Position Based Coding Scheme and Huffman Coding in JPEG2000: An Experimental analysis

Jayavrinda Vrindavanam
PhD Student, Department of E&C
NIT, Durgapur, West Bengal, India

Saravanan Chandran
Asst. Professor, Head, Computer Centre
NIT, Durgapur, West Bengal, India

Gautam K Mahanti
Professor, Dept. of E&C
NIT, Durgapur, West Bengal, India

Vijayalakshmi K
Sr.Lecturer, Dept of E&C
Caledonian College of Engineering, Muscat

Abstract- The paper compares the novel method of position based coding scheme introduced recently by the authors with Huffman coding results. The results show that Position Based Coding Scheme (PBCS) is superior in terms of image compression ratio and PSNR. In PBCS, by identifying the unique elements and by reducing redundancies the coding has been performed. The results of JPEG2000 image compression with Huffman coding and the JPEG2000 based on PBCS are then compared. The results show that the PBCS has better compression ratio with higher PSNR and better image quality. The study, which can be considered as a logical extension of the image transformation matrix, applies statistical tools to achieve the novel coding scheme as a direct extension to wavelet based image compression. The coding scheme can highly economise the bandwidth without compromising on picture quality; invariant to the existing compression standards and lossy as well as lossless compressions which offers possibility for wide ranging applications.

Keywords–Huffman coding, JPEG, JEG2000, Quantization, Discrete Cosine Transform, Discrete Wavelet Transform, Wavelet, Position Based Coding Scheme (PBCS), Compression Ratio, PSNR, Coefficient of Variation, post-transformation matrix, image compression, Standard Deviation.

I. INTRODUCTION

The studies in the field of image compression technique have been a focus area of on-going research. Compressed image transmission economizes bandwidth and therefore, ensures cost effectiveness [6]. The major milestones in this progression are the development of JPEG standard and JPEG2000 standard [2, 8]. JPEG image compression standard defines three different coding systems, such as loss baseline coding system based on DCT, an extended coding system for greater compression, higher precision, or progressive reconstruction of applications and lossless independent coding system for reversible compression [7]. As advancement [9], the latest JPEG2000 standard encompasses not only new compression algorithms, but also flexible compression architectures and formats. JPEG2000 addresses areas where current standards have limitations in producing the best quality or performance and provides low bit rate operation (below 0.25 bits/pixel) with subjective image quality performance superior to previous standards, without sacrificing performance at higher bitrates. The key differentiator is that the JPEG2000 uses a wavelet transform in place of DCT. JPEG2000 is based on DWT, which is applied on image tiles. DWT tiles are decomposed into different decomposition (resolution) levels [3,4,5]. Arithmetic coding is employed in the last part of the encoding process. JPEG2000 integrates the benefits of all four JPEG modes into single compression architecture and single code stream syntax. Any image quality or size can be decompressed from the resulting code-stream, upto and including those selected at encode time [10,11]. Thus, JPEG2000 supports progression at multiple dimensions such as quality, resolution, spatial location and component. As more and more data are received, image quality is improved. The process involved in the JPEG2000 image compression [12] can be grouped in to three segments, namely transform, quantization and coding [13]. After transformation of the image, quantization is applied before encoding the coefficients.

As has been evident from the advancements in image coding scheme, despite considerable researches taking place in this specific field, scope still exists to explore alternative approaches. This is the context in which the authors have introduced PBCS by analyzing the hitherto unexplored segment, i.e., position of coefficients after quantization, through identification of common coefficients in order to achieve better compression results. This exercise, as it further analyses the transformation matrix can be regarded as a direct extension study of the wavelet based transform coefficient matrix. The study proposes to attempt aggregation of similar coefficients or unique coefficient after quantization and the position of the unique coefficient in the quantized matrix; thereafter applies the standard deviation at the position matrix at the compression level and inverse operation will be performed at the decompression stage, as an alternative method. This, we propose, would ensure better image compression within the ambit of the existing wavelet methodology. The proposed method will work for any transform coefficients. Keeping in view the novelty of the concept, paper gives a description of PBCS and then compared Huffman coding scheme in JPEG2000 environment.

