

## FINGERPRINT RECOGNITION IN WAVELET DOMAIN

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**Abstract.** Fingerprint technique is one of the most reliable biometric technologies. In the fingerprint recognition, pre-processing such as smoothing, binarization, and thinning are needed. Then, fingerprint minutia feature is extracted. Some fingerprint identification algorithm (such as using Fast Fourier Transform, (FFT)) may require so much computation as to be impractical. Wavelet based algorithm may be the key to making a low cost fingerprint identification system that would operate on a small computer. We present a fingerprint recognition system that can match the fingerprint images based on features extracted in the wavelet transform domain. This study is implemented based on MATLAB Software and their toolbox applications, such as Wavelet and Image Processing Toolbox.

**Keywords:** Biometrics, wavelet, security, fingerprint recognition

**Abstrak.** Teknik cetak ibujari merupakan satu daripada teknologi biometrik yang paling boleh diharapkan. Beberapa pendekatan terhadap pepadanan ibujari secara automatik telah dicadangkan dalam saranan. Dalam pengesanan ibujari, pra-prosesan seperti pelicin, *binarization* dan *thinning* diperlukan. Kemudian, ciri-ciri cetak ibujari yang terperinci diambil berdasarkan algoritma pengesanan cetak ibujari (seperti dengan menggunakan *Fast Fourier Transform* (FFT)) mungkin memerlukan teknik-teknik pengkomputeran yang banyak sehingga menjadikannya tidak praktikal. Algoritma berdasarkan *wavelet* mungkin merupakan kunci untuk membina sistem pengesanan cetak ibujari kos rendah yang boleh dioperasi dalam sistem komputer bermodul kecil. Di sini, satu sistem pengesanan cetak ibujari yang boleh menjalankan pepadanan cetak ibujari berdasarkan kepada ciri-ciri yang diperolehi daripada domain jelmaan *wavelet* diperkenalkan. Kajian ini adalah berdasarkan kepada perisian *MATLAB* dan aplikasinya dalam *toolbox* seperti *Wavelet and Image Processing Toolbox*.

**Kata kunci:** Biometrik, wavelet, cetakekuriti, pengesanan cetak ibujari

### 1.0 INTRODUCTION

One of the most dangerous security threats is impersonation, in which, somebody claims to be somebody else. Identities can be stolen, passwords can be forgotten or cracked. According to a UK poll, one in three people write down their Personal Identification Number (PIN)[1].

Biometrics, which is the use of biology that deals with data statistically, provides an answer to the need for a better security in identification and verification. The uniqueness of an individual arises from his personal or behavior characteristics, with no passwords or numbers to remember.

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The fingerprint biometric has a low data collection error rate and high user acceptability. However, the research on applying the wavelets to fingerprint recognition with the wavelet theory has not gained vast of interests. This is because the fingerprint recognition technologies that have been developed for the last few decades are all concentrated on the feature-based recognition.

Many pre-processing steps and feature extraction processes have to be implemented before a fingerprint image can be applied on the matching algorithm[2]. The fingerprint recognition method in wavelet domain converts the fingerprint images directly to the desired template form, and then verify it. It preserves a potential of developing a lost cost, and small module fingerprint recognition system.

## 2.0 LITERATURE REVIEWS

Theoretically, any human physiological or behavioral characteristic can be used to make personal identification as long as it satisfies the following requirements [3]:

- (i) universality, which means that every person should have the characteristic,
- (ii) uniqueness, which indicates that no two person should be the same in terms of the characteristic,
- (iii) permanence, which means that the characteristic should be invariant with time, and
- (iv) collectability, which indicates that the characteristic can be measured quantitatively.

Table 1 [2] shows the level of quality of several most common type biometrics technologies. In practice, there are some other important requirements:

**Table 1** Comparison of biometric technologies

<b>Biometrics</b>	<b>Univer- sality</b>	<b>Unique- ness</b>	<b>Perman- ence</b>	<b>Collecta- bility</b>	<b>Perform- ance</b>	<b>Accepta- bility</b>	<b>Circum- vention</b>
Face	high	low	medium	high	low	high	low
Fingerprint	medium	high	high	medium	high	medium	high
Hand geometry	medium	medium	medium	high	medium	medium	medium
Hand vein	medium	medium	medium	medium	medium	medium	high
Iris	high	high	high	medium	high	low	high
Retinal scan	high	high	medium	low	high	low	high
Signature	low	low	low	high	low	high	low
Voice print	medium	low	low	medium	low	high	low
F. thermograms	high	high	low	high	medium	high	high

- (i) performance, which refers to the achievable identification accuracy, the resource requirements to achieve an acceptable identification accuracy, and the working or environmental factors that affect the identification accuracy,
- (ii) acceptability, which indicates to what extent people are willing to accept the biometric system, and
- (iii) circumvention, which refers to how easy it is to fool the system by fraudulent techniques.

## 2.1 Existing Fingerprint Recognition Methods

### (1) Classic Approach – The Henry System

The goal of classic fingerprint classification system is to assign a working formula to a set of fingerprints, which will enable the set of prints to be classified or located in a file. The formula consists of numerical values which are assigned to fingerprint patterns. These values are then summed 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.

Henry system is one of such method which makes use of the complete set of 10 fingerprint patterns of both hands to classify a person.

