Performance Analysis of Coiflet Wavelet and Wavelet Packet Transform for Biometric Fingerprint Image Compression

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ABSTRACT

Fingerprint image is one of the most acceptable means of biometric capturing, due to its unique features and convenient capturing process. The rapid increase in world population has led to the increase in population of people needed to be captured. Similarly, substantial storage, transmission and computation costs are obvious, thus their compression is advantageous to reduce these requirements. Coiflet wavelet is one of the best signal transformation and filtering technique. This work presents a carefully designed approach to biometric fingerprint image compression and performance analysis in wavelet and wavelet packet transform. This was achieved through the determination of the percentage Retain Energy (RE) and Number of Zeros (NZ) for different levels Coiflet-type wavelets at different threshold values of 235, 245 and 255, at fixed decomposition level 3 using wavelet and wavelet packet transform. 8-bit grayscale right thumb digitized image of size 380×400 was used for the experiment. The result shows that, at the first threshold value, Wavelet Transform (WT), RE (%) values increased from 96.75% to 98.87% while that of NZ, decreases from 97.53% to 96.67% across the five levels of coiflet wavelet. At the second threshold value, RE increased from 96.64% to 98.83% while NZ decrease from 97.58% to 96.70% across the five levels of the coiflet. At the third threshold value, RE increases from 96.53% to 98.79%, while NZ deceases from 97.63% to 96.73%. Then for WPT, at the first threshold value, RE increased from 97.02% to 98.80% and Nz also increased from 97.69% to 98.01% across the five levels of the coiflet. At the second threshold value, RE increased from 96.90% to 98.76%, also NZ increased from 97.75% to 98.03%. At the third threshold value, RE increased from 96.76% to 98.72%, also NZ increased from 97.80% to 98.06% across the five levels of the coiflet-type wavelet. This means that the Wavelet Packet Transform (WPT) has more compression rate than Wavelet Transform (WT), thereby requiring less storage space and overall cost.

KEYWORDS
Wavelet Transform, Wavelet Packet Transform, Retained Energy, Number of Zero, Biometric system, fingerprint image compression, coiflet wavelet.

I. INTRODUCTION

Biometric fingerprint image verification is one of the most reliable, acceptable and convenient means of personal identification methods, it plays key role in the administration and applications of both civilian and non-civilian affairs. In most countries of the world, personnel identification management has being a major challenge more especial in immigration and other security aspects. The archive consists mainly of inked impressions on paper cards.

A wide variety of systems require reliable personal authentication schemes to either confirm or determine the identity of individuals requesting their services. In the absence of robust authentication schemes, these systems are vulnerable to the wiles of impostor. Traditionally, passwords and ID cards have been used to restrict access to the systems. The major advantages of this traditional personal identification are that: They are very simple, they can be easily integrated into different systems with a low cost. However these approaches are not based on any inherent attributes of an individual to make a personal identification thus having number of disadvantages like tokens may be lost, stolen, forgotten, or misplaced PIN may be forgotten or guessed by impostors. Security can be easily breached in these systems when a password is divulged to an unauthorized user or a card is stolen by an impostor or evil minded person. Therefore they are unable to satisfy the security requirements of our electronically interconnected information society.

However, this research work focused more on biometric fingerprint image identification and transformation. Images irrespective of size and quality contains large amount of information that requires huge storage space and large transmission bandwidth. Image data processing and storage attracts cost which is directly proportional to the size of the data. Large amount of image data with its mass storage requirement is often a major concern to Engineer and Scientists. Despite the advancement made in mass storage and processing capacities, these have continued to fall below capacity requirements of application system (Shok et al, 2010). Prior to industrial revolution in Africa, mass migrations to the cities became order of the day, populations lived mostly in rural communities where everyone know each other and there was little need for identification. Indeed, there was no police force and other security agencies with few courts. Due to increase in population in the cities, crime rates also increased astronomically, resulting into immense security challenges which seemed ready made for the solution of automatic data processing and automated fingerprint Identification System (AFIS) was developed.

Early development and implementation of automated fingerprint systems was limited to national police agencies in Europe, North America, and Japan (Shivanand et al, 2004; Starck J. et al, 2007). But the problems associated with huge national database and the newborn status of computer technology in the 1970s limited the utility of these systems ((Sudhakar & Jayaraman, 2006; Krishnaiah et al, 2011). Government investment in AFIS was justified largely on the promise of efficiency in the processing of incoming thumbprint records. But funding these expensive systems on the local level would demand some creativity.

Following the success of the FBI's finder, Rckwell took its system to market in the mid 1970's (Krishnaiah et al, 2011). Rockwell organized users group for its Printrak system and sponsored an annual conference for customers and would-be customers. Starting with a beta-site in San Jose, California, more than a dozen installations were completed in quick succession (Krishnaiah et al, 2011). The emergence of biometrics has addressed the problems that plague traditional verification. In the world of computer security, biometrics refers to authentication techniques that rely on measurable physiological and individual characteristics that can be automatically verified. Among many biometric recognition technologies, fingerprint recognition is very popular for personal identification due to the uniqueness, universality, collectability and invariance. However, the big problem is the storage capacity of the bulk data, which obviously requires good digital storage facility (Gornale, et al, 2010). The discovery of wavelet, more especially in the field of orthonormal supported wavelet transformation by Daubechies, lead to the conceptualization of electronic storage of the fingerprint.

Iris scan, retina scan facsimile scans and other forms of biometric impressions other than fingerprint used by the law enforcement agencies was not sustainable due to poor digitization quality presented by their data. As a result of this, most agencies and organs of government had experienced serious challenges in the digital storage of the prints because of their incompatibilities in data formats. Fingerprint images are digitized at a resolution of 500 pixels per inch with 256 levels of grey-scale information per pixel. A single fingerprint is about 700,000 pixels and needs about 0.6 Megabytes to store. A pair of hands, then, requires about 6 Megabytes of storage.

