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# GENDER DETERMINATION USING FINGERTIP FEATURES

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## Abstract

Several previous studies have investigated the gender difference of the fingerprint features. However, regarding to the statistical significance of such differences, inconsistent results have been obtained. To resolve this problem and to develop a method for gender determination, this work proposes and tests three fingertip features for gender determination. Fingerprints were obtained from 115 normal healthy adults comprised of 57 male and 58 female volunteers. All persons were born in Taiwan and were of Han nationality. The age range was 18-35 years. The features of this study are ridge count, ridge density, and finger size, all three of which can easily be determined by counting and calculation. Experimental results show that the tested ridge density features alone are not very effective for gender determination. However, the proposed ridge count and finger size features of left little fingers are useful, achieving a classification accuracy of 75% ( $P$ -value $<0.001$ ) and 79% ( $P$ -value $<0.001$ ), respectively. The best classification result of 86% accuracy is obtained by using ridge count and finger size features together. This paper closes with a discussion of possible future research directions.

**Keywords:** Gender determination; Fingerprint; Dermatoglyphic; Sex determination

## Introduction

Many human body features have been used to estimate sex/gender. Some of recent examples include foot print ratio,<sup>1</sup> metatarsals,<sup>2</sup> humerus,<sup>3</sup> long bones of the arm,<sup>4</sup> foot shape,<sup>5</sup> femoral head,<sup>6</sup> foot and shoe dimensions,<sup>7</sup> patella,<sup>8</sup> teeth,<sup>9</sup> and radial and ulnar bone lengths.<sup>10</sup> Due to their uniqueness and immutability, fingerprints are also one of the most commonly employed biometric features.<sup>11</sup> Fingerprints have become increasingly popular for personal identification and verification in applications including banking security and physical access control. Despite many well developed fingerprint matching techniques and a wide range of biometric applications, a reliable fingerprint based gender determination method does not seem to be available.

Although it has been found that males tend to have more ridge counts than females,<sup>12-15</sup> inconsistent results have been obtained with regard to the statistical significance of this sex difference.<sup>16-18</sup> It has also been shown that women tend to have a higher ridge density (ridge counts divided by the size of the corresponding fingertip area) than men but the sex determination accuracy of this feature does not seem to be very satisfactory.<sup>19</sup>

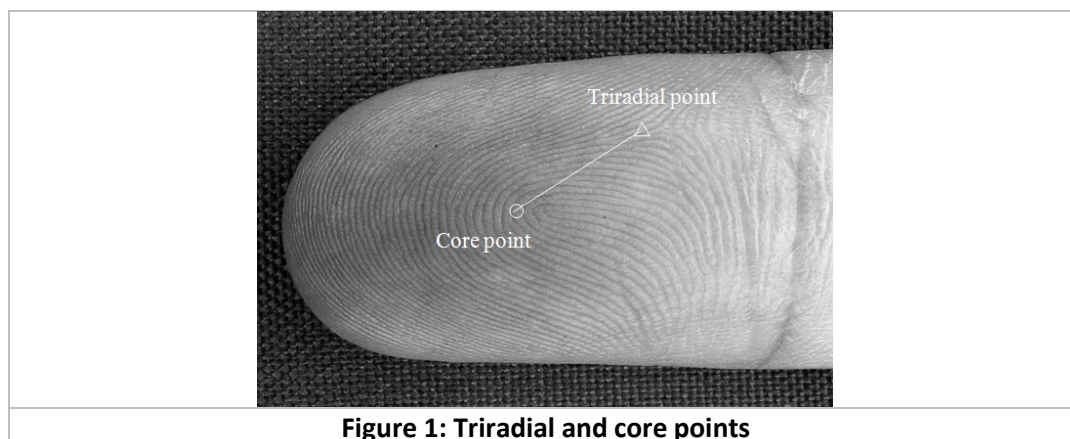
The size of the fingertip has a strong relationship to the values of ridge counts and ridge density. If males have more ridge counts and smaller ridge densities than females, then the finger size difference between males and females should be more significant than the features of ridge count and ridge density.

This work introduces and investigates gender determination methods based on finger related features. To achieve this goal, a new ridge count criterion is proposed that accounts for more ridges than the conventional approach. In addition, instead of comparing the total ridge count of the hands, ridge count on a finger-to-finger basis is explored. Finally, the potential of finger size for sex discrimination is investigated. Experimental results demonstrate the effectiveness of the proposed features for gender determination.