After the brief introductory section I, the paper reviews the major developments in the field in section II. The position based coding scheme is briefly presented in section III. Analysis of results is presented in section III and last section is by way of conclusion.

II. IMAGE CODING SCHEME MAJOR DEVELOPMENTS

As well documented in the literature relating to image compression, the review confines to the developments in the field of different coding schemes used in image compression standards after the introduction of JPEG2000 standard. In a study carried out by a group of authors [14], a new design technique for adaptive orthogonal block transforms based on vector quantization(VQ) codebooks was proposed. The results show a signal coding tool that stands between a pure VQ scheme on one extreme and fixed block transformation like DCT on the other. In a related study, the authors [15] investigated the problem of how to exploit geometric constraint of edges in wavelet based image coding. The study brought in a novel phase shifting and prediction algorithm in the wavelet space. After resolving the phased uncertainty, the authors demonstrated that highband wavelet coefficients can be better modeled by biased-mean probability models rather than the existing zero-mean probability models. In lossy coding, the coding gain brought by the biased mean model is quantitatively analyzed within the conventional DPCM coding framework. Experiment results have shown that the proposed phase shifting and prediction scheme improves both subjective and objective performance of wavelet based image coders. By taking note of the [16] property of excellent visual quality and compression rate of fractal image coding, a new fast and efficient image coder that applied the speed of the wavelet transform to the image quality of the fractal compression was presented. The proposed scheme has an average 94 % reduction in encoding – decoding time comparing to the pure accelerated fractal coding results.

An image compression algorithm based on the efficient construction of wavelet coefficient lower trees was proposed in another paper [17]. The paper grouped the coefficients and also a fast way of coding them was achieved by means of a simple two-pass coding and one-pass decoding algorithm. In a recent study [18] the authors examined the problem of approximating a block Markov source with higher order Markov sources and showed that the divergence rate between a block Markov source and the best matching higher order Markov model for that source to converge to zero exponentially fast as the memory of the model increases. This outcome is used to obtain bounds on the redundancy of certain symbol based universal codes when they are used for byte-aligned sources. In another study [19], the authors analyzed Golomb Coding compression and decompression algorithms in the Field Programmable Gate Array (FPGA). The coding scheme development in FPGA utilises the Verilog HDL. The results generated using simulation of the Golomb Encoder with the expected results which showed both of the results were identical. In yet another paper, [20] an iterative algorithm was proposed, which the authors argue that not only results in a compressed bit stream completely compatible with existing JPEG and MPEG decoders, but also computationally efficient when tested over standard test images. It achieves the best JPEG compression results to the extent that its own JPEG compression performance even exceeds the quoted PSNR results of some state of the art wavelet based image coder such as Shapiro's embedded zero tree wavelet algorithm at the common bit rates under comparison. Both the graph based algorithm and the iterative algorithm can be applied to wide range of application areas. A new similarity measure for fractal image compression was introduced in another study [21]. When the original image is corrupted by noises, the authors have argued that the fractal image compression scheme should be insensitive to those noises presented in the corrupted image, as the underlying premise it utilizes the self-similarity property in the image to achieve the purpose of compression. In order to overcome the high computational cost, the authors have applied the search technique of particle swarm optimization. In a study [22], the authors introduced a secure Exp-Golomb coding scheme by adding a stream cipher. The key stream is used to control the switching between two coding conventions.

The results showed that the proposed system can provide high level of security with the same coding efficiency compared to the regular Golomb coding.