A. Problem Statement

Due to rising world population and its consequential security challenges, personal identification system became paramount for proper identification of personals both locally and internationally. Workers in a particular location require adequate data capturing at definite intervals. Migrants in the same vain require proper identification either as emigrant or immigrant of any nation. Due to the convenient procedure of fingerprint image capturing and its unique features, it is widely adopted across the globe as a means of biometric identification system. Biometric fingerprint image requires substantial storage, transmission and computation cost,

Several research works was conducted on fingerprint image compression using wavelet and wavelet packet transform, as retained energy (RE) and number of zero (Nz) were used.as compression technique. However, most works were carried out using three stages or levels of coiflet wavelet to achieve their results, yet sizeable storage space is needed, thus further compression is very important to minimize the memory requirement for achieving high compression ratio without degrading the quality of the image. This work considered the use of five-order level coiflet wavelet, at third decomposition level. Also, vector norm was used in the computation of the retained energy, thereby increasing the compression efficiency of the image coefficient.

B. Aim and Objectives of the Study

The aim of this research work is to implement an efficient and reliable compression method that can significantly reduce the image size of fingerprint images while retaining the essential biometric features resulting in reduction of storage, transmission and computation costs.

The objectives include the following:

1. The realization of efficient compression with good quality image that retains essential fingerprint image features with significant reduction in storage and computational costs.
2. The achievement of an efficient quantization of transformed image coefficients to realize further compression with minimum distortion or degrading in the process;
3. The realization of high fingerprint image compression ratio with minimum number of error and improved image quality using coiflet wavelet
4. The analysis of the performance of both Wavelet and wavelet packet transform using Retained Energy (RE) and Number of Zeros (NZ).

C. Research questions

To achieve adequate compression of fingerprint image using coiflet wavelet, the following questions are pertinent:

1. What are the modalities towards achieving efficient compression ratio?
2. What are the experimental procedures towards achieving excellent image compression?
3. What way and manner can the objectives of this work be implemented to realize the full aim of the work.
4. Through what means can the fingerprint image storage and communication bandwidth requirements be reduced.

The answers to these questions can be provided through the following procedures, Characterizing the fingerprint image, coding of the grey level pixels representing fingerprint image, decomposition and reconstruction of the digital images using coiflet wavelet, elimination of the redundancies in the digital image and compression of the digital image using different compression technique.

II. LITERATURE REVIEW

A. Conceptual Framework

Due to the large number and size of fingerprint images, data compression has to be applied to reduce the storage and communication bandwidth requirements of those images. Obviously, data compression is important to bring down huge cost of storage. It is necessary to enable scanned data use as few bits as possible and it also have fast algorithms to extract the essential data from the finger being.

To achieve high compression ratios while retaining the essential details, wavelet transform (WT) and wavelet packet transform (WPT) were used, and comparative analysis were made to acertain the one with better compression using five levels of coiflet-type order at level three decomposition. Other various image compression techniques already exists such as; JPEG, JPEG2000, DCT etc. all these techniques having their common aim to achieve high compression ratio. Some wavelet families that exists includes: Symlets, Daubechies, Haar, Fast Haar Coiflets etcetera. One may use different types of wavelet to compress fingerprint images or any other images.

In this paper, coiflet-type wavelet have been used, and it was discovered that Coiflet-type wavelet has distinct advantage over other wavelet families due to its vanishing moments and scaling function which facilitates signal processing, image compression and numerical analysis. They are built to provide better symmetry than Dabechies wavelets while maintaining compact support. Moreover, coiflet-wavelet performs exceptionally well based on its retain energy (RE) and number of zeros (NZ), which help to achieve excellent compression ratio at minimal cost without degrading the image quality, hence a better signal transforming technique for the research work.

B. Theoretical Background

Biometric fingerprint image capturing is one of the most reliable and acceptable means of personal identification. It plays crucial role in the administration and applications of both civilian and non-civilian affairs.

The emergence of biometrics has addressed the problems that plague traditional verification. In the world of computer security, biometrics refers to authentication techniques that rely on measurable physiological and individual characteristics that can be automatically verified. Among many biometric recognition technologies, fingerprint recognition is very popular for personal identification due to the uniqueness, universality, collectability and invariance. The fingerprint has been used for personal identity verification for more than a century, and is the most widely used in biometrics today the image is acquired through live-scan sensors which undergoes the process known as optical total internal reflection. As the ridges touching scanner light, valleys reflect it, creating a high-contrast image.

The acquired Image(s) can be enhancement through some technique such as local histogram equalization, wiener filtering, and binarization (converting binary black/white). The process can as well reduce the noise level of the image coefficient through Mean square error (MSE) and Peak signal to noise ratio (PSNR). Wavelet and wavelet packet transform are similar in that both are time-frequency analysis tools used to decompose signal into localized components, utilizing multi resolution analysis (scaling and translation) to provide high-resolution frequency information. Wavelet packet transformation is considered ideal in signal transformation because it can produce arbitrary resolution of wavelet tree decomposition. In this paper we will compare the result obtained in wavelet transformation with that of wavelet packet transformation to determine the transformation that provides better result in fingerprint image compression and de-noising process.

C. Fingerprint

Finger print consists of ridges and valleys, termination is a significant feature of fingerprint, it is formed when ridges comes to an end. Bifurcation is another very important feature formed when a ridge is divided in to two separate ridges (Sonja, G., et al., 2001). These two forms the fundamental types of minutiae and by detecting the location of these points within the fingerprint an effective matching process can be implemented.

