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A Soft Computing Model of Soft Biometric Traits for Gender and Ethnicity Classification

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Abstract

There is paucity of information on the possibility of ethnicity identification through fingerprint biometric characteristics and so, this work is set to combine two soft biometric traits (Gender and Ethnicity) in order to ascertain if individual of different ethnicity and gender bias can be identified through their fingerprint. Live scan mechanism was used in order to minimize human errors and as well speed up the rate of fingerprint acquisition which unequivocally ensure good quality capturing of the fingerprint image.

In this work, fingerprints of over a thousand people from three different ethnic groups of both male and female gender in Nigeria were captured and subjected to training, testing and classification using Gabor filter and K-NN respectively. Histogram equalization was used for image enhancement and the system performance was evaluated on the basis of some selected metrics such as Recognition Accuracy, Average Recognition Time, Specificity and Sensitivity. Result of this work indicated over 96% accuracy in predicting person's ethnicity and gender with an average recognition time of less than 2secs.

Index Terms: Gender; Ethnicity, Fingerprint; Biometrics, Personal Identification Techniques, Gabor Filter, K-NN Classifier.

1. Introduction

Personal identification is ubiquitous to our daily lives. There is always the need to verify individual's identity in order to access to bank account, entering a protected site, drawing cash from an Automated Teller Machine (ATM), logging in to a computer and so on. Over time and in most cases, conventional personal identification techniques are being employed to access these various protected services.

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Conventional personal identification techniques could either be Knowledge based Technique or Token Based Technique. Example of knowledge based technique include Password, Personal Identification Number (PIN) etc while that of Token Based Technique include Driver's license, Passport, ID card, etc [1]**.** The problem with knowledge based Approach is that it is prone to fraud because passwords may be guessed; secret codes and personal identification numbers (PINs) can easily be forgotten, compromised, shared, or observed. The problem with Token Based approach is that passport, keys, access cards can be lost, duplicated or stolen. These conventional methods of verification and identification can be easily stolen or cloned to steal the personal identity, or they can also be forgotten by the owner preventing the whole identification process [2].

Biometrics therefore solves the problem faced at the level of Token based and Knowledge based identification as it attempts to answer the questions "Who are you?" and "Are you who you claim to be?" It is a unique, measurable characteristic or trait of human being for automatically recognizing or verifying identity [3]. This work is focused on seeing the possibility of employing fingerprint biometric technology to determine the gender and/or ethnicity of an individual. A model that can match and determine the similarities or differences in fingerprints of different genders and ethnicities in Nigeria is developed in order to achieve the set objective.

The work is organized as follows; section 2 discusses previous related works in gender and ethnicity determination and their approaches. Section 3 discusses the methodology employed while section 4 presents the result and thereafter, conclusion is drawn in section 5.

2. Related Works

This section presents various previous work related to subject under discussion. In this, views of various authors were put into consideration and therefore discussed hereunder.

Fingerprint has been described by [4] as an example of physiological or hard biometric technology which consists of pattern of interleaved ridges and valleys. It is further described by [5] & [6] as one of the most mature biometric technologies whose evidence is undoubtedly the most reliable and acceptable till date in the court of law

[7] considered Epidermal Ridge Breadth as an Indicator of age and Sex in Paleodermotoglyphics. It was asserted in the paper that epidermal ridges and their arrangements exhibit a number of properties that reflects the biology of an individual. Also, it was stated that dermatoglyphic features statistically differ between the sexes, ethnic groups and age categories.

Ridge breadth was defined as the distance between the center of one epidermal furrow and the center of the next furrow along a line at right angles to the direction of the furrows. The lines on fingerprint are referred to as epidermal ridges. [7]'s findings show that males have higher ridge density (i.e. distance between the centers of two adjacent valleys) than females.

[8] applied Baye's Theorem on the rolled fingerprint images belonging to South India population and found fingerprints possessing ridge density <13ridges/25mm^2 is most likely to be of male origin and ridge count >14ridges/25mm^2 is more likely to be of female origin.

[9] used Ridge density in a particular space to classify gender using fingerprint. His result showed that female have a higher ridge density compared with male.

Ridge thickness to valley thickness ratio (RTVTR) and white lines count features for the classification was used by [10]. From his result, it was discovered that female's fingerprint is characterized by a high RTVTR while the reverse is the case with male's fingerprint.

All the above stated methods/approaches are traditional (manual) ridge related analysis.

However, Frequency Domain Analysis approach for Fingerprint based gender identification was adopted by [11] in his work. In this, fingerprint was seen as one of the most mature biometric technologies and is considered legitimate proof of evidence in courts of law all over the world. Based on the varieties of information available from fingerprint, we are able to process its identity along with gender, age and ethnicity.

