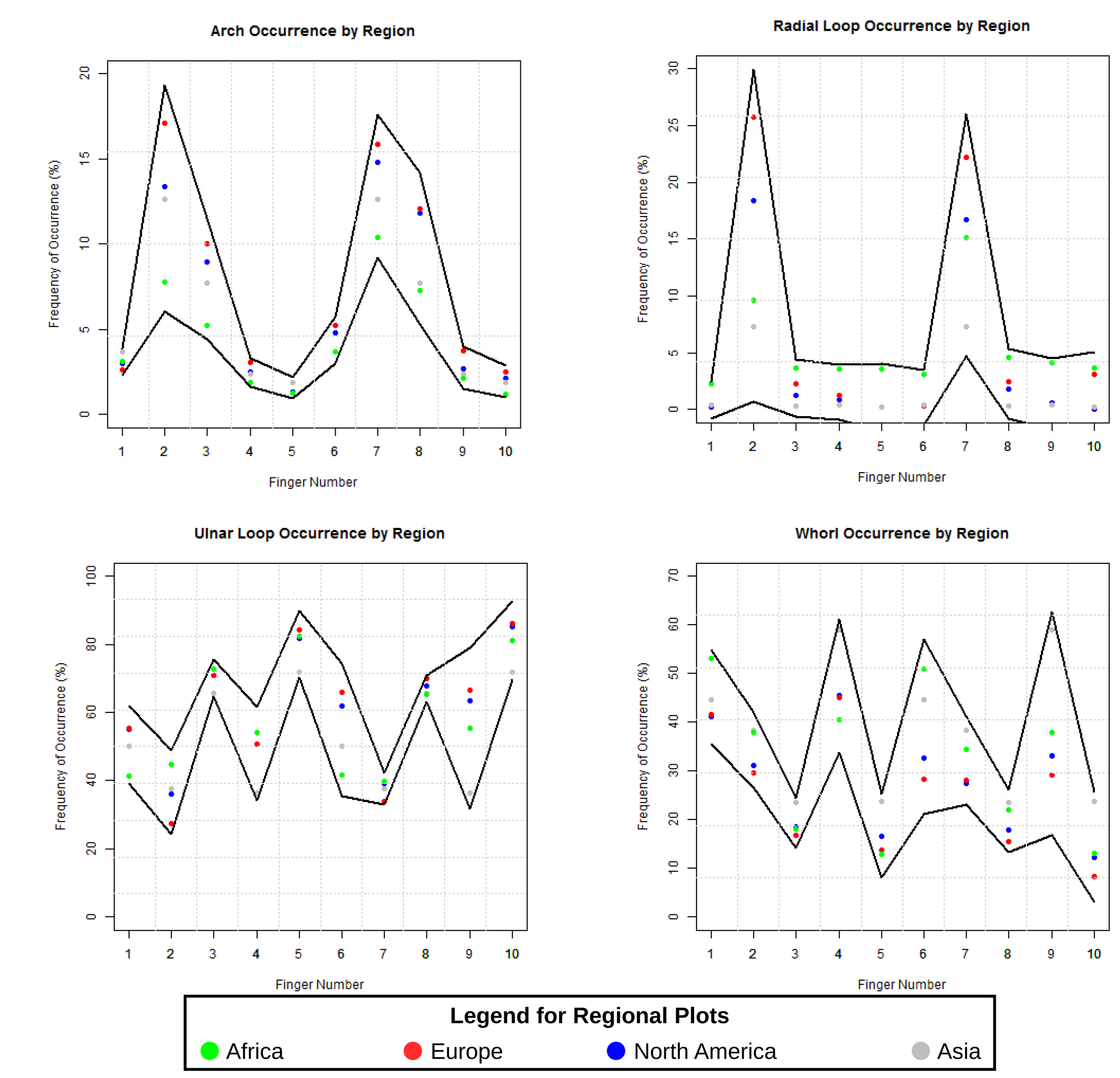


Fig 4. Comparison of fingerprint pattern frequencies between regions for each finger shown by different pattern type.

Linear Regression Table for Influence of Ethnicity
Dependent Variable: Fingerprint Pattern Frequency

Region Comparison	Difference	P-Value
South India vs Europe	-0.275 (2.0141)	0.8940
South India vs North America	-0.1625 (2.0843)	0.9400
Africa vs Europe	3.53e-15 (4.5412)	1.0000
Europe vs North America	0.1125 (0.1125)	0.9700
Africa vs North America	0.1125 (4.5728)	0.9810
Africa vs South India	0.275 (4.0926)	0.9480
y-intercept	3.085208 (1.934543)	
R-squared	0.9742	

Note: Value in parenthesis is Std. Error

- Plots of *Fig. 4* show limited spread in pattern occurrence of each finger for each region
- Pairwise linear regression analysis of each region determined exceptionally high p-values ($p \geq 0.8940$) which shows no statistically significant difference in pattern occurrence between regions

Conclusions

Validation of Small Dataset
- Local database falls outside two standard deviations for several fingers on all patterns.
- Likely due to low occurrence of some pattern type
- The trend shown by fingerprint patterns appears conserved within study of 100 even though it is not within confidence interval

Evaluation of First Level Detail Across Generations
- Observable linear trend among all studies
- No difference in fingerprint pattern frequency observed between generations

Influence of Sex on Fingerprint Pattern Occurrence
- No statistical difference between male and female fingerprint pattern frequencies
- Very high p-value (0.995) provides confidence that there is no difference in occurrence between males and females

Influence of Region on Fingerprint Pattern Occurrence
- No statistical difference between North American, European, African, or Asian regions
- Very high p-value ($p \geq 0.8940$) provides confidence that there is no difference in occurrence across different regions
- Fingerprint pattern occurrence frequency trend appears consistent across all regions

The Folding Hypothesis
- Basal layer cells proliferate rapidly exist in a compressed state due to pressure. In order to alleviate the compression, the cells migrate periodic distances away toward the soft dermis. Soft dermis is easier penetrated than the stiffer upper epidermal layers. Once the compression exceeds a certain threshold the cells move away from the centralized point of pressure [3]
- Study does not provide insight to mechanical based dermatoglyphic studies

Genetic Determination Based Theories
- A common premise of theory is that first level detail of fingerprints are influenced genetically during embryological development of the fetus [6]
- Study concludes that both sex and ethnicity do not have an influence on the fingerprint pattern determination
- Provides skepticism to genetic influence

Future Directions

Validation of Small Dataset
- Use varying database sizes to determine database size needed to fall inside confidence interval

Evaluation of First Level Detail Across Generations
- Expand study to evaluate more generations

Influence of Sex on Fingerprint Pattern Occurrence
- Expansion of male and female fingerprint patterns observed

Influence of Region on Fingerprint Pattern Occurrence
- Expansion study to encompass all geographical regions
- Attempt to control for ethnicity when observing a given region
- Inter-region comparison of fingerprint patterns

References

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