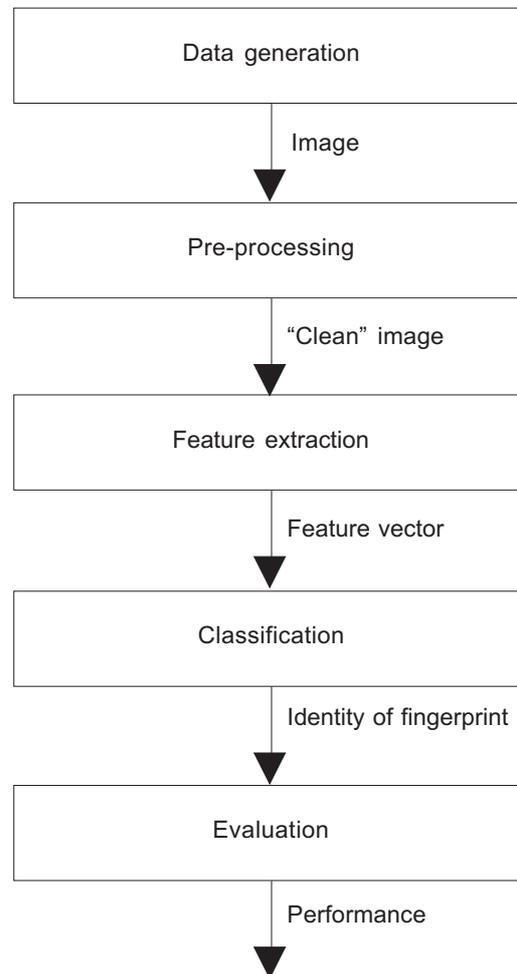
### (2) The Pattern Recognition Approach

The pattern recognition system consists of five subsystems. Data generation is the first step. It transfers the 3-dimensional print into a usable digitized grayscale 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. Figure 1 shows the functional block diagram of pattern recognition approach.

Minutia-based extraction is one of the popular methods in fingerprint recognition approach. A reliable minutiae extraction algorithm is used to extract the landmark, such ridge bifurcations and ridge ends.

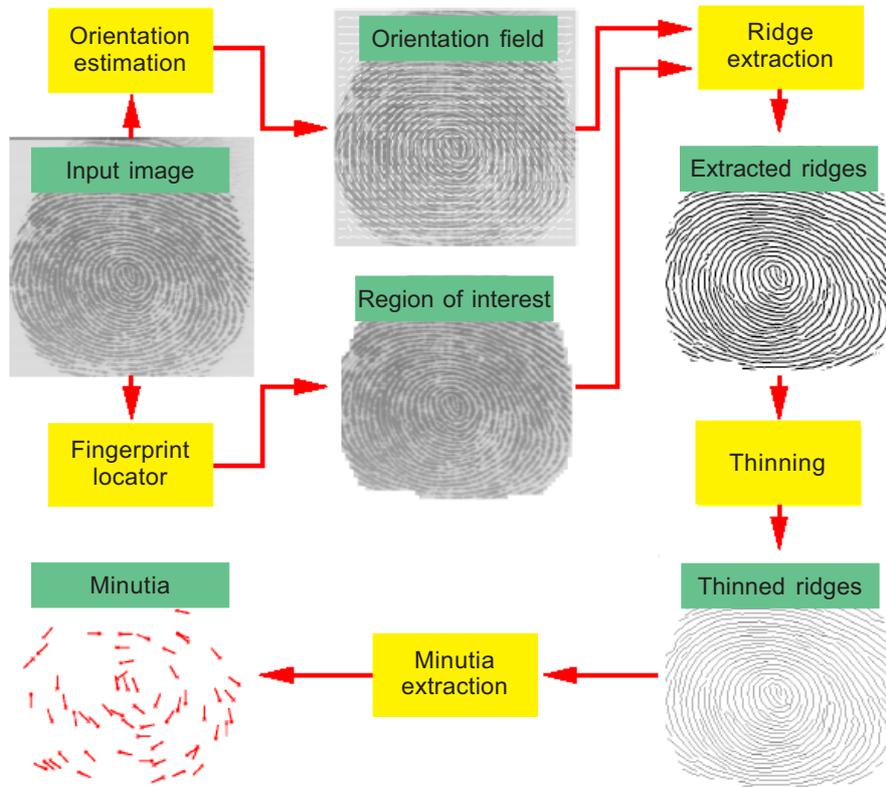
The overall idea of minutia extraction mainly consists of three components, which are orientation field estimation, ridge extraction, and minutiae extraction and post-processing. Figure 2 illustrates the algorithm of minutia extraction algorithm in fingerprint recognition.



**Figure 1** Functional block diagram of pattern recognition approach

## 2.2 Wavelet Analysis

In the recent times, enormous interest has emerged in the application of wavelets, and they have been successfully implemented into many fields of endeavor, ranging from data compression and signal processing to the more mathematically pure field of solving partial differential equations [5-11]. The fundamental idea behind wavelets (see Appendix A) is to analyze according to scale. Indeed, some researchers in the wavelet field feel that by using wavelets, one is adopting a whole new mindset or perspective in processing data.



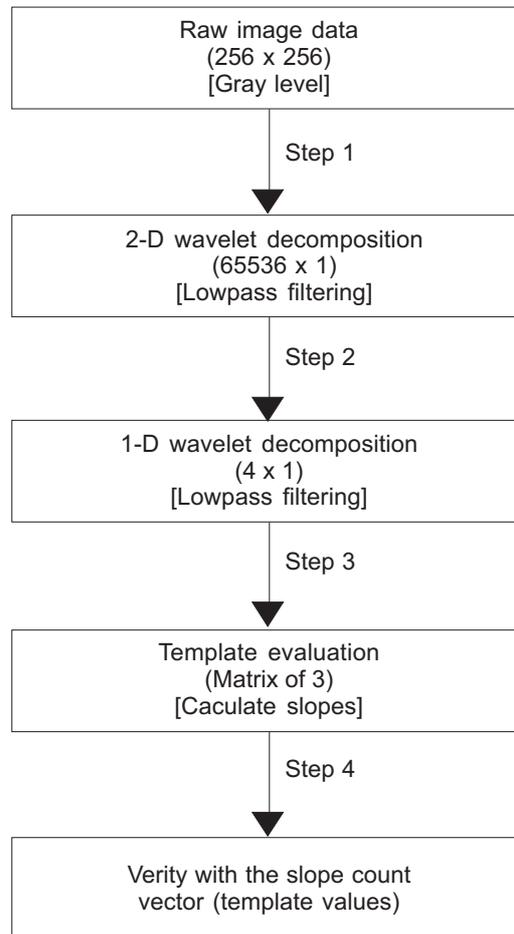
**Figure 2** Flowchart of the Minutia Extraction Algorithm [4]

Wavelets provide an alternative approach to traditional signal processing techniques, such as Fourier analysis for breaking a signal up into its constituent parts. The driving impetus behind wavelet analysis is their property of being localized in time (space), as well as scale (frequency). This provides a time-scale map of a signal, enabling the extraction of features that vary in time. This makes wavelets an ideal tool for analyzing signals of a transient or non-stationary nature.

