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Study of Ridge Based and Image Based Approach for Fingerprint Gender Classification

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ABSTRACT: Fingerprint is a pattern of ridges and valleys. Each person has a unique fingerprint structure and is developed for biometric authentication systems than others because fingerprints have advantages such as: feasible, distinct, permanent, accurate, reliable and acceptable all over the world for security and person identity. Fingerprints are considered as legal proofs of evidence in courts of law all over the world.

Fingerprint based gender classification can be studied using ridge based approach and image based approach. Ridge based approach considered ridge related parameters like ridge count, ridge density, ridge width, ridge thickness to valley thickness ratio. Image based approach do not work on physical parameters related to ridge, but work on measuring parameters like frequency and region parameters of an image. This paper compares ridge based approach and image based approach in terms of processing time, accuracy, simplicity in calculations and compatibility with other methods.

KEYWORDS: Fingerprint, gender classification, ridge based approach, image based approach, ridge parameters, measuring parameters.

I. INTRODUCTION

Fingerprints are one of the most mature biometric technologies and are considered as a legal proof of evidence in courts of law all over the world. Based on information available from the fingerprint one can process its identity along with gender, age and ethnicity [1]. In today's world of increased importance of security, identification and authentication methods are key technology. Such requirement for reliable personal identification in computerized access control has resulted in the increased interest in biometrics [2].

A Fingerprint is a pattern of ridges and valleys, where ridges are the black lines and white area between two adjacent ridges is valley. Fingertip ridges evolved over the years to help humans to grasp and grip objects. Like everything in the human body, fingerprint ridges also form through a combination of genetic and environmental factors. That's why even the fingerprint of identical twins is different.

Fingerprint analysis helps in identifying the person responsible for an audacious crime. Fingerprints are also used for the gender and age identification because of its unique nature and do not change throughout one's life [3]. Existing methods for gender classification have limited use for crime scene investigation because they depend on the availability of bones, teeth, or other identifiable body parts having physical features. Gender determination of unknown person can guide investigators to the correct identity among the large number of possible matches, means reduces the search space.

II. LITERATURE REVIEW

There are variations in ridge dimensions and sex differences in ridge pattern of every person. Ridges and their patterns have number of properties that reflect the biology of individuals. Fingerprint features differ statistically between the sexes, ethnic groups and age categories. These features help in classifying a person [4].

Earlier studies on Ridge based gender determination have used the inked fingerprints and their findings are based on the spatial domain analysis of ridges. Ridge based approach works on physical parameters such as fingerprint ridge

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count, ridge thickness to valley thickness ration, ridge density, ridge width and fingerprint patterns and pattern types as feature for gender determination. The ridge thickness depends on the pressure applied and may provide false results on gender identification [4,5]. All the methods based on the fingerprint ridges gives insight about the ridge parameters mentioned about but fails to give accurate method of measuring the parameters. Also the feature vectors obtained in these methods is of varying length and makes the calculations difficult.

Image based gender determination uses digital fingerprint images and utilizes both frequency domain analysis and spatial domain analysis and work on region properties of the image. Here, features are extracted using different methods, like Fast Fourier Transform, Discrete Wavelet Transform, Discrete Cosine Transform, and Region Properties [6, 7]. Fourier transform plays an important role in image processing applications. Discrete Cosine Transform transforms an image from the spatial domain to the frequency domain and provides better approximation of image. Discrete Cosine Transform transforms a set of data which is sampled at a given sampling rate to its frequency components. Whereas Discrete Wavelet Transform works on wavelets, a waveform of effectively limited duration that has an average value of zero. Wavelets are mathematical functions that cut up data into different frequency components, and then help to study each component with a different resolution. Here the fundamental frequency is used for gender Classification [8]. These methods give feature vectors of fixed length which makes calculations easier, and can be mapped with other methods easily.

III. ANALYSIS OF RIDGE BASED AND IMAGE BASED APPROACH

A. Ridge based approach for gender classification

Fingerprint is a pattern of ridges and valleys, where ridges are black lines and valleys are white area between two adjacent ridges. There are 3 specific classes for all fingerprints based upon their visual pattern: arches, loops, and whorls. Loop is very common pattern and 60% of people have loops, 35% of people have whorls, and 5% of people have arches. Arches are the simplest type of fingerprints which are formed by ridges that enter on one side of the pattern and exit on the other side and no deltas are present. Delta is a point at which three ridges coming from three directions meet at angles of about 120 degrees. Arches can be further classified as plain arch and tented arch. Loop pattern must have one delta and one or more ridges that enter and leave on the same side, the loop pattern have a delta and a core. The core is a ridge that is surrounded by fields of ridges which turn back on themselves at 180degrees. Loops can be further classified as radial loop or ulnar loop. Whorls should have at least one ridge that makes a complete circuit, the whorl pattern has two deltas and ridges form various patterns inside.

