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Iris Database Compression Using Haar Wavelet Decomposition and Huffman Coding

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Abstract: Iris recognition system for identity authentication and verification is one of the most precise and accepted biometrics in the world. The need for portable iris system has been increasing more rapidly which demands efficient compression techniques for its transmission through a narrow-bandwidth communication channel. In spite of rapid progress in mass storage density and processor speeds, this demand continues. This paper has investigated the effects of iris image compression based on Haar Wavelet Decomposition and subsequent Huffman Coding. The results have been examined in terms of Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) and Compression Ratio (CR). It has been found that Huffman Coding transform is an effective lossless image compression technique, as recognition performance is minimally affected and the use of Haar transform is well suited. The matching stage is implemented using Euclidean distance calculation and CASIA iris database has been used for the study.

Keywords: Iris recognition; Image compression and decomposition; Haar wavelet transform; Huffman coding; Peak signal to noise ratio

I. INTRODUCTION

In today's information technology era, biometric recognition systems are in widespread use and are gaining more and more attention all over the world. These systems exploit the discriminable behavioural or physiological characteristics like iris, retina, face, fingerprint and hand geometry etc. to identify a legitimate individual [1]–[2]. Iris, the coloured portion of the eye that surrounds the pupil, contains unique patterns which are prominent under near-infrared illumination. These patterns are permanent, unique and can withstand trauma or disease, hence they are used for identification purposes. The reasons for the popularity of iris as a biometric feature are its uniqueness, reliability, high accuracy, speed of matching and stability of the iris as an internal and protected, yet externally visible organ of the eye [3].

Iris images are digitized at a resolution of 500 pixels per inch with 256 gray levels. Therefore, a single eye iris card requires approximately 10MB of storage [4]. The requirement for collection, storage, and sharing of large volumes of data calls for compression at the point of capture to reduce the bandwidth requirements for exchanging data with other parts of the system. This actually leads us to investigate an efficient compression standard that can predominantly reduce the image size while retaining the minutiae information for accurate identification. Law enforcement, border security and forensic applications are some crucial fields where eye iris image compression plays an important role.

This paper can be organized as follows. The next section discusses the related works and the third section familiarizes the decomposition of images using Haar wavelet transform and effect of Huffman coding for image compression. The proposed method for the iris database compression has been discussed in the fourth section. The experimental results have been analysed in the fifth section. Finally, conclusions are given in the sixth section, followed by acknowledgment.

II. RELATED WORKS

Interest in the field of coding of iris images for recognition originated with Daugman's system using Gabor wavelets [5]- [6]. Other previous work was done by Wildes [7] and Boles [8]. Different types of image compression standards like JPEG, JPEG-2000 and JPEG-XR have been utilized to generate the compact iris data [9] -[11]. Daugman proposed JPEG compression technique with region of interest isolation and adopted this in one database [9]. R.W Ives investigated the result of image compression and performance of iris recognition scheme along with JPEG-2000 compression technique [12]. Funk et al. investigated and discussed the impact of JPEG, JPEG-2000 (ISO/IEC 15444), fractal, PRVQ image compression on cross over accuracy of biometric system [13]. Its use of wavelet technology results in efficiently compressed images with lower error rates than with previous image compression technologies. But the JPEG technique computes the DCT of 8x8 blocks taken from the original eye image and sometimes it is not suitable for high compression rates as the blocking artifact may occur. This paper has proposed a suitable iris image compression technique using Haar wavelets and Huffman coding that can be applied in iris recognition system.

III. IMAGE COMPRESSION

Image compression means reducing the volume of data needed in order to represent an image. The cardinal goal of image compression is to obtain the best possible image quality at an allocated storage capacity by removing redundancy and omitting irrelevancy. Redundancy helps to remove redundant information from the signal source and irrelevancy omits pixel values which are not noticeable by the human eye. There are two kinds of compression such as lossless and lossy compressions. Among the various lossless compression algorithms available today, achievable compression is of the order of 1.5:1 to 4:1. When using any lossy compression technique, some information is lost in the compression and the amount and type of information that is lost depends on several factors, including the algorithm used for compression, the amount of compression desired (which determines the size of the compressed file), and special options offered in the algorithm such as Region-of-Interest (ROI) processing. Alternatively, lossy codecs can compress images further with varying degrees of loss. The compression techniques can be divided into two techniques: transforms (DCT, JPEG, FFT, Wavelet) and non transforms (PCM, DPCM).

A. Haar Wavelet Transform

Wavelet theory is based on analysing signals to their components by using a set of basis functions. The original wavelet function, called mother wavelet, which is generally designed based on some desired characteristics associated to that function, is used to generate all basis functions. The wavelet characteristics that are well suited for image compression include the ability to take into account of Human Visual System's (HVS) characteristics, very good energy compaction capabilities, transmission robustness, high compression ratio etc.

