Distortion measure performance of quantization techniques

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Abstract—**Quantization in image processing is a lossy compression technique achieved by compressing a range of values to a single quantum value. In this paper performance comparison of scalar and vector quantization is done based on histogram distance parameters for images with different bits per pixel values. Scalar quantization is the method in which group of pixel intensity values are mapped on to a scalar output intensity value in a predefined manner. In scalar quantization, codevectors are uniformly assigned irrespective of the distribution of pixel intensities. Vector quantization is the method in which group of pixel intensity vectors are mapped on to output vectors based on the distribution of pixel intensity vectors. Codevector is assigned based on the density of population and no codevectors are wasted in unpopulated region. Here the performance of scalar and vector are compared based on histogram Euclidean distance, mean square error and peak signal to noise ratio. Experimental results shows that the distortion measure of vector is lower under lower bits per pixel. Scalar quantization outperforms vector under higher bits per pixel.**

Keywords—Histogram Euclidean distance, Mean square error, Peak signal to noise ratio,Scalar quantization, vector quantization.

I. INTRODUCTION

There are basically two types of quantization:scalar and vector quantization. Scalar quantizer encode each output value individually, while vector quantizer encode the whole sequence or values simultaneously [1].

Scalar quantization is computationally simpler approach to quantize a vector X = [X1,...,Xk] is to quantize each of its individual scalar components Xi, 1≤ i ≤ k. A codebook Ci of scalar outputs is designed independently for each scalar component Xi, 1≤ i ≤ k. Let us consider x as the output vectors, which are taken to be the centroids within each region. Mapping is accomplished by independently encoding each $X_i$to a channel symbol through a k vector codebook. The outputs of the k vector codebook are independently decoded to scalar outputs $Y_1,..,Y_k$, which constitute the output vector $Y=[Y_1,...,Y_k]$ = Q(X). Since the codebook design only involves quantization of scalar variables, and the encoding operation only entails indexing the individual input vector. As with scalar quantization, the objective is to minimize a distortion criterion such as mean squared error (MSE). An iterative error minimization algorithm developed by Lloyd for scalar quantization [1-3].Vector quantization [3-6], [7] has been found to be an efficient data compression technique for speech and image as it provides many attractive features for image compression. A vector quantizer Qof dimension kand size Nis mapped from a point in k-dimensional Euclidean space Rk, into a finite set *C* containing *N* output or reproduction points that exist in the same Euclidean space as the original point. These reproduction points are known as codewords and these set of codewords are called codebook. Scalar quantizer quantizes the pixel intensities into a scalar output irrespective of the distribution of pixel intensities. Vector quantization assigns codeword to populated region and no wastage of codeword in unpopulated region as in the case of scalar.

II. SCALAR QUANTIZATION

Scalar quantization(SQ) is computationally simpler approach to quantize a vector $X = [X_1,...,X_k]$is to quantize each of its individual scalar components X_i, 1≤ i ≤ k. A codebook $C_i$of scalar outputs is designed independently for each scalar component X_i, 1≤ i ≤ k. The outputs of the k vector codebook are independently decoded to scalar outputs $Y_1,..,Y_k$, which constitute the output vector $Y=[Y_1,...,Y_k]$ = Q(X). Since the codebook design only involves quantization of scalar variables, and the encoding operation only entails indexing the individual input vector. As with scalar quantization, the objective is to minimize distortion criterion such as mean squared error (MSE). In scalar quantization the levels are uniformly spaced.

$$d_i - d_{i-1} = \Delta,\ 1 \le i \le L \text{ and } r_i = \frac{d_i + d_{i-1}}{2},\ 1 \le i \le L$$

where L represents the maximum intensity value

In this paper a 256 x 256 image is considered. Scalar quantization is the technique in which a particular range of intensity values are quantized to a pre-defined intensity. In this paper the pixel intensities in the range of [0,255].These intensity range is dived into 4 equal intervals and thus four groups of pixel intensities are obtained .The scalar quantization is done in such a manner that each range is quantized to its mid intensity value. Here the quantization is done in a pre-defined manner and do not consider the nature of the pixel intensity distribution.

