Wavelet Application in Fingerprint Recognition

Rakesh Verma, Anuj Goel

Abstract- Fingerprint verification is one of the most reliable personal identification methods and it plays a very important role in forensic applications like criminal investigations, terrorist identification and National security issues. Some fingerprint identification algorithm (such as using Fast Fourier Transform (FFT), Minutiae Extraction) may require so much computation as to be impractical. Wavelet based algorithm may be the key to making a low cost fingerprint identification system. Wavelet analysis and its applications to fingerprint verification is one of the fast growing areas for research in recent year. Wavelet theory has been employed in many fields and applications, such as signal and image processing, communication systems, biomedical imaging, radar, air acoustics, theoretical mathematics, control system, and endless other areas. However, the research on applying the wavelets to pattern recognition is still too weak. As the ridge structure in a fingerprint can be viewed as an oriented texture pattern. The paper proposes a fingerprint recognition technique based on wavelet based texture pattern recognition method. In view to older fingerprint recognition method; based on Fast Fourier Transform (FFT) and Minutiae Extraction, the proposed wavelet based technique results in high recognition rates.

Index Terms- Fingerprint Recognition, Pattern recognition, Wavelet, Texture.

I. INTRODUCTION

In an increasingly digitized world the reliable personal authentication has become an important human computer interface activity. National security, e-commerce and access to computer networks are now very common where establishing a person's identity has become vital. Existing security measures rely on knowledge-based approaches like passwords or token-based approaches such as swipe cards and passports to control access to physical and virtual spaces, but these methods are not very secure. Tokens such as badges and access cards may be duplicated or stolen. Passwords and personal identification number (PIN) numbers may be stolen electronically. Biometrics such as fingerprint, face and voice print offers means of reliable personal authentication that can address these problems and is gaining citizen and government acceptance. Biometrics is a rapidly evolving technology which uniquely identifies a person based on his/her physiological or behavioral characteristics such as finger prints, hand geometry, iris, retina, face, hand vein, facial thermo grams and voice print [1].It relies on "something that you are" to make personal identification and therefore can inherently differentiate between an authorized person and a fraudulent impostor. Although biometrics cannot be used to establish an absolute "yes/no" personal identification like some of the traditional technologies, it can be used to achieve a "positive identification" with a very high level of confidence, such as an error rate of 0.001% [2]. Several studies show that the biometric authentication system based on recognizing the unimodal biometric template suffer from insufficient accuracy caused by noisy data, limited degrees of freedom, non-distinctive and non-universal biometric traits and performance limitations [3,4].

Among all biometric indicators, finger prints have one of the highest level of reliability [5] [6] and have been extensively used by forensic experts in criminal investigations [7]. A fingerprint image is a pattern of ridges and valleys, with ridges as dark lines while valleys as light areas between the ridges. Ridges and valleys generally run parallel to each other, and their patterns can be analyzed on a global and local level. The ridge structure in a fingerprint can be viewed as an oriented texture patterns having a dominant spatial frequency and orientation in local neighborhood. The frequency is due to inter ridge spacing and orientation is due to the flow pattern exhibited by ridges. So a finger print can be viewed as an oriented texture pattern. Jain et al. showed that for sufficiently complex oriented texture such as finger prints, invariant texture representations can be extracted by combining both global and local discriminating information in the texture [8].So this oriented texture pattern can be used for the recognition of fingerprints.

Study shows that use of texture analysis using wavelet transform can increase the recognition rates [9]. Texture is a specific kind of pattern. The texture analysis is one of the most important techniques used in the analysis and classification of images where repetition or quasirepetition of fundamental elements occurs [10]. A great number of approaches to texture analysis have been investigated over the past three decades. Three principal approaches are used in texture analysis, namely, statistical, spectral and structural [11]. But the disadvantage of the texture analysis schemes is that the image is analyzed at one single scale. Using wavelet a multi-scale representation of texture can be achieved by which we can extract the local information about the texture from the image which is utilized to increase the recognition rates. The previous work [12, 13], showed that introducing MR (multi resolution) techniques into the classification of biological images greatly improves the classification accuracy. MR tools are used because of: (a) They provide space-frequency localized information in sub bands. (b) They are fast and efficient to compute.

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The paper is organized as follows. Section 2 relates to the existing work done in fingerprint recognition whereas section 3 show brief introduction of wavelet transform and pattern recognition. In section 4, different approaches for fingerprint recognition along with their limitations is presented. The proposed work is detailed in section 5 followed by conclusion in section 6.

