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Image Compression Using Mean-Removed And Multistage Vector Quantization In Wavelet Domain

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Abstract: - The main purpose of the image compression is to reduce the size of the image with minimum degradation. Internet world use data, images and videos massively. The images are compressed with the higher compression ratios using lossy compression techniques for transmission and efficient storage of the images. The quality of the image degrades in these techniques. There are different types of technique available for the lossy image compression. Lossy image compression technique presented in this paper is easy to implement, secure and efficient which is called Vector Quantization (VQ) based on wavelet transform. In this paper design and implementation of two types of vector quantization techniques Mean-removed vector quantization, Multistage vector quantization (MSVQ) using wavelet transforms are proposed and the performance is compared or quality of the reconstructed image on the basis of quality measures. Major artifacts like blockings and loss of edge information are observed in VQ based image compression technique. The use of wavelet with the VQ technique shows improvement in this area. The performance is analyzed using special edge based quality measures MESSIM. Mean edge based similarity index. The performance of the multistage vector quantization is much better than the mean removed vector quantization in terms of PSNR and MESSIM.

Keywords- Image Compression, Wavelet transform, Vector Quantization, Mean-Remove Vector Quantization, Multistage Vector Quantization, Edge structural similarity index.

I. INTRODUCTION

The image compression is widely used in multimedia applications. File size is inversely proportional to the storage capacity of disk or memory, as file size decreases more images can be stored in a given memory. The reduction in file size makes consumption time that is required to transfer image over internet or download the same from web page, less. There are different types of image compression techniques used to compress the image for efficient storage. Lossy compression techniques or standers are JPEG, JPEG2000 and Vector Quantization etc. Though lossy compression techniques provide higher compression ratios, they have some drawbacks such as blockiness, blurring, ringing etc. which degrades quality of the image. Compression ratio and image quality are inversely related to each other. Wavelet transform is used to overcome some drawbacks present in the lossy compression techniques such as information loss, edge loss in some amount etc. Wavelet analysis is different from Fourier analysis, because individual wavelet basis function can describes different frequencies. Advantages of wavelet analysis are,

(1) It gives very good image approximation with few wavelet coefficients

(2) The edge information can be extracted & encoded by using wavelet transform.

Thus, we can easily compare different resolution of images on the basis of wavelet scheme. Wavelet transform is fast and easy to compute the images. The data contained in the image does not reduce by using wavelet transform. In this paper design and implementation of two types of vector Quantization are proposed. Mean removed vector quantization and multistage vector quantization based on wavelet transform. The important part in the Vector Quantization is generating the codebook. The codebook was designed using more than 14000 training code vectors selected from various images based on LBG algorithm. In images, edges are the main feature. Quality of the image degrades, because the edges get disturb or affected, due to blockiness. Edges preservation to maximum extend is the real effort in any compression algorithm. The canny edge operator and mean structural similarity index is used to propose Mean Edge Similarity Index. Wavelet based image compression achieved by using these two types of vector quantization. By calculating some parameter of the original and resultant images such as PSNR, MSE, edge base measure Mean Structural Similarity Index (MSSIM), spectral Frequency Measure (SFM) & Spectral Activity Measure (SAM) of the original images and spectral frequency measure & spectral activity measure of the reconstructed images, compare the quality measures. Rest of the paper is organized as follow Section (II) describes the previopus work done on the vector quantization and wavelet transform for the image compression. Section (III) gives brief discribtion of Vector Quantization and Wavelet Transform. In section (IV) we briefly discribes the method proposed in this paper. Section (V) calculate some Quality measures. Result shows in section (VI). Method conclusion & future scope is discribe in section (V).

