



Huffman Coding and Position based Coding Scheme for Image Compression: An Experimental Analysis

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ABSTRACT

The paper attempts a comparison between Huffman coding and Position Based Coding Scheme introduced by the authors. After a review of various image compression standards and image compression coders, it is observed that there is a need to study the post-transformation matrix in a JPEG environment and accordingly, brought out a coding scheme based on the position of elements of the transform coefficients matrix after performing quantization. By identifying the unique elements and by reducing redundancies, the paper presented a novel method of coding called, PBCS. Thereafter, the results of Joint Picture Expert Group (JPEG) with Huffman coding and PBCS are compared. The results show better compression ratio with higher PSNR and better image quality with quantization. The study can be considered as a logical extension of the discrete cosine transformation matrix of an image, and applies statistical tools to achieve the novel coding scheme. 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.

General Terms

Image compression, Huffman coding, low bit rate transmission, JPEG, wavelet, PSNR, PBCS.

Keywords

JPEG, image compression, wavelet, DCT, PBCS.

1. INTRODUCTION

The ever increasing bandwidth limitations have led to the introduction of different image compression techniques. Compressed image transmission economizes bandwidth and therefore, ensures cost effectiveness [1]. The important image compression techniques are JPEG standard and JPEG2000 [2, 3]. 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 [4]. At the application of JPEG, it is observed that the DCT leads to discontinuities at the boundaries of the 8 by 8 blocks. The colour of a pixel on the edge of a block can be influenced by that of a pixel anywhere in the block, but not by an adjacent pixel in another block. Further, the JPEG algorithm allows recovering the image at only one resolution. At times, it may be desirable to recover the image at lower resolutions, allowing the image to be displayed at progressively higher resolutions while the full image is downloaded [5]. As an

extension study, the paper explores other coding schemes and compares the newly introduced coding scheme with the most widely used coding scheme, Huffman coding.

Since the focus of this paper is Huffman coding scheme and its comparison with the newly introduced scheme, the second section of this paper reviews the major developments in the field of image coding schemes. The third section of the paper introduces the position based coding scheme and its methodology. Analysis and results of the proposed encoder based system in comparison with the existing image compression standards is attempted in the fourth section. The last section is by way of conclusion.

2. IMAGE CODING SCHEME-MAJOR DEVELOPMENTS

Keeping in view the focus of the paper on the coding scheme, it would be desirable to review the developments in the field of image compression coding systems starting from lossless and lossy image compression standards [2]. The feature of the lossless compression technique is that the original image can be perfectly recovered from the compressed image. It is also known as entropy coding since it uses decomposition techniques to eliminate or minimize redundancy. Lossless compression is mainly for applications like medical imaging, where the quality of image is important. Different coding system follows different methods. In the case of Run length encoding, compression is performed by counting the number of adjacent pixels with the same gray-level value [6]. This count, called the run length, is then coded and stored. The number of bits used for the coding depends on the number of pixels in a row: If the row has 2^n pixels, then the required number of bits is n . A 256×256 image requires 8 bits, since $2^8 = 256$. The other most commonly used lossless compression coding, is Huffman coding. The basic idea behind Huffman coding algorithm is to assign shorter code words to more frequently used symbols. Huffman coding can generate a code that is as close as possible to the minimum bound, the entropy [1]. This method results in variable length coding. For complex images, Huffman code alone will reduce the file size by 10% to 50%. By removing irrelevant information first, file size reduction is possible. In the case of *LZW coding* (Lempel-Ziv-Welch), coding can be static or dynamic, which is a dictionary based coding. In static dictionary coding, dictionary is fixed during the encoding and decoding processes. On the other hand, in dynamic dictionary coding, the dictionary is updated on fly. The computer industry is widely using LZW coding. It is also implemented as compress command on UNIX. On the other hand, area coding is an enhanced form of run length coding, which reflects the two dimensional character of images. It is a



significant advancement over the other lossless methods. It does not make much of a meaning to interpret the coding of an image as a sequential stream, as it is in fact an array of sequences building up a two dimensional object. The idea was to find the rectangular regions with the same characteristics. These rectangular regions are coded in a descriptive form as an element with two points and a certain structure. Area coding is highly effective and it can give high compression ratio but the limitation is non-linear in nature, which prevents the implementation in hardware.