A novel way of representing image information in a wavelet domain [23] was introduced to develop and analyze the ‘spherical representation’. The authors suggest that wavelet subbands are best characterized by spatially varying non homogeneous processes. Since edges and texture come in arbitrary locations, orientations and shapes, information about the location of high activity areas allow the coding methods to be successfully adapted the statistics of different regions. A review of the statistical based image compression scheme [24], confirmed that the wavelet based encoders have ideally suited for embedding compete human visual system models on account of the space frequency localization properties of wavelet decompositions. The authors have evolved a wavelet based image compression scheme, which employs a novel statistical encoding algorithm and the properties of the human visual system to code the wavelet coefficients in each subband. The coefficients in each subband are coded using the statistical algorithm developed by the authors. The results show that the coding scheme show significantly higher subjective and objective quality when perceptual weights is used to regulate the threshold values of different subbands. It also outperforms JPEG in higher compression ratios. In a study relating to Golomb codes, [25], the paper replaced the Embedded Block Coding with optimal truncation with Golomb codes, which have no code word and functions as a prefix of some other code word. The result gives better performance than JPEG2000. Further, it performs better at lower bpp than that of JPEG2000. In another paper, [26] the authors proposed a model for image encryption using elliptic curve cryptography (ECC) for secure transmission of image and by incorporating the Huffman data compression technique for effective utilization of channel bandwidth and enhancing the security. Every pixel of the original image is transformed into the elliptic curve points (Xm,Ym). These elliptic curve points are converted into cipher image pixels. A team of authors [27] attempted to compare the wavelet based image compression standards and viewed that out of the available algorithms Set Partitioning in Hierarchical Tree (SPIHT) found to be the best on account of its simplicity and best results in terms of compression ratio and bits per pixels.

As has been evident from the literature review, the recent advancements were essentially concentrated on the human visual system, implementation of coding in FPGA, removal of noise in the corrupted image, coding for security purposes, grouping of wavelet coefficients, redundancy of certain symbols, applying statistical algorithm on the coefficients in the subbands for coding and most of the other studies are concentrated on geometric constraints of edges in wavelet based image coding. From the perspective of position based coding scheme, it may be desirable to refer an important study carried out by Said and Pearlman [28], as an extension study of the EZW algorithm by Shapiro [29]. Said and Pearlman introduced a new algorithm called Set Partitioning in Hierarchical Tree (SPIHT); the distinguishing feature of the SPIHT is that the ordering data is not explicitly transmitted; this is based on the premise that the execution path of any algorithm is defined by the results of the comparisons on its branching points. In case both the encoder and decoder have the same sorting algorithm, then the decoder can duplicate the encoder’s execution path based on the results of the magnitude comparisons and the ordering information can be recovered from the execution path. The concentration of the study was self similarity across different scales of image wavelet transform. As an extension to Shapiro’s EZW algorithm, a recent study [30] proposed an image compression method with the support of wavelet transform, zero tree coding and adaptive arithmetic coding. The authors explored a novel static zeroth order adaptive arithmetic coder for better compression ratio. The method decomposed the image into several subband images using the discrete wavelet transform, decorrelated coefficients quantized by Shapiro's embedded zerotree wavelet algorithm and encoded using static zeroth order adaptive arithmetic coder. The results showed better compression ratio and reduced coding time.

The review makes it clear that, possibilities exist to explore further on the position of the transformation matrix. This is the context in which, the proposed research study postulates a novel statistical algorithm through identification of unique transform coefficients after quantization and position of the coefficients in the transform matrix in order to achieve better compression results. The study attempted aggregation of similar unique coefficients after performing quantization and their positions at the compression level and disaggregation at the decompression stage, as an alternative method, which we assumed, would ensure better image compression.

III. POSITION BASED CODING SCHEME

The authors propose a methodology by analyzing the position of unique elements of 256X256 image post-wavelet transformation matrix after quantization, though this can be applied to any transform matrix. An analysis of the post-wavelet transformation matrices of different types of images carried out by the authors reveals that, there are repetitions of elements in such matrices. Logically, avoiding of such repetitions can contribute to higher image compression. As explained in the section on literature review, an analysis of the elements with a view to avoid repetitions in transmission matrix has not been attempted so far, possibly on account of the complexities in the post compression restoration processes. Thus, the ideal approach is to ensure that the decoded matrix retains the same elements as that of the original transformation coefficients after quantization and also to ensure that only unique elements are transmitted. This would be lossless as no data is lost in the process of coding. Thus, the objective has been to find out the unique elements as well as their position in order to avoid repetition of similar elements while transmission. Logically, such an approach would also be independent of existing transformations and quantization processes, which can be, therefore, applied in both lossy and lossless compression methods as the coding system is applied on the post transformation matrix.