II. RELATED WORK

Osama Yamanaka et al. [5] [10] introduced discrete wavelet transform with the vector quantization for image compression. DWT is the multi-resolution analysis where the signal energy is concentrated to specific DWT coefficients. To compress the DWT coefficient vector quantization was used with the variable block size. Jayanta Kumar Debnath [9] performed three levels DWT on the original image, result gives 10 separate subbands. The self organizing feature map algorithm was used to generate the codebook. Jyoti Singhai et al. [6] used multistage vector quantization for the image compression in which codebook was generated by using LBG algorithm and partial distance search method. This method is most suitable in multimedia application where faster encoding is required. This method is used but using simple LBG algorithm. G. Bhoopati [4] proposed image compression techniques based on wavelet transform and vector quantization. Generation of the codebook is the major step in the vector quantization. In this paper to generate the codebook radial basic function was used. By proposing the radial basic function for image compression based on vector quantization and wavelet transform gives better result. The area where high precision reconstructed image is required, this approach is very helpful for those areas such as medical imaging and criminal investigation etc. This method reduces the mean square error and provides better PSNR values. He also provides survey on vector quantization [7] .Chaur-Heh & Yong-Jzu [2] presented several fast encoding algorithm based on multiple triangular inequality using wavelet transform. The purpose of this method was to reduce the need of expensive computation for searching closest vectors, but the experimental result shows that new algorithm performs more efficiently than the algorithm proposed in this paper. Y. H. Dandawate et al. [8] proposed enhanced vector quantizer codebook. Self-organized feature maps were used for the quality improvement using different images. The performance was analyzed by using different quality measures. The result is compared with jpeg in terms of file size and quality measure. Y. H. Dandawate et al. [15] proposed Generic and wavelet based Generic VQ in terms of edge information and blockiness parameters. Edge preservation was improved by wavelet based Generic VQ, very little difference in blockiness parameter. PSNR was also improved; the only drawback is file Size becomes 10 KB. S. Esakkirajan et al. [9] proposed new image coding techniques using adaptive wavelet packet & multistage vector quantization. In this paper instead of single stage vector quantization multistage vector quantization was used to reduce codebook size so the computational complexity also reduces.

III. VECTOR QUANTIZATION

Principle of Vector Quantization-:

"Vector Quantization assists to project a continuous input space on a discrete output space, while minimizing the loss of information. To define zones in the space, the set of points contained in each zone being projected on a representative vector." [4].

Use of Vector Quantization in Image compression

The vector quantization methodology is also known "block quantization" or "pattern matching quantization" which is used for lossy image compression [4].

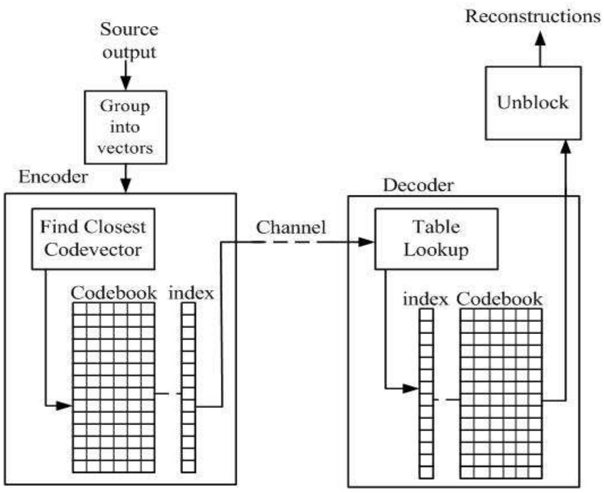

Fig.1. Block Diagram for Vector Quantization

IV. PROPOSED METHOD

In this paper, we proposed wavelet based image compression using two types of Vector Quantization, Mean Removed Vector Quantization and Multistage Vector Quantization (MSVQ). Initial codebook is very important. The future performance of the codebook is decided by selection of proper initial vector. Y.H. Dandawate and M.A. Joshi [15] have selected code vectors from images which contain different statistical and structural features. Initial codebook was prepared from these blocks. The training vectors were more than 14000.

A] Wavelet based Mean-Removed Vector Quantization (MRVQ)-:

The mean-removed vector quantization (MRVQ) is a modified or advanced version of the VQ scheme [14]. The goal of MRVQ is to provide better image quality than actual VQ. To divide the image in blocks is the basic idea of mean-removed vector quantization. First take mean of each block arranged as vector then the mean of each is subtracted from the intensity of each pixel in the block. The resultant vector is known as residual vector. Using separate codebook the mean and the residual vectors are coded. Thus the original vectors are decomposed into separate features, general background level is represented by the mean & departure of the vector about its mean represented by the residual vectors. To achieve the goal, index of the residual vector and the block mean value are used to encode each image block in mean-removed VQ. Therefore, the required bit rate of MRVQ is much higher than that of VQ. Basically, the MRVQ scheme consists of three procedures: the codebook generation, image encoding, and image decoding. To generate the codebook LBG algorithm is applied here .The training images are used for mean-removed VQ codebook design. The wavelet transform is applied to the codebook and separate out the approximation and detail part. Take the input image divide the image into 4*4 blocks. Apply the wavelet transform to the image code vector. Take the mean of each block and separate it from original vectors the resulted vector is called as residual vector. The Euclidean distance calculates the minimum difference between the codebook vectors and image vectors. Using inverse wavelet transform, reconstruct the image and quality measures are calculated.