II. RELATED WORK

Jian-De Zheng et al. [14] introduced fingerprint matching based on minutiae. The proposed algorithm uses a method of similar vector triangle. The ridge end points are considered as the reference points. Using the reference points the vector triangles are constructed. The fingerprint matching is performed by comparing the vector triangles. S.D.Sawarkar et.al. [15] focused on a reliable method of computation for minutiae feature extraction from fingerprint images. A fingerprint image is treated as a textured image. Improved algorithms for enhancement of fingerprint images, which have the adaptive normalization based on block processing, are proposed. An orientation flow field of the ridges is computed for the fingerprint image. To accurately locate ridges, a ridge orientation based computation method is used. After ridge segmentation a method of computation is used for smoothing the ridges. The ridge skeleton image is obtained and then smoothed using morphological operators to detect the features. A post processing stage eliminates a large number of false features from the detected set of minutiae features algorithm. Ishmael S. Msiza, et. al. [16]; showed the problem of Automatic Fingerprint Pattern Classification (AFPC) which is being studied by many fingerprint biometric practitioners. It is an important concept because, in instances where a relatively large database is being queried for the purposes of fingerprint matching, it serves to reduce the duration of the query. The fingerprint classes discussed in this document are the Central Twins, Tented Arch, Left Loop, Right Loop and the Plain Arch. The classification rules employed in this problem involve the use of the coordinate geometry of the detected singular points. Zhang quinghui and Zhang Xiangfie [17] proposed the algorithm for fingerprint Identification. Fingerprint image pretreatment processes like gamma controller standardization, Directional diagram computation, image filtering, binarization processes and image division were applied for improving the image quality. K. Thaiyalnayaki, S. Syed Abdul Karim, P. Varsha Parmar [18] introduced a fingerprint recognition system using texture analysis to overcome the problem of minutiae based techniques with an effective combination of features for multi-scale and multi-directional recognition. The features include standard deviation, kurtosis, and skewness. The most common approach for fingerprint analysis is using minutiae that identifies corresponding features and evaluates the resemblance between two fingerprint impressions. Minutiae based techniques suffer from false, missed, and displaced minutiae, caused by poor fingerprint image quality and imperfections in the minutiae extraction stage. Avinash Pokhriyal, Sushma Lehri [19] proposed an approach for fingerprint verification based on wavelets and Pseudo Zernike Moments (PZMs) to extract global and local features. PZMs are robust to noisy images, invariant to rotation and have a good image reconstruction capability making it useful for global analysis and to global features (the shape of the fingerprint image) extraction. Wavelets are good at local analysis and so they help to extract local features (minutiae) from a fingerprint. Therefore, this hybrid approach extracts most significant features from the fingerprint images and achieve better verification rate.

III. OVERVIEW OF WAVELET TRANSFORM AND PATTERN RECOGNITION

Wavelet transform is used on texture pattern of the fingerprints to increase the fingerprint recognition rates. So a very brief qualitative description of Wavelet Transform and Pattern Recognition is discussed, mainly to point out the aspects relevant to our study.

A. Wavelet Transform

Before going to wavelet transform we must know about the wavelets. A wavelet is a waveform of effectively limited duration that has an average value of zero. In mathematical term wavelets are mathematical functions that cut up data into different frequency components, and then study each component with a resolution matched to its scale [20]. Fig.1 shows the comparison of wavelets with sine waves, which are the basis of Fourier analysis. Sinusoids do not have limited duration they extend from minus to plus infinity. Where sinusoids are smooth and predictable, wavelets tend to be irregular and asymmetric. Fourier analysis consists of breaking up a signal into sine waves of various frequencies. Similarly, wavelet analysis is the breaking up of a signal into shifted and scaled versions of the original (or mother) wavelet.