After performing such an analysis for the wavelet transformation matrix after quantization, the authors observed that, the compression ratio is not significantly reduced in comparison with the existing results including Huffman coding. We observe that the main reason for this is the size of the position matrix, which is still a factor which may not yield better compression ratio as we need to transmit position matrix and unique elements matrix for enabling the decoding process. Therefore, further reduction needs to be performed to reduce the position matrix size keeping in view the ease of decoding without disturbing the restorability of unique positions. In order to reduce the size of the position matrix, we have applied, the most commonly used statistical measure of dispersion, standard deviation, at the position matrix. Standard deviation takes into account the dispersion of the elements from the mean of the matrix. With the support of mean and the standard deviation, the reversal operation can also be performed without compromising on the position of elements. Since standard deviation takes the difference of elements with the mean, most of the resultant elements in the position matrix would be similar and also carries lesser bits to represent each number. Accordingly, for the reconstruction purpose, transmission of the reduced position matrix after applying standard deviation along with mean and unique elements matrix will be sufficient. This process can also be seen as a direct extension of the 256X256 post-transformation matrix after quantization, and accordingly, the coding scheme is simple to comprehend and works as logical extension to the transformation matrix. The results are highly encouraging in comparison with the existing coding schemes. The test results of the position coding scheme as per this methodology offer better compression ratio without compromising on quality of the image and results into better PSNR.

The methodology explained above is demonstrated with the support of a process flow as given in the Figure 1.

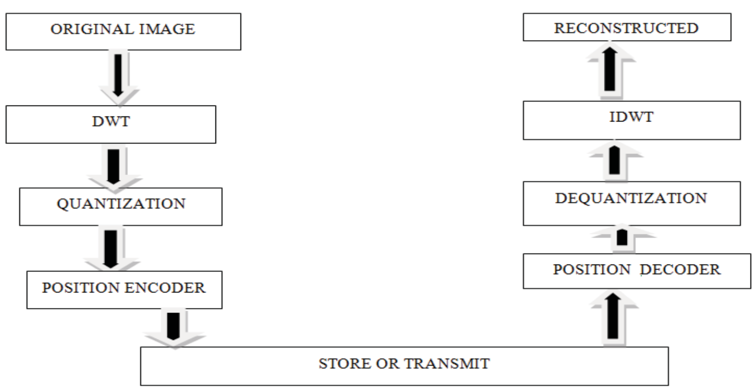

Figure 1. Position Based Coding Scheme

In our experiment, the original image is transformed by using DWT. Thereafter, quantization is performed prior to encoding with the support of the position encoder. The resultant output of the PBCS coding scheme, such as position matrix after performing standard deviation, unique element matrix after quantization and mean of position matrix are transmitted. At the receiving end inverse coding is applied. Thereafter dequantization and IDWT is applied to retrieve the original image. An illustration of the methodology is explained below.

For example, the Quantization matrix is assumed as Q, after transformation (Table 1) .Thereafter, from Q generate the unique element matrix U and its position matrix P. From P standard deviation matrix is generated, which is called S. Matrices U, S and mean of S are transmitted after this process. At the receiving end decoding process is applied and original matrix is retrieved.

Along with the unique element matrix, the position of each element is also created. For example the element '0' is repeating in C254 to C256. To represent such characters, the column or row address can be indicated with a special character in the matrix, such as all the rows of C254,C255 and C256 has to be filled with element '0'.

Table- 1 Some selected rows and columns of an (256x256) image after quantization

Row\Col	C1	C2	C3….	.C254	C255	C256
R1	31	44	48	0	0	0
R2	41	40	34	0	0	0
R3	36	38	30	0	0	0
R4	37	30	23	0	0	0
R5	29	25	15	0	0	0
R6	25	17	11	0	0	0
R7	13	10	8	0	0	0
R8	9	7	7	0	0	0
R9	41	59	65	0	0	0
R10	55	55	48	0	0	0
R254	47	67	75	0	0	0
R255	63	63	54	0	0	0
R256	55	59	48	0	0	0

Table- 2 Unique elements matrix U of the matrix Q.

