A review on identification of gender using fingerprints

Anjali Mishra
Student, Department of Computer Science & Engineering,Shri Ramdeobaba College of Engineering and Management, Nagpur, India
Corresponding author email: mishraaj_1@rknec.edu

Prof. Sweta Jain
Asst. Professor, Department of Computer Science & Engineering, Shri Ramdeobaba College of Engineering and Management, Nagpur, India
Email: jains@rknec.edu

Abstract---Every person in the world has unique biometrics characteristics such as iris, face, voice, palm or finger-vein patterns, and fingerprints. Biometrics, such as fingerprints are even more distinctive than DNA. Although identical twins can share DNA, they cannot have identical fingerprints. The fingerprint impressions are created by using ridges and valleys which are present on the surface of fingers. Fingerprints help to afford an infallible means of personal identification because the ridge arrangement on each person's finger is unique and does not change with growth or age. Some studies in machine learning and data mining investigate a relationship between fingerprint and gender. Hereby using ridges present on the finger it can be identified that fingerprint is of male or female, as males have larger body size than females, the equal number of ridges on a larger surface area means males have a lower fingerprint ridge density; finding out the gender from fingerprints can reduce the search space to half. The criminal justice system uses fingerprints to authenticate a convicted offender's identification and track their previous arrests and convictions, criminal tendencies, known associates, and other important information in the absence of DNA. Many authors used various techniques like Association Rule Mining, Naive Bayes, SVM, Neural Network, etc.

Keywords---fingerprints, fingerprints impression, biometrics, machine learning, data mining, ridge density, SVM, neural network.

Introduction

Individuals can be identified using biometrics, which are biological measurements or physical features. Nowadays biometric identification plays a vital role in our everyday security. Even in the event of twins, each person on the planet has a unique biometric identity. Individuals are identified and authenticated in a reliable and timely manner employing this type of unique identity. Examples of biometrics identification are Voice Recognition, Fingerprint Scanning, Facial Recognition, Iris Recognition, Heart-Rate Sensors, etc. Every single person on earth has a distinct fingerprint, two people can have the same face, DNA, and anything else, but they cannot have the same fingerprints. Therefore fingerprints play an indispensable role in authentication purposes. Some studies have claimed that we can identify the gender by using the fingerprint's impression i.e. whether the given fingerprint is man or woman.

What are the Fingerprints?

Fingerprints are those little ridges on the tips of the fingers, which are essentially folds of the outer layer of skin, the epidermis. Before we were born, our fingerprints began to form. The epidermal of a finger is represented by a pattern of interlaced ridges and valleys, which is called a fingerprint; it having a sequence of connected ridges and valleys. There are 3 specific classes for all fingerprints such as arches, loops, and whorls.

Archfingerprints:The ridges in arch fingerprints represent a hill. Some arches have a pointed tent shape to them. The least common type of fingerprint is an arch only 5% of people having arch.
Loop fingerprints consists one or more friction ridges entering on one side of the print, curving up and around and back down, then flowing out on the same side of the print from which it entered.

Fig 1. Arch Pattern

Fig 2. Loop Pattern

Fig 3. Whorl Pattern

Whorl fingerprints have a shape made up of one or more friction ridges that form a complete circuit and two deltas.

Terms of Fingerprints

For understanding the methodology related to fingerprints it is very necessary to understand the terminology of the fingerprints.Fingerprint consists of many physical properties which are described as below:
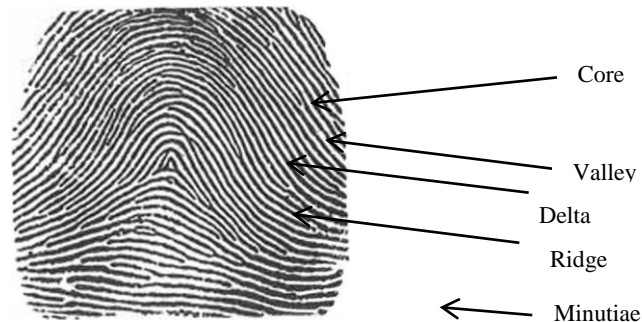

Fig 4. Fingerprint Detail

Core: The innermost turning point where the fingerprint ridges form a loop.
Delta:It is defined as the point where these ridges form a triangulating shape
Ridge: It is a curved line in a finger image.
Valley: Valleys are white line or spaces between the ridges in a fingerprint.
Minutiae: It refers to specific plot   points on a fingerprint.

