Identifying Fingerprint using Wavelet

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Abstract— Fingerprint evidence is undoubtedly the most reliable and acceptable evidence till date in the court of law. Fingerprints are obtained at the site of crime and in many old monuments and in excavated things. Estimating the gender of fingerprints is an emerging field and many methods using the fingerprint physical features like the ridge count and the ridge thickness have been used so far. Due to the immense potential of fingerprints as an effective method of identification an attempt has been made in the present work to analyze their correlation with gender of an individual using frequency domain technique and a pattern recognition technique. The performance of a fingerprint recognition system highly relies on the quality of the fingerprint images. The enhancement is an essential step required to improve the quality of the fingerprint image. In this paper, we propose a enhancement method based on Gabor filtering in wavelet domain.

Key words: Fingerprint Identification, Gabor Filter, Wavelet Transform

I. INTRODUCTION

The term biometric recognition or simply biometrics refers to the use of various characteristic called biometric identifier or trait for automatically recognizing the individual. The characteristic can be physiological i.e. related to the shape of the body (e.g. face, fingerprint, hand and palm geometry etc.) or behavioral i.e. related to the behavior of a person [1].

The most popular and widely used bio-identification system is fingerprint recognition system because of the fact that fingerprints of human are unique and persistent. Fingerprints of even identical twins are different. A fingerprint can be seen as smoothly varying pattern formed by alternating crest (ridges) and troughs (valleys) on the surface of the finger. The ridges are the dark lines and valleys are the light lines in the fingerprint image pattern. 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 in a so-called minutiae set. By representing the minutiae set as a point pattern, the fingerprint verification problem can be reduced to a minutiae point pattern matching problem [4]. Due to variations that may occur between two minutiae sets extracted from different impressions of the same finger, determining whether they indeed represent the same finger can be an extremely difficult problem.

The wavelet (WT) was developed as an alternative to the short time Fourier transform (STFT). A wavelet is a waveform of effectively limited duration that has an average value of zero. Compare wavelets with sine waves, which are the basis of Fourier analysis. Sinusoids do not have limited duration, they extend from minus to plus infinity and where sinusoids are smooth and predictable, wavelets tend to be. Wavelet analysis is the breaking up of a signal into and permanence, are among the most reliable human characteristics that can be used for people identification

Advantages of Fingerprints over other Biometrics [3]:

- High universality
- High distinctiveness
- High permanence
- Easy collectability
- High performance

A. High universality:

A large majority of the human population has legible fingerprints and can therefore be easily authenticated. This exceeds the extent of the population who possess passports, ID cards or any other form of tokens.

B. High distinctiveness:

Even identical twins who share the same deoxyribo nucleus acid (DNA) have been shown to have different fingerprints, since the ridge structure on the finger is not encoded in the genes of an individual. Thus fingerprints represent a stronger authentication mechanism than DNA. Furthermore, there has been no evidence of identical fingerprints in more than a century of forensic practice. There are also mathematical models that justify the high distinctiveness of fingerprint patterns.

C. High permanence:

The ridge patterns on the surface of the finger are formed in the womb and remain invariant until death except in the case of severe burns or deep physical injuries.

D. Easy collectability:

The process of collecting fingerprints has become very easy with the advent of online sensors. These sensors are capable of capturing high resolution images of the finger surface within a matter of seconds. This process requires minimal or no user training and can be collected easily from co-operative or non-cooperative users [7, 8]. In contrast, other accurate modalities like iris recognition require very co-operative users and have considerable learning curve in using the identification system.

E. High performance:

Fingerprints remain one of the most accurate biometric modalities available to date with jointly optimal false accept rate (FAR) and false reject rate (FRR). Forensic systems are currently capable of achieving FAR of less than 10.

The fingerprint recognition problem can be grouped into two sub-domains: one is fingerprint verification and the other is fingerprint identification. In addition, different from the manual approach for fingerprint recognition by experts, the fingerprint recognition is also referred as AFRS (Automatic Fingerprint Recognition System). Fingerprint identification is to specify one person's

identity by his fingerprints. Without knowledge of the person's identity, the fingerprint identification system tries to match his fingerprints with those in the whole fingerprint database. All fingerprint recognition problems, either verification or identification, are ultimately based on a well-defined representation of a fingerprint. As long as the representation of fingerprints remains the uniqueness and keeps simple, the fingerprint matching, either for the 1-to-1 verification case or 1-to-m identification case, is straightforward and easy.

Different Fingerprint Identification Approaches

- Classic Approach - The Henry System
- The Pattern Recognition Approach
- Minutiae Based Approach

1) Classic Approach - The Henry System:

The Henry Classification System allows for logical categorization of ten-print fingerprints records into primary groupings based on fingerprint pattern types. A well-defined 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.

2) The Pattern Recognition Approach:

The pattern recognition system consists of five subsystems. Data generation is the first step. It transfers the 3-dimensional print into a usable digitized grey scale image. The image is used in the second subsystem, which performs pre-processing, 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.

3) Minutiae Based Approach:

Minutia-based extraction is one of the popular methods in fingerprint recognition. 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. The overall idea of minutia extraction mainly consists of three components, orientation field estimation, ridge extraction, and minutiae extraction and post processing.