0	31	65
7	34	67
8	36	75
9	37	54
10	38	55
11	40	59
13	41	63
15	44	29
17	47	30
23	48	25

The corresponding row and column position matrix:-

$P_{row} = [\$ \quad \$ \quad \$ \quad 8 \quad 8 \quad 7 \ldots\ldots 6 \;\; 5]$

$P_{col} = [254 \quad 255 \quad 256 \quad 2 \quad 3 \quad 3 \ldots\ldots 1 \;\; 2]$

The row matrix is \$ and column matrix 254 , 255 and 256. The next element '7'position is R8,C2 and R8, C3.i.e the row matrix is 8,8 and column matrix 2,3 as shown above. This will be repeating for all elements. After deriving the position matrix, the mean and standard deviation of the matrix is calculated. An example of position matrix and statistical results is explained below.

$P_{row} = [\,1 \;\; 2 \;\; 1 \;\; 2 \;\; 3 \;\; 1 \;\; 2 \;\; 3 \;\; 1 \;\; 2 \;\; 3 \;\; 3\,]$

$P_{col} = [\,1 \;\; 3 \;\; 2 \;\; 1 \;\; 3 \;\; 3 \;\; 2 \;\; 4 \;\; 4 \;\; 4 \;\; 1 \;\; 2\,]$

Here, P_{row} represents the row position of the elements in U. P_{col} represents the column position of the elements in U. After forming the row and column matrix, standard deviation is applied to both the matrices by taking the difference between the mean and the elements of the position matrices, shown below.

$Mean(P_{row}) = 2$, $Mean(P_{col}) = 2.5$

S_{row} =[1 0 1 0 -1 1 0 -1 1 0 -1 -1]

S_{col} =[1.5 -0.5 0.5 1.5 -0.5 -0.5 0.5 -1.5 -1.5 -1.5 1.5 0.5]

After deriving the difference between the mean and the elements of the position matrix, the authors found most of the values are similar and less number of bits are required to represent the elements of the position matrix. This will lead to more compression at the position matrix. At the decoder side, inverse operation is performed to get the position matrix and unique elements matrix and the image is reconstructed. Also the coefficient of variation (CV) of unique elements matrix is calculated to understand the degree of dispersion, as CV being an invariant measure, higher CV as a percentage shows higher degree of dispersion. Logically, pictures with higher degree of colour variation might show high degree of dispersion can have higher CV. Therefore, CV as a measure can also be compared with compression ratio and PSNR.

Since no loss of information takes place during the coding process, the proposed method is not a probabilistic method like Huffman and arithmetic coding. It can be categorized under lossless coding technique, though it can be used in both lossy and lossless compression. Further, the PBCS simplifies the computation and makes it easily comprehensible as simple matrics operations are applied to the position matrix. In order to derive the best results, the novel coding scheme presumably can be applied to images with lesser variations in colour or more similar coefficients as the number of the unique elements matrix can be logically at a reduced level. Since the novel approach is not probabilistic and lossless, it can also be used at environments where high quality image is of prime importance.

IV. ANALYSIS OF RESULTS

In order to experiment PBCS, MATLAB software based algorithms were developed. This involves development of JPEG image compression, JPEG2000 compression with Huffman coding and the PBCS coding scheme. Huffman coding scheme is chosen for implementation implemented as it is a fair representation of lossless coding scheme. The experiment has been done with and without quantization and conducted on four standard images for testing purposes with different colour schemes and background. The results in terms of compression ratio, PSNR, CV etc. are compared. The results are shown in Table 3.

Table- 3 Compression Ratio, CV and PSNR of PBCS with and without quantization

IMAGES	PBCS With Quantization			PBCS Without Quantization		
	Compression Ratio	PSNR	CV	Compression Ratio	PSNR	CV
FRUITS	**9.289:1**	**27.24**	**89.93**	**8.715:1**	**36.13**	**188**
MARADONA	**9.291:1**	**28.56**	**90.31**	**8.471:1**	**36.13**	**194**
LENA	**9.293:1**	**28.37**	**88.71**	**8.422:1**	**36.12**	**171**
PISA	**9.293:1**	**28.60**	**92.36**	**8.333:1**	**36.122**	**177**

The compression ratio of the test images for PBCS with quantization ranges between 9.289:1to 9.293:1. Without quantization, the compression ratio ranges between 8.333:1to 8.715:1. In general, both compression ratio and CV moves on the same direction for these test images. The CV has a range between 88.71% to 92.36% and 171% and 194% with quantization and without quantization respectively. The CV being the ratio between the standard deviation and mean of the position matrix broadly explains as a measure the degree of dispersion within the matrix. Hence it is natural to observe higher CV for the matrix without quantization. Further, the PSNR of PBCS shows improvement without quantization. The quality of reconstructed image is better in comparison with earlier standards.