Figure 1: fingerprint image capturing

D. Types of Digital Image

A digital image can be considered as a large array of discrete dots, each of which has a brightness associated with it. These dots are called picture elements or simply pixels. Spatial resolution is the density of pixels over the image. High spatial resolution simply means more pixels are used to display the image. Spatial frequencies define the amount by which image pixel values change with distance. High frequency components are characterized by large changes in pixel values over small distance and these are attributed to edges and noise. Low frequency components are parts characterized by little change in the pixel values and these are attributed to background and textures of images. There are four basic types of digital image, namely:

1. Binary image;
2. Grayscale image;
3. True colour image; and
4. Indexed image.

E. Binary Image

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In this image type, each pixel is either black or white. There are only two possible values for each pixel (0, 1). Only one bit is needed to represent a pixel. Data for which a binary representation may be suitable include text, fingerprint and architectural plans.

F. Grayscale Image

This is an image in which each pixel is a shade of gray that is from 0 (black) to 255 (white). This range means that each pixel can be represented by 8 bits, or exactly one byte. The grayscale levels are suitable for representing any type of natural images. Other grayscale range exist (-255 to 255), such image representations are often used in medical imaging applications.

G. True Colour Image

In this format, each pixel has a particular colour which is described by the amount of Red, Green, and Blue (RGB) in it. With image component range of 0 to 255, this gives a total of 2563 = 16,777,216 different possible colours in the image. Since the number of bits required for representing each pixel is 24 bits, such images are referred to as 24-bits colour images.

H. Indexed Image

In this colour image type, the images only have a small subset of the 2563 possible colours. For ease of storage and data handling, the image has an associated colour-map, or colour palette which is simply a list of all the colour components in the image. As opposed to the RGB image, each pixel of the indexed image has a value which does not give its colour but an index to the colour in the map. In the compression of a digital grey-scale fingerprint, the source image has a lot of redundancies that need to be removed to achieve compression. These redundancies are not obvious in the spatial domain. Therefore, some kind of transformation method is needed to convert the image into another analysis domain that makes the redundancies more obvious. This process will lead to image decomposition and pixel energy de-correlation.

I. Redundancy

Redundancy is duplication of pixels, as well as irrelevancies which are not noticeable by the Human Visual System (HVS) (Iqbal, 2004). In digital image compression, three basic data redundancies can be identified and exploited as given bellow:

1. Coding redundancy
2. Interpixel redundancy
3. Psychovisual redundancy

Image compression is achieved when one or more of these redundancies are reduced or eliminated.

J. Coding Redundancy

This occurs when the grey level pixels representing an image are coded in a way that uses more code symbols than absolutely necessary to represent each grey level pixel. Put differently, coding redundancy results when the codes assigned to pixel values of an image signal have not been selected to take full advantage of the probabilities of occurrence of the values.

K. Interpixel Redundancy

This is an important form of data redundancy. It directly relates to the interpixel correlation within an image. The value of any given pixel can be reasonably predicted from the value of its neighbours. As a result, the information carried by individual pixel is relatively small. In other words, much of the visual contribution of a single pixel to an image is redundant and it can as well be derived from the values of its neighbours. The level of correlation between image pixel values is responsible for interpixel redundancy. This correlation is as a result of structural or geometric relationship between objects in the image. Consequently, interpixel redundancy is also referred to as spatial redundancy or geometric redundancy (Gonzalez and Woods, 2002). In order to reduce the interpixel redundancy in an image, its array of pixel values must be transformed into a mathematical domain where the image energy correlation of the constituent pixels can be lowered. This is achievable by the 2-D discrete wavelet transform.

L. Psychovisual Redundancy

The human eye does not respond with equal sensitivity to all visual information. Certain information simply has less relative importance than other information in normal visual processes. Such information with less relative importance are said to be psych visually redundant (Gonzalez & Woods, 2002). This redundancy can be eliminated using suitable technique without any visually perceptible loss in image quality. Since the elimination of psych visually redundant data results in a loss of quantitative information, the compression process is said to be lossy at this stage. Image compression addresses the problem of reducing the amount of data required to represent a digital image. The basis for this reduction process is the removal of redundancies in the digital image data.

M. Characteristics of Fingerprint Image

Fingerprint is the biometric features of a finger. The development of these features is congenital and maintains uniqueness among the population (Kazi et al., 2011). A fingerprint usually appears as a series of dark lines that represents the high peaking portion of the friction ridge skin, while the valleys between these ridges appear as white space and are the low shallow portion of the friction ridge skin. Minutia is the term used to describe the location and direction of the ridge endings and bifurcations along a ridge path. The upper most point on the inner most ridge of the fingerprint image is known as core. The fingerprint has been used for personal identity verification for more than a century, and is the most widely used in biometrics today. Fingerprint images are digitized at a resolution of 500 pixels per inch (ppi) with 256 levels of grey-scale information per pixel. A single fingerprint is about 700,000 pixels and needs about 0.6 Mbytes for storage. A pair of hands, then, requires about 6 Mbytes of storage (Kumar et al., 2010). This huge storage requirement by fingerprint images impacts adversely on the efficiency of biometric application systems. The only way to improve on these resource requirements is to compress these images, such that they can be cost-effectively stored, transmitted and then reconstructed without compromising the essential biometric features such as the fingerprint's core, ridge endings and bifurcations. These features are shown in Figure.

Figure 2: Biometric Features of a Fingerprint Image

N. Transform Based Image Compression System

Image compression techniques are broadly classified as lossy compression techniques and lossless compression techniques, depending on whether or not an exact replica of the original image could be constructed using the compressed image. Lossless image compression techniques are limited in terms of compression ratios, they encode data exactly such that decoded image is identical to the original image. Lossless compression uses predictive encoding which uses the grey level of each pixel to predict the gray value of its right neighbour, the Overall result is the reduction of redundancy in the data. Lossless image compression techniques are mainly preferred for applications with stringent requirements such as medical imaging and diagnosis etc. (Islam et al, 2012; Gornale, et al, 2010). Lossy compression techniques result in high compression ratios and are widely used based on the fact that decompressed image is only a close approximation to the original image.