The impressionswhich are generally marked by the papillary ridges of human fingers are known as fingerprint impression. There are three types of fingerprint impressions such as Latent impression, patent impression and plastic impression.

a) Latent impression: This is type of impression which is not visible by the naked eyes, and made of the sweat and oil on the skin's surface.
b) Patent impression: This is created by liquid on the fingers like ink or blood.
c) Plastic impression: This is impression takes place when we touch something soft and malleable like wax or fresh paint.

As per the past studies it has been already proved that the relationship between fingerprint and gender exists, the explanation on this, in brief, is given by 'Mark A. Acree' (Acree, 1999). According to the author, males have larger body sizes

than females, the equal number of ridges on a larger surface area means males have a lower fingerprint ridge density than females. So many authors have been proved the identification of gender by using various Data mining algorithms like association rule mining, SVM, kNN, etc., and Machine Learning algorithms like ANN and CNN. In this review paper, we will have a brief discussion on the various method of 'Identification of Gender using Fingerprints'.

Related Work

(Yong Qi 2022)**,** has focused on extraction of feature, rather than manually extracting the feature he has used the deep learning-based methods, which includes deep autoencoder neural networks such as VGG and ResNet and some others. As a dataset author collected the fingerprints from 200 people (102 females and 98 males) which is a total of 6000 images. Here author hasproposed an effective network by considering the global reception field in the gender identification task, which was becomeeffective by replacing normal convolutions with dilated convolution in the extraction method, with an average accuracy of 96.5%. For comparing the average and separate-gender accuracies 6 feature extraction methods coupling with 9 classifiers. Train:Test is 4:1. The DDC-ResNet coupled with CNN to test the 10 sets the result indicates that for each specific finger, the right ring finger providesthe highest accuracy, reaching 92.455%.[1]

(Shima Jalali 2021)Here, the author performed operation on real-time identification of fingerprints i.e.real fingerprints were captured from crime scenes, this captured fingerprint consists of noise,and thereforetheremulti-stage preprocessing was necessary so that preprocessing stages were consists of segmentation, normalization, median filter, binarization and thinning. After this stage, gender-related features were extracted by 5 efficient features for fingerprints, such as RTVTR, LBP, Entropy, DCT, Minutiae points then this all followed by classification stage as kNN, Support Vector Machine (SVM), random forest, Adaboost, Linear Discriminant Analysis (LDA) and a one hidden layer neural networkclassifiers separately. By this paper, the author wants to focus on evaluating the effect of different features for the gender-identification and conclude that Adaboost and SVM generated the results performs the best among the compared classifiers.[2]

(Ahmad Ilham Gustisyaf 2021)Convolutional Neural Network is used by the author for estimating the gender using fingerprints. Here three models were designed to determine the gender, with total images of 49270 that included test data and training data.The training data processing is a stage, where CNN is trained for obtaining high accuracy from the classification conducted then the pooling process (max pooling) was performed, this is a fully connected layer process, where flattens are used, and performing 2 stages dense, dense with RELU (Ratified Linear Unit) activation and sigmoid activation. The three models weredesignedby the author to find that which model provides higher accuracy to find the problem statement in a better way. So in model 1 the training part was defined as,input image was provided then it passed to 32-convolution layer with kernel = 5 and forwarded towards Max_Pooling where pool size was 2 these two steps were repeats again with 64-convolution layer and Max_Pooling followed by flattens and dense, in this model accuracy was 99.73%.Model 2, here two 32-