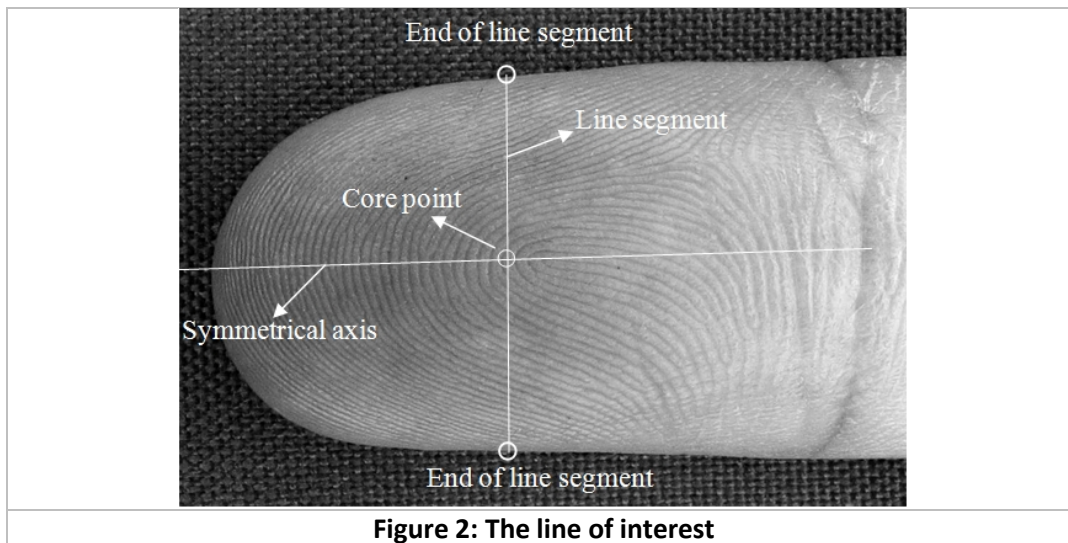
## Material and Method

In this work, fingertip images were obtained from 115 normal healthy adults comprised of 57 male and 58 female volunteers. All persons were born in Taiwan and were of Han nationality. The age range was 18-35 years.

Traditionally, fingerprints have been extracted by creating an inked impression of the fingertip on paper. However, this acquisition procedure is sensitive to environmental factors and skin condition.<sup>20</sup> Since many fingerprint images acquired this way are of poor quality, this work relies on fingertip images captured using a digital camera (Canon G3, resolution 2272 × 1702 pixels). **Figure 1** gives an example of such an image. (Based on our experience, taking pictures of thumbs is much more time consuming than other fingers. As such, this work has not studied images from thumbs.)



Ridge count is traditionally defined as the number of ridges intersected by a line between the triradial points (also called the delta point) and the core point. The core is the topmost point of the innermost curving ridge and the triradius is defined as the meeting place of three dermal lines that make angles of approximately  $120^\circ$  with one another, as shown in **Figure 2**.



**Figure 2: The line of interest**

This ridge count measure has several weaknesses. First, some fingers have no triradial points and other fingers may have more than one. Second, due to the randomness of the locations of the core and triradial points and the fact that the line that joins these two points only covers a small portion of the fingertip, it is questionable whether the traditional ridge count measure can reliably represent the overall ridge count of the finger. To remedy these problems, the ridge count feature used in this work is determined by the following procedure:

- From the image captured by the digital camera, segment the finger by finding the skin-color region of the image.
- Based on the boundary of the segmented finger region, determine a symmetrical axis for the finger.
- Draw a line passing through the core point that is perpendicular to the symmetrical axis determined in the previous step.
- Determine the line segment of interest by first finding the intersection of the line drawn in the previous step and the segmented finger region obtained in step 1.
- Shorten the line segment of interest by removing 5% of its length from both ends of the line since in such regions the finger surface often varies rapidly, making accurate ridge counting rather difficult.
- Determine the ridge count by counting the number of ridges along the line segment from the previous step.
- Determine the length of the line segment of interest. Note that this work uses this length to characterize the size of the finger.

With the exception of core point detection and ridge number counting, the procedure can be executed automatically using a computer program. The line segment employed in this work, as shown in **Figure 2**, intersects the entire finger. Consequently, the number of ridges obtained by the proposed approach is considerably larger than that found conventionally. It is posited that the proposed ridge count measure can characterize the ridge count of the entire finger and offers a more meaningful metric.