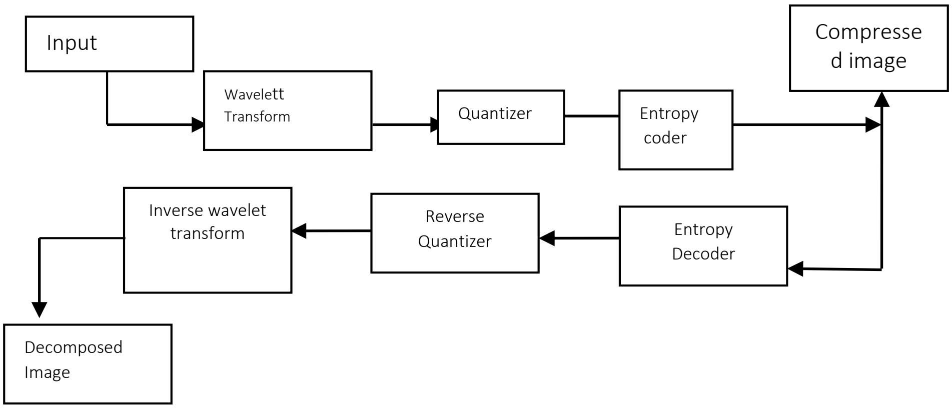

Figure 3: Transform based image compression system

Transform based compression techniques are the mostly used lossy compression techniques, as shown in Fig 3

Initially the input image is processed with selected wavelet transform to decorrelate the input image; the transform coefficients so obtained are quantized to eliminate the psych visual redundancy. A good quantize normally assigns more bits for coefficients with more information content or perceptual significance and fewer bits for coefficients with less information content. The choice of a quantize depends on the wavelet transform selected. The last step in transform based quantization is entropy coding, which removes redundancy in the form of repeated bit patterns in the output of the quantize. Here frequently occurring symbols are replaced with longer bit patterns, resulting in a small bit pattern. The most common entropy coding techniques are Run-Length. Encoding (RLE), Huffman encoding, Arithmetic coding and Lempel-Ziv algorithms (LZW) .Arithmetic coder is more effective than others allowing arithmetic codes to outperform Huffman codes and consequently Arithmetic codes are more commonly used in wavelet based algorithms. This has made it extremely difficult for researchers and prospective purchasers to evaluate competing systems. The veil of secrecy has generally carried over to the sharing of AFIS operational performance data by agency personnel who often develop a strong sense of loyalty to their AFIS vendor.

III. WAVELET TRANSFORM

A wavelet is a localized function that can be used to capture efficient and useful information of signals for transformation. It is a pair of filters. Known as low pass filter (lpf) and high pass filter (hpf). Each of the filters is down sampled by two, and low frequency signals, of those two output signals can be further transformed. Similarly, this process can be repeated recursively several times, resulting in a tree structure called the decomposition tree. At high frequencies WT provides good time resolution, whereas at low frequencies it provides good frequency resolution. Hence both time and frequency analysis of signals can be done using wavelets. It also cuts data into different frequency components, and then study each component with a resolution matched to its scale. A wavelet transform is the representation of a function by wavelets.

There are various basic families of wavelets available in the literature, among them are Daub chis, coif lets, Simplest, Hear, Fast hear, etcetera. Daub chis wavelets, is family of orthogonal wavelets defining a Discrete Wavelet Transform (DWT). With wavelet of this class, there is a scaling function which generates multi-resolution analysis. Simplest are more symmetric than external phase wavelets and are also known as Daub chis least asymmetric wavelets. Coiflets are popular in DSP applications due to their sampling approximation property and their associated near linear-phase filter banks. Wavelet and continuous wavelet transform are given in equation 1, and 2.

Mother wavelet $\Psi_{S,T}(t) = \left(\frac{1}{\sqrt{5}}\right) \Psi \left(\frac{I-T}{5}\right)$ 1.

Were, S = scale factor
T = translational factor

CWT $W_f(S, T) = \int f(t)\Psi^*_{S,T}(t)\, dt$ *2.*

$S = 2^i$ (scale factor)

A. Wavelet Packet Transform

Wavelet Packet Transform has the same characteristics as the Wavelet Transform. However, wavelet packets transform provide more flexible decomposition at any node of the decomposition by allowing the coefficient of the transformed signal pass through further decomposition process, in order to obtain the best decomposition tree (Iman & Sadegh, 2009). Wavelet packets transform has the advantage of better representation of image. The major difference between wavelet transform (WT) and wavelet packet (WPT) is in the filter design associated with the wavelet analysis method, which involves iterating the low-pass and high pass filter, and down sampling procedure only on the low-pass branch of the WT. While, wavelet packet (WP) presenting an extension of the octave band wavelet decomposition to full decomposition tree (Gornale, et al, 2010). Essentially, high frequency oscillation is associated with wavelet packet transform (WPT), which helps to speed up the decomposition process and also produces higher compression of images with large amount of texture and improved image quality. WPT can be obtained through further filtration of equation 3.

DWT $Wf(\mathrm{i},\mathrm{j}) = \frac{1}{\sqrt{2^1}}\int f(t)\Psi^*\left(\frac{t-j2^1}{2^1}\right)dt$ 3.

Where, $T = j2^i$ (translational factor)

B. Discrete Wavelet Transform (DWT)

Discrete wavelet transform (DWT) filter is used for reliable fingerprint image transformation. The DWT is recognized for its capability of space-frequency decomposition of images, energy compaction of law frequency sub-bands, and space localization of high frequency sub-bands (Xiong, Z. et al., 2021). DWT decomposes a discrete image signal into bands that vary in spatial frequency and orientation. In DWT, a space-frequency representation of the digital image signal is obtained using digital filtering techniques. The signal to be analyzed is passed through filters with different cutoff frequencies at different scales. For a discrete sampled signal sequence f(x), where integer x = 0, 1, 2 … m-1. There is m number of samples in the sequence.

