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REVIEW ARTICLE

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A Review on Fingerprint Recognition using Wavelet based Pattern Recognition Techniques

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***Abstract*—** Wavelet analysis and its applications have become one of the fastest growing research areas in recent years. 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. This paper presents the overview of fingerprint recognition system using pattern recognition techniques based on wavelets. Fingerprint biometric is very useful in application which requires identity to be claimed. Here the study presents the fingerprint recognition system that uses wavelets. In comparison to older fingerprint recognition system that is based on minutiae, the wavelet based system has high recognition rates.

Keywords- Pattern recognition, fingerprint recognition, Wavelets, Minutiae, Texture

I. INTRODUCTION

Biometric recognition is used for the identification of individuals based on their physiological or behavioral characteristics. There are many applications that require reliable schemes to confirm the identity of an individual. Applications that require reliable personal identifications are gaining access to electronic equipments like computer over the internet, accessing services of the banks like withdrawing money using credit cards. The advantages of using biometric characteristic over the traditional identification methods are that information can not be lost or forgotten. Human's characteristics such as Face, Fingerprint, Hand, Iris, Retina, Voice, Signatures can be used to confirm the identity. Among them fingerprint biometric is the most widely used and accepted by the user as the acquisition of fingerprint image is minimally invasive and require little hardware. 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. Fingerprint image classification systems fall into one of the two major categories: minutiae-based or image-based methods.

Traditional fingerprint recognition system uses minutiae based approach [1].The minutiae based fingerprint recognition system always achieves very high accuracy. The shortcomings of the minutiae based fingerprint recognition system are (a) These systems are not useful for the compressed or noisy images. They always require high quality of images but storing of high quality images requires large amount of storage. (b) These systems are slow for the real time applications as these systems requires steps like preprocessing, registration and orientation flow estimations which leads to slowness of system.(c)These systems have low recognition rates as these not deals with translated, rotated and scaled images. The alternative to minutiae based approach is the image based approach. In this approach we extract features directly from the original image without preprocessing so they are computationally efficient. Study shows that use of texture analysis using wavelet transform can increase the recognition rates [2]. 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 [3]. 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 [4]. 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. Some image based approach require elaborate algorithm to make them robust to low image quality.

The most of image based algorithms uses multiresolution (MR) techniques. The previous work [5, 6], showed that introducing MR 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 adaptive to the data at hand. (c) They are fast and efficient to compute. To classify an image local decision made at the level of each sub band were combined into a global decision using a weighting algorithm. This showed that the sub bands had a discriminative power and that the adaptively provided by the weighting procedure helped increase the classification accuracy over a system that did contain neither the MR decomposition nor the weighting algorithm.

In this paper firstly we presented brief introduction to pattern recognition and wavelet transform than we presented various fingerprint recognition approaches and showed that due to the time-frequency localization characteristics wavelets are the good tools for the extraction of the information from the sub bands of images.

II. PATTERN RECOGNITION AND WAVELET TRANSFORM

Finger prints are graphical ridge patterns present on human fingers and wavelet transform is used along with these Patterns to increase the recognition rates. So a very brief qualitative description of Pattern Recognition and Wavelet Transform is discussed, mainly to point out the aspects relevant to our study.

A. 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.

They can easily read documents printed in a wide variety of type fonts, including handwritten documents. Such ability is all the more amazing because it often seems to require little conscious effort. 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. For example, reading handwritten addresses on pieces of mail is a simple task in principle, but is made difficult by the repetitive nature of handling a large number of pieces of mail. 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.

B. Wavelet Transform:

Before going to wavelet transform we must know about the wavelets. Wavelets are mathematical functions that cut up data into different frequency components, and then study each component with a resolution matched to its scale [7]. They have 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 1.

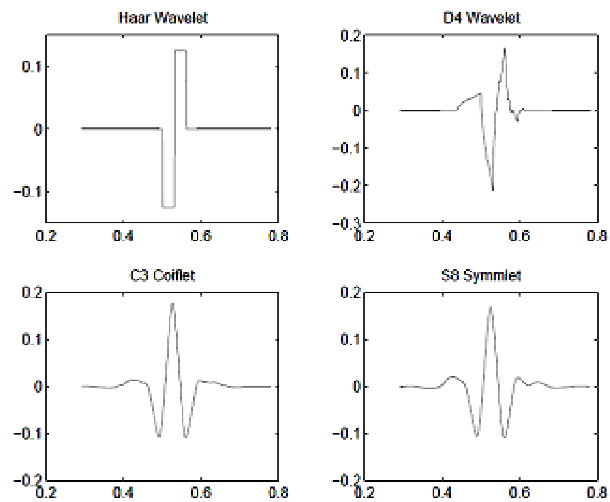

Figure 1. Some single wavelet families [7]