III. VECTOR QUANTIZATION

Vector quantization(VQ) has been found to be an efficient data compression technique for speech and image as it provides many attractive features for image compression. Let **X**be a random vector in R_k with probability density function p(**x**). An Npoint *k* dimensional vector *Q*: $R_k \longrightarrow R_k$ is a function whose domain is the set of all possible values of **X**and whose range is a set of N vectors C = {$\mathbf{y}_1$,...,$\mathbf{y}_N$}called a codebook. The quantizer is designed to minimize the expected distortion, D_k =E{d(X,Q(X))}between its input and output. Here, E{ }denotes expected value. The distortion measure that we will be using is the mean-squared error (MSE) as :

$$D_k = \frac{1}{k} E\{ ||X - Q(X)||^2 \}$$

where || || denotes Euclidean distance.

The two necessary conditions for a quantizer to be optimal with respect to the MSE distortion are that (i) the **y**iare chosen to be the centroid of ***x*** in Si, i.e. $\mathbf{y}_i = E\{\mathbf{X} \mid \mathbf{x} \in S_i\}$and (ii) each input ***x*** is quantized to one of the $\mathbf{y}_i$'s according to a nearest neighbor rule. These two conditions are the basis for the iterative codebook design algorithm.

A. Vector quantization algorithm

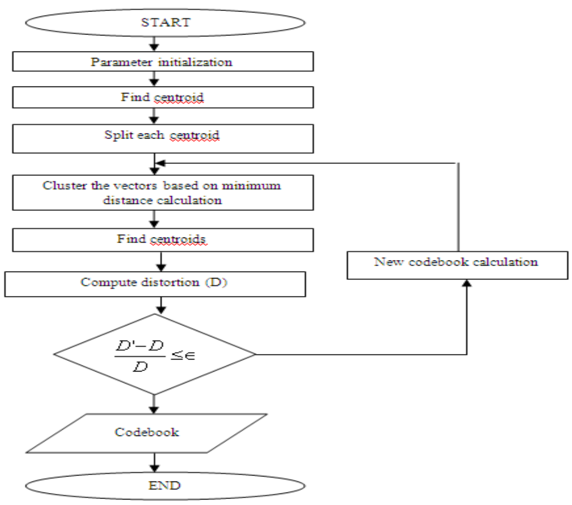

Fig.1.Vector quantization flowchart

Here the training vectors are clustered by computing the minimum distortion of the training vectors against the initial codewords C. The centroids of the clusters thus formed become the new codewords for the next iteration. This procedure continues until there is no significant change in the total distortion between cluster members and the codewords around which they are clustered. The final set of code vectors obtained constitutes the codebook.

IV. PERFORMANCE PARAMETERS FOR THE COMPARISON OF SQ AND VQ

In this paper the performance of scalar and vector quantization is compared based on the parameters like (i) Histogram Euclidean distance(E_dist) (ii)Mean square error(MSE) (iii)Peak signal to noise ratio(PSNR).

(i)The Histogram Euclidean distance is the difference between the histogram of the input image compared to the output image and the equation is given by:

$$E\_dist = \sqrt{\sum (h - h1)^2}$$

Here, h= histogram of the input image
h1= histogram of the output image

(ii) Mean square error is the cumulative squared error between the compressed and the original image. The mathematical formula is given by:

$$MSE = \frac{1}{MN} \sum_{y=1}^{M} \sum_{x=1}^{N} \left[I(x,y) - I'(x,y) \right]^2$$

where I(x,y) is the original image, I'(x,y) is that of compressed image and M,N are the dimensions of the images.

(iii) Peak signal to noise ratio(PSNR) is a measure of peak error given by:

$$PSNR = 20 * \log_{10}(255/\sqrt{MSE})$$

Lesser value of MSE means lesser error and high value PSNR means the signal to noise ratio is higher ie, noise is lesser. Here signal represents the original image.