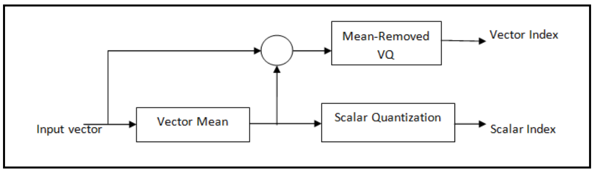

Fig.2. Block Diagram of Mean-Removed VQ

B) Wavelet based Multistage Vector Quantization (MSVQ)-:

Single stage vector quantization have some drawbacks, it requires excessive size of codebook, which increase storage complexity. Single stage vector quantization is alternatively called cascade vector quantization or Multistage vector Quantization (residual vector quantization). Quantization process is divided into number of stages in multistage vector quantization. In the first stage, using relative small codebook vector quantizer quantize input vector. The error is calculated between input vector and quantized vector. In the second stage this error is again quantized by using different codebook. The next stage of MSVQ quantizes the error between quantized outputs of the previous stage and input vector of the previous stage. Instead of transmitting quantized input vector and quantized error vector, simply transmit the indices corresponding to quantized input vector and quantized error vector. Multistage vector quantization reduces storage & computational complexity as the size of codebook reduces [6].MSE and PSNR obtained in multistage vector quantization are much better than mean removed vector quantization using wavelet transform.

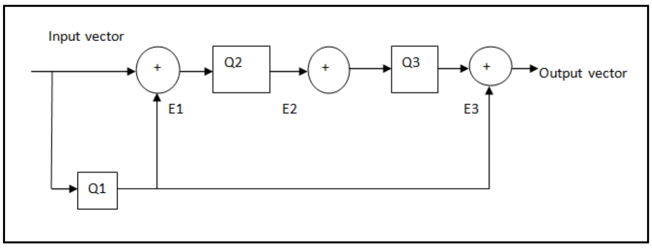

Fig.3. Multistage Vector Quantization [9]

V. QUALITY MEASURES AND MEAN EDGE STRUCTURAL SIMILARITY MATRIX

A major problem in image compression system is to describe the type and amount of degradation in reconstructed image. Mean square error (MSE) and peak signal to noise ratio (PSNR) are the most common measures of image quality, but they are not sufficient as perceptually meaningful measures.

1) Mean Square Error (MSE)-:The simpler form of the image quality measurment is the mean square error. MSE is defined as [12],

$$MSE = 1/MN\sum_{m=1}^{M}\sum_{n=1}^{N}(x(m,n)-x^{m,n}))^2$$

2) Peak Signal to Noise Ration (PSNR)-: The value of the PSNR is directly proportional to image quality. As the PSNR increases the quality of the image also increases. PSNR is defined as [12],

$$PSNR = 10\log 255^2 / MSE$$

3) Structural Content (SC)-: The large value of the Structural Content (SC) means that image is poor quality. SC is defined as follow [8].

$$SC = \sum_{m=1}^{M}\sum_{n=1}^{N}x(m,n)^2 / \sum_{m=1}^{M}\sum_{n=1}^{N}\bar{x}(m,n)^2$$

4) The Special Frequency Measurement (SFM)-: SFM indicates the overall activity level in images. SFM is defined as follows [12].

$$SFM = \sqrt{R^2 + C^2}$$

$$R = \sqrt{\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=2}^{N}(x(m,n)-x(m,n-1))^2}$$

$$C = \sqrt{\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=2}^{N}(x(m,n)-x(m-1,n))^2}$$

Where R= row frequency, c=column frequency, x(m,n)=denotes the sample of images, M &N denotes no. of pixels in row & column direction respectively. The large value of SFM means that image contain component in high frequency area. Blockiness degrades the quality of the images in image compression using VQ. It is determind by using edge similarity matrix and blockiness measurement which is developed by canny operator and mean structural similarity index(MSSIM). The quality of images compressed using VQ is degraded due to blockiness present in it. The assessment is done using blockiness measurement and edge similarity metric which is developed using canny operator and Mean Structural Similarity Index (MSSIM) [15]. MESSIM is use for edge preservation [15].

