Development of a Fingerprint Gender Classification Algorithm Using Fingerprint Global Features

S. F. Abdullah
Optimisation, Modelling, Analysis, Simulation and Scheduling (OptiMASS) Research Group
Universiti Teknikal Malaysia Melaka
76100 Durian Tunggal, Melaka, Malaysia

Z.A.Abas
Optimisation, Modelling, Analysis, Simulation and Scheduling (OptiMASS) Research Group
Universiti Teknikal Malaysia Melaka
76100 Durian Tunggal, Melaka, Malaysia

A.F.N.A. Rahman
Optimisation, Modelling, Analysis, Simulation and Scheduling (OptiMASS) Research Group
Universiti Teknikal Malaysia Melaka
76100 Durian Tunggal, Melaka, Malaysia

W.H.M Saad
Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka
76100 Durian Tunggal, Melaka, Malaysia

***Abstract*—In forensic world, the process of identifying and calculating the fingerprint features is complex and take time when it is done manually using fingerprint laboratories magnifying glass. This study is meant to enhance the forensic manual method by proposing a new algorithm for fingerprint global feature extraction for gender classification. The result shows that the new algorithm gives higher acceptable readings which is above 70% of classification rate when it is compared to the manual method. This algorithm is highly recommended in extracting a fingerprint global feature for gender classification process.**

Keywords—fingerprint; gender classification; global features; algorithm

I. INTRODUCTION

Fingerprint and other skin ridges are called dermatologlyphics. Fingerprint skin ridges have a special characteristic that can differentiate the gender of a person. The statistics of dermatologlyphics differ between gender, ethical groups, and age categories[1][2]. These categories were defined during the early investigation of fingerprint structure by looking at the intensity of ridges and ridge count [3][4][5][6][7][8].

Based on previous research [3][4][5][6][7][8], ridge density is the criteria which is most prominent to differentiate the sex of a person [9]. From these studies, we can infer that ridge density is a good feature for identifying the gender.

Many research publication works discover and appraise the weakness of gender classification accuracy problem [10], while some researcher propose of a new classification methods for gender classification problem [11][12][13] and several publications enhance the accuracy by comparing the classification rate using different classifier [3][14].

Within the last few years, researchers are still finding the best technique to estimate gender-based on fingerprint. So far, various methods have been used using fingerprint physical features like the ridge count, the ridges density and the ridges thickness. Due to the great potential of fingerprints as an efficient classification method, a researcher keeps analysing the fingerprint correlation with gender of an individual [11].

Based on the previous research in forensic area for gender classification [4][5][7][15][16][17][18][19][20][21], the process ridge count had been done manually. This process is done by calculating the ridge under a 5 mm x 5 mm square drawn on a transparent film. The ridge is also count under Fingerprint Laboratories Magnifying Glass. The process of the ridge count takes long time and a lot of energy and focus in order to avoid any error in calculation. [4][5][7][15][16][17][18][19].

Nowadays, the existence of the fingerprint gender classification method is not very good in recognizing the gender of a real person. This is due to the human errors when the process of the ridge count begins. As a feature extraction and classification part is an important step in the fingerprint gender classification process, researcher's keeps finding the best classification method in performing the best and highly accurate method [22].

The problem always happens in gender classification because of their problem in feature extraction. The effectiveness of feature extraction depends on the quality of the images, representation of the image data, the image processing models, and the evaluation of the extracted features [22]. The calculation exactness is also depends on the quality of latent fingerprint images. If the fingerprint images are not clear and blurred, then the fingerprint images need to be recaptured and this makes the classification process longer as it is done manually. As the calculation involves human, human error factors need to be considered too before any conclusion can be derived. Image enhancement is a very important step to ensure the extraction of reliable features, especially on poor quality fingerprints [23]. The image quality of the fingerprint is important due to the fact that it is affecting the success of classification accuracy [24].

Thus, this study aims to develop a new algorithm for calculating the fingerprint global features for making the process of classifying to be easier than before.

II. METHODOLOGY

The sample of this study consists of 3000 fingerprint images which 1430 fingerprints are from male and another 1570 are from female. The fingerprint images are taken manually using the data collection form and was scanned using Fuji Xerox Docuscan C4250 with the format of Grayscale, 600dpi and JPEG.