V. EXPERIMENTAL RESULTS AND DISCUSSIONS

A. Scalar quantization

Fig.2.input image

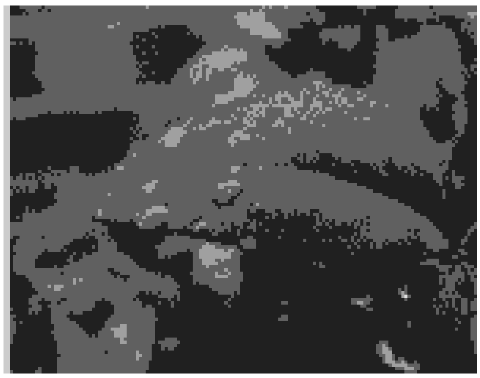

Fig.3.scalar quantized 1 bit image

Fig.4.Scalar quantized 8 bit image

Fig.5.Scalar quantized 24 bit image

Fig.3. shows the scalar quantized output image of a 1 bit image. Fig.4. shows the scalar quantized output of 8 bit image and fig.5as that of 24 bit input image.

B. Vector quantization

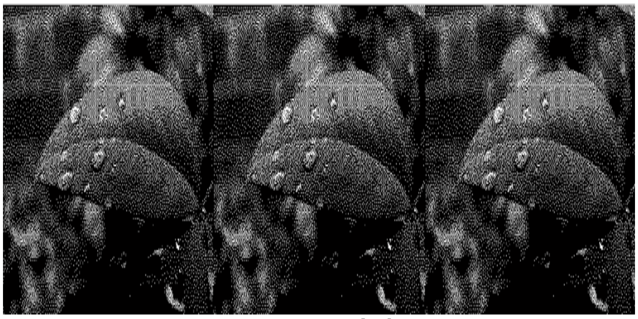

Fig.6.Vector quantized 1 bit image

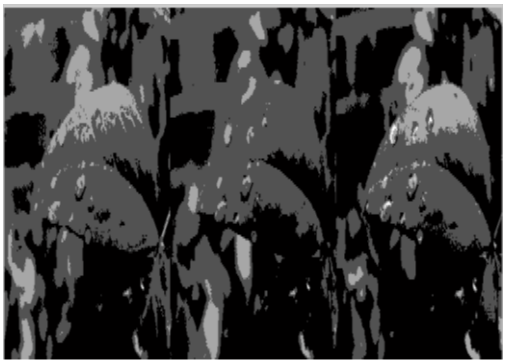

Fig.7. Vector quantized 8 bit image

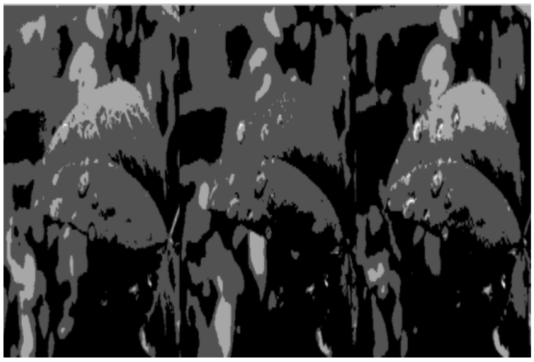

Fig.8.Vector quantized 24 bit image

Fig.6.,fig.7.,fig.8. shows the vector quantized output of 1 bit,8 bit and 24 bit input image respectively. Vector quantization is done based on the codebook values.