The scaling function $w_{\emptyset}(j_o, k)$ and wavelet function $w_{\Psi}(j, k)$ are given by (Xiong, et al. 2021):

$$w_{\varphi}(j_o, k) = \frac{1}{\sqrt{m}}\sum x f(x)\varphi j_o, k^{(x)} \quad 4$$

$$w_{\Psi}(j, k) = \frac{1}{\sqrt{m}}\sum x f(x)\Psi_{j,k}(x) \quad 5$$

Note that $\frac{1}{\sqrt{m}}$ is a normalizing term. This is to ensure that the energy of the signal in the two transformation domain remains the same.

$$f^1(x) = \frac{1}{\sqrt{m}}\sum_k w_{\varphi}(j_o, k)\varphi_{j_o,k}(x) + \sum_{j=j_o}^{\infty} \sum_k w_{\varphi}(j, k)\Psi_{j,k}(x) \quad 6$$

Where:

$f(x)$ **=** Original Signal Sequence

$f(x)$ = Reconstructed Signal Sequence

$\varphi_{j_o,k}(x)$ = Scaling Parameter

$\varphi_{j,k}(x)$ = Wavelet Parameter

Equations (4) and (5) can be called forward discrete wavelet transform while equation (6) is the inverse discrete wavelet transform. Every mathematical transformation involves the original signal, the transformed signal and the transformation kernel. In this case, the transformation kernels are $W_{\emptyset}(j_o, k)$ and W_{Ψ} (j, k.) (Xiong, Z. et al. 2021).

C. Fingerprint De-noising Problem

The key source of noise in finger print image arise during image acquisition (digitization) or transmission. The image quality is affected during image acquisition as light levels of camera and sensor temperature, in the same way, atmospheric disturbance in the transmission channel also degrades the image quality. Stationary wavelet transform (SWT), is used to reduce the noise level present in the finger print images. The shift invariant property of this transform is the main reason to choose SWT for proposed wavelet analysis to remove noise, whereas Discrete Wavelet Transform is shift variant. The SWT is a wavelet transform algorithm designed to improve the lack of translation–invariance of the Discrete Wavelet Transform (DWT). The Translation invariance characteristics of SWT are achieved by removing up samplers and down samplers present in the DWT.

IV. METHODOLOGY

A. Materials and Method Used

The materials used for this research work includes; 8-bit grayscale right thumb digitized image of size 380×400, threshold vales for the coiflet wavelet, which incldes; 235, 245 and 255 as chosen from spatial thresholding method (Sezgin, M. Sankr, R. 2004), compression methods such as Retained Energy (RE), Number of Zero (NZ), Mean-square error (MSE), Peak signal to Noise ratio (PSNR), which measures the values and success of the process, and the MATLAB SIMULINK model which integrates computation, visualization, and programming in an easy-to-use environment where problem and solution are expressed in familiar Mathematical notation.

Parameters: There are many parameters used to measure the success of the task, the ones used in this work includes Mean Square Error (MSE) and Peak signal to noise ratio (PSNR):

B. Mean Square Error (MSE)

Mean-square error (MSE) can be simply explained as square of the average sare difference between transmitted and received signals, indicating signal fidelity and noise degradation. It plays important role in determining the result of image de-noising and image compression. For example, image is said to be denoised if the MSE value decreases and it can be determined as

$MSE = A - B$

Where A is the total number of bits of image and B is the total number of pixels present in images.

C. Peak Signal to Noise Ratio (PSNR)

It is one of the parameter that determines the result of the image that is de-noised, by comparing the de-noised image with the original image, and noised image with the original image. Image is said to be de-noised if its PSNR value increases. PSNR value of image can be calculated as

$PSNR = 20 \log_{10} PSNR = 20 \log_{10} M \quad = \quad \sqrt{MSE}$

Where, M is the maximum signal value that exists in their respective original images. And MSE is the Mean-square error

$$NZ = \frac{100 \times (\mathrm{ZCD100})}{\mathrm{NO\ of\ Coefficients}} \qquad 7.$$

$$RE = \frac{100 \times (V(cco \times 2))}{(V_n(Original\ signal))^2} \qquad 8.$$

Where; $\mathbf{V_n}$ is vector norm

CCD is the Coefficient of the current decomposition .

ZCD is the number of zeroes of the current decomposition.

Wavelet and wavelet packet transform have been used for the signal transformation process and most useful Coiflet-type wavelet has been chosen based on retain energy (RE) and number of zeros (NZ).The algorithm in Coiflet's wavelet and wavelet packet transform for a fingerprint image compression in this work, uses 8-bit gray scale Right thumb digitized fingerprint image of size 380-by-400 in MATLAB programme For all Coiflet-type wavelets, the global threshold values of 235, 245 and 255 was used at constant decomposition of level 3.