### 3.0 METHODOLOGY

The methodology adopted by this study is shown in Figure 3.

Given the digitized image of a fingerprint, the image is pre-processed to obtain the binarized data. Next, two dimensional Discrete Wavelet Transform (DWT) is performed on the binarized image and then followed by one dimensional DWT. Finally, a resolution of  $4 \times 1$  row vector of wavelet-based representation is obtained. With this feature vector, identification can be made by comparing it with other fingerprint features.



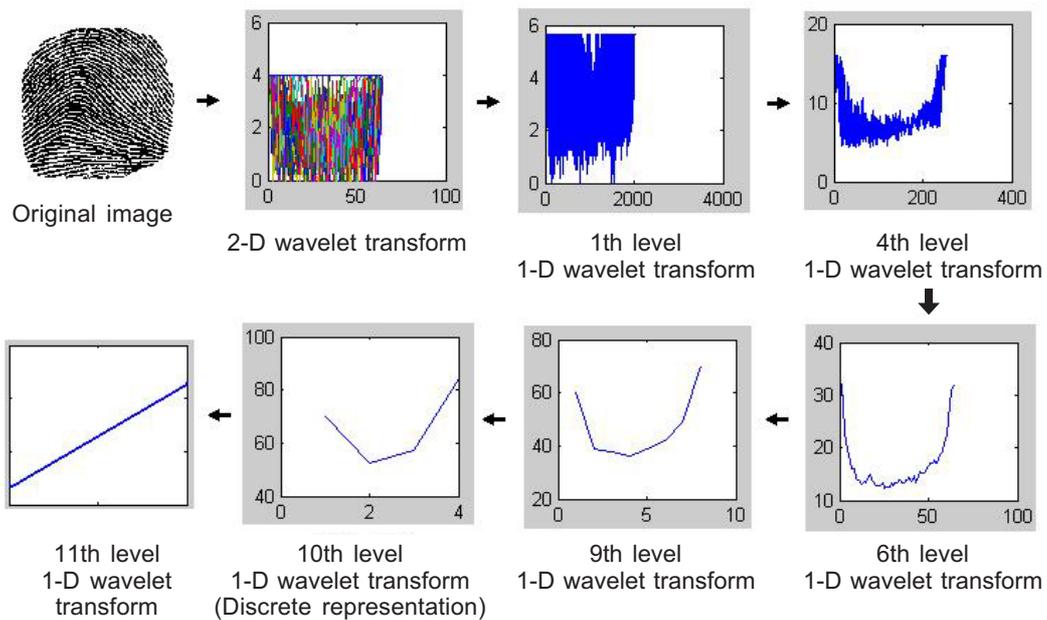
**Figure 3** Block diagram of fingerprint recognition algorithm

### 3.1 Feature Extraction Using DWT

During the wavelet transformation, low frequency components in the image will be filtered out as approximations and high frequency components will be filtered out as details. Figure 3 in Appendix A illustrates how the wavelet decomposition filters the high and low frequency signals.

The approximations will then be filtered again iteratively until a satisfactory and suitable representation is obtained. In this case, the raw image will first go through a two dimensional DWT to produce a one dimensional coefficient plot. This is a large scale and high frequency plot. It will later undergo a series of one dimensional DWT at different scale levels until a discrete form of representation is produced. In this method, we found that DWT coefficient plot has become a discrete representation after the 10<sup>th</sup> level of DWT.

During the 9<sup>th</sup> level of DWT, the produced representation is not yet in a discrete form. However, during the 11<sup>th</sup> level of DWT, the graph will become a straight line, and this is also not a practical result. Therefore, the 10<sup>th</sup> level of wavelet decomposition is the optimum method to produce the template, where the produced templates are considered as analyzable and comparable. The transformation from raw image to wave-based representation is shown in Figure 4.



**Figure 4** Transformation of raw fingerprint image into a wavelet-based representation in different DWT feature extraction levels

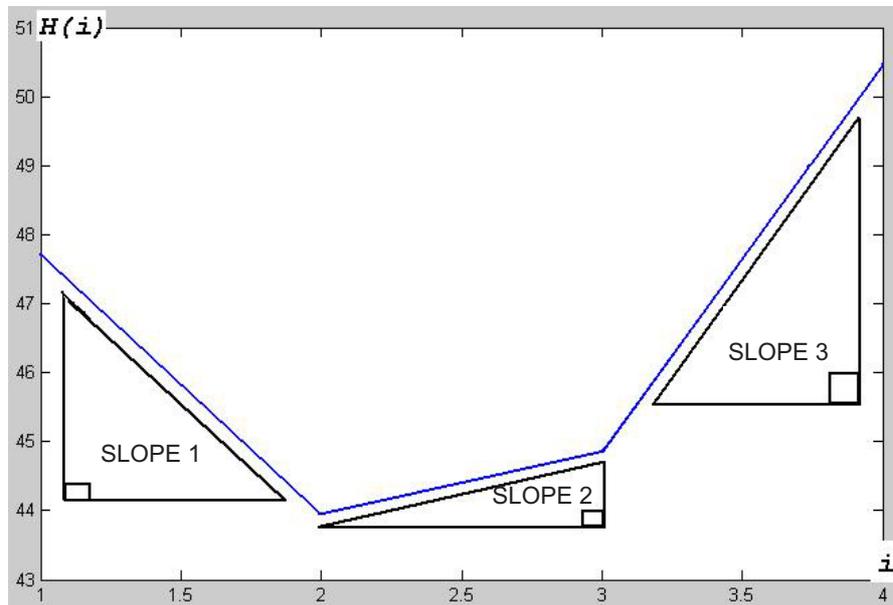
### 3.2 Template Evaluation

Three linear lines are obtained after the 10<sup>th</sup> level of DWT. The slope of these lines are then evaluated to give a numerical value. These values, a matrix of 3, are then taken as the template value of the fingerprint image. It is more practical to represent and store the particular fingerprint image in a matrix form instead of the entire graph. Figure 5 illustrates this operation.