The segment of lossy compression technique provides higher compression ratio than lossless compression. In this method, the compression ratio is high; the decompressed image is not exactly identical to the original image, but close to it. Since the quality requirements of the reconstructed image vary across different applications, different types of lossy compression techniques are widely used. The quantization process applied in lossy compression technique results in loss of information. After quantization, entropy coding is done like lossless compression. The decoding is a reverse process. The entropy decoding is applied to compressed data to get the quantized data. Dequantization is applied to it and finally the inverse transformation is performed to get the reconstructed image. The compression performance is evaluated with the factors like Compression ratio, SNR (Signal-to-Noise Ratio) and Speed of encoding & decoding [2].

In another paper, [7] it was shown that sometimes image processing units inherit images in raster bitmap format only, so that processing is to be carried without knowledge of past operations that may compromise image quality (e.g. compression). To carry further processing, it is useful to not only know whether the image has been previously JPEG compressed but also to learn what quantization table was used. In this paper a fast and efficient method is provided to determine whether an image has been previously JPEG compressed. After detecting compression signature, the paper estimated parameters specifically and developed a method for the maximum likelihood estimation of JPEG quantization steps. First, the image processing module receives the bitmap image and processes it. In order to remove possible artifacts, it first has to determine whether the image has been compressed in the past and estimate its quantization table. The information is then used to remove possible compression artifacts.

In yet another paper, [8] an iterative algorithm was proposed, which the authors argue that it not only results in a compressed bit stream completely compatible with existing JPEG and MPEG decoders, but is 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 application areas such as web image acceleration, digital camera image compression, MPEG frame optimization and transcoding etc. A new similarity measure for fractal image compression was introduced in another study [9]. 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 is 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 technique. The authors demonstrated that the proposed HFIC is robust against others in the image unlike the least square based regression technique. It can also reduce the encoding time while retaining the quality of the retrieved image.

Transforms such as DFT (Discrete Fourier Transform) and DCT are used to change the pixels in the original image into transform coefficients. These coefficients have several properties like energy compaction property that results in most of the energy of the original data being concentrated in only a few of the significant transform coefficients; those few significant coefficients are selected and the remaining are discarded. The selected coefficients are considered for further quantization and entropy encoding. DCT coding has been the most common approach to transform coding, which is also adopted in JPEG. Entropy coding is achieved by means of an arithmetic coding system that compresses binary symbols relative to an adaptive probability model associated with each of 18 different coding contexts. This algorithm has been selected in part for compatibility reasons with the arithmetic coding engine used by the JBIG2 compression standard and every effort has been made to ensure commonality between implementations and surrounding intellectual property issues for JBIG2 and JPEG2000 [1, 10]. The recursive probability interval subdivision of Elias coding is the basis for the binary arithmetic coding process. With each binary decision, the current probability interval is subdivided into two subintervals, and the code stream is modified (if necessary) so that it points to the base (the lower bound) of the probability subinterval assigned to the symbol, which occurred. Since the coding process involves addition of binary fractions rather than concatenation of integer code words, the more probable binary decisions can often be coded at a cost of much less than one bit per decision.

The review makes it amply clear that, if one looks at further advancements on the transformation matrix as an extension of the discrete cosine transform, the studies are rather few. This is the context in which, the proposed research study postulated a novel algorithm through identification of common coefficients in order to achieve better compression results. The study proposes to attempt aggregation of similar coefficients at the compression level and disaggregation at the decompression stage, as an alternative method, which we hope would ensure better image compression within the ambit of the existing wavelet methodology.

3. POSITION BASED CODING SCHEME

The authors propose an alternative methodology by analyzing the position of unique elements of 256X256 image post-discrete cosine transformation matrix. An analysis of the post-discrete cosine transformation matrix after quantization of different 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 process. Thus, the challenge is to ensure that the decoded matrix retains the same elements as that of the original post-cosine transformation coefficients after quantization and also to ensure that only unique elements are transmitted. 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. Accordingly, a position coding scheme needs to be

developed to address the above approach. Further, 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-cosine transformation matrix.