Arch Loop Whorl

Fig. 1. Types of fingerprint

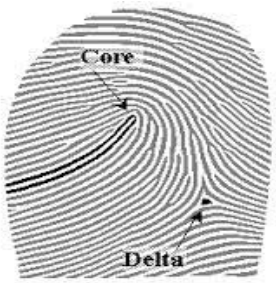

Fig. 2. Core and Delta

Various parameters based on ridges and valleys like ridge count, ridge density, ridge thickness to valley thickness ration, ridge breadth are used for gender classification.

In ridge count based gender classification males have a slightly higher ridge count than the females. To calculate the ridge count of any fingerprint find delta, place a point at farthest corner of it and place dot at core of fingerprint and join a line to count the number of ridges. Number of ridges between delta and core is the ridge count of that fingerprint. For an arch pattern, the ridge count is zero. For a whorl pattern a ridge count is made from each delta to the centre of the fingerprint, and only the higher of the two possible counts is used (Figure 3).

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Fig. 3. Ridge Count of fingerprint

A fingerprint can be classified using ridge density based approach where 5 mm*5 mm square is drawn on fingerprint. This ridge count value within the square represents the ridge density of that fingerprint. If fingerprint is of the right hand, the square is placed at the upper left of the core. For fingerprints of the left hand, the square is placed at the upper right of the core. Ridge density based approach is useful in the case of arch pattern, where the ridge count is zero according to traditional method of ridge counting. Also the ridge counts are not analyzed in central core regions due to the variability of pattern shapes and re-curving ridges, which are sometimes counted more than once in these regions and may lead to false result. The fingerprint ridge density of < 13 ridges/25 mm^2 is of male and fingerprint ridge density of > 14 ridges/25 mm^2 is of female. Females have finer ridges than male and hence have greater ridge density.

Another approach based on ridge parameter uses ridge to valley area as basis for gender classification. Ridges are the black lines in fingerprint and valleys are white area between ridges, the number of black pixels is the ridge area in image (Ar) and number of white pixels is the valley area in image (Av). Then ridge to valley area is calculated by taking the ration of Ar and Av. Females have higher ration than males.

B. Image based approach for gender classification

Image based approach do not use physical parameters based on ridges rather uses frequency based energy features. High frequencies corresponds to pixel values that changes rapidly across the image and corresponds to edge components of the image. Low frequency components correspond to large scale features in image. Low frequency contains visually significant information of an image. Various frequency domain approaches like dwt, dct, fft are used for the energy based feature extraction and gender classification.

Frequency domain approach uses 2D Discrete Wavelet Transform for extracting the features of the fingerprint image. A wavelet is a waveform of effectively limited duration that has an average value of zero (figure4). In mathematical term wavelets are mathematical functions that cut up data into different frequency components, and help to study each component with a resolution matched to its scale.

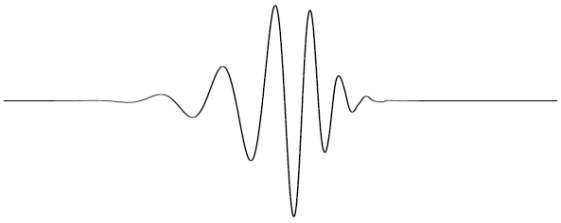

Fig. 4. Wavelet

In 1D Discrete wavelet transform a signal is decomposed into two parts, high frequency part & low frequency part. 1d dwt is applied on 1D signal and as image is 2D data 2d dwt is used for image decomposition.

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Two dimensional DWT decomposes an image into different frequency sub-bands that are localized in orientation (Horizontal, vertical, diagonal). The decomposition of images into different frequency sub-bands permits the isolation of the frequency components and helps in identifying small changes in image to study fine details of the image.

The 2-D wavelet decomposition of an image is results in four decomposed sub-band images referred to as low–low (LL), low–high (LH), high–low (HL), and high–high (HH). Each of these sub-bands represents different image properties. As most of the energy of images is in the low frequencies so decomposition is generally repeated only on the LL sub band.

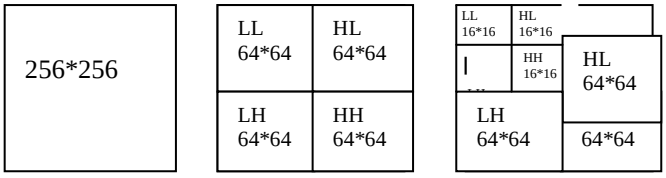

Image to be decomposed

1st level 2d dwt

2nd level 2d wt

Fig. 5. DWT decomposition of an image

Many signals or images contain features at various levels of detail (i.e., scales) and multi-resolution helps in studying that details. Small size objects should be examined at a high resolution. Large size objects should be examined at a low resolution.