[11] defined fingerprint as an impression of friction ridges, from the surface of the fingertip. He went further to identify some important characteristics that makes it viable evidence in crime scene investigations

i. Its uniqueness to a particular individual
ii. Fingerprint does not change over the course of person's lifetime (even after superficial injury to the finger)
iii. Fingerprint patterns can be classified and those classifications can be used to narrow the range of suspects.

In [11]'s work, instead of the traditional ridge related analysis, a frequency Domain Analysis of fingerprint to identify gender is proposed. The proposed algorithm produced an accurate decision of 90% for female and 79.7% for male.

Another approach to Fingerprint Gender Classification is the use of Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) which was carried out by [12]. In this, it was stated that fingerprint primary dermal ridges (ridge counts) are formed during the gestational weeks 12-19 and the resulting fingerprint ridge configuration is fixed permanently.

The SVD approach was considered because of its good information packing characteristics and potential strength in demonstrating result. SVD uses Principal Component Analysis procedures (PCA) to concentrate information before examining the primary analytic issues of interest.

K-nearest neighbor was used as the classifier and the choice of KNN is due to the fact that it gives a strong consistent results. It uses database which is generated at the learning stage of the proposed system to classify gender of fingerprint.

Equally, [13] carried out a study of fingerprint in relation to Gender and Blood Group among Medical Students in Uttarakhand region. In the study, it was established that there is an association between distribution of fingerprint patterns, blood group and gender; thus, prediction of gender and blood group of a person is possible based on fingerprint pattern.

[14] in his study predicts Ethnicity and Gender from Iris Texture. He looked into the possibility of analyzing iris texture to determine soft biometrics or demographics such as ethnicity and gender. It was revealed that just like fingerprint, iris has a fine texture that is determined randomly during embryonic gestation and as such, even identical individuals have completely independent iris textures.

Result of the work indicated that 90%+ accurately predicted ethnicity while 60%+ accurately predicted gender. In essence, Bower's conclusion is that gender is more difficult to predict from iris texture than ethnicity and that ethnicity of men are easier to predict.

[15]'s work proposes the use of fingerprint technology to capture the fingerprint of a number of people in order to identify and verify their identities as regards gender and ethnic groups through the use of trained classifiers which detect shapes and then determine the pattern type of the images. The result shows that over 98% test cases accurately identified person's ethnicity and gender with average recognition time of 2seconds

In essence, most past related works were carried out using ridge characteristics like ridge density and ridge for classification purpose while some other authors using ink method of fingerprint capturing in which case, human error is inevitable. In the same vein, it was discovered that many except for insignificant few of the authors delve into identification of ethnicity through fingerprint; most of the authors focused on gender and other areas of interest[16][17].

Summarily, it has been discovered that not much work has been done on checking out for the possibility of ethnicity identification through fingerprint biometrics characteristics and so, this work is meant to combine two soft biometric traits (Gender and Ethnicity) in order to ascertain if individual of different ethnicity and gender bias can be identified through their fingerprint. In this case, live scan mechanism is used in order to minimize human errors and as well speed up the rate of fingerprint acquisition; using live scan mechanism through the employment of fingerprint biometric sensor will as well ensure good quality capturing of the fingerprint image. Equally, attention will not just be paid to the dermatoglyphic features which were dominant in previous works but rather, go further in making use of minutiae features of individual's fingerprint for the purpose of classification.

3. Methodology

This section discusses the overall design approach for the proposed system as well as the design of its internal components which include fingerprint image preprocessing/enhancement, feature extraction, template matching and classification into gender and ethnicity.

The process is meant to find the right approach towards proffering answers to the questions in section one as regards the possibility of identifying individual gender through fingerprint and the possibility of classifying different captured fingerprint images into their corresponding ethnic group.

Figure 1 above gives a detailed and concise description of the flow of activities within the system. The architecture consists of Enrolment Module, Identification Module and storage. The enrolment module consists of fingerprint image acquisition, image preprocessing, feature extraction and template file creation. It is used to get the minutiae sets and stored template information in the database.

Figure 2 above presents the identification module which does the work of detecting similar minutiae group from multiple template images generated from the same finger and thereby create a cluster core set. It identifies which finger the test image is from.

