Fingerprint Image Compression using Retain Energy (RE) and Number of Zeros (NZ) through Wavelet Packet (WP)

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Abstract

Fingerprint analysis plays crucial role in crucial legal matters such as investigation of crime. But a fingerprint image consists of enormous amount of data. Therefore we have to reduce the amount of its data. To do this, we need some powerful image compression technique. There are many image compression techniques available, but still there is need to develop faster, and efficient and reliable techniques to compress fingerprint images. The main difficulty in developing compression algorithms for fingerprint is the need for preserving the minutiae i.e. ridges endings and bifurcations, which are subsequently used in identifications. To achieve high compression ratios while retaining these fine details, wavelet packets are used. In this paper we have done experimental analysis to determine compression ratio by Wavelet packet. We have used three wavelet transforms to select their threshold values and to calculate Retain Energy (RE) and Number of Zeros (NZ) in percentage. We have applied Haar; Daubechies (db1) and Symlet (sym2) transforms for noisy and noiseless fingerprint image of size 374 x 388 and determined their compression ratio. All these transforms give higher compression ratio for a noiseless fingerprint image than, noisy one.

Keywords: Image Compression, wavelets, wavelet packet, retain energy, number of zeros,

1. INTRODUCTION

An image contains large amount of information that requires much storage space, and large transmission time. Therefore it is often necessary to compress the image by storing the necessary data to reconstruct the image. Image compression involves reducing the amount of data (bits) required to represent a digital image [13] [15] [16]. Removing redundant information can achieve this. i.e. redundancy reduction removes the duplication in the image[1][2]. According to Saha[5] there are two different types of redundancy pertaining to an images: spatial redundancy and spectral redundancy. While compression an image, de-noising is one of the challenging tasks/problems for researchers because noise removal introduces artifacts and causes blurring of the images. The compression ratio is different before and after de-noising the image. To increase compression ratio, First image must be de-noised and then compressed. Many different methodologies are used for noise reduction (or de-nosing) giving an insight as to which algorithm should be used to find the most reliable estimate of the original image data given its degraded version. Various thresholding techniques based on wavelet domain-filtering techniques such as SUREthresh, Visuthresh and Bayesthresh etc. Out of which SUREthresh is one of the best algorithms for de-noising operation i.e. Wavelet Thresholding is an effective method of de-noising the noisy signals which plays an important role in de-noising an image and is treated as widely investigated noise reduction method [19][5][6][7][8]. There are two basic approaches used for image de-noising, spatial filtering method & transform domain filtering method. Again, spatial filtering is further classified as Non-linear and linear filters. Transform domain filtering can be divided into data adaptive & data non-adaptive. Non-adaptive transforms are more popular, and can be classified as wavelet domain & spatial frequency domain.

2. BACKGROUND

One of the major applications where the compression plays crucial part in fingerprint, which is used for application in scientific especially medical, field legal matters as in the investigation of crime etc. There are many image compression techniques available. Still there is need to develop faster, more efficient and reliable algorithms for fingerprint images [4]. One of the main difficulties in developing compression algorithms for a fingerprint is preserving the minutiae i.e. ridges endings and bifurcations, which are subsequently used in identifications. To achieve high compression ratios while retaining these fine details, wavelet packet are used. Wavelet packets also save computational effort, transmission, and storage costs etc. Various image compression techniques already exists like DCT, JPEG, and JPEG2000 [2][43] and Wavelet etc. all these techniques have their common aim to achieve high compression ratio. Among the exiting compression techniques Wavelet gives better results for lossless as well as lossy image compression.

3. WAVELETS AND WAVELET PACKET FOR COMPRESSION

Fingerprint images can be seen as texture patterns of flow orientations with sharp discontinuities. For this particular nature of fingerprint images and the need for retaining fine details of the ridges and their inter relation, the wavelet decomposition method is most useful [4][11].

3.1 Wavelets

Wavelet analysis has proved to be very important development in the search of more efficient methods of image compression. Like most Lossy image coders, wavelet based image coders typically comprise three major components. Wavelet filter bank decomposes an image into wavelet coefficients, which are then quantized in Quantizer, and finally an entropy encoder encodes these quantized coefficients into out bit stream i.e. compressed image as shown in figure1

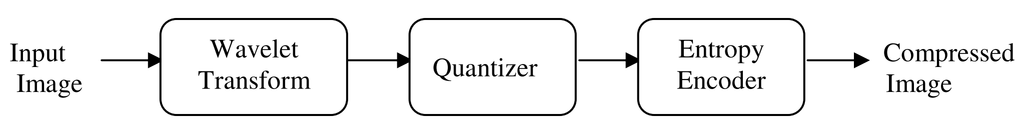

FIGURE-1 Shows the Lossy Image Coding System

3.2 Structure of Wavelet

Wavelet transform is a pair of filters. The way we compute the wavelet transform by recursively averaging and differentiating coefficients is called the filter bank [27], where one is a low pass filter (lpf) and the other is a high pass filter (hpf). Each of the filters is downsampled by two. Each 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. Wavelet transform can be used to analyze or decompose signals and images called decomposition [11][28][29][30].The same components can be assembled back into the original signal without loss of information; this is called reconstruction or synthesis and the same has been shown in figure 2.