Then, fingerprint recognition is done based on verifying the template value from the input image and the stored templates in database.

### 3.3 Verification (Matching)

By analyzing several transformed templates, the variation in template slopes and its values are observed. Since the calculated template values are in the degree of  $10^3$  to



**Figure 5** The slopes count for wavelet-based representation

$10^5$ , the variations in slopes which are in the degree of  $10^1$  to  $10^2$  are relatively small, compared to them. Therefore, a tolerance within the slope variation range will be used to set as the threshold of verification. However, the tolerance still depends on the characteristics of the wavelet feature extraction. With the intention of how far the rotated, shifted, and distorted images are set to be recognizable from the original image, an optimum value is considered necessary. This is because, the greater magnitude in tolerance will produce lower system accuracy, and reliability.

The input template values are compared with the saved template values from the database, one by one. The degree of variation of the input template is measured and the magnitude of dissimilarity is calculated. If the dissimilarity of slope is beyond the tolerance, this particular slope from the input template is considered unmatched.

An improved matching algorithm is done to increase system resistance to the input variations in positions by having two more sets of template value calculated from shifting-left, and shifting-right of the input image. The image will be verified by matching all three sets of template value, to find the most similar pair.

#### 4.0 RESULTS

All input fingerprints are in the format of  $256 \times 256$  resolution. The test input images are divided into two groups, which are enhanced fingerprint images (E-input), and unprocessed (raw) fingerprint images (U-input). The template conversion in this study uses the direct DWT of fingerprint images. There is no any intermediate step in feature

extraction during the transform. Therefore, the produced templates had only very limited resistance to the variations in position, scale, and rotation angle. On the other hand, they are only recognizable in this system if the inputs (test samples) are invariant to the stored templates in the database.

Based on the designed analysis in the DWT characteristics, we shifted the input images in different directions and scales to observe the characteristic responses. Figures B.1 and B.2 in Appendix B show the transition for both U-input and E-input images in all four possible directions.

The effects of shifting-up and shifting-right of the input image in DWT coefficient plot are shown in Figures 6 to 9.

From Figures 6 to 9, it can be seen that the shifting in vertical directions (up and down) resulted in a more uniform transition of DWT coefficient plots. It means that these shifted plots still approximate the shape of original plots. However, shifting left and right encountered significant changes. This is because DWT transforms fingerprint images from 2-D ( $256 \times 256$  resolutions) image to a 1-D coefficient plot. Hence, all the row pixel values are cascaded into a column to yield a 1-D ( $65536 \times 1$ ) coefficient plot. Thus, the variation in horizontal direction greatly affected the transformation results.

## 5.0 CONCLUSION

Over the past decades, biometric technique and its applications have undergone tremendous development and growth. More than ever, fingerprint technique is one of the most popular applications in both identification, and verification.

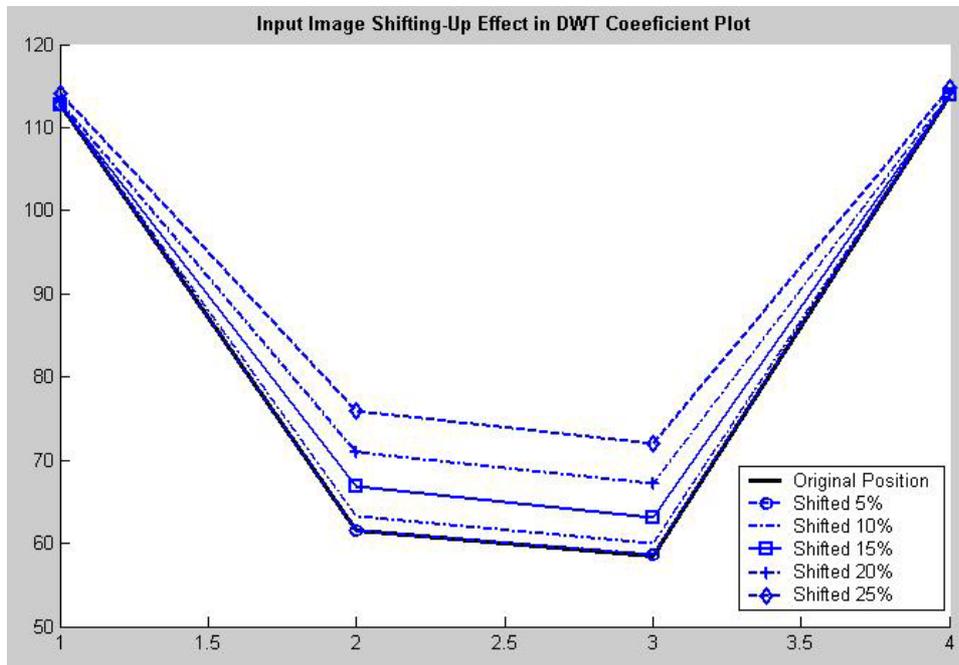
An instance of fingerprint recognition in wavelet domain has been implemented in this study. This can be considered as an 'evolutional' method in fingerprint recognition, compared to the existing approaches in the past decades. Image-based feature extraction approach in fingerprint recognition gains the advantages in developing a low cost system since it does not require a lot of redundant works on pre-processing, and tone of the mathematical algorithm analysis.

Furthermore, enormous interest has emerged in the application of wavelets in the recent time. Hence, the study and research in wavelet applications will become a domain concern in the future development.