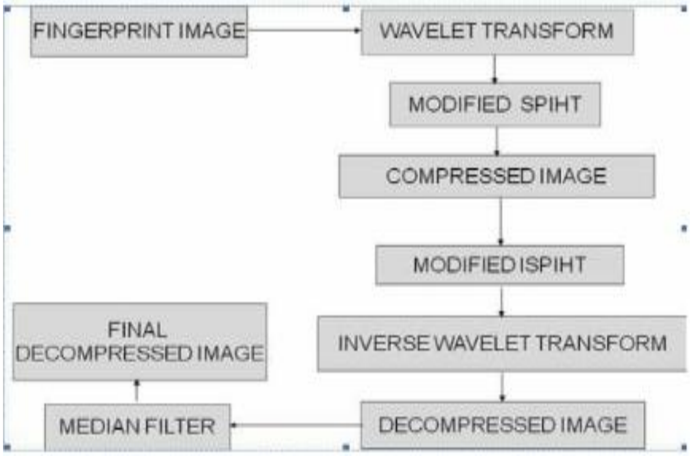

Figure*: 4* the bock representation of fingerprint image compression procedure

The wavelet transform was applied on the fingerprint image of size 380-by-400 at each level of coiflet-order and threshold vale.Decomposition was performed on the fingerprint image (level three decomposition). Maximum information content of that image after the transform frequency,

Coefficients are obtained. Then basic SPIHT was applied on the decomposed fingerprint image and compressed bit stream was obtained. SPIHT exploits the hierarchical tree structure produced by the transform process (It codes the individual bits of the image).

Wavelet transform coefficients following a bit plane sequence. It compresses the pixels with the maximum information content first and then progressively proceeds towards the less important pixels. The redundancy of original SPIHT was removed by using Modified SPIHT. The frequency coefficients obtained after transform are taken as input and the Modified SPIHT eliminates the correlation in same level sub bands. Then reconstruction was done by applying inverse SPIHT on the compressed bit stream. Then inverse wavelet transform was applied to recover the original fingerprint image.

The output was compared based on a set of quality measures like Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE).

V. RESULTS AND ANALYSIS

A. Results

The computation of the results for wavelet and wavelet packet transformations based on the Retain Energy (RE) and Number of Zero (NZ) were obtained using the global threshold values of 235,′ 245 and 255. Their various percentages are presented in tables 1, 2, 3 and 4.

B. Result of the Computations using Wavelet Transform

Table 1. Retained Energy (RE) for Wavelet Transform

	Type of Wavelet Transform at 3rd Level				
Threshold Value	Coif let 1 (Coif 1) Re%	Coif let 2 (Coif 2) Re%	Coif let 3 (Coif 3) Re%	Coif let 4 (Coif 4) Re%	Coif let 5 (Coif 5) Re%
235	96.75	97.91	98.36	98.68	98.87
245	96.64	97.84	98.32	98.63	98.83
255	96.53	97.76	98.26	98.59	98.79

Table 2. Number of Zeroes (NZ) for Wavelet Transform

	Type of Wavelet Transform at 3rd Level				
Threshold Value	Coif let 1 (Coif 1) NZ%	Coif let 2 (Coif 2) NZ%	Coif let 3 (Coif 3) NZ%	Coif let 4 (Coif 4) NZ%	Coif let 5 (Coif 5) NZ%
235	97.53	97.32	97.13	96.87	96.67
245	97.58	97.36	97.16	96.91	96.70
255	97.63	97.40	97.20	96.94	96.73