C. Histogram Euclidean distance Vs bits per pixel of scalar quantization

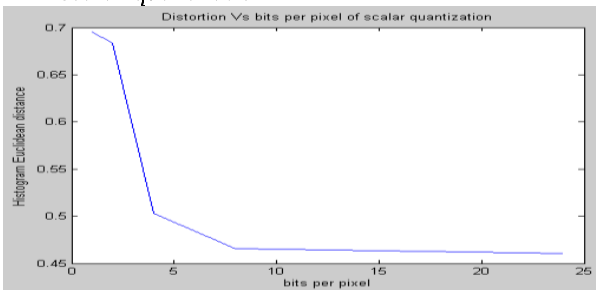

Fig.9.Histogram Euclidean distance Vs bits per pixel of scalar quantization

D. Histogram Euclidean distance Vs bits per pixel of vector quantization

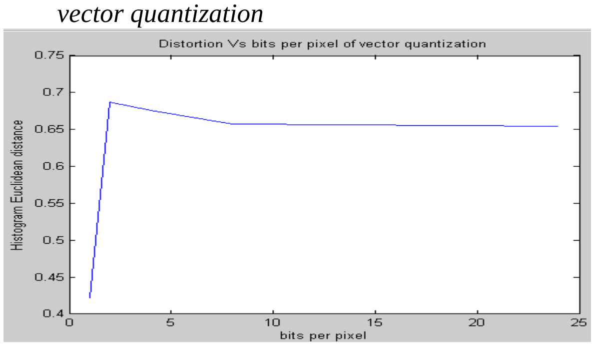

Fig.10.Histogram Euclidean distance Vs bits per pixel of vector quantization

Histogram Euclidean distance is used to calculate the distortion between the input histogram and the output histogram for each input for different values of bits per pixel. From fig.9. and fig.10. it is obvious that the distortion decreases with increase in bits per pixel in the case of scalar quantization and in the case of vector quantization the distortion is less under lower bits per pixel and the distortion increases for higher bits per pixel.

Table.1.Comparison of scalar and vector quantization

bits per pixel		**1**	**2**	**4**	**8**	**24**
SQ	***E_dist***	0.6955	0.6832	0.5029	0.4659	0.4605
	MSE	0.0019	0.0013	0.0012	0.0013	0.0013
	PSNR	50.6dB	77.1dB	77.23dB	77.13dB	77.0dB
VQ	***E_dist***	0.4215	0.6869	0.6753	0.6573	0.6548
	MSE	0.0206	0.0269	0.0310	0.0346	0.0340
	PSNR	40.3dB	39.2dB	38.6dB	62.7dB	62.8dB

The table.1. shows the comparison of scalar and vector quantized output based on its histogram Euclidean distance, MSE(mean square error) and PSNR (peak signal to noise ratio).From the table also it is obvious that the distortion or the Euclidean distortion decreases with increase in bits per pixel in the case of scalar and in vector quantization the distortion is minimum under lower bits per pixel and increases with increase in bits per pixel. Thus vector quantization is better under lower bits per pixel compared to scalar quantization. Scalar quantization outperforms vector in higher bits per pixel.PSNR performance of vector quantization is better at lower bits per pixel and the PSNR of scalar quantization increases with increase in bits per pixel.

VI. CONCLUSION

The performance of scalar and vector quantization techniques are compared based on the histogram Euclidean distance, mean square error and PSNR values. The MSE and PSNR of scalar quantization increases with increase in bits per pixel. But in vector quantization the MSE is minimum and betterPSNR performance is seen at lower bits per pixel. The distortion measure of vector quantization is lower than scalar under lower bits per pixel. Scalar quantization outperforms vector in higher bits per pixel.

REFERENCES

[1] Alon Orlistsky, “Scalar Versus Vector Quantization: Worst Case Analysis”, IEEE Transactions on information Theory, vol.48,no.6.june 2002.

[2] John Makhoul, Salim Roucos and Herbert, “Vector Quantization in Speech Coding”, Proceedings of IEEE, vol.73.no.11, november 1985.

[3] Linde, A. Buzo, and R. M. Gray, "An algorithm for vector quantizer design," IEEE Trans. Commun., vol. COM-28, pp. 84-95, Jan. 1980.

[4] Gray, R.M.: “Vector quantization”. IEEE ASSP Magazine, April 1984, pp. 4–28.

[5] Gersho, A.: “On the structure of vector quantization”, IEEE Trans. Inf. Theory, 1982, IT-28, pp. 157–166.

[6] Andres buzo, Augustine h. Gray, Robert Gray, and John d. Markel “Speech Coding Based Upon Vector Quantization” IEEE Transactions on acoustics, speech, and signal processing, vol. Assp-28, no. 5, october 1985.

[7] Tzu-Chuen Lu and Ching-Yun Chang, “A Survey of VQ Codebook Generation” Journal of Information Hiding and Multimedia Signal Processing Volume 1, Number 3, July 2010.