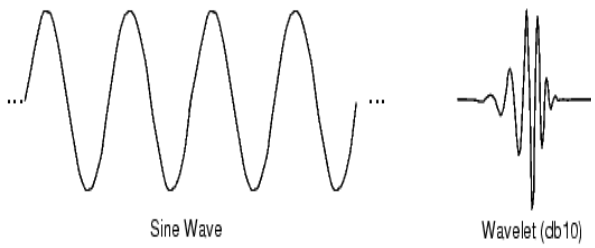

Fig. 1 Comparison of sine wave and wavelet

Fig.1 shows that signals with sharp changes might be better analyzed with an irregular wavelet than with a smooth sinusoid. It also makes sense that local features can be described better with wavelets that have local extent. So wavelet has advantages over traditional Fourier methods in analyzing physical situations where the signal contains discontinuities and sharp spikes. Wavelets were developed independently in the fields of mathematics, quantum physics and electrical engineering. There are many kinds of wavelets one can choose between smooth wavelets, compactly supported wavelets, wavelets with simple mathematical expressions, wavelets with simple associated filters etc. some single wavelet families are shown in Fig 2.

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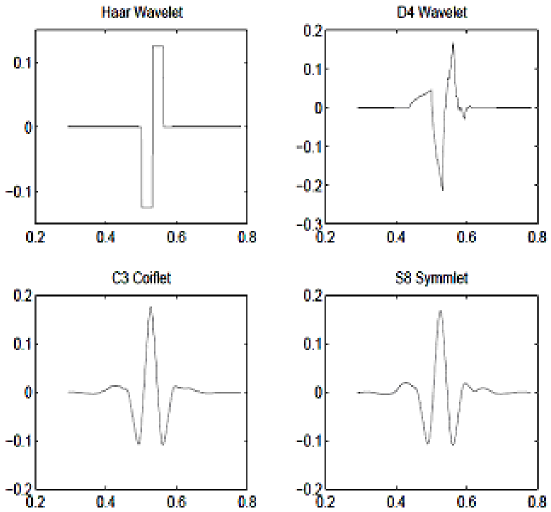

Fig. 2 some single wavelet families [20]

Wavelet Transform is used to split the signal into a bunch of signals and represents the same signal, but all corresponding to different frequency bands. The principle advantage is they provide what frequency bands exists at what time intervals. Wavelet transform of any function f at frequency a & time b is computed by correlating f with wavelet atom as

$$Wf(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} f(t)\psi\left(t - b/2\right)dt \qquad (1)$$

It provides time-frequency localization. Wavelet transform is always defined in terms of a 'mother' wavelet ψ and a scaling function ϕ, along with their dilated and translated versions. Applying wavelet transform on 1D signal, it can correctly detect the singularity in a signal. For images, the 2D scaling function $\phi(x,y)$ and mother wavelet $\psi(x,y)$ is defined as tensor products of the following 1-D wavelets $\psi(x)$, $\psi(y)$ and scaling functions $\phi(x), \phi(y)$.

Scaling function

$$\phi(x,y) = \phi(x) \times \phi(y) \qquad (2)$$

Vertical wavelets

$$\psi^{y}(x,y) = \phi(x) \times \psi(y) \qquad (3)$$

Horizontal wavelets

$$\psi^{x}(x,y) = \psi(x) \times \phi(y) \qquad (4)$$

Diagonal wavelets

$$\psi^{d}(x,y) = \psi(x) \times \psi(y) \qquad (5)$$

The use of wavelet transform on image shows that the transform can analyze singularities easily that are horizontal, vertical or diagonal. So we can use the directional resolving power of wavelet in the fingerprint recognition to track the variation in orientation of fingerprint ridges [21]. Wavelet transform is used in many applications some examples are: Analysis & detection of singularities, For detection of shapes of objects, Invariant representation of patterns, Handwritten & printed character recognition, Texture analysis & classification, Image indexing & retrieval, Classification & clustering, Document analysis. Wavelet have been mostly implemented from fields of data compression and signal processing to more mathematically pure field of solving partial differential equations [22-25]. Wavelets provides time-scale map of any signal it can provide extraction of features that vary in time. Above features makes wavelet an ideal tool for analyzing signals of a transient or non-stationary nature. Hence the use of wavelet in fingerprint recognition system increases performance of system.

