

The Impact of Gender on Image Quality, Henry Classification and Performance on a Fingerprint Recognition System

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Abstract—This is a follow on paper to which examined the impact of gender on a fingerprint recognition system. In that study, the authors used two different technologies (capacitance and optical) single finger sensors. In this study, the authors examined the differences in gender using images automatically segmented from a 10-print fingerprint sensor. Therefore, we analyze in detail the fingerprint locations and assess the performance, image quality and Henry Classification. Our results concur with recent literature which shows no significant difference in Henry Classification across gender, although there is a significant difference across the different fingerprint locations. We do show that there is a difference in image quality (females averaging 81.929 and males averaging 84.196), with a resulting difference in performance. The female dataset performed at an Equal Error Rate of 0.42%, and the male dataset performing at an EER of 0.68%).

Index Terms—biometrics, image quality, classification, performance

I. INTRODUCTION

THERE is continued interest in how different factors impact the performance of a fingerprint recognition system. As biometrics, particularly fingerprints, become pervasive, the performance of such systems is of paramount importance. Fingerprint sensors can now be found on a variety of consumer devices, including mobile phones and computers; in the corporate environment such as retail; and in the government sector for immigration purposes. A recent report highlighted two issues – first the diffusion effect and secondly the recognition of biometric limitations [1]. The diffusion effect is important, and argues that if individuals see and use biometrics at the border successfully, they may be more likely to use biometrics for other needs. Anecdotal evidence at the author's institution show that many people have biometric sensors on their laptops, but still opt for the traditional authentication of a password. In order to increase

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adoption of the biometric, not only does the biometric sensor need to be on the device, but the user needs to use it. They may decide not to use the biometric security because they might not be able to successfully enroll or verify – the issue of performance, which can be impacted by a number of factors. For example, image quality can be impacted by the physical characteristics of the finger, whether through age, oiliness, moisture and elasticity of the skin; the way an individual interacts with the sensor; and how the users are instructed to use the sensor. Other research examined image quality of fingerprints and their resulting performance. Other papers have examined the role that gender plays in the performance of a fingerprint recognition system – the focus of this paper. Frick et. al reported that there was a difference in performance rates between males and females, and reported differences in image quality $H_{(.95,2)}=156.50$, resulting in a p-value less than 0.05 [2]. The same authors noted that in their dataset, there was no significant difference between males and females when minutiae distribution was taken into account. A more recent study that examined the gender distribution and fingerprint classification among South Indian populations noted that the Henry classification made no difference based on the gender [3]. Ridge width is also different between males and females[4]. Badawi studied 1100 males and females and analyzed the ridge count and pattern types. They found that Ulnar loop was the most frequent, then the monocentric whorl. They also noted that there was only slight difference between the male and female pattern type [5].

II. MOTIVATION

This paper builds on previous work undertaken by one of the authors [2]. Since the paper was published in 2008, we have conducted several other fingerprint studies using different sensors. In this study, we wanted to expand the number of fingers to be analyzed and capture them from a different sensor.

III. ANALYSIS FRAMEWORK

A commercially available matcher and image quality tool were used to analyze the images collected. The image quality scores ranged from 0-100. This is an updated tool from that

used in the previous study. Furthermore, the following research questions are asked:

- Does gender impact quality?
- Does finger location impact image quality?
- Is minutiae count affected by gender?
- Are there differences in Henry classification between males and females
- Does gender impact performance?

IV. DATA COLLECTION

The dataset, sub-sampled from a larger dataset, included only those individuals who disclosed their gender as either male or female, had three impressions from their index, middle, ring, and little finger from both their left and right hands, and the Henry classifier provided a response. This resulted in the following demographic breakdown in Table I. Manual, office and not given refer to the subject's self-disclosed occupation type.

TABLE I
DEMOGRAPHIC INFORMATION

Total Population	Male	Female
196	115	81
Manual	Office	Not Given
32	149	15

The samples were collected on a commercially available fingerprint sensor – Crossmatch Guardian LScan. The sensor specifications are shown in Table II.

TABLE II
SENSOR INFORMATION

Specifications	
Fingerprint Types	Single-finger rolls, Single-finger flats, Four-finger slaps, Both thumbs
Resolution	500 ppi
Capture area	3.2" x 3.0" (81 mm x 76 mm), single prism, single imager, uniform capture area
Operating Temperature	35F to 120F (1.6C to 49C)
Humidity Ranges	10-90% non-condensing
Dimensions	6" x 6" x 4.7" (152 mm x 152 mm x 120 mm)
Weight	4.0 lbs (1.8 kg)

V. ANALYSIS AND RESULTS

The assertion of this paper is that gender is a contributing factor to the performance of a fingerprint recognition system. In order to ascertain this claim, the following results are presented; the examination of image quality and gender, the breakdown of image quality and finger location, the distribution of minutiae across males and females, Henry classification and performance. Image quality, Henry Classification and Performance are calculated using commercially available tools.