A Haar wavelet is the simplest type of wavelet and one of the basic transformations from the space domain to a local frequency domain. Haar wavelet transform has a number of advantages such as it is conceptually simple and fast, memory efficient, exactly reversible and gives high compression ratio and PSNR. In discrete form, it is related to a mathematical operation called the Haar transform that decomposes a discrete signal into two sub signals of half its length, one is called average (approximation) or trend and the other is known as difference (detail) or fluctuation [14]-[15]. The Haar transform is represented in the following form:

$$T = HFH^T$$

where, F is an image matrix of size NxN, H is an Haar transformation matrix of size NxN and T represents the subsequent decomposed NxN transform. Also H is an invertible matrix. Hence we can retrieve back the original image by the following equation,

$$A = H^{T^{-1}} M H^T$$

The 8x8 Haar Wavelet Transformation matrix is as given below:

$$\begin{pmatrix} \frac{1}{8} & \frac{1}{8} & \frac{1}{4} & 0 & \frac{1}{2} & 0 & 0 & 0 \\ \frac{1}{8} & \frac{1}{8} & \frac{1}{4} & 0 & -\frac{1}{2} & 0 & 0 & 0 \\ \frac{1}{8} & \frac{1}{8} & -\frac{1}{4} & 0 & 0 & \frac{1}{2} & 0 & 0 \\ \frac{1}{8} & \frac{1}{8} & -\frac{1}{4} & 0 & 0 & -\frac{1}{2} & 0 & 0 \\ \frac{1}{8} & -\frac{1}{8} & 0 & \frac{1}{4} & 0 & 0 & \frac{1}{2} & 0 \\ \frac{1}{8} & -\frac{1}{8} & 0 & \frac{1}{4} & 0 & 0 & -\frac{1}{2} & 0 \\ \frac{1}{8} & -\frac{1}{8} & 0 & -\frac{1}{4} & 0 & 0 & 0 & \frac{1}{2} \\ \frac{1}{8} & -\frac{1}{8} & 0 & -\frac{1}{4} & 0 & 0 & 0 & -\frac{1}{2} \end{pmatrix}$$

B. Huffman Coding

Huffman coding is a form of statistical coding which attempts to reduce the amount of bits required to represent a string of symbols. It is a particular type of optimal prefix code that is commonly used for lossless data compression. The output from Huffman's algorithm can be viewed as a variable-length code table for encoding a source symbol. The algorithm derives this table from the estimated probability or frequency of occurrence (weight) for each possible value of the source symbol. As in other entropy encoding methods, more common symbols are generally represented using fewer bits than less common symbols. Huffman's method can be efficiently implemented, finding a code in linear time to the number of input weights if these weights are sorted [16].

Consider a source generating four different symbols {a1,a2,a3,a4} with probability {p1,p2,p3,p4}. A binary tree is generated from left to right taking the two least probable symbols and putting them together to form another equivalent symbol having a probability that equals the sum of the two symbols. The process is repeated until there is just one symbol. The tree can then be read backwards, from right to left, assigning different bits to different branches. The standard way to represent a signal made of four symbols is by using 2 bits/symbol, but the entropy of the source is 1.74 bits/symbol. If Huffman code is used to represent the signal, then the average length is lowered to 1.85 bits/symbol.

The decompression process simply means, translating the stream of prefix codes to individual byte values, usually by traversing the Huffman tree node by node as each bit is read from the input stream (reaching a leaf node necessarily terminates the search for that particular byte value). However, prior to this the Huffman tree must be reconstructed. In the simplest case, the character frequencies are fairly predictable and hence the tree can be reconstructed and reused every time, at the expense of the compression efficiency. Otherwise, the information to reconstruct the tree must be sent a priori.

Other methods such as arithmetic coding and LZW coding often have better compression capability and provide more efficient coding by adapting to the actual input statistics. However, these methods have higher computational complexity and are time consuming. Therefore, Huffman coding finds applications in real-time applications. The multimedia data compression standards for image compression such as the JPEG and JPEG2000 standards use it in their entropy coding phase.

IV. FLOW DIAGRAM OF THE PROPOSED METHOD

The proposed iris database compression with Haar wavelet transform and subsequent Huffman coding can be described in the following flow diagram.

First enter the decomposition level (lying between 1 and 8). The number of decompositions determines the quality of compressed image and the resolution of the lowest level in wavelet domain. Then images of the original database are taken one by one and processed as follows. Firstly, the image is resized to 512 × 512 and then decomposed by applying Haar wavelet transform. Subsequently quantized information is encoded with Huffman encoding scheme and the resulting image is saved into a new folder. Once all the images are compressed, the newly created folder yields the compressed database. The iris image required for identification purpose is then selected and compressed similarly. This compressed image is compared with the new database images based on Euclidean distance calculation to give the matching stage. The analysis stage is done in parallel to yield the MSE, PSNR and CR.