B. Pattern Recognition

Pattern recognition is a branch of science that develop "classifiers" that can recognize unknown instances of objects. To recognize an object means to classify it, or to assign it to one of a set of possible classes or labels. This class assignment of objects is based on an analysis of the values of one or more features of the object. Pattern recognition techniques are used in a wide variety of commercial applications. Common examples include character recognition, such as the scanning of a printed page of text into a word processor; natural language recognition, such as using voice commands to relay a set of possible responses to a computer system over the phone; analysis of fingerprint, face, or eye images in order to verify a person's identity; analysis of images taken from airplanes or satellites, perhaps in order to detect and track oil. Humans have a powerful ability to classify objects based on sensory input. Although humans have the ability to read patterns, there are at least two potential advantages to using computer systems for pattern recognition. Even if a person with minimal training could perform a certain task, he or she might not be able to handle the volume of work in a timely fashion, or without becoming bored and error-prone. In other cases, such as recognizing signs of cancer in x-ray images, the task requires specialized training, and there simply may not be as many human experts as needed. Pattern recognition technology has many important uses beyond those already mentioned. For example, pattern recognition techniques might be used to spot credit card fraud, or to detect attempts to break into computer systems. Pattern recognition techniques can also be used in the area of robotics to help robots interpret visual input and move from one place to another. In summary, it should be clear that pattern recognition technology lies at the core of many applications that involve "intelligent" decisions made by computer.

IV. FINGERPRINT RECOGNITION APPROACHES

The task of identifying the fingerprints has attracted much attention in different areas. Here are some of the well-known approaches.

A. Classical approach - The Henry System

This is the Henry system approach [26]. The Henry Classification System allows for logical categorization of ten-print fingerprints records into primary groupings based on fingerprint pattern types. Fig. 3 shows the fingerprint patterns used in Henry System.

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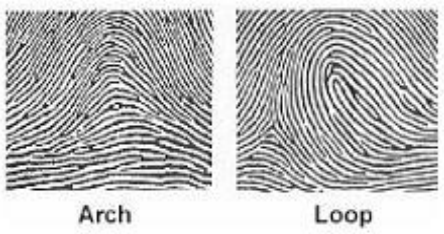

Fig. 3 Fingerprint Patterns in Henry System

Here a working formula is assigned to a set of fingerprints, which will enable the set of prints to be classified or located in a file. The formula has some numerical values which are assigned to fingerprint patterns. These values are then used to form a numerical description of the set of fingerprints, which are used in conjunction with the type of pattern appearing in the index fingers, and numerical values computed from the ridge counts of various fingers. This system reduces the effort necessary to search large numbers of fingerprint records by classifying fingerprint records according to gross physiological characteristics.

B. Minutiae Based Approach

Fingerprints are actually the ridge and furrow patterns on the tip of fingers, which due to their uniqueness and permanence, are among the most reliable human characteristics that can be used for people identification. The characteristics to be extracted in a given fingerprint image can be divided into two main categories, global or high level features and local or low level features. Core and delta are the global features while ridge ending and bifurcation of fingerprint ridges are the local features. Local features are commonly named as minutiae [27].

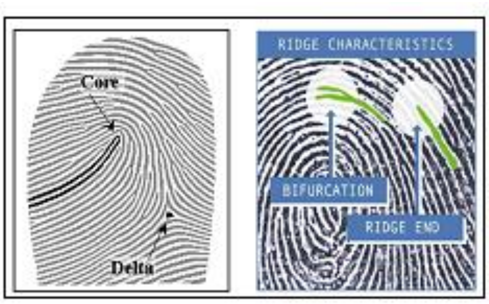

Fig. 4 (a) Global Features: Core and Delta (b) Local Features: Minutiae

A minutia detected in a fingerprint image can be characterized by a list of attributes that includes the minutia position, the minutia direction, and the type of minutia (ending or bifurcation).The representation of a fingerprint pattern thus comprises the attributes of all detected minutiae. By representing the minutiae set as a point pattern, the fingerprint verification problem can be reduced to a minutiae point pattern matching problem. Minutia-based extraction is one of the popular methods in fingerprint recognition. A reliable minutiae extraction algorithm is used to extract the landmark, such ridge bifurcations and ridge ends. The overall idea of minutia extraction mainly consists of three components, orientation field estimation, ridge extraction, and minutiae extraction and post processing. Fig. 5 illustrates the different steps for minutia extraction algorithm in fingerprint recognition.

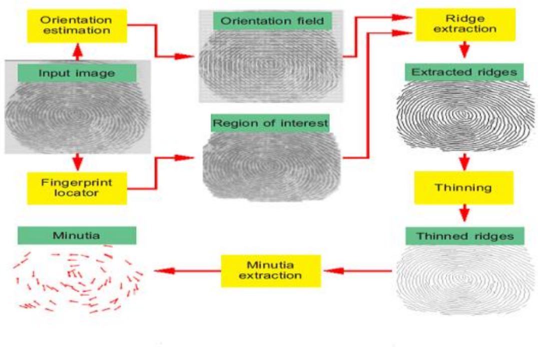

Fig. 5 Flowchart of Minutiae Extraction Algorithm [28]

The minutiae based fingerprint recognition systems achieves very high accuracy. The shortcomings of this approach are:

(a) These systems require high quality fingerprint images.