The process of developing an algorithm begin with the calculation of the correlation of pixel value with the inch value. In order to get the value of 5 mm x 5 mm square area in pixel, some calculation needs to be proved. The process of calculation is shown below:

600 dpi =
(600 pixel)/(1 inch)≡(600 pixel)/(25.mm)≡(23.622 pixel)/(1 mm)≡(118 pixel)/5mm)

The size of pixel use in the calculation after the conversion process is 118 pixels per 5 mm. The process of developing this algorithm is involved in two phases which are Image Pre-processing and Feature Extraction. Image preprocessing focused on removing the unimportant data information of the fingerprint images. The preprocessing is implemented to get the separated of ridges and valleys image. In this study, the image is processed using normalization, binarization, complement image, and filtering image in order to get a high quality fingerprint image.

Fig. 1. Normalization

Fig. 2. Binarization

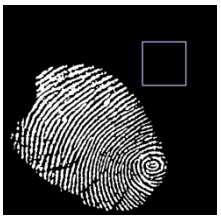
Fig. 3. Complement the image

Fig. 4. Filtering Image

For feature extraction, the calculation of Ridge Density is done by calculating the connected black and white line. The process of translating the forensic manual method to the proposed algorithm is shown in Table I.

TABLE I. COMPARISON OF FORENSIC MANUAL METHOD WITH PROPOSED METHOD

Phase	Conventional Method	Proposed Method
Image Preprocessing	1.Ten-print card containing all ten inked fingerprint impressions of an individual	1.The 10 fingerprint image has been taken manually using a data collection form and thumbprint pad. 2.The data collection document is scanned using Fuji Xerox DocuScan C4250 with the properties as below: Item Type: JPEG Image Resolution: 600dpi Dimension: 4961 x 7016 Width: 4961 pixel Height: 7016 pixel 3.From the scanned document, the process of image cropping for all ten fingerprints for each respondent is done using Matlab. 4.The image is cropped to the fixed size for all ten fingerprint of the respondent. The fixed size image is 1 inch x 1 inch. 5.Then, the image undergo a preprocessing image which is normalization, binarization, filtering, image inverting/ complement in order to get the clear ridge and valley image in order to make the calculation of the ridge easier.

Feature Extraction	1.Epidermal ridges from fingerprint samples of both men and women were counted within a 5 mm × 5 mm square drawn on transparent film. 2.The value represents the number of ridges/25 mm^2 and will be referred to as the ridge density value. 3.Fingerprints from the left hand, the square was placed to the upper right of the central core area and for the right hand, the square was placed to the upper left of the central core. The ridges are calculated on the specific square using a magnifying lens	1.In order to convert the value in inch to millimeter and find the correlation of millimeter and pixel, some calculation need to be proved. The calculation as shown below: 600dpi = (600 pixel)/(1 inch)≡ (600 pixel)/(25.4 mm)≡ (23.622 pixel)/1mm≡(118 pixel)/(5 mm) 2. The size of 5 mm after the conversion calculation is equivalent to 118 pixels. 3.Build the rectangle with the size of 118 x 118 pixels to the ulnar/ radial position and crop the specific image.  Fig. 5. Fingerprint image with the 25mm^2 square area  Fig. 6. Fingerprint images after crop to the 25mm^2 square size 4. Calculate the connected black and white from the image. The value of connected black and white is the number of ridge count in the image. 5. Calculate the Ridge Density using formula,
		Ridge Density = (Number of Ridge Count)/〖25mm〗^2 using formula,

III. Result and Discussion

The performance of the proposed algorithm is tested on how many readings that come out from the algorithm which can be accepted. The acceptable value is getting from the value of the ± standard deviation to the mean of each fingerprint features. The acceptable value must be in the range of the ±standard deviation with the mean of each fingerprint features.

A. Ridge Density Extract from Forensic Manual Method

Table II shows the class of mean number of ridges count and the percentages of the mean number of ridge count of male and female. The result shows that the male respondents tend to have a lower mean number of ridges density with a maximum number of 15.1-15.9 mean of ridges counts compared to female respondents with a maximum of 18.1-18.9 mean number of ridges count. In terms of percentage, 38% of the male respondents tend to have 11.1-11.9 mean number of ridges while for female respondent, the majority of the group have 15.1-15.9 mean number of ridges which accumulate 45%.