## Results

The proposed features were tested by performing a series of gender discrimination experiments. With the multilayered perceptron (MLP) as the classifier,<sup>21</sup> the dataset was divided into training, validation and testing subsets with an 8:1:1 ratio. The training subset is used to adjust the connection weights of the MLP, the validation subset is used by the early-stop technique to avoid overfitting, and the testing subset is used to characterize the generalization accuracy of the MLP. For the sake of reliability, the training process was repeated 1000 times using randomly partitioned training, validation and testing subsets. The sample mean and standard deviation values of the testing subset classification accuracy are reported.

In presenting the experimental results, the index, middle, ring and little fingers of the right and left hands are represented by  $R_2, R_3, R_4, R_5, L_2, L_3, L_4$  and  $L_5$ , respectively. Symbols  $m_R, m_L$  and  $m_B$  are used to signify the average of these fingers for right, left and both hands, respectively. In specific, they can be calculated by the following equations:

$$\begin{aligned} m_R &= \frac{1}{4} (R_2 + R_3 + R_4 + R_5) \\ m_L &= \frac{1}{4} (L_2 + L_3 + L_4 + L_5) \\ m_B &= \frac{1}{2} (m_R + m_L) \end{aligned}$$

The first part of the experiment tests the effectiveness of separate features, i.e., ridge count, ridge density, and finger size for gender determination. The results are summarized in **Tables 1, 2 and 3**.

**Table 1: Summary of results for ridge counts**

Finger	Male		Female		$P$ -value	Classification Accuracy
	$\mu$	$\sigma$	$\mu$	$\sigma$		
$L_2$	38.32	3.11	35.57	3.30	$1.14 \times 10^{-5}$	66.57
$L_3$	42.26	3.93	39.64	4.02	$5.77 \times 10^{-4}$	59.75
$L_4$	41.88	2.98	39.31	3.30	$2.74 \times 10^{-5}$	62.05
$L_5$	36.47	2.80	32.69	2.56	$1.15 \times 10^{-11}$	74.95
$R_2$	37.67	3.21	34.38	3.16	$2.02 \times 10^{-7}$	65.15
$R_3$	42.26	3.64	38.24	3.51	$2.11 \times 10^{-8}$	68.85
$R_4$	41.79	3.26	38.81	3.41	$5.14 \times 10^{-6}$	64.49
$R_5$	35.93	2.74	32.47	2.30	$3.93 \times 10^{-11}$	72.00
$m_L$	39.73	2.63	36.80	2.88	$9.49 \times 10^{-8}$	67.87
$m_R$	39.41	2.73	35.97	2.62	$3.40 \times 10^{-10}$	72.08
$m_B$	39.57	2.59	36.39	2.67	$2.34 \times 10^{-9}$	69.95

Table 2: Summary of results for ridge density (counts/mm)						
Finger	Male		Female		<i>P</i> -value	Classification Accuracy
	$\mu$	$\sigma$	$\mu$	$\sigma$		
$L_2$	2.18	0.20	2.20	0.24	$5.03 \times 10^{-1}$	46.45
$L_3$	2.33	0.27	2.39	0.28	$2.36 \times 10^{-1}$	49.01
$L_4$	2.44	0.23	2.51	0.24	$8.12 \times 10^{-2}$	55.36
$L_5$	2.37	0.24	2.41	0.25	$4.91 \times 10^{-1}$	47.16
$R_2$	2.07	0.21	2.05	0.24	$7.34 \times 10^{-1}$	47.64
$R_3$	2.25	0.24	2.23	0.26	$6.22 \times 10^{-1}$	49.20
$R_4$	2.37	0.26	2.43	0.26	$2.08 \times 10^{-1}$	51.25
$R_5$	2.31	0.21	2.33	0.23	$5.71 \times 10^{-1}$	46.34
$m_L$	2.33	0.20	2.38	0.23	$2.24 \times 10^{-1}$	50.19
$m_R$	2.25	0.20	2.26	0.22	$7.65 \times 10^{-1}$	46.13
$m_B$	2.29	0.20	2.32	0.22	$4.33 \times 10^{-1}$	46.81