Conv. Filters were used after this Max_Pooling and again two 64-Conv. Filter with kernel =5 used then Max_Pooling, flattens and dense operation performed, in this model accuracy was 99.96%. Now about the last model i.e. model 3, here each time every convolution Filter was immediate followed by Max_Pooling, there were three Convolution filters as 32-Conv Filter, 64-Conv. Filters and 128-Conv. Filters after this flatten and dense were given, in this model accuracy is calculated as 99.88%.[3]

(S. D. Ashish Mishra 2021)In this paper, the author has determined the gender by using the Association Rule Mining here the standard a priori algorithm is used forming attractive rules and then minimizingassociation rules in the filtered dataset usingpredefined minimum confidence and minimum conditional support. The author had selected CASIA fingerprint dataset to operate. On dataset images first preprocessingwasperformed in preprocessing cropping and resizing of images and some morphological operations were done. After Pre-processing Correlation-based identification procedure gives the 'K' position in the database then thumb-ridge density was calculated. So by this author concluded that none of the men have a mean ridge density of more than 27 and no women have mean ridge densities below 23. Womenhave a considerably greater combined ridge density than men.By this proposed work 82.1 % of success rate is achieved. [4]

(Ejiogu 2020)For improving the performance of gender classification using fingerprints the author has designed the fused combinations amongst the five right-hand finger types.CNN is used for the training purpose, the proposed architecture consists 20 layers comprising 5convolutional layers, 6 Rectified linear unit (RELU)layers, 5 max pooling layers, 2 fully connectedlayers, softmax and classification layers. Grayscale image is given as input to the system from c1 to c5 the convolution layersare presented with these numbers of activation layers 128,128, 128, 256 and 256, respectively. Max pooling immediatelyfollows each of the first four convolutionallayers. RELU layers as R1, R2, R3, R4, R5, and R6 following whether there is max pooling or not. This network ends with two fullyconnected layers, F1 and F2, then softmax andclassification layers.The improvement in performances of the best fusedmodels is quantified so as per the result the best fused model was the thumb-middle-ring fused model with an overall accuracy of 91.3%. [5]

(Kruthi R 2019), in this work the author has performed the fusion of two well-known features of fingerprints i.e. Local Binary Pattern (LBP) and Local Phase Quantization (LPQ). LBP is useful for gathering all local and small appearance information whereas LPQ collects the global information of image over a broader range of scale. From LBP 56 features were extracted and then from LPQ 256 features extracted so by these 314 features were being collected for each person. Using fusion of LBP and LPQ provided better result rather than using them alone. After this phase training and testing are performed; SVM which is statistical learning based classifier. By using SVM as classification technique the author has received accuracy of 97%. Apart from SVM, he perform same method on 3 different methods also such as Linear Discriminant Analysis, Quadratic Discriminant Analysis and Nearest Neighbour classifier and results were as 85.1%, 70.1, and 92.7% respectively by using their own dataset. [6]

(P. Gnanasivam 2019)Here gender is identified from fingerprint ridge count (RC) and fingertip size (FTS) using the optimal score assignment (OSA) method. The author had collected the fingerprint samples from the people residing in various regions of Tamil Nadu, India, and thenclassified all fingerprints in 4 age groups as 8–12, 13–18, 18–25 and above 25. By using core and delta RC were determined. RCs were determined for all 8130 fingerprints of 403 male and 410 female fingerprints. Calculating the sum of RC and FTS, if the male score (MS) is higher than the female score (FS), the decision was declared as male otherwise, it was declared as female. The maximum success rate achieved was 88.41% for the age group18–25 years and a success rate of 90.11% was achieved for the right-hand ring finger. [7]
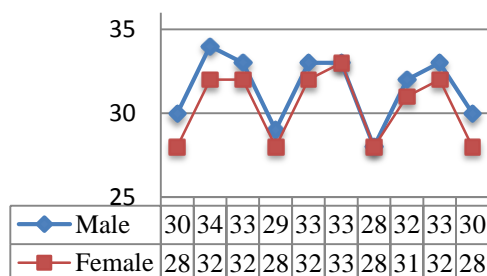