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

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

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 1D wavelets $\psi(x)$, $\psi(y)$ and scaling functions $\phi(x),\phi(y)$,

Scaling function:

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

Vertical wavelets:

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

Horizontal wavelets:

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

Diagonal wavelets

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

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 [8]. 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, Iris pattern recognition, Face recognition, Image fusion, Few other security related application can be seen in artificial intelligence, information security, biomedical science, air acoustic etc..Wavelet have been mostly implemented from fields of data compression and signal processing to more mathematically pure field of solving partial differential equations [9-12]. 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.

III. FINGERPRINT RECOGNITION APPROACHES

A. Classical Approach:

This is the Henry system approach [13]. This approach uses the complete set of 10 fingerprint patterns of both hands to classify a person. 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.

B. Minutiae Based Approach:

Finger prints are graphical ridge patterns present on human fingers, which due to their uniqueness and permanence, are among the most reliable human characteristics that can be used for people identification. A common hypothesis is that certain features of the fingerprint ridges, called minutiae, are able to capture the invariant and discriminatory information present in the fingerprint image. 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. 3 illustrates the flowchart of minutia based approach in fingerprint recognition.

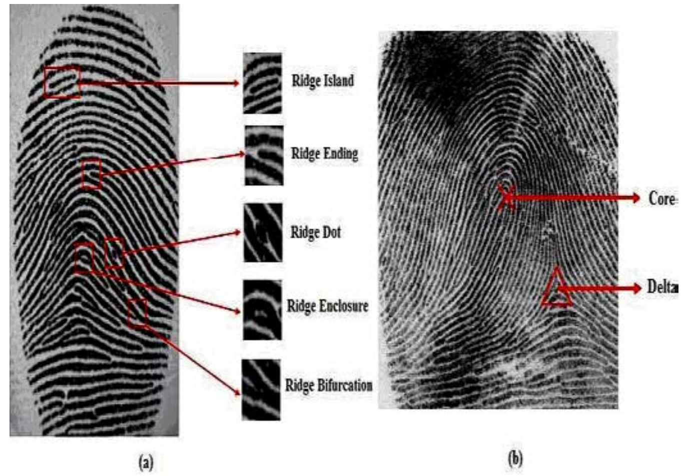

Figure 2. Fingerprint minutiae [14]

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

a. Images with artifacts such as compressed (or noisy) images can not be used with these recognition systems as they require high quality fingerprint images;
b. Minutiae based systems are slow for real time applications;
c. These systems have low recognition rates.

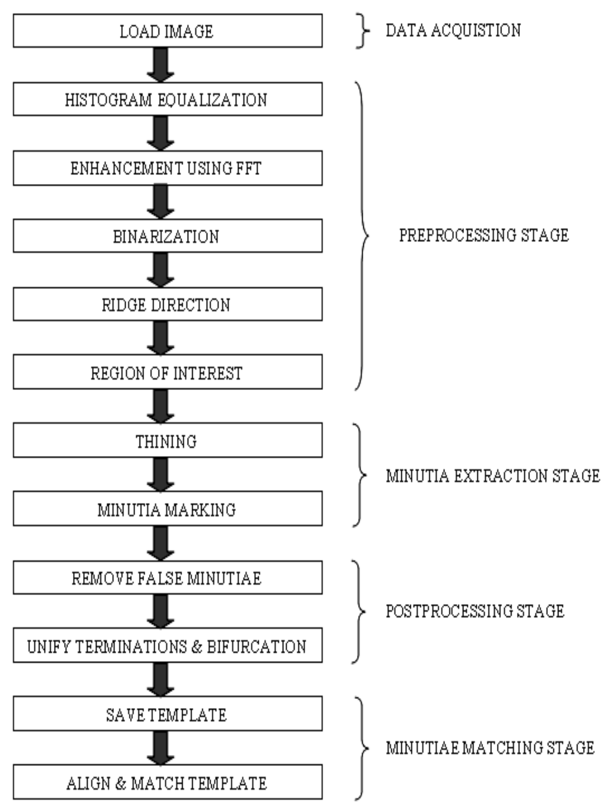

Figure 3. Flowchart of the Minutia Based Approach [14]

C. Pattern Recognition Approach

This is image based fingerprint recognition approach. The pattern recognition system consists of five subsystems [13]. The first step is Data generation that transfers the 3-

dimensional print into a usable digitized grayscale image. Preprocessing step follows the data generation. It is used to crop each fingerprint image about the core point and then normalized to store in the data base. Threshold before feature extraction results better. Sauvola's algorithm [15] can be used for thresholding. Feature extraction follows the preprocessing. This subsystem tries to generate a unique feature vector for the data, which was generated in the first step. The next step is classification that is used to train the vectors generated during the feature extraction phase. The examples of classifiers are Gaussian classifiers (classifiers constructed on the assumption that the feature values of data will follow a Gaussian distribution) and k-nearest-neighbors (a classifier that assigns a class label for an unknown data item by looking at the class labels of the nearest items in the training data) 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. 4 shows the functional block diagram of pattern recognition approach.