TABLE II. No. of Ridge Count Using Forensic Manual Method

		Male		Female	
Class	**Mean Number of Ridge**	**No of Participant**	**(%)**	**No of Participant**	**(%)**
A	9.1-9.9	5	4	0	0
B	10.1-10.9	35	24	0	0
C	11.1-11.9	53	38	0	0
D	12.1-12.9	33	23	0	0
E	13.1-13.9	13	9	2	1
F	14.1-14.9	2	1	12	8
G	15.1-15.9	2	1	70	45
H	16.1-16.9	0	0	35	22
I	17.1-17.9	0	0	24	15
J	18.1-18.9	0	0	14	9
Total:		143	100	157	100

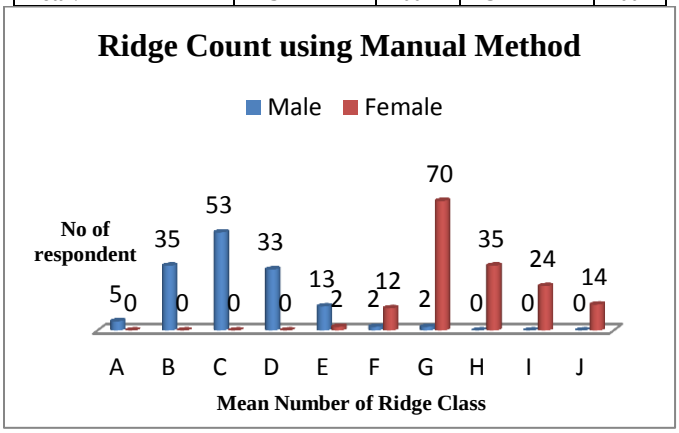


Fig. 7. Data Visualization of Ridge Count using Manual Method

Figure 7 shows the histogram the data visualization of the respondents and its ridge in both genders. It shows that the male respondents tend to have a lower number of ridges densities with maximum of it in group G compared to female respondents with maximum of it in group J. On the other hand, no female respondents were found in class A, B, C and D in which the mean number of ridge count is between 9.1 and 12.9 and no male respondents is in a class of H, I, J in which the mean number of ridges count is between of 16.1 and 18.9. From the histogram, there are an escalating number of female respondents having more ridges when the number of ridge increases from class E to class J. While for male respondents, it can be seen that the pattern is totally contrary, when the mean numbers of ridges increase after 11.1-11.9. After the calculation have been made, it is shown in Table III that mean for male and female in Malaysia is around 11.4 and 15.7 each with the standard deviation of 1.3822 and 0.9496.

TABLE III. STATISTICAL OF RIDGE DENSITY IN BOTH MALE AND FEMALE

	Male	**Female**
Mean	11.4	15.7
Standard Deviation	1.3822	0.9496

B. Ridge Density Extract from Proposed Method

Table IV shows the mean number of ridge count for all 10 fingerprints for each participant and percentages of mean ridges count for every class of mean. The result shows that the male respondent tends to have lower mean number of ridges with the maximum number of it in the range of group H which is 16.1-16.9 compared to female respondent with a maximum mean no of ridge in group J which is 18.1-18.9. In terms of percentage, the majority of 41% of female respondents are in group H with the range of 16.1-16.9 of a mean number of ridge while the majority of 35% of male respondent are in group C with the range of 11.1-11.9.

TABLE IV. NO OF RIDGE COUNT USING PROPOSED METHOD

		Male		**Female**	
Class	**Mean Number of Ridge**	**No of Participant**	**(%)**	**No of Participant**	**(%)**
A	9.1-9.9	3	2	0	0
B	10.1-10.9	37	26	0	0
C	11.1-11.9	50	35	0	0
D	12.1-12.9	31	22	0	0
E	13.1-13.9	13	9	2	1
F	14.1-14.9	2	1	12	8
G	15.1-15.9	4	3	39	25
H	16.1-16.9	3	2	65	41
I	17.1-17.9	0	0	24	15
J	18.1-18.9	0	0	15	10
Total:		143	100	157	100

Table V shows the descriptive statistical of ridge count for both male and female respondent. It shows that the mean for male and female respondent for Malaysian population is around 11.8231 and 16.3494 each with the standard deviation of 1.3793 and 1.1143. The standard error for each gender is 0.1153 for male respondent and 0.8922 for female respondent.