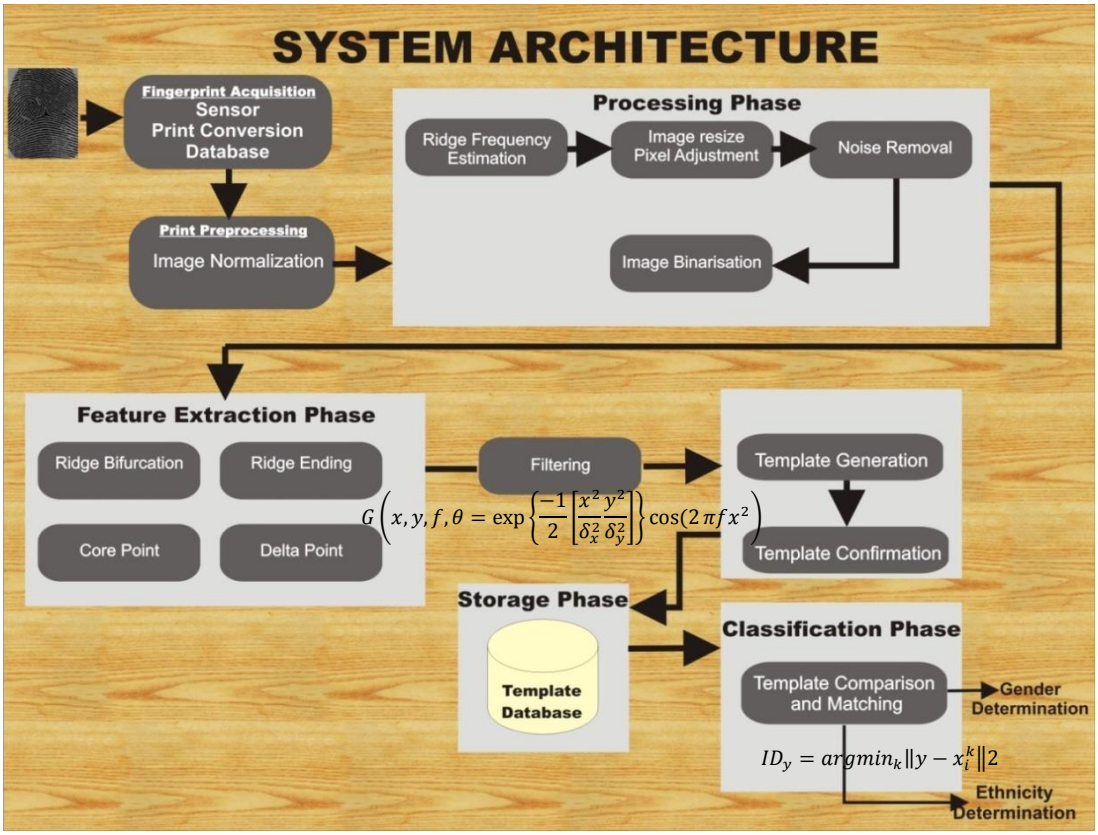

Fig.1. System Architecture

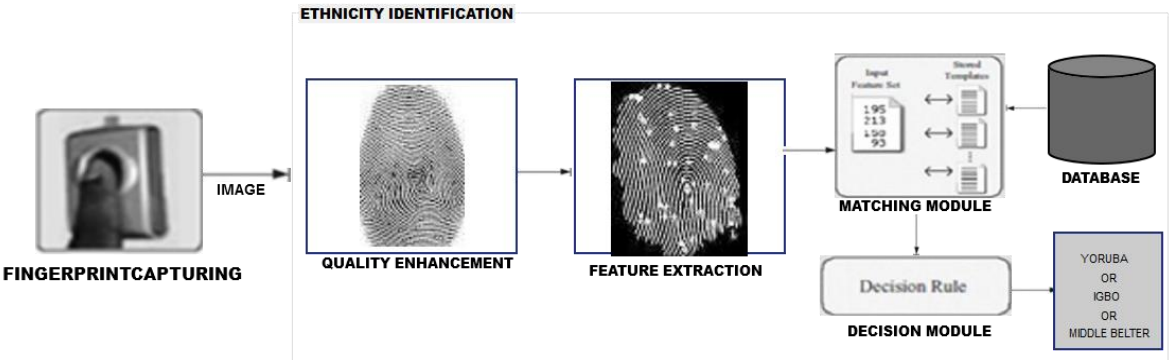

Fig.2. Proposed Model

Test Image, I (Grey Level Fingerprint Image)

$$Let\ F_i = \{F_{ij} = 1, .. m\}, i = 1, .. m \tag{1}$$

The template image set of the ith collected finger where m is the image database & n is the number of template sample for fingers

$Let\ M^I = \{M^I_{ij} = 1, \dots L^I$ be the minutiae set of the test image

$$Let\ M^F_{i,j} = \{M^F_{i,j,k,} K = 1, \dots\ L^T_{i,j}\}, i = 1, \dots m = 1, \dots n \tag{2}$$

be the minutiae set of the jth template image of the ith finger,

$L^T_{i,j}$ is the minutiae number of the template image

$$Let\ N = \{e_{1,} \dots, e_n\} be\ a\ set\ of\ n\ minutiae \tag{3}$$

And $Let\ C = \{c_1, \dots, c_i$ be a partition of N into disjoint subsets; Each subset is called a cluster and C is called a clustering.