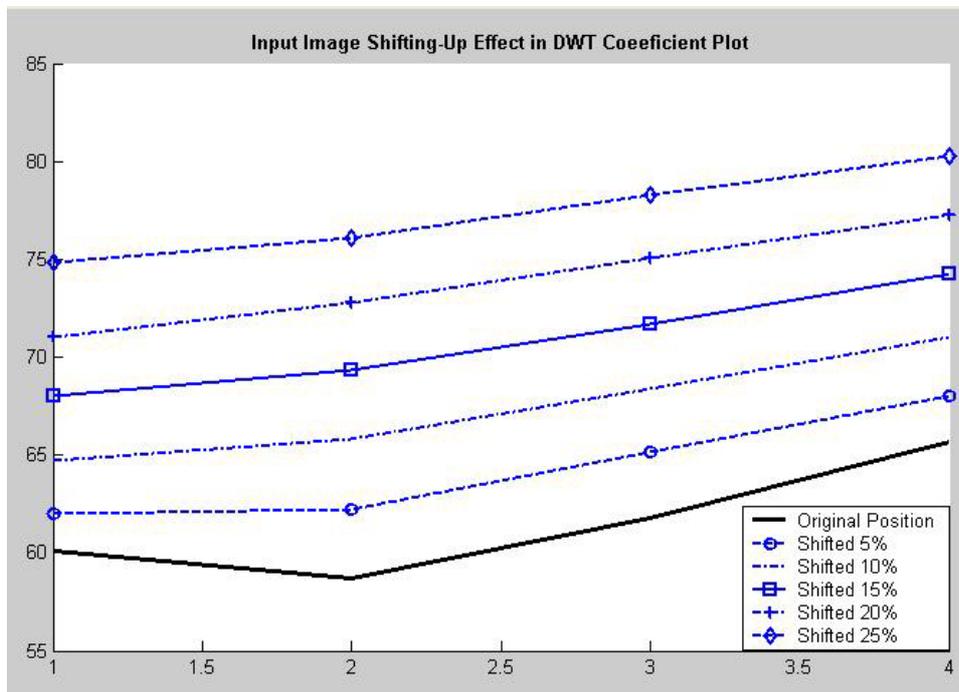
## 6.0 FUTURE WORK

There are some weaknesses of this designed system, especially in the variation of positions. However, it gained a satisfactory result in matching and recognizing in this approach.

To overcome this 'weakness' in the system, several areas of improvement were identified since this kind of study is still an immature field, and many new methods can be expected to appear in the literature in the future.

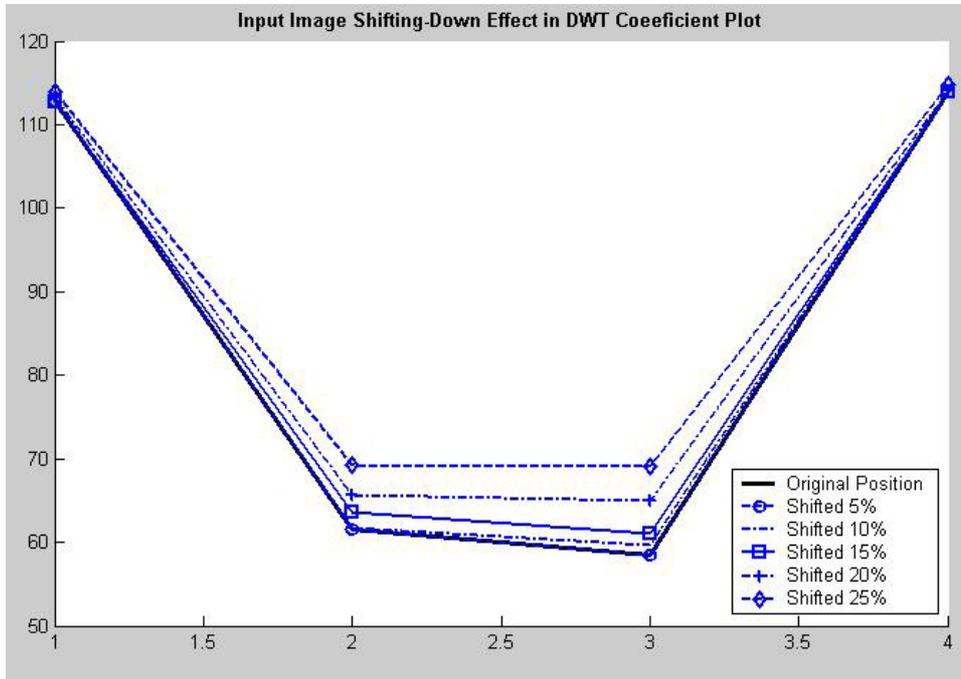


(a)