Table 3: Summary of results for finger size (mm <sup>2</sup> )						
Finger	Male		Female		<i>P</i> -value	Classification Accuracy
	$\mu$	$\sigma$	$\mu$	$\sigma$		
$L_2$	17.66	1.18	16.20	1.02	$1.35 \times 10^{-10}$	70.78
$L_3$	18.27	1.31	16.67	1.02	$6.12 \times 10^{-11}$	74.21
$L_4$	17.27	1.21	15.70	1.01	$1.45 \times 10^{-11}$	75.92
$L_5$	15.43	1.10	13.65	0.93	$1.20 \times 10^{-15}$	79.01
$R_2$	18.28	1.24	16.82	1.17	$2.34 \times 10^{-9}$	69.98
$R_3$	18.88	1.28	17.25	1.08	$4.34 \times 10^{-11}$	73.62
$R_4$	17.70	1.27	16.00	0.97	$1.31 \times 10^{-12}$	77.74
$R_5$	15.62	1.10	14.00	0.99	$2.13 \times 10^{-13}$	75.91
$m_L$	17.16	1.16	15.55	0.94	$8.32 \times 10^{-13}$	75.20
$m_R$	17.62	1.17	16.02	0.99	$2.12 \times 10^{-12}$	75.48
$m_B$	17.39	1.15	15.79	0.95	$8.14 \times 10^{-13}$	74.88

Comparing the results of these three tables indicates that the finger size feature gives the best results. In particular, as demonstrated by **Table 3**, all of the tested finger size features achieve statistical significance ( $P < 0.001$ , two-sided t-test) and the best classification accuracy is about 79%. In addition, as shown by **Table 1**, the tested ridge count features all yield statistically significant results. However, their classification accuracy is

inferior to that of the finger size feature. As shown by **Table 2**, none of the tested ridge density features achieve statistical significance and the best classification accuracy is only about 55%.

The second part of the experiment investigates the potential of improving the classification accuracy by combining features. Specifically, the first feature set consists of ridge count and finger size features. As shown by **Table 4**, this feature set improves the classification accuracy in contrast to the results obtained by the finger size features alone. The best classification accuracy of almost 86% is generated from the little finger of the left hand. By including the ridge density, the second feature set employs all three features and its classification results are summarized in the last column of **Table 4**. It shows that the addition of the ridge density feature does not improve the effective classification accuracy. This can be explained by the poor performance of the ridge density features for gender determination.

**Table 4: Classification accuracy by using multiple features**

Finger	Features employed	
	count and size <sup>a</sup>	count, density and size <sup>b</sup>
$L_2$	76.41	76.24
$L_3$	76.79	76.89
$L_4$	76.26	76.41
$L_5$	85.78	85.55
$R_2$	76.20	76.03
$R_3$	81.88	80.86
$R_4$	79.83	81.62
$R_5$	81.73	82.23
$m_L$	79.75	79.86
$m_R$	82.05	81.76
$m_B$	82.10	82.49

<sup>a</sup>Finger ridge and finger size index

<sup>b</sup>Finger ridge, finger density and finger size index

## Discussion and Conclusion

This work proposes the use of three fingertip features for gender determination. Compared with conventional methods, the proposed approach has several distinct properties. First, since the traditional inked impressions are sensitive to factors such as skin condition, in this work finger images are captured using a digital camera.

Second, compared with the conventional ridge count measure obtained by inspecting a small portion of the fingertip, the ridge count feature proposed here is obtained from a line segment that intersects the entire fingertip. Third, the possibility of using the finger size as a feature for gender differentiation is investigated. To the best of our knowledge, this has not been studied previously.

The experimental results clearly demonstrate the potential of the proposed features for gender determination. However, several issues require further study. First, among the three tested features, finger size provides the best classification accuracy. However, unlike the permanence of ridge count, finger size may change with time. Therefore, future work is needed to investigate the age effect on finger size. Second, the effectiveness of the proposed approach for different populations also requires further investigation, as gender determination may be a population specific phenomenon.<sup>22</sup> Third, although some previous studies have a higher finger ridge count on their right hand than on their left,<sup>23,24</sup> our experimental results did not support this finding. In particular, as shown in **Table 1**, for males, the mean ridge count for the left and right hands were  $39.73 \pm 2.63$  and  $39.41 \pm 2.73$  (P-value = 0.525), respectively. For females, the mean ridge counts for the left and right hands were  $36.80 \pm 2.88$  and  $35.97 \pm 2.62$  (P-value = 0.110), respectively. It is not clear whether this inconsistency is caused by the new ridge count measure employed or by the difference between the tested populations. In closing, the proposed methods look promising for gender determination. More extensive experiments are planned.

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