A. Image Quality and Gender

Image quality is critical in understanding the performance of a biometric system. The image quality for this study was scored from 0 to 100, with the results shown in Figure 1 below.

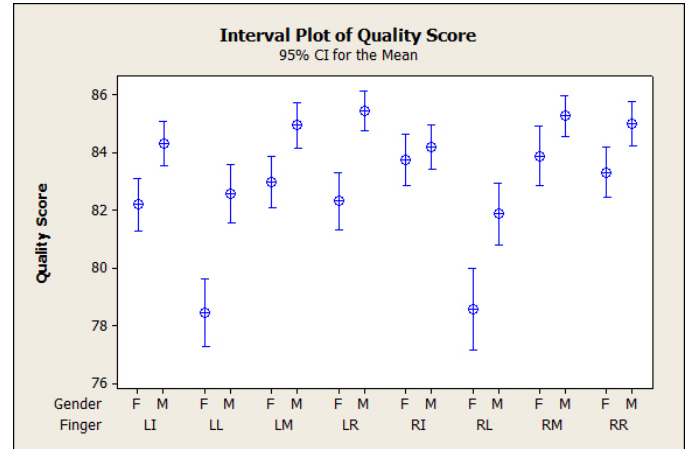


Fig 1: Image Quality and Gender

In a 8x2 ANOVA with finger location (left index, left little, left middle, left ring, right index, right little, right ring and right middle) and gender (male, female) as between-subjects factors revealed a main effects of finger location, $F_{(7,4688)} = 26.01$, $p < 0.001$, gender, $F_{(1,4688)} = 92.00$, $p < 0.001$. These main effects were qualified by an interaction between finger location and gender, $F_{(7,4688)} = 3.12$, $p < 0.001$. Subsequent analysis by finger showed that gender and image quality were statistically significant at the following locations shown in Table III

TABLE III
FINGER LOCATION AND STATISTICAL SIGNIFICANCE FOR IMQ

Finger Location	F	P
LI	12.20	0.001
LM	10.47	0.001
LR	28.20	<0.001
LL	27.14	<0.001
RI	0.53	0.467
RM	5.17	0.023
RR	8.14	0.004
RL	313.88	<0.001

Note that the only finger location that did not differ between the genders was the right index.

B. Minutiae Count and Gender

The numbers of minutiae were calculated from image quality tool, and shown below in Figure 2.

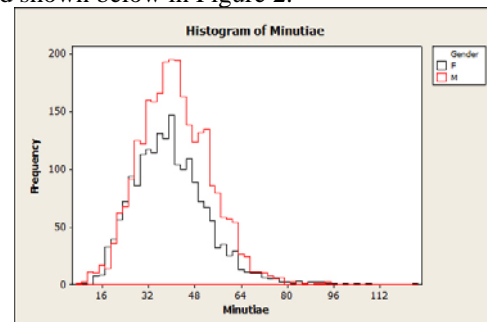


Fig 2: Histogram of Minutiae Distribution

This figure shows that there is overlap between males and females, and there is no statistically significant difference between the two groups. Table IV shows the p-value results from analyzing minutiae counts and gender. Note here that there is only one finger location that is significantly different in minutiae count (Right Ring); one-way ANOVA $F_{(1,586)} = 12.77$, $p < 0.001$).

TABLE IV
FINGER LOCATION AND STAT SIG MINUTIAE

Finger Location	F	P
LI	1.37	0.243
LM	0.44	0.508
LR	1.96	0.163
LL	0.22	0.640
RI	1.27	0.260
RM	2.83	0.093
RR	12.77	<0.001
RL	3.47	0.063

VI. HENRY CLASSIFICATION

Henry classification, named after Edward Henry, is a method of organizing different types of patterns. The classifications include left loop, right loop, arch, whorl, and tented arch. Additional sub-categories sometimes exist, and in the classifier that was used in this paper, there was an additional classification of scar, and while other categories were renamed left slant loop (left loop), right slant loop (right loop), and plain arch (arch).

TABLE V
FINGER LOCATION AND STAT SIG MINUTIAE

Henry Classification	Male	Female
Left Slant Loop	38.5%	36.1%
Plain Arch	1.8%	3.4%
Right Slant Loop	32.6%	33.1%
Scar	0.1%	0.3%
Tented Arch	1.9%	3.4%
Whorl	25.1%	23.7%

Both genders exhibit the same rankings of Henry Classifications, with left slant loop the most frequent, followed by the right slant loop and then the whorl. This is similar to the findings of other studies. Table VI provides more detailed information relating to Henry Classification and the percentage of occurrence at each of the finger locations.