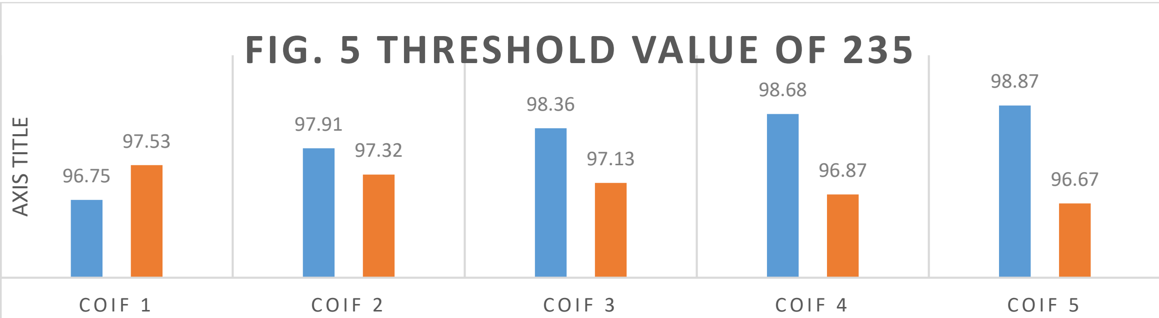

Figure: 5. Graph of RE and NZ for threshold value of 235, in Wavelet Transform

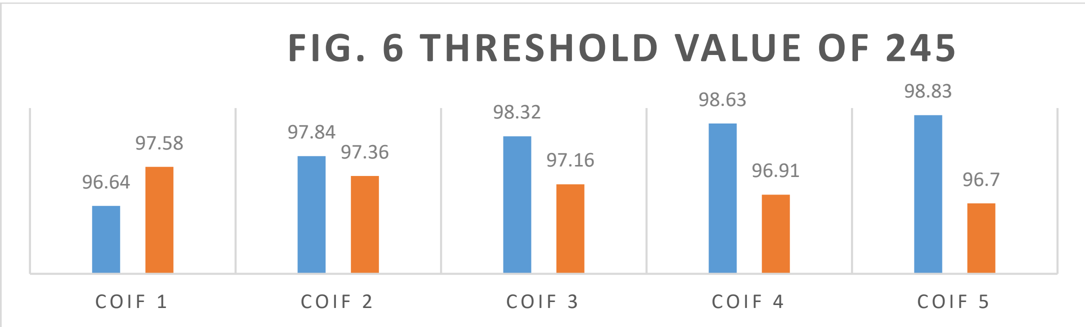

Figure: 6. Graph of RE and N Z for threshold value of 245 in Wavelet Transform

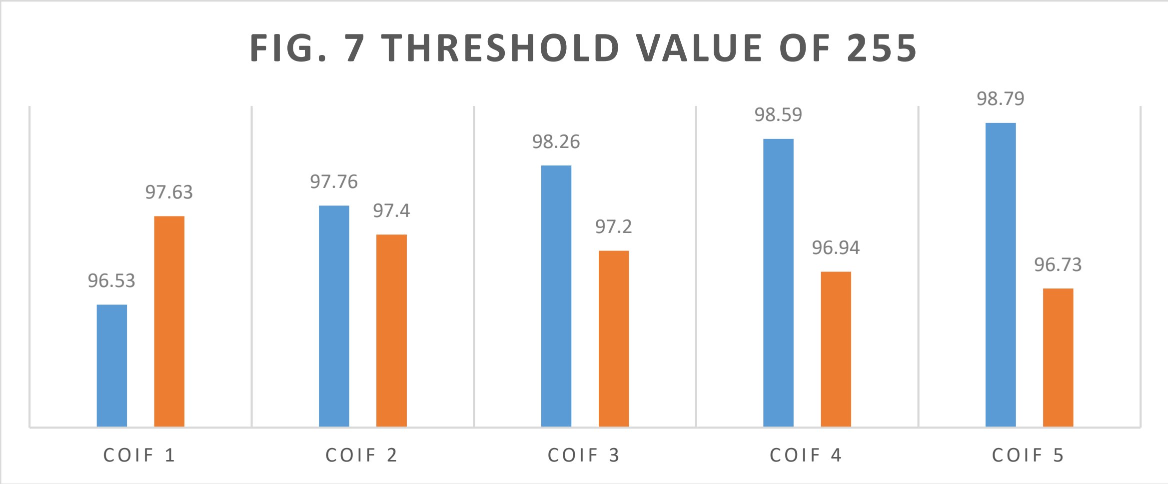

Figure: 7. Graph of RE and N Z for threshold value of 255 in Wavelet Transform

C. Result for the Computations using Wavelet Packet Transform

Table 3. Retained Energy (RE) for Wavelet packet transform

	Type of Wavelet Transform at 3rd Level				
Threshold Value	Coif let 1 (Coif 1) RE%	Coif let 2 (Coif 2) RE%	Coif let 3 (Coif 3) RE%	Coif let 4 (Coif 4) RE%	Coif let 5 (Coif 5) RE%
235	97.02	98.02	98.39	98.65	98.80
245	96.90	97.94	98.33	98.59	98.76
255	96.76	97.86	98.25	98.54	98.72

Table 4. Number of Zeroes for Wavelet Packet Transform

	Type of Wavelet Transform at 3rd Level				
Threshold Value	Coif let 1 (Coif 1) RE%	Coif let 2 (Coif 2) RE%	Coif let 3 (Coif 3) RE%	Coif let 4 (Coif 4) RE%	Coif let 5 (Coif 5) RE%
235	97.69	97.80	97.89	97.96	98.01
245	97.75	97.83	97.92	98.00	98.03
255	97.80	97.87	97.96	98.02	98.06

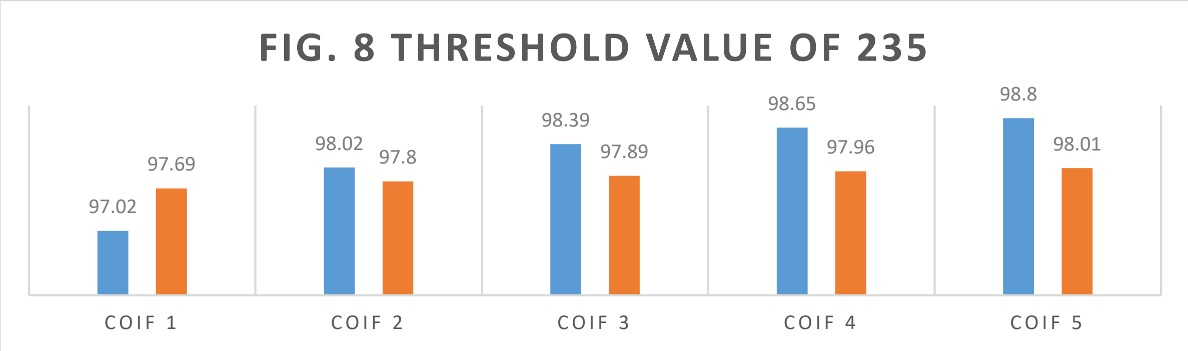

Figure: 8. Graph of RE and N Z for threshold value of 235 in Wavelet Packet Transform

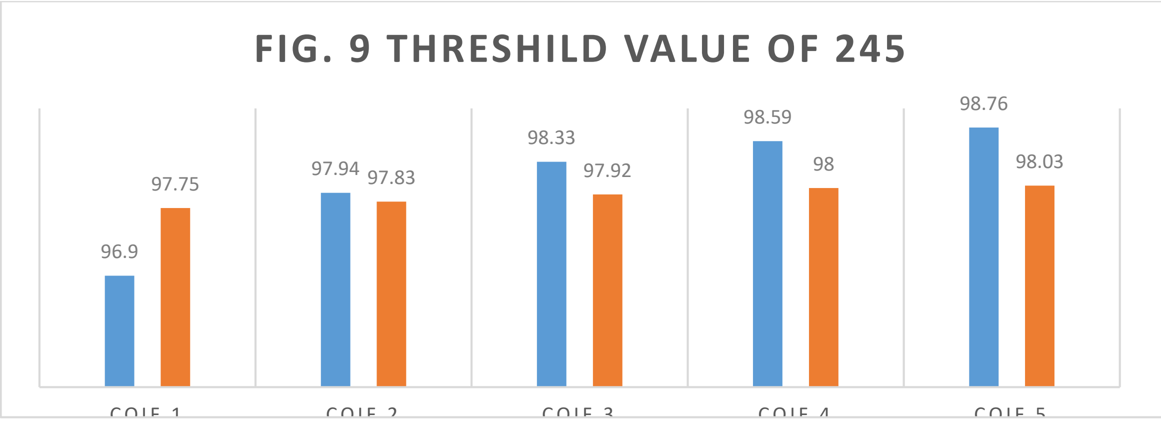

Figure: 9. Graph of RE and N Z for threshold value of 245 in Wavelet Packet Transform