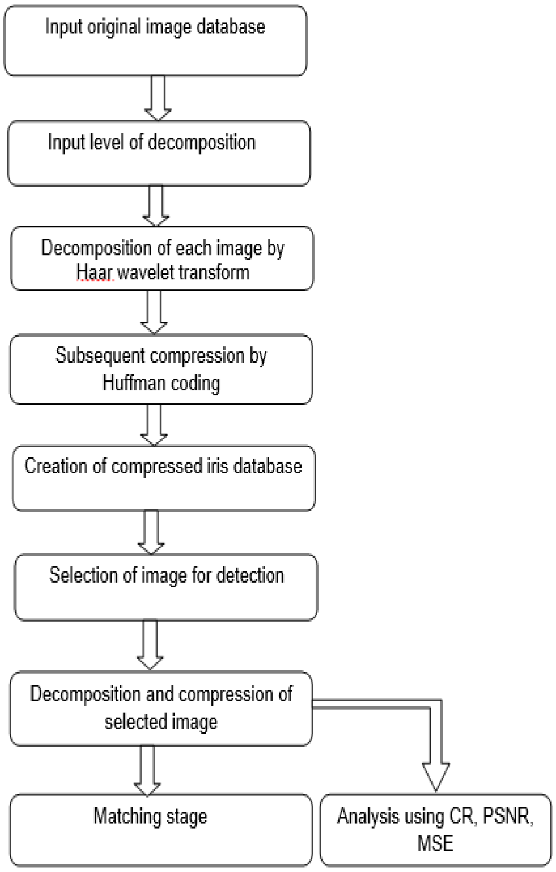

Fig.1. Flow Diagram of the proposed method

V. ANALYSIS AND RESULTS

In order to evaluate the performance of the image compression coding, it is necessary to define a measurement that can estimate the difference between the original image and the decoded image; commonly used ones are the Mean Square Error (MSE) and the Peak Signal to Noise Ratio (PSNR). Compression Ratio is another important parameter of a compression system.

A. MSE (Mean Squared Error)

The MSE represents the average of the squares of the "errors" between our actual image (I) and our compressed image (I'). The error is the amount by which the values of the original image differ from the degraded image. Mathematically given as:

$$\mathrm{MSE} = \frac{1}{\mathrm{mn}} \sum_{x=1}^{m} \sum_{y=1}^{n} (\mathrm{I}(x, y) - \mathrm{I}'(x, y))^2$$

B. PSNR (Peak Signal-to-Noise ratio)

Peak signal-to-noise ratio (PSNR) is an expression for the ratio between the maximum possible value (power) of a signal and the power of distorting noise that affects the quality of its representation. Because many signals have a very wide dynamic range, (ratio between the largest and smallest possible values of a changeable quantity) the PSNR is usually expressed in terms of the logarithmic decibel scale. Mathematically given as:

$$\mathrm{PSNR\ (dB)} = 20\times \log_{10}\left(\frac{255}{\sqrt{MSE}}\right)$$

C. Compression Ratio (CR)

The compression ratio can be defined as the ratio of the size the original image to the size of the compressed image; expressed by the equation:

$$\mathrm{CR} = \frac{Size\ of\ the\ original\ image}{Size\ of\ the\ compressed\ image}$$

TABLE I: ANALYSIS BASED ON VARIOUS PARAMETERS OF COMPRESSION

Level of Decom-position	MSE (Mean Square Error)	PSNR (Peak Signal to Noise Ratio)	CR (Compression Ratio)
1	206.58	25.05	2.36
2	227.18	24.63	3.33
3	263.38	23.96	3.71
4	351.62	22.69	3.82
5	628.11	20.16	3.84
6	926.61	18.46	3.84
7	1063.78	17.81	3.85
8	1117.34	16.51	3.85

The PSNR values obtained are close to the range of FBI database compression standards (around 25). Also, appreciable compression ratios are obtained. It is observed that MSE increases and PSNR decreases as the decomposition level increases. Since we implement a simple recognition system based on Euclidean distance matching, the recognition rate and system efficiency cannot be correctly determined.

VI. CONCLUSION

The Haar Wavelet decomposition and subsequent compression by Huffman coding is able to provide an efficient compression means without much data loss for large databases such as Iris based identification Databases that are now widely used for personal identification in various spheres of life like in offices, Aadhar cards, highly confidential areas of defence department etc. Thus it enables us to reduce the storage space required and hence transfer of databases from one place to another can be easily done within no time without losing the important parameters needed for iris based identification. Decomposition level selection of wavelet transform is also an important task, because computational complexity and decompression efficiency depends on it. As a future work we would like to implement a commercial iris recognition algorithm as the recognition system, to effectively analyse the total system efficiency. Better coding techniques such

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as SPIHT, STW wavelets etc. can be used to increase the system performance.

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