After performing such an analysis, the authors observed that, the compression ratio is not significantly reduced in comparison with the existing coding scheme including Huffman coding. The main reason for this is the size of the position elements, which is still a factor which may not yield better compression as we need to transmit position matrix and unique coefficient matrix with or without quantization for enabling the decoding process. Therefore, further reduction needs to be performed to reduce the 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 elements, we have applied, the most commonly used measure of dispersion, standard deviation, to 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, the resultant elements 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 coefficient matrix will be sufficient. This process can also be seen as a direct extension of the 256X256 post-transformation matrix, and accordingly, the coding scheme is simple to comprehend and works as logical extension to the wavelet 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 Fig 1.

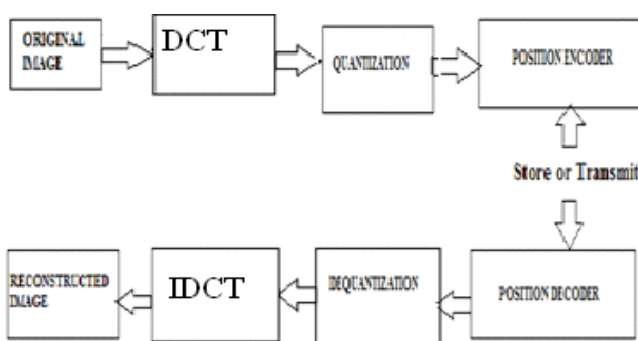


Fig 1: Position Based Image Compression

The original image is transformed by using DCT. Thereafter, encoding is performed with the support of the position based coding scheme (PBCS) encoder. The resultant output of the PBCS coding scheme, such as position matrix

after performing standard deviation, unique coefficients, and mean of position matrix are transmitted. At the receiving end inverse coding is applied and the original matrix is retrieved. Thereafter IDCT is applied to retrieve the original image. Further, in a position matrix, the values are always positive. This property gives the comfort to perform statistical operations on the position matrix, which has supported the use of standard deviation to generate the reduced position matrix. During the implementation of PBCS, after taking 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 on position matrix. At the decoder side inverse operation is performed to get the position matrices and unique coefficient matrix. Also the coefficient of variation (CV) is calculated to understand the degree of dispersion, as CV being an invariant measure, higher CV as a percentage shows higher degree of dispersion. Therefore, CV as a measure can also be compared with compression ratio and PSNR. Higher the CV compression ratio will be less and lower CV will have higher compression ratio.

As a next step, the elements and the position of the elements are the input to the position decoder. At the decoder side, it decodes and as a reverse operation, gets the original wavelet coefficient matrix. Since no loss of information takes place during the coding process, the proposed method shall be categorized under lossless coding technique. Further, the PBCS simplifies the computation and makes it easily comprehensible. 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 size of the unique coefficient matrix can be logically at a reduced level. Since the novel approach is not probabilistic and lossless, it can also be used to environments where high quality image is of prime importance.

As has been evident from the process flow, the process makes quantization redundant and hence, it can be applied to any type of images where the quality is of prime priority. Since better compression ratio is obtained without quantization, we have the range of options available taking into account enhanced compression ratio requirements and image quality.




4. EXPERIMENTAL RESULTS

In order to experiment PBCS, MATLAB software based programs were developed. This involves development of JPEG image compression with Huffman coding and the PBCS coding scheme. Huffman coding has been chosen for comparison as it supports lossless compression, as the proposed system can apply without quantization as a lossless compression. The authors are done a comparative analysis of both the methods with quantization. The experiment has been conducted on three test images for testing purposes with different colour schemes and background.

A comparison between JPEG with Huffman coding and JPEG with position based coding scheme in terms of compression ratio and PSNR are shown in Table 2. From the table it is evident that the PBCS shows better performance than Huffman coding in terms of PSNR. The comparison of compression ratio for a fixed PSNR was also performed. As the compression ratio of PBCS depends on the number of unique coefficients.