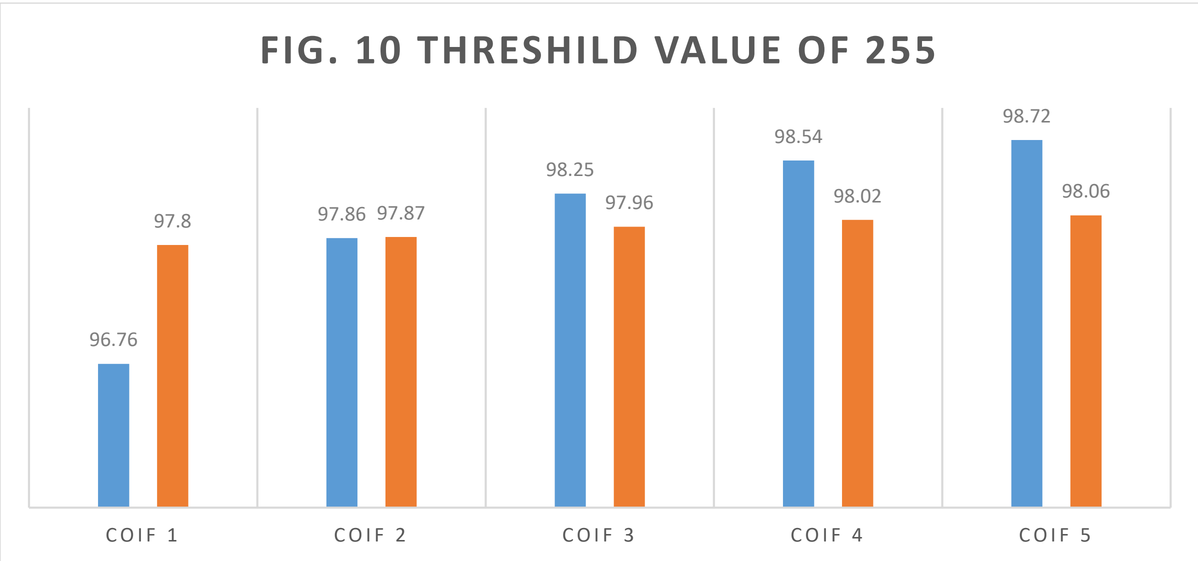

Figure: 10. Graph of RE and NZ for threshold value of 255, in Wavelet Packet Transform

VI. DISCUSSION

The effects of the implementation process of Coiflet-type wavelet for the compression of fingerprint image of size 380-by-400, was quite impressive. The results were observed from the graphs. For wavelet transform, all the figures show that RE increased throughout the experiment (96.75% to 98.87%), (96.64% to 98.83%) and (96.53% to 98.79%,) but Number of Zero (NZ) were decreasing with the increment in Coiflet order for each threshold value, (97.53% to 96.67%). (97.58% to 96.70%) and (97.63% to 96.73 %.).The increment observed in the wavelet transform retained energy (RE), indicates higher compression while the decrease in number of zero (NZ) indicates lower compression. For wavelet packet transform all the figures indicate that both retai0ned energy (RE) and Number of Zero (NZ) increased with the increase in Coiflet wavelet order at each threshold value, (97.02% to 98.80%), (97.69% to 98.01%) and (96.76% to 98.72%). From the results obtained from the experiment, it is obvious that the wavelet packet transform (WPT) has better compression efficiency than wavelet transform (WT).

VII. CONCLUSION

This work presents the analysis of the performance of coiflet wavelet transform and wavelet packet transform using 8-bit gray scale right thumb digitized fingerprint image of size 380-by-400. At three different threshold values and at the decomposition level three (3). Several research works were conducted using three stages or levels of coiflet wavelet, at third decomposition level, which yielded good result yet sizeable storage space was needed, thus further compression is required to minimize the memory requirement by achieving higher compression ratio without degrading the quality of the image. This work considered the use of five-order level coiflet wavelet, at third decomposition level. Also, vector norm was used in the computation of the retained energy and number of zero, thereby increasing the compression efficiency of the image coefficient. The result of this experiment shows that the Coiflet 5, performs much better than other levels of coiflet wavelet (coiflet; 1, 2, 3 and 4) for fingerprint image compression using wavelet transform (WT). In the same way, Coiflet 5, performed much better than other levels of coiflet-type wavelets using wavelet packet transform (WPT) for the same fingerprint image compression.

Furthermore, it was observed that the percentage of Retain Energy (RE) increased across the levels of coiflet, while the percentage of Number of Zeros (NZ) decreased. But in the case of wavelet packet transform the percentage of both RE and NZ increased with the increase in threshold values. Hence, wavelet packet transform performs better than the wavelet transform in fingerprint image compression.

RECOMMENDATION

1. It is also recommended that further work be carried out using coiflet-5 as optimal order for the fingerprint image compression at the tested threshold values.
2. It is also recommended that the evaluation of additional wavelet families be made under the same conditions.
3. It is also recommended that MSE and PSNR be used as parameters for measuring the success of the work alongside, RE and NZ.

Furthermore, it is recommended that stakeholders and practitioners in biometric system design, researchers in signal processing, and policy bodies overseeing biometric database standard, Should use more advanced learning algorithm and deep learning methods, such as auto encoders, for more compact representations while preserving high image quality.

Contribution to knowledge

Increased decomposition and compression of digital image coefficient is realized with wavelet packet transform (WPT) at higher level of coiflet wavelet, and at third decomposition level due to the inherent orthonormal frequency-time resolution from their corresponding functions.

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