TABLE V. STATISTICAL OF RIDGE DENSITY IN BOTH MALE AND FEMALE

	Male	**Female**
Mean	11.8	16.3
Standard Deviation	1.38	1.11

From the information retrieved on the analysis shows in Table III, the results were based on 300 fingerprint images, among which 143 were males fingerprint only 111 readings from this algorithm are in the range of acceptable reading while 32 readings are out of the range. For female fingerprints, only 113 readings from 157 females fingerprint are in the acceptable range, while another 44 fingerprint reading is out of the range. This algorithm achieved 77% of the algorithm applicability for male and 72% for female. Overall acceptability of this algorithm achieved 74.5%. This result is shown in Table VI.

TABLE VI. INFORMATION RETRIEVE FROM THE ANALYSIS OF RIDGE COUNT

	Acceptable	**Not-Acceptable**	**Percentage Acceptability**
Male	111	32	77%
Female	113	44	72%

The calculation of percentage relative error using formula (1) is done in order to see the error disburse of the proposed algorithm with the manual method.

Percentage of Error =(|Actual Value- Measured Value|/ Actual Value) x 100% (1)

Male Relative Error = $|11.4-11.8231|11.4\ x\ 100\% = 3.7\%$

Female Relative Error = $|16.3494-15.7|15.7\ x\ 100\% = 4.1\%$

Several studies have been done by the researcher on gender classification using fingerprint, but the process of extract and calculating the fingerprint features is done manually using fingerprint laboratories magnifying glass [4][5][7][15][16][17][18][19][20][2][25][26]. Based on the previous research, the study on gender classification using fingerprint ridge density are still in trend from 2001 until 2016. The development of this algorithm will make the work easier in extracting feature and reduce the time taken in classifying gender.

From the result, it can be said that the proposed algorithm helps in extracting and calculating a fingerprint global feature which help the previous study that are done manually and the result gives a higher acceptable reading which is above 70% with the relative error is 3.7% for male and 4.1% for female. More than 2100 fingerprint images are classified as male and female. This algorithm is recommended for classifying gender using the fingerprint global feature.

IV. CONCLUSION

For conclusion, the development of this algorithm will give a benefit to the forensic area where this method is adopted from the forensic manual works in classifying gender. This algorithm achieved 74.5% of correctly classified of male and female when it is comparing with the manual method.

Our future work will be continued with the implementation of this algorithm with the data mining classifier and developing an application on gender classification using fingerprint global level features.

ACKNOWLEDGMENT

This work was supported by research grants RAGS/2013/FTMK/ICT02/01/B00039 under the Ministry of Higher Education of Malaysia for financial support.

REFERENCES

[1] Nigeria, Yaba Lagos. "Analysis, Design and Implementation of Human Fingerprint Patterns System "Towards Age & Gender Determination, Ridge Thickness To Valley Thickness Ratio (RTVTR) & Ridge Count On Gender Detection." *Analysis* 1, no. 2 (2012).

[2] Gnanasivam, P., and Dr S. Muttan. "Estimation of age through fingerprints using wavelet transform and singular value decomposition." *International Journal of Biometrics and Bioinformatics (IJBB)* 6, no. 2 (2012): 58-67.

[3] Ceyhan, Eyup Burak, and Seref Sagiroglu. "Gender inference within Turkish population by using only fingerprint feature vectors." In *Computational Intelligence in Biometrics and Identity Management (CIBIM), 2014 IEEE Symposium on*, pp. 146-150. IEEE, 2014.

[4] Gutiérrez-Redomero, Esperanza, Concepción Alonso, Esther Romero, and Virginia Galera. "Variability of fingerprint ridge density in a sample of Spanish Caucasians and its application to sex determination." *Forensic Science International* 180, no. 1 (2008): 17-22.

[5] Acree, Mark A. "Is there a gender difference in fingerprint ridge density?."*Forensic science international* 102, no. 1 (1999): 35-44.

[6] Nithin, M. D., B. Manjunatha, D. S. Preethi, and B. M. Balaraj. "Gender differentiation by finger ridge count among South Indian population." *Journal of forensic and legal medicine* 18, no. 2 (2011): 79-81.

[7] Nayak, Vinod C., Prateek Rastogi, Tanuj Kanchan, K. Yoganarasimha, G. Pradeep Kumar, and Ritesh G. Menezes. "Sex differences from fingerprint ridge density in Chinese and Malaysian population." *Forensic science international* 197, no. 1 (2010): 67-69.