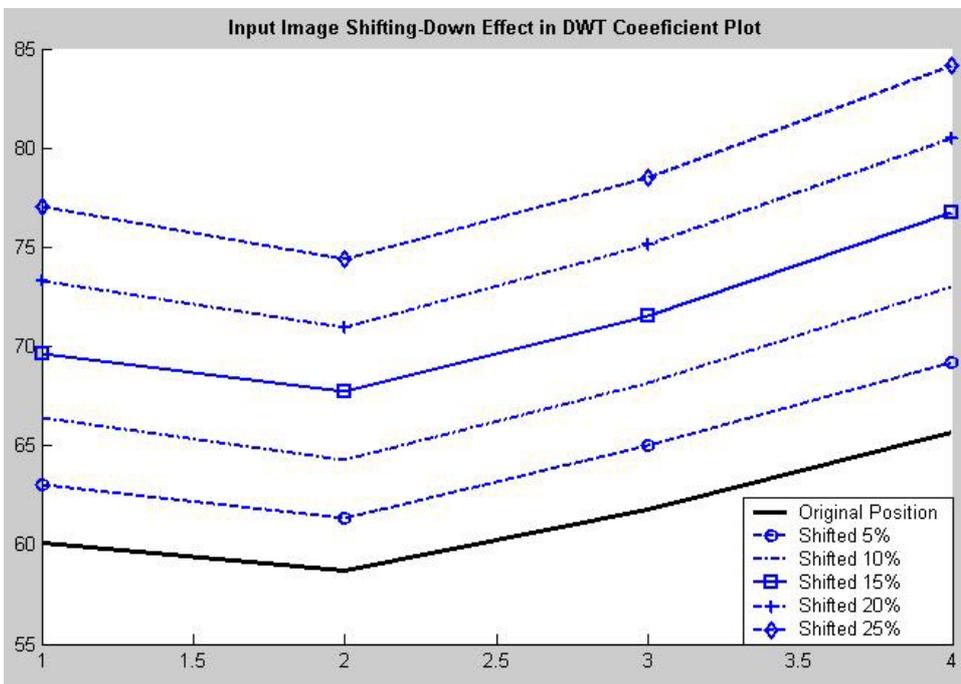


(b)

**Figure 6** Shifting-up effect in DWT coefficient plot of (a) U-input and (b) E-input

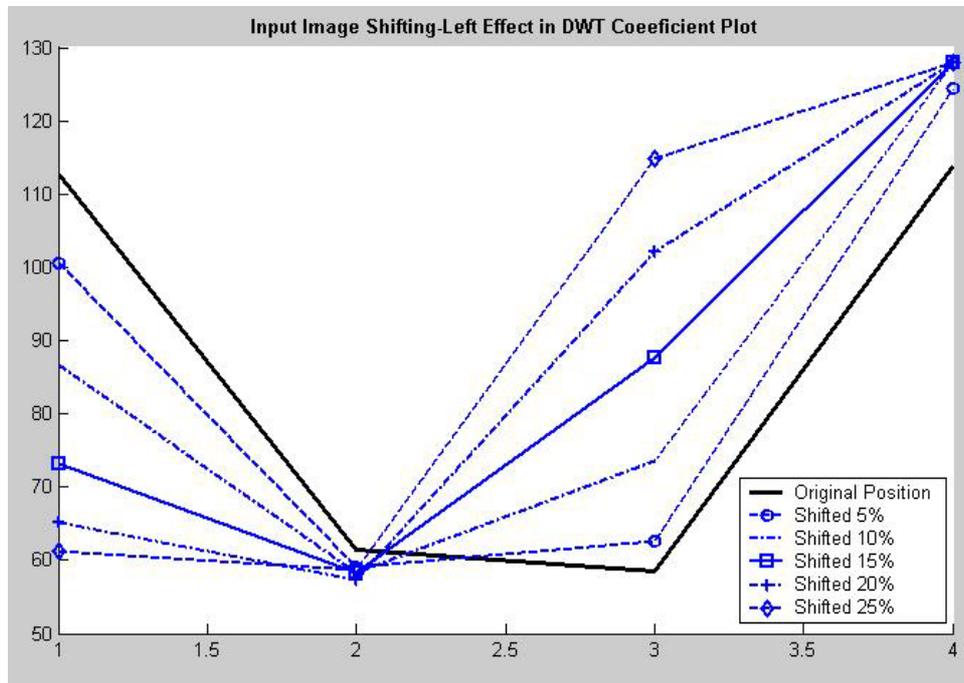


(a)

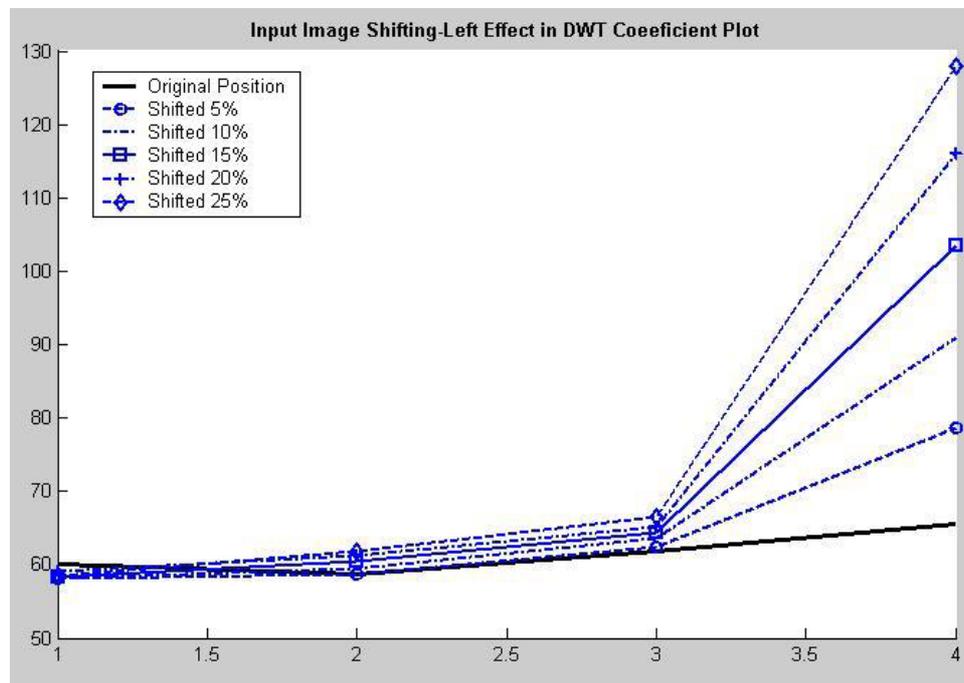


(b)