TABLE VI
PERCENTAGE OF OCCURRENCES OF HENRY CLASSIFICATION*

Henry Classification	LI		LM		LR		LL	
	M	F	M	F	M	F	M	F
Left Slant Loop	40	39	75	67	67	69	92	87
Plain Arch	5	3	3	4	1	1	1	3
Right Slant Loop	22	21	1	3	2	2	-	2
Scar	-	-	1	1	-	-	-	1
Tented Arch	4	7	3	5	-	3	-	-
Whorl	29	30	17	20	30	25	7	9

Henry Classification	RI		RM		RR		RL	
	M	F	M	F	M	F	M	F
Left Slant Loop	27	17	4	2	2	5	2	2
Plain Arch	3	9	1	5	1	2	1	1
Right Slant Loop	37	35	72	69	45	54	45	45
Scar	1	1	-	1	-	-	-	-
Tented Arch	5	6	2	3	1	1	1	1
Whorl	29	32	20	20	51	40	51	51

Note, that due to rounding some of the finger locations will not add to 100%.

VII. PERFORMANCE

Performance analysis of the dataset was performed using a commercially available minutiae based matcher (Neurotechnology Megamatcher 3.0.0). The evaluation of the performance of the male and female datasets is shown below by two different Detection Error Trade-off (DET) curves. By overlaying the DET curves of the male and female datasets, the performance and relative differences are shown. The DET curves show that the relative performance of the males and females are different. The EER for the males is 0.68%, and the females is 0.42%

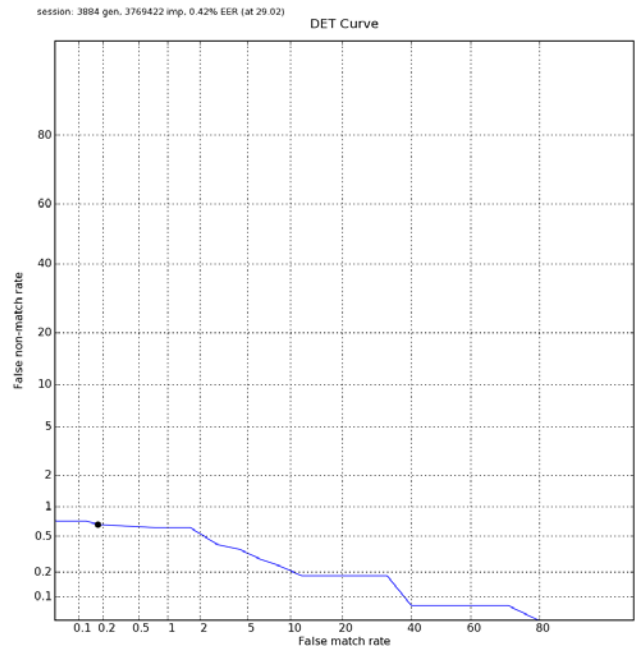


Fig 3: DET curve for Female

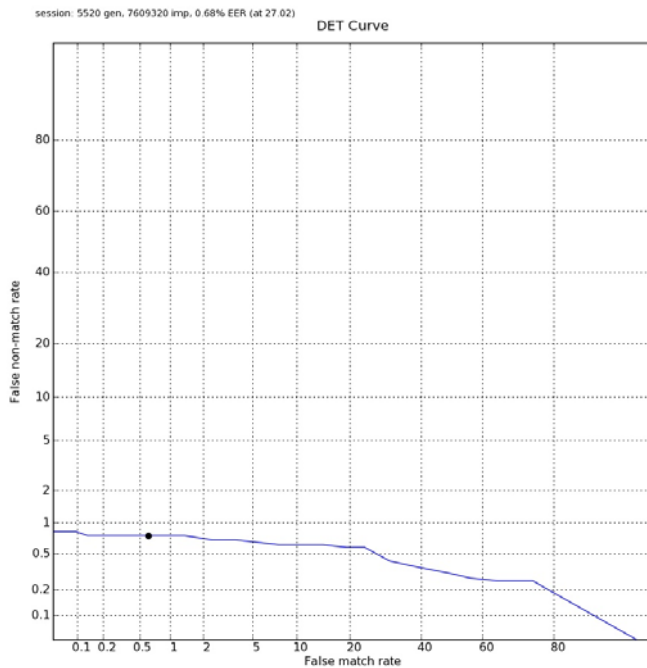


Fig 4: DET curve for Male

VIII. CONCLUSIONS AND FUTURE WORK

Work undertaken in this paper shows that there are still performance issues across both males and females. This difference in performance was shown in [2], although the optical sensor performance in this paper is significantly better than that paper. One interesting aspect relates to image quality. In our results, we see that there is a significant difference in image quality across gender in the right index finger. This is interesting to note, as it was initially thought that this was due to the sensor (the right index finger can be placed towards the edge of the sensor). However, this should have been the case with the left hand index finger too, and it was not. Further investigation of this image quality issue is required, and as the data collection had audio and video recording, analysis of this information and their associated interactions is still available. The distribution of Henry classification is similar to that in [6] although that paper did not break down gender, the cumulative figures are similar. Although the male group had better image quality, their EER was 0.68% as opposed to the females (0.42%). This is an interesting result as well, as the image quality of males was significantly better than females. Further investigation of the Henry Classification distribution across gender is also warranted.

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