Table- 4 PSNR and compression ratio of JPEG2000 with Huffman coding and JPEG2000 with PBCS.

Images	JPEG2000 with PBCS		JPEG2000 with Huffman coding	
	Compression Ratio	PSNR	Compression Ratio	PSNR
FRUITS	**9.2891:1**	**27.2368**	**5.9811:1**	**27.2368**
MARADONA	**9.2916:1**	**28.5572**	**7.5004:1**	**28.5572**

LENA	**9.2935:1**	**28.366**	**7.5846:1**	**28.3660**
PISA	**9.2931:1**	**28.6045**	**7.8208:1**	**28.6045**

From the table 4 it is clear that the PBCS offer better performance in terms of compression ratio and PSNR. The compression ratio of the four test images show a range of 9.289 to 9.293, which is higher than that of JPEG2000 with Huffman coding. At the same time, the PSNR almost remains the same. This is also further corroborated by the visual quality of the compressed image. A graphical representation of these parameters is shown in the Fig. 2.

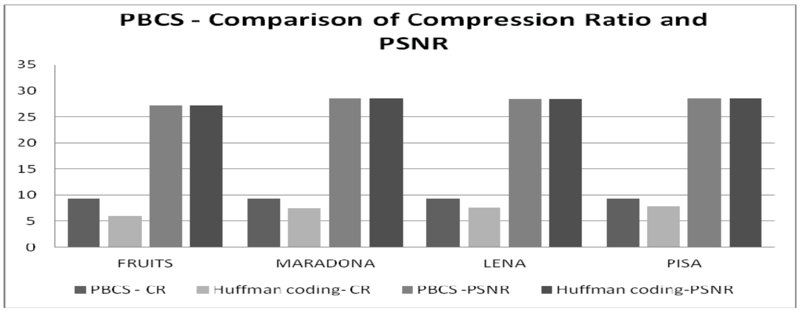

Figure 2. Comparison between PBCS and Huffmancoding

An analysis is also attempted to explore the relationship between the Huffman's coefficient and the unique elements produced by PBCS for the four test images. For this purpose, the number of coefficients in the JPEG2000 and the PBCS are calculated (Table 5). From the Table 5, it is clear that the unique element size is smaller than the Huffman's DC and AC coefficient size. The compression rate per pixel depends on the Huffman's AC coefficient size. The unique elements of PBCS has the lower size than the Huffman's coefficients. The size of the unique elements depends upon the types of images. An image with less dispersion will have relatively smaller number of unique elements and image with higher dispersion will have larger number of unique elements.

Table- 5 Comparison between Huffman coefficients and unique elements

IMAGES	**JPEG2000**		**PBCS**
ORIGINAL IMAGE	**Huffman DC-Coefficient (Number)**	**Huffman AC-Coefficient (Number)**	**Unique Elements (Number)**
	**3,415**	**84,244**	**10,808**
	**3,211**	**66,690**	**9,583**
	**3,225**	**65,900**	**9,342**
	**2,888**	**64,150**	**8,893**

To demonstrate the visual quality achieved using PBCS coding scheme and JPEG2000, the reconstructed images based on MATLAB software based programs are shown in Fig. 4. A visual verification of the results at the Fig. 4 reveals that the proposed technique outperforms JPEG2000 with Huffman coding in terms of visual quality. The authors also observed that the compression rate for JPEG2000 with Huffman coding ranges from 1.022 to 1.337 bpp and JPEG2000 with PBCS is slightly at a higher side. Further PBCS without quantization offers better PSNR and visual quality. The proposed coding scheme uses simple statistical operations and the process of encoding and decoding is easily comprehensible than the other standard coding schemes like Huffman and arithmetic coding which are computationally expensive.