Two element e_i and e_j are called mates with respect to C if they are members of the same cluster.

At the highest level, all fingerprint recognition systems contain two main modules ***feature extraction*** **and** ***feature matching***. Feature extraction is the process that detects singular and all other minutiae points which are ridge ending and ridge bifurcation which differentiate one fingerprint from another which impart individuality to each fingerprint. Feature matching involves the actual procedure to identify the unknown person by comparing extracted features from his/her fingerprint with the ones from a set of known persons.

For the purpose of this work, fingerprints one thousand and fifty-four (1054) persons of three different ethnic groups (Yoruba, Igbo and Middle Belt) of both genders in Nigeria were captured with 673 from Yoruba ethnic group while Igbo and Middle Belt has 179 and 197 respectively; in essence, a total of 10,054 fingerprints were captured directly.

The images captured were run through MATLAB for the purpose of training and testing. In this, 1-D Gray Scale histogram equalization was adopted for image enhancement [18][19] while 3D Gabor filter was used for feature extraction[20] and K-NN classifier algorithm was as well adopted for classification.

4. Result

In this work, the model was on the dataset acquired locally and which cut across both gender of the three ethnic groups under consideration. Training and testing were performed on images of subjects within the ethnic groups due to the fact that by observation, they are the most predominant ethnic groups in Nigeria. However, the proposed model can equally be applied to wider range of ethnic groups and in any part of the world.

Gabor filter was used for the purpose of training and testing as shown in figs. 3 and 4. In the process of training, salient features of the prints on each finger were extracted and sum up for both left and right fingers. The extracted features were thereafter used to determine the gender and ethnicity of each individual.

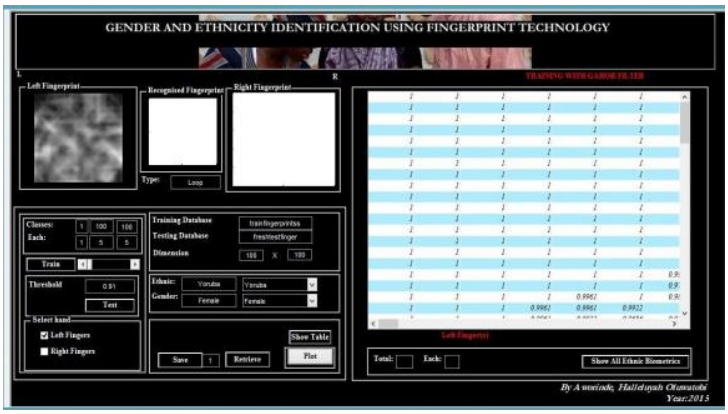

Fig.3. Training Phase

Fig.4. Testing Phase

We thereafter evaluated performance of the system on the basis of four different metrics; Recognition accuracy, Average Recognition Time, Specificity and Sensitivity.

The results of the work are presented in form of graphs as shown in figs. 5, 6 and 7 while bar chart is generated to demonstrate gender and ethnicity identification in fig. 8.