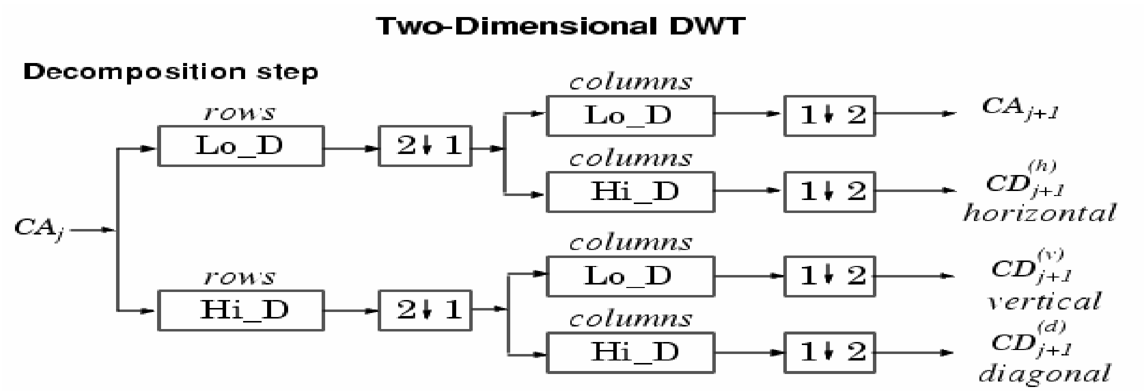

FIGURE 2 Analysis of 2D DWT shows one stage filter

The structure of Wavelet can be represented as a four channel perfect reconstruction of filter bank. Each filter is 2D with subscript indicating the type of filter (HPF or LPF) for separation of horizontal and vertical components. The resulting four-transform components consist of all possible combinations of high and low pass filtering in the two directions. By using these filters in one stage an image can be decomposed into four bands. There are three types of details of images for each resolution Diagonal (HH), Vertical (LH) and Horizontal (HL). The operations can be repeated on the low low (LL) i.e. on approximation band using the second identical filter bank [31]. The decomposition process can be iterated, with successive approximations being decomposed. However, in practice, more than one decomposition level is performed on the image data. Successive iterations are performed on the low pass coefficients (approximation) from the previous stage to further reduce the number of low pass coefficients. Since the low pass coefficients contain most of the original signal energy, this iteration process yields better energy compaction. The quality of compressed image depends on the number of decompositions. Compression of an image can be obtained by ignoring all coefficients less than the threshold value. If we use decomposition iteration, it will be more successful in resolving DWT coefficient because Human Visual System (HVS) is less sensitive to removal of smaller details. Decomposition iterations depend on the filter order. Higher order does not imply better image quality because of the length of the wavelet filter. This becomes a limiting factor for decomposition. Usually, five levels of decompositions are used in current wavelet based image compression [16, 32].

3.3 Wavelet properties

To achieve a high compression rate, it is often necessary to choose the best wavelet filter bank and decomposition level, which will play a crucial role in compressing the images. The selection of wavelet filters plays a crucial part in achieving an effective coding performance, because there is no filter that performs the best for all images [33]. The Current Compression system uses the biorthogonal wavelet filters instead of orthogonal. Because orthogonal filters have a property of energy preservation whereas biorthogonal filters lack it [34],[35]. The choice of optimal wavelets has several criteria. The main criteria are:

1. Orthonormality

2. Filter Length
3. Vanishing order or moment
4. Smoothness
5. Filter magnitude response
6. Group delay
7. Decomposition level
8. Regularity

