Modified Haar Wavelet based Method for Compressing Medical Images

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ABSTRACT

Nowadays, many researchers are attracted by image compression techniques because of the minimization of storage and transmission cost over the internet. The main objective of image compression is to reduce the redundant and irrelevant information from the original data. Haar Wavelet Transformation (HWT) is an efficient transform coding among the lossy image transform techniques. This proposed work has two stages of process: Vector Quantization and Thresholding. In the first stage, Haar Wavelet Transformation is implemented which results categorized into two matrices; Approximation Co-efficient (AC) matrix and Detailed Co-efficient (DC) matrices. The second stage of proposed method is applied Vector Quantization(VQ) to improve the compression efficiency. This proposed work achieved higher compression ratio without compromising the image quality. The performance of the proposed method is compared using the traditional Haar Wavelet transform based method which has been evaluated using some popular parameters such as Peak Signal to Noise Ratio (PSNR), Structural Similarity Index(SSIM), Compression Ratio (CR) and Bit Rate(BR). The computation cost is minimized using proposed method. The comparative analysis of the proposed method has witnessed the achievement of good compression ratio and image quality as well.

Key words: Image Compression, Haar Wavelet Transform, Vector Quantization, Run Length Encoding (RLE), Thresholding Technique.

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INTRODUCTION

Image compression creates a fine solution for the problem of massive data storage and transmission. Nowadays, the people need enormous data to send and receive through the internet. The main process of image compression is the reduction of redundant information from the original data [1]. It is also used to reduce the size of the original image data in bytes without much degradation in the quality of the image.

The encoder creates a set of symbols representing the input image $f(x,y)$. The decoder at the receiving end uses the symbols to reconstruct the input image. The basic process of image compression is shown in Fig.1.

Fig 1. General process of Image Compression

Generally, the compression process can be classified into lossless or lossy [2]. In lossless compression, original image is perfectly reconstructed without loss any information. In lossy compression, there is some loss in the form of redundant and irrelevant information from the original image. Haar Wavelet Transform is one of the simple lossy compression technique. Several methods are proposed for compressing images based on vector quantization [3-5] and transforms[6].

HAAR WAVELET TRANSFORM

Haar Wavelet is a one of the traditional wavelet technique to extend the quality of an image. The process of haar wavelet is easy to manage the complex task through their performance. It has 2 different outputs like approximation (average) coefficient matrix and Detail (difference) coefficient matrices. General representation of the Haar wavelet is visually presented in Fig.2.

Approximation Coefficient	Detail Coefficient (Horizontal)
Detail Coefficient (Vertical)	Detail Coefficient (Diagonal)

Fig 2. Decomposition of Haar Wavelet Transform

The principle behind this concept of Haar wavelet is easy to calculate the average and differences of neighbourhood pixels.

VECTOR QUANTIZATION

Vector quantization(VQ) is a lossy compression method. known for its ease of implementation and efficiency. It achieves compression by representing a large set of vectors with a few vectors called the codebook which is generated through the encoding process. The decoder, at the receiving end uses the code vectors and the code indices to reconstruct the input image. The performance of the VQ depends on the quality of the codebook which is influenced by several

factors like initial seeds, number of iterations and vector dimension. The process of vector quantization is presented in Fig.3.

Fig 3. Vector Quantization process

RELATED WORK

There are various existing methods are proposed using Haar wavelet and RVQ techniques.

Gopal Lakhani.,[7] proposed a novel technique based on JPEG arithmetic coding (JAC) algorithm for enhancing image quality. L. Li., et al. [8] developed a prediction model based on shanon's rate-distortion theorem. Kharate., et al. [9] proposed an algorithm of wavelet packet entropy best tree based on threshold entropy with lossy enhanced run length encoding. Deng Wang., et al. [10] developed a novel image coding system in which Original EEG signals are represented by wavelet packet coefficients and feature extraction using the best basis-based wavelet packet entropy method. Mukesh Mittal., et al.[11] presented a review of various vector quantization algorithms used for the designing of the codebook to obtain better quality. D.Aruna Kumari., et al. [12] proposed a technique for preserving data and has described the process of quantization on training data samples that will produce transformed data set. S.Vimala., [13] developed a novel algorithm based on vector quantization technique to enhance the quality of image. The author describes about the high detail blocks which are identified based on the maximum and minimum pixel values of the blocks.

The rest of the paper is structured as follows: Section 3 describes the process of the proposed method in a detail form of description about the methodology. Performance and comparative analysis of the proposed method is presented in Section 4. The merits and future enhancements are pointed out in Section 5.

PROPOSED WORK

In this proposed work, investigates a novel methodology using Haar Wavelet Transform (HWT) and Thresholding. Generally, the Haar wavelet transformation has a set of four coefficient matrices like Approximation Co-efficient(AC) matrix and three Detail Co-efficient(DC) matrices. These matrices are further subjected to achieve compression to enhance compression ratio. The approximation co-efficient matrix is compressed using Vector Quantization(VQ) and DC Matrices are compressed using Run-length coding prior to compression, The DC matrices

are converted to sparse matrices by applying thresholding and the sparse DC matrices are compressed using run length coding in the next stage.

The Proposed Method (HWT_VQ)

The proposed method work is briefly described in three stages.

Stage 1: Haar Wavelet Transformation of the input image

Stage 2: Compression of Approximation Coefficient matrix obtained in stage1 using Vector quantization

Stage 3: Compression of Detail Coefficient(DC) matrices obtained in stage1 using thresholding and run length encoding.