The fundamental idea of wavelet transforms is that the transformation should allow only changes in time extension, but not shape. This is affected by choosing suitable basis functions that allow for this. Changes in the time extension are expected to conform to the corresponding analysis frequency of the basis function.

II. FUNDAMENTALS OF PATTERN RECOGNITION AND WAVELET TRANSFORM

A wavelet is a wave-like oscillation with an amplitude that begins at zero, increases, and then decreases back to zero. It can typically be visualized as a brief oscillation like one might see recorded by a seismograph or heart monitor. Generally, wavelets are purposefully crafted to have specific properties that make them useful for signal processing. Wavelets can be combined, using a "reverse, shift, multiply and integrate" technique called convolution, with portions of a known signal to extract information from the unknown signal. As a mathematical tool, wavelets can be used to extract information from many different kinds of data, including – but certainly not limited to – audio signals and images. A set of "complementary" wavelets will decompose data without gaps or overlap so that the decomposition process is mathematically reversible. Thus, sets of complementary wavelets are useful in wavelet based compression/decompression algorithms where it is desirable to recover the original information with minimal loss.

A. Pattern Recognition and Wavelet Transform

Wavelet transform is used on texture pattern of the fingerprints to increase the fingerprint recognition rates.

B. Pattern Recognition

Pattern recognition is a branch of science that develop "classifiers" that can recognize unknown instances of objects. To recognize an object 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, analysis of fingerprint images in order to verify a person's identity, analysis of images taken from airplanes or satellites. 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. Pattern recognition technology has many important uses beyond those already mentioned.

C. Wavelet Transform

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 [9]

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

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 wavelet $\psi(x)$, $\psi(y)$ and scaling functions $\phi(x),\phi(y)$

1) Usage:

The use of wavelet transform on image shows that the transform can analyses singularities easily that are horizontal, vertical or diagonal. Hence, the directional resolving power of wavelet in the fingerprint recognition is useful for tracking the variation in orientation of fingerprint ridges [20]. 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. Wavelets have been mostly implemented from fields of data compression and signal processing to more mathematically pure field of solving partial differential equations.

D. Wavelet Signatures:

1) Energy Signatures:

The wavelet energy signatures reflect the distribution of energy along the frequency axis over scale and orientation. They have proven to be very powerful for texture characterization.

2) Histogram Signatures:

Histogram Signatures 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.

3) Co-occurrence Signatures:

Co-occurrence Signatures reflect the second order statistics of the coefficients. The element (j,k) of the wavelet 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.

III. Simulation Model

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. If you have an active Internet connection, you can also watch the working in the Development Environment video demo, and the writing a MATLAB Program video demo and also the other helpful demoes for the major functionality [12]. Typical uses include the following:

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization

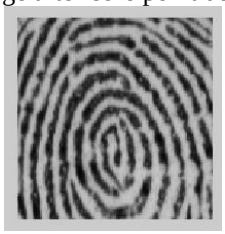
MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Using the MATLAB product, you can solve technical computing problems faster than with traditional programming languages, such as C, C++, and FORTRAN. You can use MATLAB in a wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modelling and analysis, and computational biology. Add-on toolboxes (collections of special-purpose MATLAB functions, available separately) extend the MATLAB environment to solve particular classes of problems in these application areas. MATLAB provides a number of features for documenting and sharing your work. MATLAB code can be integrated with other languages and applications, and distribute your MATLAB algorithms and applications.

IV. Results & Analysis

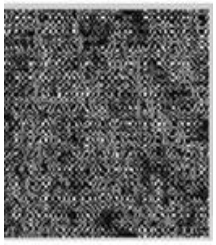
There are a number of fingerprint images shown for each step of the processes. In order to test the performance of the fingerprint identification system, fingerprint images from database of Fingerprint Verification Competition 2002 (FVC 2002) were used. The original size of the fingerprint image is 388 x 374 pixels. Image after finding the core point is shown in figure 1.1.

(a) Original Image

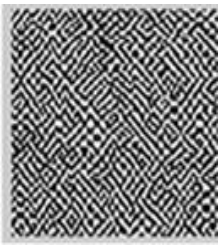
(b) Image after core point detection



(c) Cropped 128 x 128 pixels image



(d) 1st level diagonal information



(e) 2nd level horizontal information

(f) 2nd level vertical information

V. CONCLUSION

The work explored the use of wavelet transform to reduce the size of fingerprint images with less pre-processing and post-processing operations which made the system simple and less space and time consuming. It has also explored the use of new feature vector wavelet co-occurrence signatures to match the database fingerprint images with the input fingerprint images using Euclidian distance.

After this proposed work, it can be concluded that it is more efficient, than previous techniques of fingerprint recognition due to the following reasons –

- The use of wavelets directional resolving power in horizontal, vertical and diagonal direction of the fingerprint image increases the recognition rate.
- The use of multi resolution, compactness and denoising property of wavelets makes it useful in fingerprint recognition system.
- Wavelet transform reduced the size of fingerprint.
- The system cropped out only the core location (small portion of image) of the fingerprint image to make it translation invariant.

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