Table 1. Comparison between JPEG with Huffmancoding and PBCS

Original Images	JPEG with Huffman coding		JPEG with PBCS	
	PSNR	Compression Ratio	PSNR	Compression Ratio
 FRUITS	8.4038	7.8626:1	8.4038	9.2867:1
 AUTUMN	9.2966	7.0147 : 1	9.2966	9.2910:1
 LENA	11.6051	9.1771:1	11.6051	9.2950:1



An analysis is also attempted to explore the relationship between the Huffman’s coefficient and the unique coefficients produced by PBCS for the test images. For this purpose, the number of coefficients in the JPEG with Huffman coding and the PBCS arecalculated in Table 2.

Table 2.Comparison between Huffman Coefficient and Unique Coefficient.

ORIGINAL IMAGE	Huffman DC-Coefficient (Number)	Huffman AC-Coefficient (Number)	Unique Coefficient (Number)
	6650	60031	10808
	5870	68871	11089
	6582	47596	9342

From the Table 2, it is clear that the unique coefficient size is smaller than the Huffman’s DC and AC coefficient size. For instance, the image ‘autumn’ has higher value of Huffman’s AC coefficient than all other images and the compression rate per pixel is also higher for JPEG with Huffman coefficient. The unique coefficient of PBCS has the lower size than the Huffman’s coefficients. The size of the unique coefficients depends upon the types of images. An image with less dispersion will have relatively smaller number of unique coefficients and image with higher dispersion will have larger number of unique coefficients. The image ‘Lena’ has lesser number of dispersion so the unique coefficient number is very less at 9342.Accordingly the correlation coefficient ‘r’ between Huffman’s AC coefficients of JPEG and PBCS unique coefficient coding scheme stands at 0.66 shows higher positive correlation.

5. CONCLUSION

A study of coding schemes along with PBCS in the context of compression ratio, PSNR is presented in the paper. 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 transformation matrix, which until now continues to be an under researched area, for achieving better image compression with higher

PSNR and image quality. Most importantly, the area of study features as a direct logical extension to the DCT based approach and calculations are extremely simple to comprehend without adding complications in calculations. Since the authors did not use 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. This can also applied for JPEG2000 with wavelet transform. As a next step forward, the authors would also be studying other alternatives in the similar domain to achieve better results.

6. REFERENCES

- [1] Gonzalez R. C, E. R., and W.2008 Digital Image processing, New Delhi: Pearson Pentice Hall, Third Edition, Low price edition,1-904.
- [2] Jayavrinda V., Chandran. S., and Mahanti, G. K .2012.Asurvey of image compression methods.;International Journal of computer application. Proceedings on International Conference and workshop on Emerging Trends in Technology (ICWET),(March.2012), 12–17, Mumbai, India.
- [3] ISO/IEC JTCl/SC29/WGI N1646R. 2000.JPEG 2000 Part I Final Committee Draft Version 1.0 March.
- [4] Sonja Grgic, M. M. 2001. Comparison of JPEG Image Coders.; In Proceedings of the 3rd International symposium on Video Processing and Multimedia Communications, (June.2001),79-85. Zadar, Croatia.
- [5] Grgic, S ,K. K. and Grgic, M.1999.Image Compression using Wavelets.IEEE International Symposium on Industrial Electronics, ISIE'99, Bled, Solvania.
- [6] Sonal, D. K. 2007. A study of various image compression techniques. COIT, RIMT-IET. Hisar.
- [7] Querioz, Z., Fan, Ricardo,L. 2003. Identificaiton of Bitmap Compression History: JPEG Detection and Quantizer Estimation.In IEEE Transactions on Image Processing,(Feb.2003), Vol. 12, No. 2.
- [8] Longji, W. E.-h.2009. Joint Optimization of Run-Length coding,Huffman coding and Quantization Table with Complete Baseline JPEG DecoderCompatibility.IEEE Transactions on Image Processing , (Jan.2009),Vol18, No.1
- [9] Jeng, J. H., Tseng, C. C., and Hsieh, J. G. 2009. Study on Huber Fractal Image Compression. In IEEE Transactions on Image Processing,vol. 18, no. 5, 995-1003.
- [10] ISO/IEC.1991. Digital Compression and Coding for Continuous Tone Still Images.