Figure. 3 shows the visual quality achieved by using JPEG2000 with Huffman coding, PBCS without quantization and PBCS with quantization for different images. Image 1(a) gives a compression of 5.98:1, image 1(b) 8.3:1 and image 1(c)9.3:1. Image 2(a), (b) and (c) the compression ratios are 7:1, 8.3:1 and 9.3:1 respectively. The compression ratios of the remaining images are within these ranges. The visual quality is observed to be superior to other standards. The main advantages of the proposed coding scheme over JPEG2000 with Huffman coding and arithmetic coding are: 1) It produces better visual quality at higher compression ratio.2) It is much simpler from the perspective of computation and implementation. Since the method is developed based on the position of unique elements, it is easy to perform statistical operations.

JPEG2000 With Huffman coding | PBCS Without Quantization | PBCS With Quantization

Figure 3.Visual Quality of images of different coding scheme

V.CONCLUSION

The paper has introduced a novel coding scheme which offers better compression ratio without compromising PSNR and visual quality. After a detailed analysis and observation of the existing coding schemes and image quality outputs, and also based on observed gaps in the existing coding schemes, the paper has attempted to exploit the repetitive values in quantization matrix, which until now continues to be an under researched area within the domain of image compression. Since the authors neither used probabilistic approach nor estimations for obtention of the PBCS, the resultant images are not impaired. This approach has several advantages, as it economizes the bandwidth apart from ensuring better image quality. Its quality of invariance to quantization makes it independent for use in different environments depending upon the requirement of image quality. This novel coding scheme can be applied to all segments in general and areas where precision is required in particular. As a next step forward, the authors would also be studying other alternatives in the similar domain to achieve better results.

REFERENCES

[1] V. Jayavrinda, C. Saravanan, G.K.Mahanti and K.Vijayalakshmi, "JPEG,JPEG2000 and PBCS Based Image compression :An Experimantal Analysis," International Journal of Computer applications -, vol. 58,No.10,pp.16-21,November 2012.

[2] V. Jayavrinda, C. Saravanan and G.K.Mahanti ,"A Survey of Image Compression Methods", International Journal of computer application, Proceedings on International Conference and workshop on Emerging Trends in Technology, pp. 12–17,March 2012.

[3] V. Jayavrinda, C. Saravanan and G.K.Mahanti ," Wavelet and JPEG Based Image Compression: An Experimental Analysis", International Journal of computer application,Proceedings on International Conference and workshop on Emerging Trends in Technology, pp.36-42 ,March 2012.

[4] W.Poorva and V. Jayavrinda,":Low Bit rate Movie Transmission: An Exploratory Analysis",Proceedings of the Second International Conference on Industrial and Information Systems, Sri Lanka(2007)

[5] V.Jayavrinda,"Video Compression for Movie Transmission: A Comparative Analysis",Proceedings on International Conference and workshop on Emerging Trends in Technology , pp.173–175,Feb 2010.

[6] R. C.Gonzalez, E.Richard, and Woods," Digital Image processing", New Delhi.Pearson Pentice Hall, Third Edition, Low price edition, pp. 1-904, 2008.

[7] G.Sonja Grgic, M.Mark and M.Grgic,"Comparison of JPEG Image Coders",Proceedings of the 3rd International symposium on Video Processing and Multimedia Communications. Zadar, Croatia, June 2001.

[8] ISO/IEC JTCI/SC29/WGI N1646R.JPEG 2000 Part I Final Committee Draft, Version 1.0, March 2000.

[9] S.Grgic,K.Kers and M.Grgic," Image Compression using Wavelets",IEEE International Symposium on Industrial Electronics, ISIE'99, Bled, Solvania 1999.

[10] A.Graps,"An introduction to wavelets", http:// www.amara.com.1995.Accessed 2011.

[11] T. Acharya and P. S. Tsai,"JPEG 2000 Standard for Image Compression: Concepts, Algorithms and VLSI Architecture",Wiley, Hoboken, 2005.

[12] R.Singh, R.Verma and S.Kumar,"JPEG 2000: Wavelet Based Image Compression",EE678 Wavelet Application Assignment 1, IIT, Mumbai.