(b) Minutiae based systems are slow for real time applications;

(c) These systems have low recognition rates.

C. Pattern Recognition Approach

This is image based fingerprint recognition approach. The pattern recognition system consists of five subsystems [26].Data generation is the first step. It transfers the 3-dimensional print into a usable digitized gray-scale image. The image is used in the second subsystem, which performs preprocessing, such as the finalization, etc. Feature extraction follows the pre-processing. This subsystem tries to generate a unique feature vector for the data, which was generated in the first step. Feature extraction is followed by classification. In this subsystem, a classifier is used that was trained on the vectors generated during the feature extraction phase. The result of classification is the identity of the fingerprint. The final step is the post processing stage where the results of the classifier are evaluated. Fig. 6 shows the functional block diagram of pattern recognition approach.

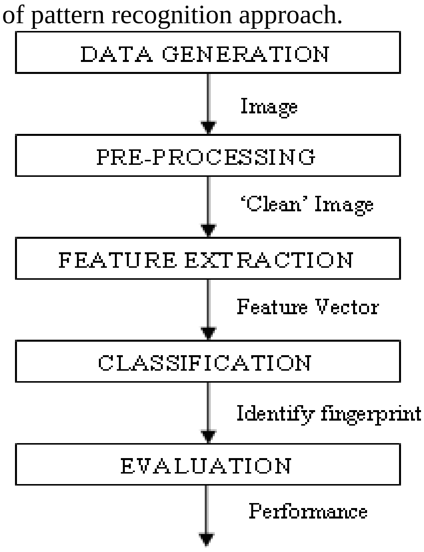

Fig. 6 Functional diagram of Pattern Recognition Approach [26]

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D. Wavelet in Pattern Recognition

For pattern recognition [29], wavelet uses two approaches

1. System-component-oriented
2. Application-task-oriented

Fig. 7 shows the two approaches. It is clear that the two sides are related to each other. Each group of the right side relates to the component of left side. For instance, singularity detector and invariant representation are related to feature extraction. Here the paper is presented with the application-task oriented approach. As the ridge structure in a fingerprint can be viewed as an oriented texture patterns having a dominant spatial frequency and orientation in local neighborhood. The frequency is due to inter ridge spacing and orientation is due to the flow pattern exhibited by ridges so this oriented texture pattern can be used for the recognition of fingerprints. In the most pattern recognition approach fingerprint images are analyzed only at single scales so this gives less information about the texture of image. So if wavelet is used in Pattern recognition approaches, then the image can be analyzed by multi-scale representation of this oriented texture and also the use of wavelets directional resolving power in extracting information from any pattern makes it useful. Hence more information about the texture of the fingerprint image is obtained by using the multi-resolution property of the wavelets.

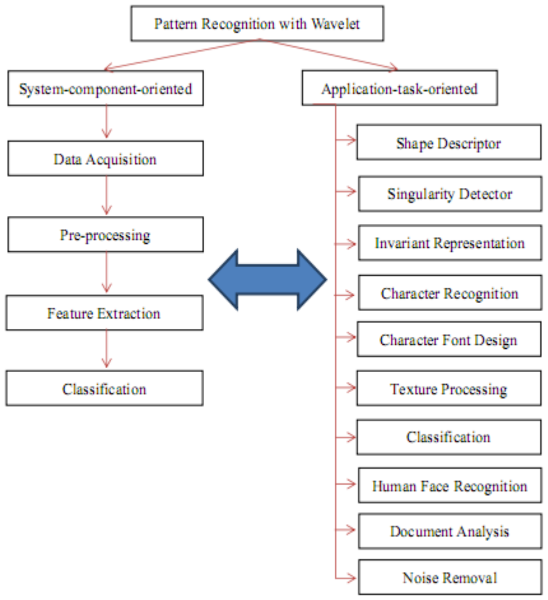

Fig. 7 Pattern recognition with wavelet [29]