Male	30	34	33	29	33	33	28	32	33	30
Female	28	32	32	28	32	33	28	31	32	28

Fig 5. Comparison of average ridge count in male and female fingerprints*Source: (P. Gnanasivam 2019)

(Mahendra Kanojia 2018)Digital Image processing and Artificial Neural Networks (ANN) are most familiar technique to use. So here author used the Digital Image processing along with ANN to classify gender by fingerprints. Digital image processing was used to perform various preprocessing techniques such as cropping, resizing and thresholding were carried out on each image. After preprocessing Feature extraction was carried out using Discrete Wavelet Transform (DWT) at 6 levels of decomposition. Then the outputs of the extracted features were used for implementing ANN which usesthe Back Propagation algorithm; so this can be explained in better way by using figure 6.By usingthis method satisfactory result (80%) is achieved. [8]
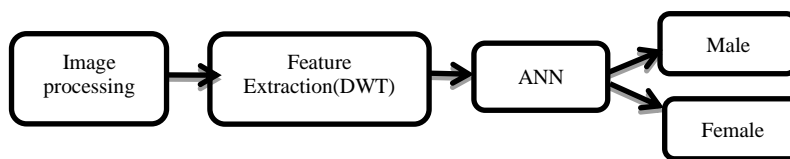

Fig 6. Work Flow

(S.S. Gornale, Fingerprint Based Gender Classification Using Local Binary Pattern 2017)In this paper, the author has proposed another way for identifying a gender by fingerprints where Local Binary Pattern and kNN classifierare used. By using this proposed method authorachieved a success rate of 95.88%. First step is based on preprocessingof images and then it is followed by feature extraction which was performed by using Local Binary Pattern, which is one of the most

useful methods for texture analysis. The features which were extracted by the LBP was used to classify the result as male or female by the classifier. So here extracted features are classified using kNN (K-nearest neighbour) classifier. [9]

(Liton Devnath 2016)By the proposed study, the author wants to identify the gender by using 2D Discrete Wavelet Transform, Pixels calculation and Binary Transform. Here the author had 200 male fingerprints and 200 female fingerprints, MATLAB programming language was used for implementing the algorithm. The first step was to perform WT on input images andafter compression of transform images were converted to a grayscaleimage than into a binary image. Binary images are helpful for calculating the Block and White pixels. Block pixel number converted into binary number; length of the above binary number was calculatedwhich was set to 15 digits. If the result of binary lengthis more or equal to 15 digits, the decision is male otherwise (binary Length<15), the decision will be female. By this proposed process 90% of accuracy for males and 87.5% for females fingerprints are achieved. [10]

(Eyüp Burak CEYHAN 2015)In this study, theauthor has taken a total of 600 fingerprints where 300 fingerprints of males and 300 of females. The age group was from 18-24,and all of them were Turkish citizens. The database was divided into two parts where 66% for the training set and 34% for the testing set. For finding the gender by using the feature vector they followed the steps as the core points of each fingerprint were identified. Secondly, the right index fingerprint was selected and a 5mm 2-square section from upper left part of the core point was taken, the selected part was cropped and saved as a new image. This new image was analyzed, and the ridge thickness[1], ridge counts[2] and average ridge thickness[3] features were found and recorded to find gender[4]. The Naive Bayes method is used for gender classification. Above four features from all subjects were used, and testing was performed using two different methods. [11]

i. The first testing process Naive Bayes, Decision Tree and Support Vector Machine algorithms were used and66% of all the data was used as the training set and34% of all the data as the testing set.
ii. The second testing process was done by using 10-fold cross-validation technique where Naive Bayes, kNN, Decision Tree and Support Vector Machine algorithms were performed.