DWT is mostly used for edge detection in images. LL (low low) frequency sub-band is upper left block which consists of all the coefficients and represents the approximated version of original image at half the resolution. LL preserves essential visional features for the original image. LL corresponds to low frequency rows and low frequency columns of original image. HL (high low) frequency sub-band shows horizontal edges of original image very clearly. HL corresponds to high frequency rows and low frequency columns of the original image. LH (low high) frequency sub-band shows vertical edges of the image clearly where HL corresponds to high frequency rows and low frequency columns of the image. HH (high high) frequency sub-band shows the edges in diagonal direction where HH corresponds to high frequency rows and high frequency columns. All these sub-bands help in studying fine details of the image.

For k level DWT, there are (3*k) + 1 sub-bands available. The energy of all the sub-bands is used as feature vectors individually which is called as sub-band energy vector (Ek). The level which gives optimal result is selected. The energy of each sub-band is calculated by using the equation.

$$E_k = \frac{1}{NM}\sum_{i=1}^{N}\ \sum_{j=1}^{M}|X_k(i,j)| \qquad \text{eq. (1)}$$

Following figure shows the overall process, before classification process all the training sample images are pre-processed. Training sample contains the fingerprints of various males and females. Using 2D DWT method features of fingerprint are extracted. After extracting features of all fingerprint images we get feature vector for each image and is stored in database. This database is used as lookup table.

Testing fingerprint which is to be classified as male or female fingerprint is taken as input. This image is pre-processed and features are extracted using the same method used for training sample to get feature vector. This testing fingerprint feature vector is compared with all the feature vectors of training sample using minimum distance classifier, which uses Euclidean distance measure for classifying testing fingerprint as male or female fingerprint.

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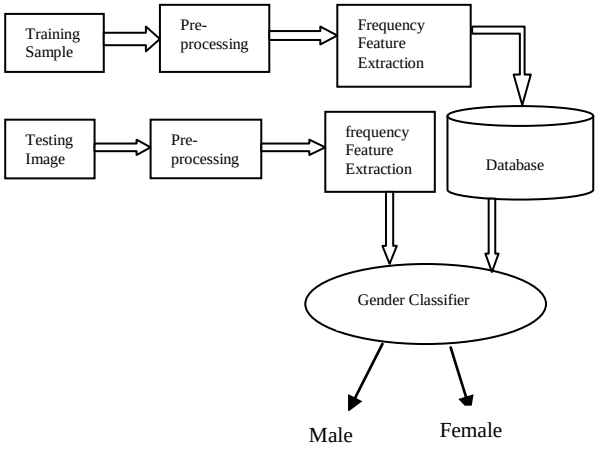

Fig. 6. Image based method for fingerprint gender classification

Another approach based on frequency domain is the discrete cosine transform, which uses cosine as its basis function which gives energy based features of an image. DCT takes the transformation of image and separates relevant coefficients. DCT of an image consists of three frequency components low, middle and high, where low frequency component contains the average intensity of an image means most of the visually significant information of an image is concentrated in just few coefficients. DCT coefficients of an image is calculated using following equation

$$C(u,v) = \alpha(u)\alpha(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)cos\left[\frac{\pi(2x+1)u}{2N}\right]\cos\left[\frac{\pi(2y+1)v}{2N}\right] \qquad \text{eq. (2)}$$

$$\alpha(u)\alpha(v) = \begin{cases} \sqrt{\frac{1}{N}}\ for\ u,v \neq 0 \\ \sqrt{\frac{2}{N}}\ for\ u,v = 0 \end{cases}$$

Where, x and y are index values of an image of which coefficients have to be calculated. u and v are index values of dct coefficient image. M and N is the size of an image.

Using this formula calculate the dct coefficients of all the images in dataset and select the needed coefficients according to raster scan order as features of images and create feature vector database and testing fingerprint is classified using classifier.

IV. CONCLUSION

This paper compares fingerprint based gender classification using two approaches; ridge based approach and image based approach based on processing time, accuracy, simplicity in calculations and compatibility with other methods.

In Ridge based approach the extraction of ridges from fingerprint and finding distance between them is tedious and require more time, also the feature vector obtained in this methods is of varying length and make the calculations difficult. Image based approach takes less time and fixed length feature vector make the calculations easier.

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