**Figure 7** Shifting-down effect in DWT coefficient plot of (a) U-input and (b) E-input

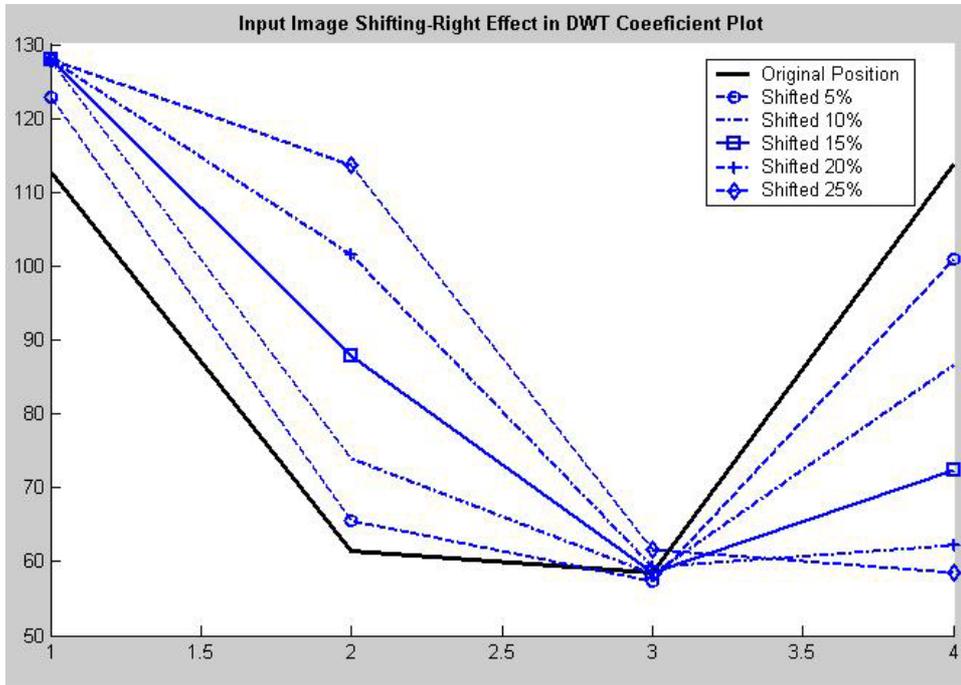


(a)

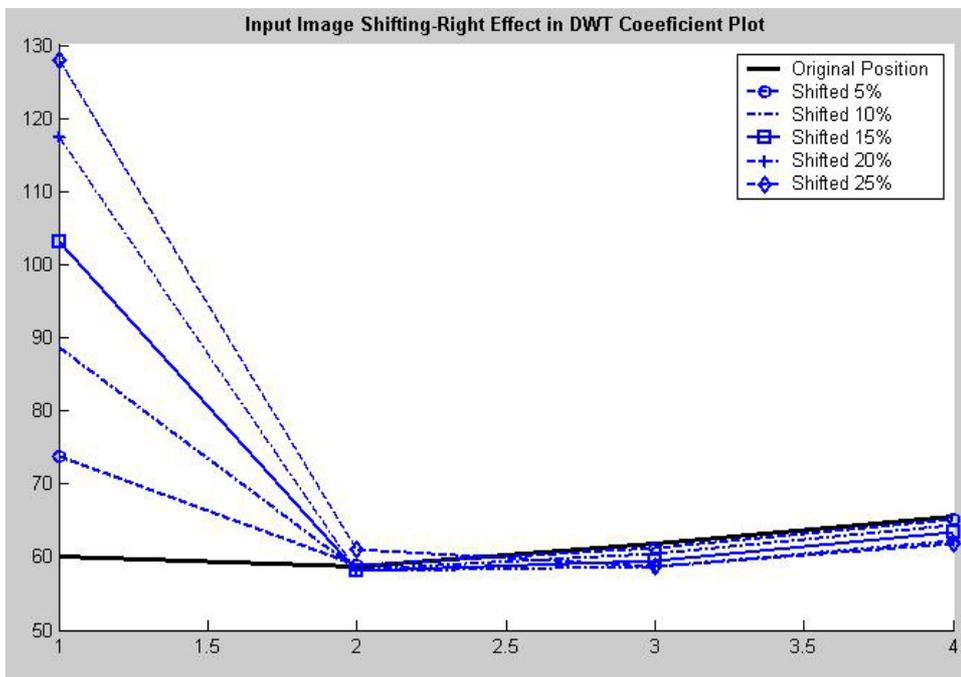


(b)

**Figure 8** Shifting-left effect in DWT coefficient plot of (a) U-input and (b) E-input



(a)



(b)

**Figure 9** Shifting-right effect in DWT coefficient plot of (a) U-input and (b) E-input

For variation in position, it can be cancelled by registering the input images in respect to a reference point, which can be consistently detected in different instances of the same finger. Such a reference point may be the core point for the fingerprint image. Thus, increasing the reliability of the system when it is applied in a live-scan input domain.

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## APPENDIX A

### A.1 Discrete Wavelet Transform (DWT)

DWT means that only a subset of scales and positions is chosen to be analyzed. Since calculating the entire wavelet coefficients at every possible scale (continuous wavelet transform) is a fair amount of work, it generates an awful lot of data.

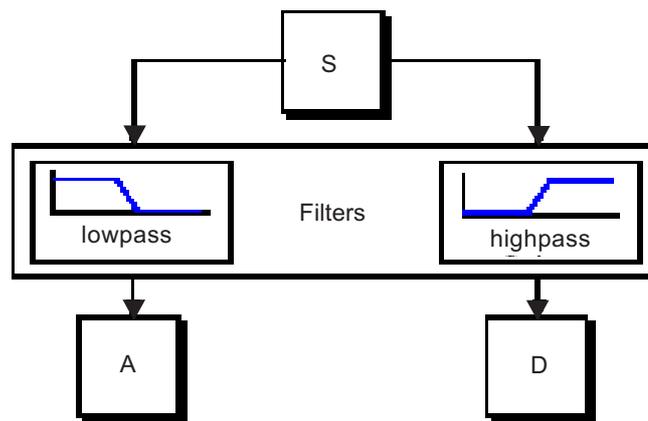
It turns out, rather remarkably, that if we choose scales and positions based on powers of two – so-called dyadic scales and positions – then our analysis will be much more efficient, and just as accurate. We obtain such an analysis from the discrete wavelet transform (DWT). The mathematical expression of DWT is shown as follows:

$$\psi_{j,k}(t) = \frac{1}{\sqrt{s_0^j}} \psi\left(\frac{t - k\tau_0 s_0^j}{s_0^j}\right)$$

### A.2 Approximations and Details

For many signals, the low-frequency content is the most important part. It is what gives the signal its identity. The high-frequency content, on the other hand, imparts flavor only. Consider the human voice. If you remove the high-frequency components, the voice sounds different, but you can still tell what is being said. However, if you remove enough of the low-frequency components, you only hear gibberish.