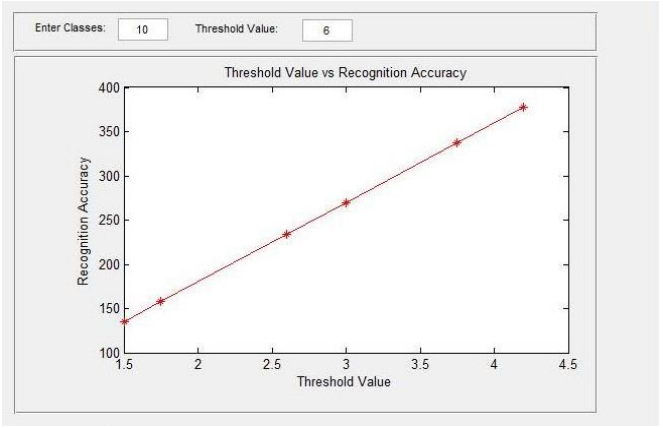

Fig.5. Graph Showing Recognition Accuracy

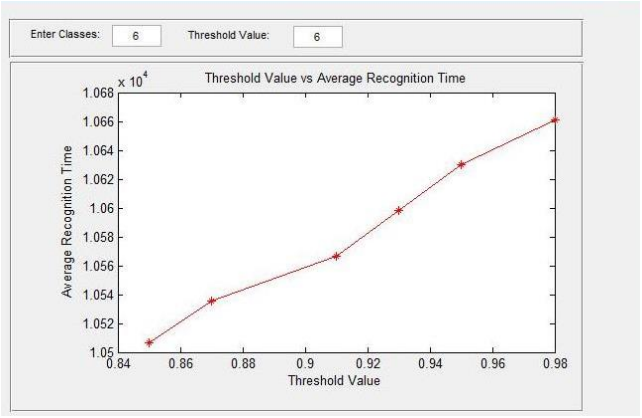

Fig.6. Graph Showing Average Recognition Time

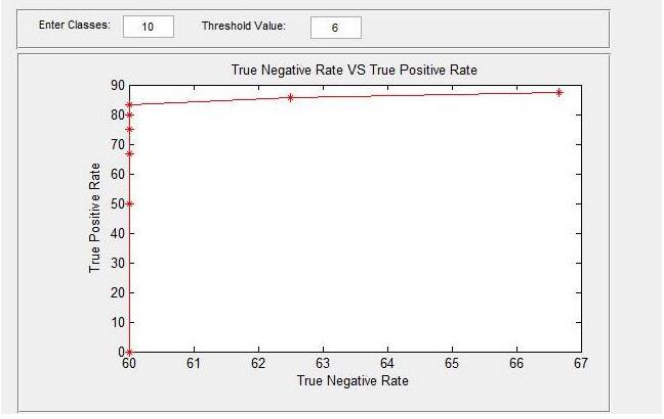

Fig.7. Graph Showing % Specificity and Sensitivity

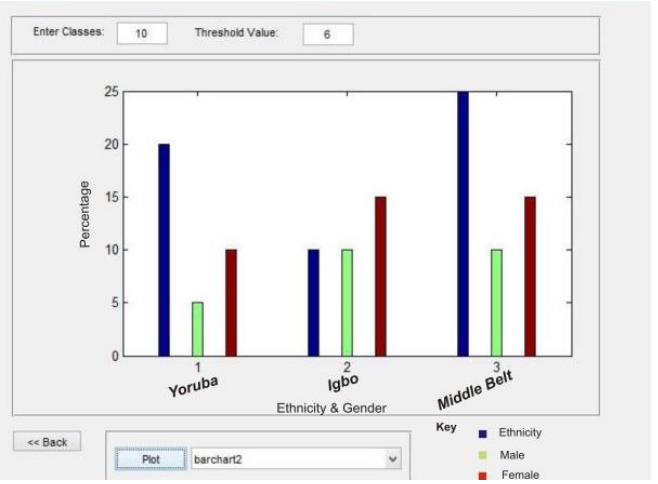

Fig.8. Gender & Ethnicity Bar Chart

The result from the figs 5and 6 above shows that increase in threshold value resulted to increase in recognition accuracy and average recognition time for six consecutive trial of threshold values 1.50, 1.75, 2.60, 3.00, 3.75, 4.20. Also, Fig. 7 gives a clear picture of the system's sensitivity of above 96% and specificity of over 66.7%; while figure 8 shows gender and ethnicity distribution. From this work, it was observed that Arch pattern is more prevalent amidst Yoruba ethnic group while loop and Whorl patterns are more dominant amidst the Igbos and Middle Belters respectively. Result of this work indicated that 95%+ accurately predicted person's ethnicity and gender with an average recognition time of less than 2secs.

In the cause of capturing data, it was observed that there are fingerprints with extremely low quality; this is particularly predominant amidst elderly people and farmers in the rural area. The algorithm used for feature extraction and filtering in this work (Gabor filter) helped to an extent in enhancing image quality of even low quality fingerprints which were captured while K-NN was used for classification and decision making.

With this research work, the possibility of identifying person's ethnicity and gender through fingerprint technology has been ascertained and confirmed

5. Conclusion

The results of the above research evidently show that a system has been designed for the purpose of training and testing fingerprint using Gabor Filter and K-NN classification in order to determine the ethnicity and gender of such individuals. Performance evaluation proved beyond reasonable doubt the efficiency of the system to achieve this purpose.

With this research work, the possibility of identifying person's ethnicity and gender through fingerprint technology has been ascertained and confirmed.

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