V. PROPOSED WORK

This section shows the proposed method which consists of two main modules as shown in Fig. 8 which represents the methodology of the implementation. The whole fingerprint identification system includes enrollment module and identification module. Enrollment module involves the storage of fingerprint images into database, while the identification module processes the input fingerprint image, compares it with the fingerprint images from database and matches it to the correct fingerprint image from database. Both of the enrollment module and identification module have feature extraction process. In this process, after finding the core point of the fingerprint image, Region of interest (ROI) is extracted around this core point so as to make the system translation invariant. After that apply multilevel wavelet decomposition on the extracted ROI. At each level, the wavelet transform decompose the given image into three directional components, i.e. horizontal, diagonal and vertical detail sub bands in the direction of 0, 45 and 135 respectively apart from the approximation (or) smooth sub band. At each level and in each direction wavelet signatures are obtained as feature set for the recognition purpose.

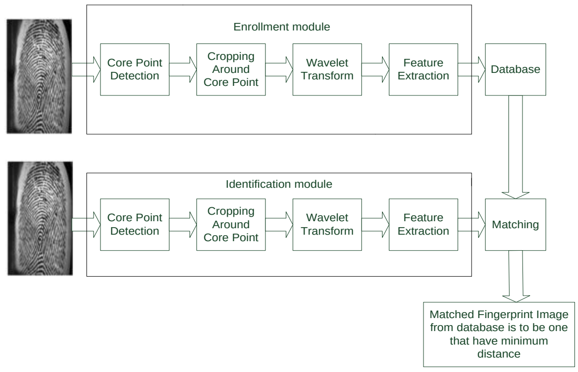

Fig. 8 Proposed methodology for Fingerprint identification

In [30], conjectures that the texture can be characterized by the statistics of the wavelet detail coefficients and therefore introduces wavelet signatures as feature set as shown below:

Wavelet Signatures:

Energy Signatures: The wavelet energy signatures reflect the distribution of energy along the frequency axis over scale and orientation and have proven to be very powerful for texture characterization. Energy signatures are defined as

$$E_{ni} = \frac{1}{N}\sum_{j,k}(D_{ni}(b_j, b_k))^2 \qquad (6)$$

Where N is the total number of coefficients, D_{ni} is decomposed image at level n and in a direction i (horizontal, vertical and diagonal).

Histogram Signatures: It captures all first order statistics using a model based approach from the detail histogram ($h_{ni}(u)$) where n is the level of decomposition and i is the direction (horizontal, vertical and diagonal) of decomposition. The detail histogram of the natural textured images can be modeled as a family of exponentials [31].

$$h(u) = ke^{-(|u|/\alpha)^{\beta}} \qquad (7)$$

Where α and β are wavelet histogram signatures, which are easily interpreted as specific, independent characteristics of the detail histogram.

Co-occurrence Signatures: It reflects the second order statistics of the coefficients. The element (j,k) of the co-occurrence matrix $C_{ni}^{\delta\theta}$ is defined as the joint probability that a wavelet coefficient $D_{ni} = j$ co-occurs with coefficient $D_{ni} = k$ on a distance δ in direction θ.Formulas for eight common co-occurrence features are provided in [30].

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These features extracted from the detail images are referred to as the wavelet concurrence signatures.

In [32] proposed that the combine use of rotated wavelet filter (RWF) and discrete wavelet transform (DWT) based texture features increases the texture recognition rates. So the use of RWF and DWT based fingerprint texture features (Wavelet Signatures) can be used to increase the fingerprint recognition rates.

All these texture features contains the characteristics of the fingerprint image and it can represent the fingerprint image. This texture feature is compared and matched with the texture feature of images from database. The matched fingerprint image from database is the one that have minimum distance value. For the matching of database template and test template features different distance metrics can be used like Euclidean distance, Canberra distance, and Manhattan Distance metrics.

VI. CONCLUSION

The paper proposes a fingerprint recognition technique based on wavelet based texture pattern recognition method. It is observed that the directional resolving power of wavelets extracts the texture information in Horizontal, Vertical and Diagonal directions of the fingerprint images. The use of this local texture information can be used to increase the performance rate. Combine use of DWT and RWF based Wavelet Signatures (Energy Signatures, Histogram Signatures and Co-occurrence Signatures) can increase the recognition rates. Wavelet based approaches do not require any preprocessing and post processing steps so they are fast as compare to earlier minutiae based systems. The use of multi-resolution, compactness and de-noising property of wavelets makes it useful in fingerprint recognition system.

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