Table 1 shows the success rates of gender classification which was observed by the author

	Method	Success
Naïve Bayes	Train 66% Test 34%	95.3%
Naïve Bayes	10-fold cross-validation	94.7%
kNN	K=5, 10-fold cross-validation	94%
kNN	K=10, 10-	93.7%

	fold cross-validation	
Decision Tree	Train 66% Test 34%	94.3%
Decision Tree	10-fold cross-validation	94.2%
SVM	Train 66% Test 34%	93.8%
SVM	10-fold cross-validation	94.2%

Table 1. Success Rate *Source:(Eyüp Burak CEYHAN 2015)

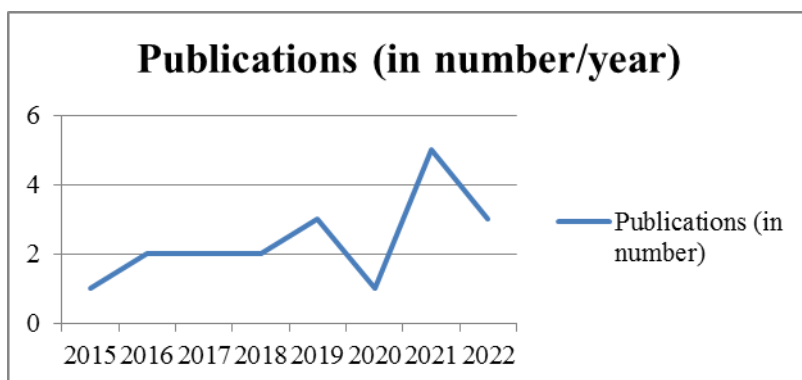**Publications of Papers per Year**

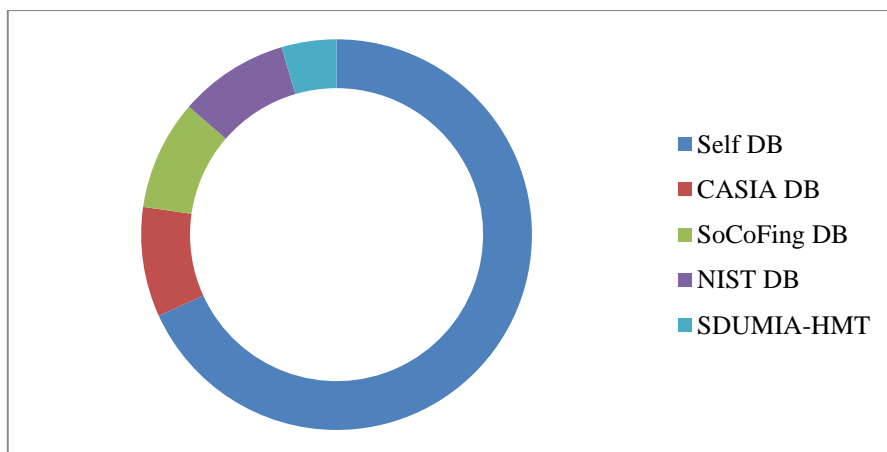Fig 7.Number of publication per year

Database Use

Fig 8.Review on database

In figure 8, given chart describes that most of the authors have use only their own dataset to the identification of gender using fingerprints.
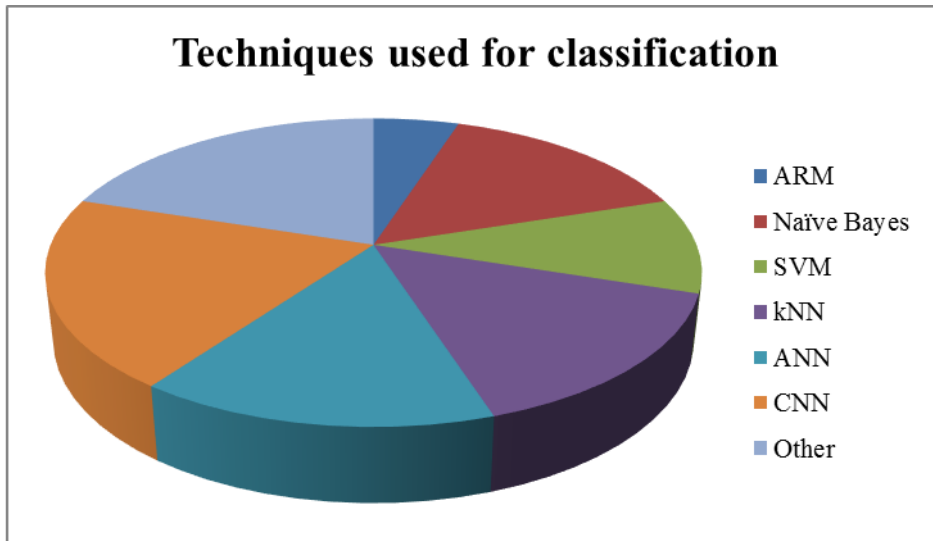
Classification Techniques

Fig 9. Review on various classification techniques

Accuracy calculation of using various feature extraction with classification

Table 1.Accuracy on using feature extraction and classification

Method for extraction	Method for Classification	Accuracy	Author