[8] Gutiérrez-Redomero, E., M. C. Alonso, and J. E. Dipierri. "Sex differences in fingerprint ridge density in the Mataco-Mataguayo population." *HOMO-Journal of Comparative Human Biology* 62, no. 6 (2011): 487-499.

[9] Malickas, Algimantas, and Rimantas Vitkus. "Fingerprint Pre-Classification Using Ridge Density." *Informatica* 11, no. 3 (2000): 257-268.

[10] Dongre, Ganesh B., and Dr SM Jagade. "A Review and Study on Fingerprint Based Gender Classification using Classified Techniques." *International Journal of Scientific & Engineering Research* 6, no. 3 (2015): 596.

[11] Tom, Rijo Jackson, T. Arulkumaran, and M. E. Scholar. "Fingerprint based gender classification using 2d discrete wavelet transforms and principal component analysis." *International Journal of Engineering Trends and Technology* 4, no. 2 (2013): 199-203.

[12] Wadhwa, Ravi, Maninder Kaur, and Dr KVP Singh. "Age and Gender Determination from Finger Prints using RVA and dct coefficients." *IOSR Journal of Engineering (IOSRJEN)* (2013).

[13] Rajesh, D. Gnana, and M. Punithavalli. "Wavelets and Gaussian mixture model approach for gender classification using fingerprints." In *Current Trends in Engineering and Technology (ICCTET), 2014 2nd International Conference on*, pp. 522-525. IEEE, 2014.

[14] Badawi, Ahmed M., Mohamed Mahfouz, Rimon Tadross, and Richard Jantz. "Fingerprint-Based Gender Classification." In *IPCV*, pp. 41-46. 2006.

[15] Cummins, Harold, Walter J. Waits, and James T. McQuitty. "The breadths of epidermal ridges on the finger tips and palms: a study of variation."*American journal of Anatomy* 68, no. 1 (1941): 127-150.

[16] Sudesh Gungadin, M. B. B. S. "Sex determination from fingerprint ridge density." *Internet Journal of Medical Update* 2, no. 2 (2007).

[17] Kaur, Ritu, and Susmita Ghosh Mazumdar. "Fingerprint Based Gender Identification using frequency domain analysis." *International Journal of Advances in Engineering & Technology* 3, no. 1 (2012): 295-299.

[18] Kumar, Lalit, Sandeep Agarwal, Rajesh Garg, Amit Pratap, and V. K. Mishra. "Gender Determination Using Fingerprints In the Region of Uttarakhand."*Journal of Indian Academy of Forensic Medicine* 35, no. 4 (2013): 308-311.

[19] Promponmaung, P., and S. Nanakorn. "Finger ridge density of northeast Thai population." *KKU Sci J* 40 (2012): 52-58.

[20] Abdullah, S. F., A. F. N. A. Rahman, and Z. A. Abas. "CLASSIFICATION OF GENDER BY USING FINGERPRINT RIDGE DENSITY IN NORTHERN PART OF MALAYSIA." (2006).

[21] Abdullah, S. F., A. F. N. A. Rahman, Z. A. Abas, and W. H. M. Saad. "Multilayer Perceptron Neural Network in Classifying Gender using Fingerprint Global Level Features." *Indian Journal of Science and Technology* 9, no. 9 (2016).

[22] Bhuyan, Monowar H., and D. K. Bhattacharyya. "An Effective Fingerprint Classification and Search Method." *arXiv preprint arXiv:1211.4503* (2012).

[23] Khan, Asif Iqbal, and M. Arif Wani. "Strategy to extract reliable minutia points for fingerprint recognition." In *Advance Computing Conference (IACC), 2014 IEEE International*, pp. 1071-1075. IEEE, 2014.

[24] Dolezel, Michal, Eva Brezinova, Jaroslav Urbanek, Martin Drahansky, and Tai-hoon Kim. *Influence of Skin Diseases on Fingerprint Quality and Recognition*. INTECH Open Access Publisher, 2012.

[25] Soanboon, Pattanawit, Somsong Nanakorn, and Wibhu Kutanan. "Determination of sex difference from fingerprint ridge density in northeastern Thai teenagers." *Egyptian Journal of Forensic Sciences* (2015).

[26] Taduran, Richard Jonathan O., Anna Katrina V. Tadeo, Nadine Anne C. Escalona, and Grant C. Townsend. "Sex determination from fingerprint ridge density and white line counts in Filipinos." *HOMO-Journal of Comparative Human Biology* (2015).