$$l(x,y) = \frac{2\mu_x\mu_y + c_1}{\mu_x{}^2 + \mu_y{}^2 + c_1}, c(x,y) = \frac{2\sigma_x\sigma_y + c_2}{\sigma_x{}^2 + \sigma_y{}^2 + c_2}, s(x,y) = \frac{\sigma_{xy} + c_2}{\sigma_x{}^2 + \sigma_y{}^2 + c_2}$$

$$SSIM(x,y) = [l(x,y)]^{\alpha}[c(x,y)]^{\beta}[s(x,y)]^{\gamma}$$

$$MESSIM(X,Y) = \frac{1}{M}\sum_{j=1}^{M}SSIM(x_j, y_j)$$

They used contrast, luminance and structural information to develope a matric called as MSSIM. At the last, mean is taken, to calculate luminance mean and standard deviation is used. For contrast and structural information we use MSSIM based edge similarity matric. In which instead of using structural information, it uses structural information obtained from the image after applying Sobel edge operator. Canny edge operator is used in this paper since some inherent limitation is observed in Sobel edge poerator to optain more information about edges.In MSSIM structural information of Canny based edge image is substituted. This is called as MESSIM.

VI. RESULTS

The main intention of the image compression is to minimize the size of the image with minimum degradation. In this paper we use two types of vector quantization, mean-removed vector quantization and multistage vector quantization, which gives below results. The performance of the reconstructed images is analyzed using various quality measures along with conventionally used PSNR. Blockiness degrades the quality of the images in image compression using VQ. It is determind by using edge similarity matrix and blockiness measurement which is developed by canny operator and mean structural similarity index(MSSIM). The experimental result shows that, performance of multistage vector quantization is better than mean-removed vector quantization in terms of quality measures. The experiment is performed on five different images with 256x256 pixel sizes and having wide variation from texture to frequency, the PSNR and other image quality parameters are shown in the table. The simulation and algorithm is done on MATLAB Ver 12 platform with image and wavelet toolbox. Processor Intel(R) core (TM) i5-3337UCPU at 1.80GHz. Installed memory (RAM) 40GB. System Type-64 bit operating system, x64 based processor.

1) Results for wavelet based Mean-removed Vector Quantization-:

Name	Bird	Camera Man	Finger print	Lenna	Women
PSNR (dB)	36.54	26.19	27.43	30.16	31.87
MSE	14.422	156.015	117.34	62.657	42.232
SC	0.999	1.0048	1.0018	1.002	1.009
Messim	0.8922	0.8019	0.9438	0.8804	0.7604
SFMor	113.38	402.394	372.02	247.76	269.76
SFMre	117.62	389.596	429.35	228.45	267.60

2) Results for wavelet based Multistage Vector Quantization -:

Name	Bird	Camera Man	Finger print	Lenna	Women
PSNR (dB)	39.62	32.50	38.05	39.746	33.179
MSE	1.0971	36.564	10.270	6.893	31.264
SC	0.9996	1.0004	0.9986	0.9988	1.0006
Messim	0.9763	0.9648	0.9936	0.9841	0.9414
SFMor	300.21	402.394	372.02	247.76	269.76
SFMre	299.42	361.383	379.61	241.17	220.265

Original Images -:

Fig.4. Original Images- a) Bird, b) cameraman, c) Lenna, d) Fingerprint, e) Women.

A) Reconstructed Images of Mean-removed vector quantization-:

Fig.5.Reconstructed Images of Mean-removed Vector Quantization

B) Reconstructed Images of Multistage Vector Quantization:-

Fig.6 Reconstructed Images of Multistage Vector Quantization.

VII. CONCLUSION & FUTURE SCOPE

In this paper, image compression based on wavelet transform and vector quantization are performed. The codebook generation of vector quantization is done by using LBG algorithm. In mean-removed vector quantization residual vectors are used. Single stage vector quantization required large codebook size which increases the memory and computational complexity, therefore multistage VQ is used. In this paper, we used three stages Vector Quantization. In multistage vector quantization codebook was generated from error code vector using LBG algorithm, as size of the codebook is reduced computational complexity is also reduced. Result obtained from multistage vector quantization is much better than mean-removed vector quantization in terms of PSNR and other quality analysis. We analyzed blockiness and edge information using wavelet based VQ. Wavelet based VQ improved the PSNR and edge preservation in both type of VQ. The only drawback is computational time required for multistage VQ is nearly twice, compared to mean removed VQ.

The method described in this paper is performed on the gray scale images only. This method can be further extended to the color images for image compression.

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