[13] A.Skodras, C.Christopoulos and Ebrahimi "The JPEG 2000 Still Image Compression Standard",IEEE Signal Processing Magazine, September 2001.

[14] H.Caglar, S.Gunturk,B. Sankur and E. Anarim, "VQ-adaptive block transform coding of images", IEEE Transactions on Image Processing-, Vol .7, Issue No. 1, pp. 110-115. January 1998.

[15] X. Li, "On Exploiting Geometric Constraint of Image Wavelet Coefficients", IEEE Transaction on Image Processing ,Vol. 12, No.11, November 2003.

[16] Cruz, Y. L. F.Silverstre da Silva and A. L.Mendes,"A Fast and Efficient Hybrid Fractal - Wavelet Image Coder", IEEE Transactions on Image Processing-,Vol 15, No.1, January 2006.

[17] M.Oliver and J.Malumbes,"Low - Complexity Multiresolution Image Compression Using wavelet lower trees",IEEE Transactions on Circuits and Systems and Video Technology-, Vol. No. 16, November 2006.

[18] D.A.Nagy, A.Gyorgy and T. Linder," Symbol-Based Modeling and Coding of Block Markov Sources", IEEE Transactions on Information Theory-, Vol. No. 52, Issue 12, pp. 5570-5578, December 2006.

[19] G.H.H'ng, M.Salleh and Z. A.Halim,"Golomb Coding Implementation in FPGA," ELEKTRIKA ,Vol No. 10 No. 2,pp 36-40, 2008.

[20] Longji, W. E.Yang ,"Joint Optimization of Run-Length coding, Huffman coding and Quantization Table with Complete Baseline JPEG Decoder Compatibility", IEEE Transactions on Image Processing, pp. Vol 18, No. 1, January 2009.

[21] J. H. Jeng, C. C.Tseng and J. G.Hsieh "Study on Huber Fractal Image Compression", IEEE Transactions on Image Processing,vol. 18, no. 5, pp. 995-1003,2009.

[22] J.Zhou,O.C. Au and A.Y. Wu," Secure Exp-Golomb coding using stream cipher", IEEE International Conference on Acoustics, Speech and Signal Processing,pp. 1457-1460, April 2009.

[23] F.A.Hasan and T.Michael ",Spherical Coding Algorithm for Wavelet Image Compression,IEEE Transactions on Image Compression, Vol.18, No. 5, pp.1015-1024, 2009.

[24] P. B.Zadeh, A.S. Akbari, T. Buggy and J. Soraghan," Multiresolution HVS and Statistically based Image Coding Scheme", Springer Issue 49, pp. 347-370, 2010.

[25] K.Somasundaram and P.Sumitra," A Novel method to compress still Images using Golomb Code (GC) in JPEG2000", International Journal of Computer Science and Network Security,Vol.10, No.8, August 2010.

[26] R.Srinivas and P.S. Setty " Huffman Compression Technique in the Context of ECC for Enhancing the Security and Effective Utilization of Channel Bandwidth for Images",International Journal of Science and Advanced Technology (ISSN 2221-8386),Vol.1, No 8,October 2011.

[27] D S. Puja, S.Deepti ,S.Amit and G.Neetesh "Comparisons of wavelets based image compression methods ",Proceedings of " National Conference on Emerging Trends in Computer Technology (NCETCT-2012)"Held at R.C.Patel Institute of Technology, Shirpur, Dist. Dhule, Maharashtra,India.April 2012.World Journal of Science and Technology(2012),2(3):10-13 ISSN: 2231 – 2587 Available Online: www.worldjournalofscience.com.

[28] A. Said, and W.A.Pearlman "A New,Fast, and Efficient Image Codec Based on Set Partitionaing in Hierarchical Trees", IEEE Transactions on Circuits and Systems for Video Technology,Vol. 6,NO.3, June 1996.

[29] J.M. Shapiro,"Embedded image coding using zerotrees of wavelets coefficients",IEEE Transactions on Signal Processing,Vol, 41,pp.3445-3462, December 1993.

[30] N.S.Sulthana and C.Mahesh",Image Compression with Adaptive Arithmetic Coding",International Journal of Computer Applications 1(1):31–34, February 2010.