Global features of fingerprints	Neural Network	97.25%	(S. F. Abdullah 2016)
DWT	kNN	65%	(Suchita Tarare 2015)
WT, Block & White pixel	---	88.75%	(Liton Devnath 2016)
DWT, SVT	kNN	76.84-80.4%	(Mangesh K. Shinde n.d.)
Local Binary Pattern	kNN	95.88%	(S.S. Gornale 2017)
Ridge Density	Naïve Bayes	95.30%	(Eyüp Burak CEYHAN 2015)
RC & FTS	OSA	88.41%	(P. Gnanasivam 2019)
Fusion of LBP and LPQ	SVM	97%	(Kruthi R 2019)
Thumb Ridge Calculation	ARM	82.10%	(S. D. Ashish Mishra 2021)

---	CNN	99%	(Ahmad Ilham Gustisyaf 2021)

Conclusion

In the presented research we can elucidate that there is difference exists between the fingerprint patterns of male and female. Males are with high ridges whereas females having low. We can identify gender by extracting the various features from the fingerprints like calculating the ridge-density, ridges, minutiae, finding fingertip-size (FTS), etc. Numerous researchers have used the neural network like ANN and CNN and data mining techniques.Convolution Neural Network has achieved the maximum success rate for the work. The classification of gender is useful for the identification of criminals.By using this concept we can reduce the searching time for finding the criminals.