These are discussed in [28][34][35][36]. Orthogonal Filters lead to orthogonal wavelet basis functions; therefore the resulting wavelet transform is energy-preserving; this implies the Mean Square Error (MSE) introduced during the quantization of the DWT coefficients is equal to the MSE in the reconstructed signal. In biorthogonal wavelet the basis functions are not orthogonal; therefore they do not preserve the energy but conserve it. The efficiency of a transform depends on how much energy compaction is provided by the transform. Wavelet Filter can be used to analyze or decompose signals and images called decomposition. The same components can be assembled back into the original signal without loss of information, which is called reconstruction or synthesis. Shorter synthesis basis functions are desirable for minimizing distortion that affects the subjective quality of the image. Longer filters are responsible for ringing noise in the reconstructed image at low bit rates [36]. Each wavelet family is parameterized by an integer N called the filter order, which is proportional to the length of the filter. The length of the filter is related to the degree of the smoothness of the wavelet and can affect the coding performance. This relation is different for different wavelet families [37] and non-smoothness basis function introduces artificial discontinuities are reflected as spurious artifacts in the reconstructed images. Higher filter order gives more energy and increases the complexity of calculating the DWT coefficients, while lower order preserves the energy. i.e. it preserves the important edge information. Therefore, we must take care of wavelets in image compression application concerning that good balance between filter orders, degree of smoothness and, computational complexity. These properties depend on the image contents. Vanishing order is the measure of compaction property of the wavelet and it corresponds to the number of zeros in the LL sub band [36][38].

Filter Response is another critical property that affects the subjective quality of the reconstructed image. The filter responses approach the ideal rectangular response with the increase in the number of zeros and these numbers of zeros also corresponds to vanishing order of the wavelet. Group Delay Difference (GDD) measures the deviation in group delay of the orthogonal wavelets from the linear phase group delay. A non-GDD introduces a phase distortion that affects encoding and decoding by alerting the DWT Subband structure. Wavelet Transform can be used to analyze or decompose signal and image called decomposition. The same components can be assembled back into the original signal without loss of information called reconstruction or synthesis. The decomposition process can be iterated with successive approximations being decomposed. However, in practice more than one decomposition level is performed on the image. Successive iterations are performed on approximation coefficients; this successive iterations process yields better energy compaction. The quality of the compressed image depends on the number of decompositions, and these decomposition iterations depend on the filter order. Higher order does not imply better image quality because of the length of wavelet filter. This becomes a limiting factor for decomposition. Usually five levels of decomposition are used in current wavelet based compression [16][32][39]. Regularity is one of the properties of the wavelet; greater regularity often does not improve the visual quality.

3.4 Wavelet Packet

In addition to the above properties of wavelet transform, wavelet packets provide more flexible decomposition at any node of the decomposition by allowing decomposition at any node of the decomposition tree and also to obtain the best decomposition tree [4]. The benefit of the wavelet packets over the wavelet decomposition comes from the ability of the wavelet packets to better represent high frequency (this is how image may contains a noise) content, and high frequency oscillating signals in particular. This allows wavelet packet to perform significantly better than wavelets for compression of images with large amount of texture (like fingerprint images, Barbara images etc) and also points out that the perceived image quality is significantly improved using wavelet packets instead of wavelets especially in the textured regions of the images [12][41][42]. The major difference between wavelet and wavelet packet is: The filter design associated with the wavelet analysis method involves iterating the low-pass and high -pass filtering and downsampling procedure only on the low-pass branch of the previous. While, wavelet packet (WP) provides an extension of the octave band wavelet decomposition to full tree decomposition i.e. the high pass output of each branch is also filtered and downsampled up to maximum number of decomposition this is one of the key differences between the wavelet and wavelet packet [40].

4. IMPLEMENTATION

In this paper we have performed Wavelet transform on Fingerprint Image of size 374-by-388 taken form FVC 2002 Database [17]. We have taken this image in two forms i.e. Image without noise and image with noise. Through this paper our aim is to highlight compression ratio achieved in Haar, Daubechies1 and Symlet transforms at third level with varying threshold value. For every threshold value of these transform for both types of images different compression ratio is achieved. This compression ratio is determined on the basis of 2-D Wavelet packet analysis i.e. threshold value, retain energy and number of zeros present in the image after compression. The 2-D Wavelet packet analysis for both noiseless and noisy fingerprint images is shown in Figure 3 highlighted through graphs. Retain Energy (RE) and Number of Zeros (NZ) are calculated by following formulas:

$$RE = \frac{100 * (\text{Vn (CCD,2)})^2}{(\text{Vn}(origional\ Signal))^2}$$

and

$$NZ = \frac{100 * (\text{ZCD})}{No. of\ coeificients}$$

Where, Vn is the Vector norm, CCD is the coefficients of the current decomposition and ZCD is the Number of zeros of the current decomposition.