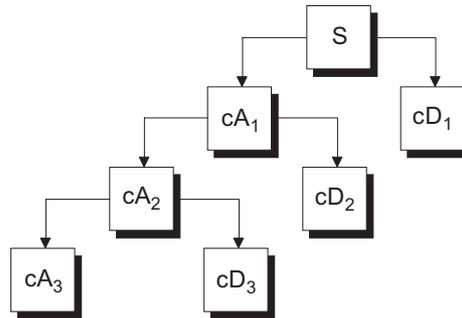
In a wavelet analysis, we often speak of approximations and details. The approximations are the high-scale, low-frequency components of the signal. The details are the low-scale, high-frequency components of the signal. The filtering process, at its most basic level, looks like this:



**Figure A.1** Block diagram of wavelet filtering

The original signal,  $S$ , passes through two complementary filters and emerges as two signals.  $A$  represents the approximations (low frequency signals), and  $D$  represents the details (high frequency signals).

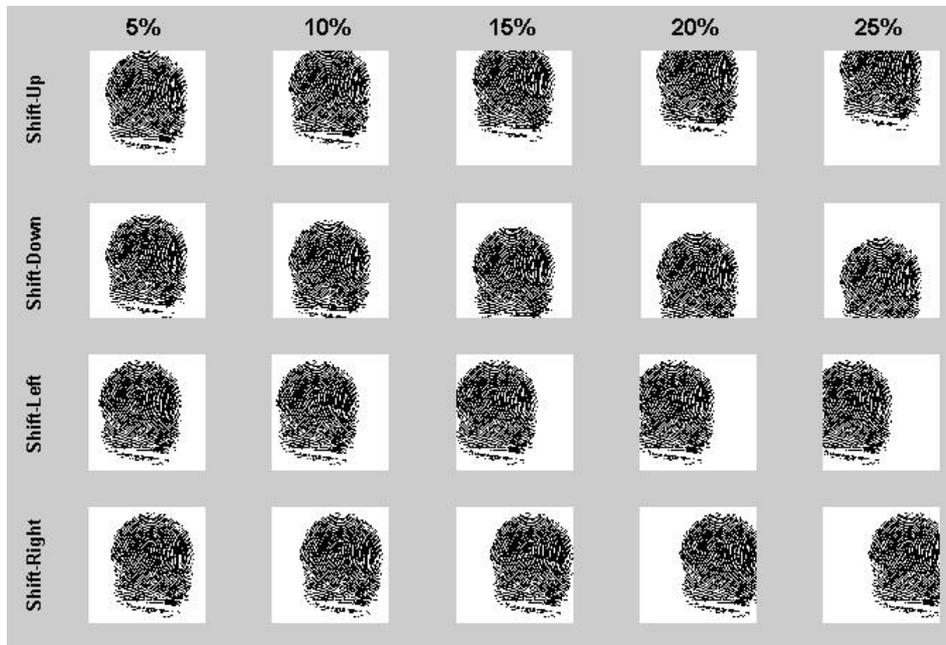
The decomposition process can be iterated, with successive approximations being decomposed in turn, so that one signal is broken down into many lower resolution components, as shown in Figure A.2. This is called the wavelet decomposition tree. Looking at a signal's wavelet decomposition tree can yield valuable information.



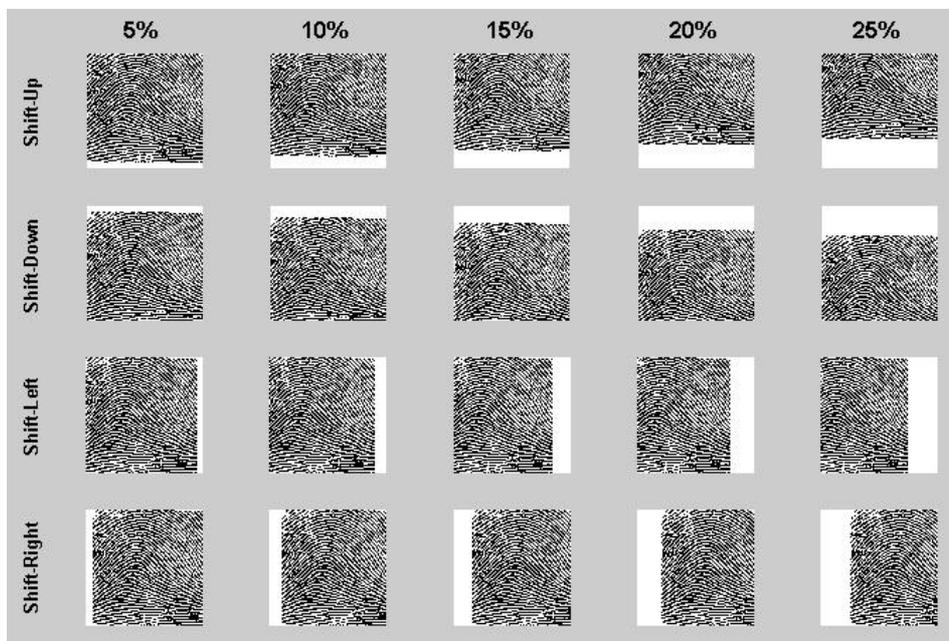
**Figure A.2** Diagram of multiple level wavelet decomposition



**APPENDIX B**



**Figure B.1** Transition of U-input in all four possible directions with confined extents of variation



**Figure B.2** Transition of E-input in all four possible directions with confined extents of variation