Stage One: The input images is read and transformed by applying HWT, The output of HWT has four matrices one AC matrix and three DC matrices

Stage Two: The AC matrix obtained from Stage 1 is compressed further by applying Vector Quantization. K-means clustering algorithm is used to generate the codebook, set of cluster centroids. The AC matrix is divided into small blocks of size (block size*block size), The value of block size may be chosen based on the desired image quality for good image quality. The block size should be kept small for achieving good quality image, The training vectors (blocks) are clustered using K-means algorithm The output of K-means is a set of optimal cluster centroids which form the codebook. The size of the codebook also determine the image quality.

Stage Three : The three DC matrices are subject to hard thresholding to make the DC matrices more sparse. Sparse matrix is one which consists of “high proportion of zero entities. A non zero threshold is select and all the pixels with intensity less than the threshold are reset to zero. As sparse matrices can be compressed heavily using Run-Length Encoding, the three sparse DC matrices are compressed using Run-Length Encoding. Thus the proposed method compresses an image at three different levels with appropriate compression algorithms to achieve higher compression ratio without compromise the image quality.

a) Proposed Algorithm

Stage1: Read the input image

Stage2: Apply Haar Wavelet Transform

Stage3: Apply Vector Quantization to Approximation Co-efficient Matrices (AC)

Stage4: Apply Thresholding to three Detail Co-efficient matrices (DC)

Stage5: Compress the Detail Co-efficient Matrices using Run-Length Coding

The process of encoding and decoding of the proposed algorithm is represented in Fig.4. and Fig.5.

Fig.4. Encoding Process of the Proposed Method

Fig 5. Decoding Process of the Proposed Method

RESULTS AND DISCUSSION

Experimental results of the proposed method is tested using five different medical test images. Evaluation process is conducted using some standard compression metrics such as Peak Signal to Noise Ratio(PSNR), Structural Similarity Index(SSIM), Compression Ratio(CR), Bit Rate (BR) and Computation Time(CT) which has proved the prominence of the proposed method.

Peak Signal Noise ratio (PSNR)- The quality of the proposed method is evaluated using PSNR value. Normally, it is measured in decibels using Eq.(3).

$$PSNR = 20 \log_{10} \frac{255}{\sqrt{MSE}} \quad (3)$$

Structural Similarity (SSIM) - Similarity is measured between original and compressed image using Eq. (4)

$$Q = \frac{4\sigma_{xy}\mu_x\mu_y}{(\sigma_x^2\sigma_y^2)(\mu_x^2\mu_y^2)} \quad (4)$$

Compression Ratio(CR) - Compression efficiency of the proposed method is measured using Eq.(5).

$$CR = \frac{\text{Original Image size}}{\text{Compressed Image Size}} \quad (5)$$

Bit- Rate (BR) - Pixel representation of the Bit rate is calculated using Eq.(6).

$$Bpp = \frac{\text{Original Image Size in Pixels}}{\text{Total number of bits in Compressed image}} \quad (6)$$

The efficiency of the proposed method is witnessed by its computation time and it must be a least value. The performance of the proposed method presented in Table 1.

Table 1. Performance of the Proposed Method (HTVQ)

Image	Quality Metrics		Compression Performance		CT
	PSNR	SSIM	CR	BR	
MRI_Brain	37.343	0.97	12.63	0.63	0.92
MRI_Knee	37.239	0.94	13.18	0.61	5.05
MRI_Spine	44.593	1.00	12.82	0.62	6.84
Mammogram	38.251	0.94	12.77	0.63	0.41
X-ray Image	40.753	1.00	13.15	0.61	0.82

Table 1 demonstrates the better performance of the proposed method based on the quality metrics. At the same time, compression performance also witnessed the enhanced performance of the proposed method. As the desired range of PSNR for medical image diagnosis is (30-40)db, this method is a great choice for medical image compression. The comparative analysis of the proposed method is tabulated in Table 2.

Table 2. Comparison between Existing [14] and Proposed Method

Methods	File size	CR	MSE	PSNR
SBC	507540	0.9982	4.757	41.356
SVD	507544	0.9966	26.562	33.888
DCT	507544	0.9966	33.346	32.900
SPHIT	507540	0.9982	6.110	40.269
NN	507544	0.9966	12.482	37.167
VQ	507408	0.9984	45.710	31.530
BTC	507452	0.9983	11.961	37.353
Proposed Method (HTVQ)	524288	12.63	12.032	37.327

The comparative analysis between the existing and proposed method is presented in Table 2. Table 2 examined the superior performance of the proposed method through the higher compression ratio. The performance of the comparative analysis is graphically represented in Fig.6. and Fig.7.

Fig 6. Comparative Analysis of Compression Ratio

Fig 7. Comparative Analysis of PSNR Value

The visualization of the proposed method is presented in (Fig.8 - Fig 12) for five test medical images such as MRI_Brain, MRI_Knee, MRI_Spine, Mammogram and X-ray images. The achievement of the proposed method has been proved by the quality of images.

Fig.8. a) Input Image of MRI_Brain, Reconstructed Image using b) HWT Method
 c) Proposed Method

Fig.9. a) Input Image of MRI_Knee, Reconstructed Image using b) HWT Method
 c) Proposed Method

Fig.10. a) Input Image of MRI_Spine, Reconstructed Image using b) HWT Method
c) Proposed Method

Fig.11. a) Input Image of Mammogram, Reconstructed Image using b) HWT Method
c) Proposed Method

Fig.12. a) Input Image of X-ray, Reconstructed Image using b) HWT Method
c) Proposed Method

CONCLUSION

In this paper, a novel method has been examined by combining HWT and VQ to enhance the compression ratio without compromising the image quality. The proposed work achieves higher PSNR and Compression ratio with acceptable range for medical diagnosis. Experiments were done for different test medical images and the performance is analyzed based on standard compression metrics. This method could be a ideal choice for transmitting the medical images.

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