5. ANAYLYSIS AND INTERPRETATION

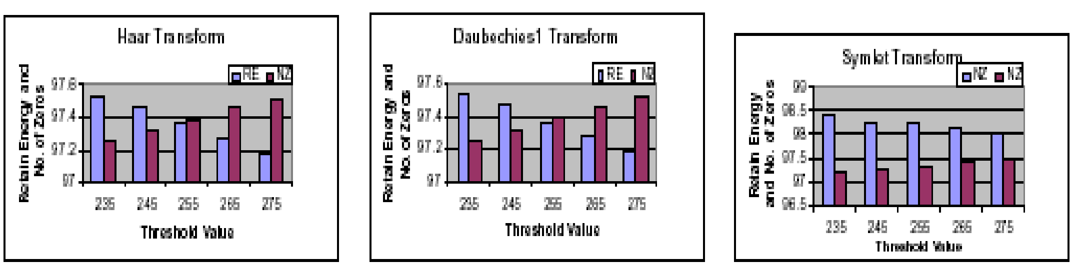

Fig. 1: RE and NZ of Noiseless fingerprint image for Haar, Daubechies1, and Symlet Transforms

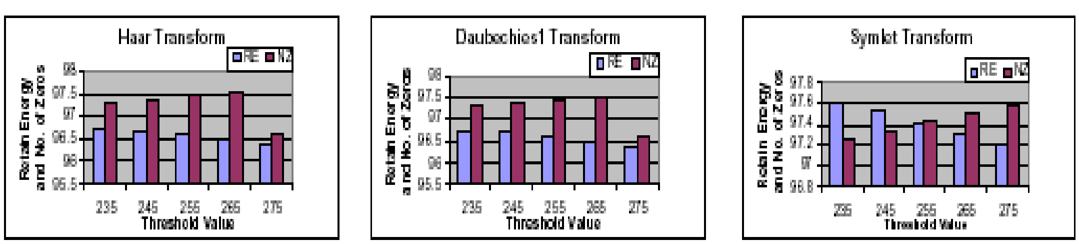

FIGURE 3: RE and NZ of Noisy fingerprint image for Haar, Daubechies1, and Symlet Transforms

In, the above graph for different threshold values, Retain Energies (RE) and Number of zeros (NZ) are determined for noiseless and noisy fingerprint images of size 374 x 388 of fingerprint database FVC2002 for compression. One can decide the threshold level to have complete control over de-noising the images by choosing different threshold for different levels [3]. A central question about many threshold procedures is how to choose the threshold, because it is trade off between closeness of fit and smoothness. A small threshold yields a result close to the input, but this result may still be noisy. A large threshold produces the large number of zeros of wavelet coefficients. This sparsely is short of smoothness the output is simple, paying too much attention to smoothness, however, destroys some of signal and it may cause blurs and the artifacts. Throughout this, paper result of Haar, Daubechies (db1), and Symlet (sym2) transforms of Wavelet packet at level 3 is considered. It is very difficult to find the good threshold value and to develop good algorithm to select threshold value [3]. In this paper we have selected a suitable initial threshold value and further used it in increasing order of 10 for every transform. The Retain Energy (%) and Number of Zeros (%) are determined for different threshold values. In Haar and Daubechies1 wavelet packet transforms when we increase the threshold value, the Retain Energy decreased; whereas, the Number of Zeros increased. It shows that when we increase the threshold value, we get higher compression ratio for both noisy and noiseless fingerprint images. Even in Symlet (Sym2) we get the same results for noisy and noiseless fingerprint images. We get higher compression ratio for Symlet wavelet packet transform rather than Haar and Daubechies for noisy and noiseless fingerprint images, and also retain energy is more in Symlet wavelet packet transform compared with Haar and Daubechies transforms. Hence, we get higher Compression ratio and retain energy in Symlet wavelet packet transform. Thus, these transforms are useful in the application area where it is necessary to reconstruct the compressed image same as the original.

6. CONCLUSION

Through this paper we have highlighted different transforms of wavelet packet and their compression ratio for noisy and noiseless fingerprint images. We have also highlighted compression ratio can be increase by selecting appropriate threshold value. The compression ratios of noisy and noiseless fingerprint images are determining by considering number of zeros and retain energy. Higher compression ratio we have achieved in noiseless fingerprint image rather than noisy fingerprint images. Wavelet packet transform definitely have an effect on the Retain Energy (RE) and Number of Zeros (NZ) but how well its effect is, depends on decomposition level, type of image, threshold and also type of transform used. For maximum threshold value and greater level of decomposition, more energy can be lost because at higher levels of decomposition there is higher proportion of the coefficients in the detail subsignals. Hence, it is always necessary to select the optimal threshold value to get higher compression and to achieve minimum loss of images. The future work of this area can be extended to find compression ratio of noisy image before and after de-noising it. It is also essential to develop faster, more efficient and reliable algorithms for fingerprint images so that they may be more useful in forensic science.

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