Most of the Pattern recognition approaches uses texture feature of the images for classification. But the shortcoming of this approach is the analysis of image at one single scale.

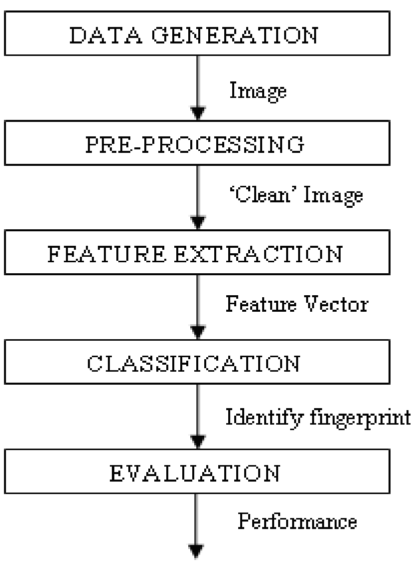

Figure 4. Functional block diagram of pattern recognition approach [13]

D. *Wavelet in Pattern Recognition:*

For pattern recognition [13], wavelet uses two approaches, system component oriented approach, and application-task oriented approach. In system-component- oriented approach, four components are enclosed in a recognition system, i.e. data acquisition, pre-processing, feature extraction and classification. While application-task oriented approach deals with the different application tasks of pattern recognition, such as biometric recognition, character recognition, texture recognition, etc. these two sides are related to each other. Each group of the application task side is related to the component(s) in the system component approach. 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 multiresolution property of the wavelets. [16] conjectures that the texture can be characterized by the statistics of the wavelet detail coefficients and therefore introduces wavelet signatures as feature set.

Wavelet Signatures:-

a. *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

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

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).

b. *Histogram Signatures:*

Which capture 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 [17].

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

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

c. *Co-occurrence Signatures:*

Which reflect 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 [16]. These features extracted from the detail images are referred to as the wavelet concurrence signatures.

Fingerprint matching using wavelet transform can be stepped as follows:

i. Wavelet Statistical Feature Extraction
ii. Wavelet Statistical Feature Matching

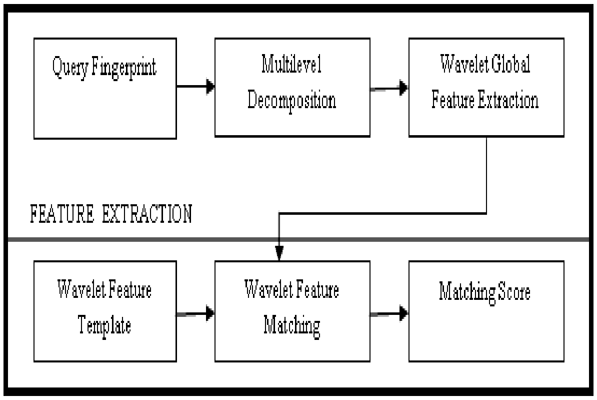

Figure 5. Block diagram of fingerprint recognition algorithm[18]

The Query fingerprint image is a gray scale fingerprint image. After locating the center point from the image we extract the region of interest where maximum detail of the fingerprint is present. On the extracted ROI we apply the multilevel wavelet decomposition. At each level, the wavelet transform decompose the given image in to 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. For the matching of database template and test template features we can use Euclidean distance, Canberra distance, Manhattan Distance and Bray Curtis Distance.

IV. CONCLUSION

This paper presents the different fingerprint recognition approaches along with the algorithms. The advantages and shortcomings of each approach are studied. Wavelet signatures (Energy Signatures, Histogram Signatures and Co-occurrence Signatures) are presented as a feature set for the recognition of the fingerprint texture. The increase in the performance of the fingerprint recognition system by wavelet signatures is due to the use of wavelets directional resolving power in horizontal, vertical and diagonal direction of the fingerprint image. The use of multiresolution, compactness and denoising property of wavelets makes it useful in fingerprint recognition system.

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