References

1. Yong Qi, Menzhe Qiu, Huawei Lin, Jiashu Chen, Yanping Li, Hongguang Lei. "Research on Gender-related Fingerprint Features, Extracting Fingerprint Features Using Autoencoder Networks for Gender." (Research Square) March 2022: 13
2. Shima Jalali, Reza Boostani, Mokhtar Mohammadi. "Efficient fingerprint features for gender recognition." (Springer) Aug 2021.
3. Ahmad Ilham Gustisyaf, Ardiles Sinaga. "Implementation of Convolutional Neural Network to Classification Gender based on Fingerprint." (I.J. Modern Education and Computer Science, 2021, 4, 55-67) Aug 2021.
4. Ashish Mishra, Shivendra Dubey, Amit Sahu. "Gender Classification Based on Fingerprint Database using Association Rule Mining." *Springer Nature Singapore Pte Ltd*, 2021: 13.
5. Ejiogu, Ogechukwu N. Iloanusi & Ugochi C. "Gender classification from fused multi-fingerprint types." (Information Security Journal: A Global Perspective) March 2020.
6. Kruthi R, Abhijit Patil, Shivanand Gornale. "Fusion of Local Binary Pattern and Local Phase Quantization features set for Gender Classification using Fingerprints." (International Journal of Computer Sciences and Engineering) 7, no. 1 (Mar 2019).
7. P. Gnanasivam, R. Vijayarajan. "Gender classification from fingerprint ridge count and fingertip size." *Springer*, March 2019: 10.
8. Mahendra Kanojia, Niketa Gandhi, Leisa J. Armstrong, Chetna Suthar. "Fingerprint Based Gender Identification Using Digital Image Processing and Artificial Neural Network." (Springer International Publishing AG, part of Springer Nature 2018) 2018.
9. S.S. Gornale, Basavanna M, and Kruthi R. "Fingerprint Based Gender Classification Using Local Binary Pattern." (International Journal of Computational Intelligence Research) 13 (2017)
10. Liton Devnath, Arindam Kumar Paul, Md. Rafiqul Islam. "A Study on Binary Number of Gender Identification Based on Fingerprints." (International Journal of Scientific & Engineering Research) 7, no. 2 (February 2016).

11. Eyüp Burak CEYHAN, Şeref SAĞIROĞLU. "Gender Inference within Turkish Population by Using Only Fingerprint Feature Vectors." *IEEE*, 2015: 5

12. Acree, Mark A. "Is there a gender difference in fingerprint ridge." (Elsevier) 1999.

13. Ashish Mishra, Preeti Maheshwary. "A Novel Technique for Fingerprint Classification based on Naive Bayes Classifier and Support Vector Machine." (International Journal of Computer Applications) 169 – No.7 (July- 2017).

14. Beanbonyka Rim, Junseob Kim & Min Hong. "Fingerprint classification using deep learning approach." (Springer Nature 2020) July 2020.

15. Eyüp Burak Ceyhan, Şeref Sağıroğlu. "Determining relationship between fingerprint and gender using 10 finger attributes." (SAKARYA UNIVERSITY JOURNAL OF SCIENCE) 2017.

16. GANESH B. DONGRE, S.M. JAGADE. "Verification of Fingerprint of Transgender with Male and Female." (IRE Journals) 3, no. 4 (Oct 2019).

17. Javier L, Villalba G, Cicirello V, Hsiao C, Lin C,Wang P, Wu. "Application of Convolutional Neural Network for Fingerprint-Based Prediction of Gender, Finger Position, and Height." 24 (2022).

18. Mangesh K. Shinde, Prof. S. A. Annadate. "Analysis of Fingerprint Image for Gender Classification or Identification using Wavelet Transform and Singular Value Decomposition." (International Conference on Computing Communication Control and Automation) n.d.

19. Pattanawit Soanboon, Somsong Nanakorn, Wibhu Kutanan. "Determination of sex difference from fingerprint ridge densityin northeastern Thai teenagers." *Egyptian Journal of Forensic Sciences* (Elsevier), Sep 2015.

20. Rhee, W. S. Jeon and S. Y. "Fingerprint pattern classification using convolution neural network." (Internation Journal of Fuzzy Logic and Intelligent System) 17 (2017).

21. S. F. Abdullah, 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(9) (March 2016).

22. Suchita Tarare, Akhil Anjikar, Hemant Turkar. "Fingerprint Based Gender Classification Using DWT Transform." (International Conference on Computing Communication Control and Automation) 2015.

23. Sudharshan Duth, Megha P Mirashi. "Fingerprint Based Gender Classification using ANN." (International Journal of Engineering and Advanced Technology (IJEAT)) 8, no. 5 (July 2019).

24. Yadav and Saxena, J Biom Biostat. "A Review on Gender Identification Using Machine Learning Technologies." (Journal of Biometrics & Biostatistics) October 2018.