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Improved Compression ratio for Image Signal using First Order Differential Huffman Coding

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Abstract - One of the most popular variable length coding technique for lossless image compression is Huffman coding in which fewer bits are assigned to the symbols having less probability of occurrence and vice versa. Huffman coding has significant application in JPEG coding and hence some extensions of Huffman coding technique like Adaptive Huffman coding, Canonical Huffman coding and minimum variance Huffman coding have been proposed. All these extensions are subjected to reduce decoding complexity or variance for encoding whereas our proposed algorithm is designed to improve compression ratio achieved by conventional Huffman coding. By using simple first order differential operator before applying Huffman coding technique, we have obtained significant improvement in compression ratio in case of image signal.

Keywords - Lossless image compression; Entropy coding; Huffman coding; JPEG; Differential Huffman Coding

I. INTRODUCTION

An exhaustive research has been done in the field of lossless image compression and still it continues. There are very popular types of lossless compression methods are available which are categorized as Entropy type and dictionary type methods. In this paper, we are going to discuss about an Entropy type method for lossless image compression named as Huffman coding proposed by David A. Huffman [1] in 1952. The key idea of Huffman coding is to dynamically assign number of bits to the given symbol based on their probabilities of occurrence. For the symbols which are having higher probability i.e. frequency of occurrence will be represented by fewer number of bits whereas symbols having lower probability will be represented by higher number bits. Hence, using Huffman coding average number of bits are reduced since fewer number of bits are used to represent the symbols which occurs frequently which in turn reduces compression ratio.

Huffman coding is a lossless compression entropy based coding scheme in which it is assumed that the message sequence i.e. in our case the whole image is available. Using that we prepare Huffman dictionary which is actually list of all symbols (intensities in case of image signal) with their corresponding probabilities and assigned binary representation. Interestingly, in many of the communication methods, the message sequence is not available simultaneously and due to that we are unable to prepare Huffman dictionary which limits the use of conventional Huffman coding algorithm. This limitation demands to make Huffman coding algorithm adaptive such that it dynamically form Huffman dictionary based on arrival of symbols. An initial results had been shown which satisfies above paradigm is by J. Vitter [2] in 1967. J. Vitter has shown that we can dynamically update Huffman dictionary based on arriving symbols which causes more number of bits to be wasted.

Another important perspective of Huffman coding scheme to determine the maximum length of Huffman code to determine complexity of decoder. An empirical proof had been given by M. Buro [3] in 1993. In that paper, he has investigated that maximum length of binary Huffman codes rely on the symbols whose are having lowest probabilities. Apart from that, author had provided improved upper bound on Huffman trees.

The major concerns regarding Huffman coding scheme are number of computations per codeword, height of Huffman tree and length of codeword. By optimizing above parameters, we can optimize the Huffman coding and make the scheme efficient. Initial efforts has been done by M. Aggarwal and A. Narayan [4] to make Huffman scheme more efficient.

Although various parameters of Huffman coding has been improved as per the literature but little efforts has been done in the direction of improvement in compression ratio. In this paper, we have proposed a new algorithm to improve Huffman coding compression ratio using differential operator. The key idea of our approach is to increase the occurrence of symbols (i.e. intensities) using first order differentiation of input image column wise. Since, differential operator reduces the range of intensities, we can increase the occurrence which in turn improves compression ratio at encoder. At the decoder side, we can compensate the differential effect by use of integral action in order to retrieve original image signal. Hence, this paper is summarizes as follows:

Section – II gives overview of some recent applications of Huffman coding scheme in the field of image, video and wireless broadcast systems. Section – III describes the proposed algorithm to improve compression ratio based on first order Differential Huffman coding. Section – IV shows results for various images from different classes and for different scales.

II. APPLICATIONS

Yu-Ting Pai, fan-Cheng, Shu-Ping Lu, and Shanq-Jang Ruan had proposed [5] a technique for Stuffing Bits Reduction and Efficient NRZI Data Transmission". They mainly focused on the data transmission and multimedia compression and considered this problem as the encoding of compression and transmission to develop a low bit rate transmission scheme based on Huffman encoding. The proposed method could balance "0" and "1" bits by analyzing the probability of the mismatch in the typical Huffman tree. Huang-Chih Kuo and Youn-Long Lin [6] had proposed a simple and effective lossless compression algorithm for video display frames. They combined the dictionary coding, the Huffman coding and innovative scheme to achieve a high compression ratio. They quantitatively analyzed the characteristics of display frame data for designing the algorithm. First, a two-stage classification scheme to classify all pixels into three categories was proposed. Second, employ the dictionary coding and propose an adaptive prefix bit truncation scheme to generate codeword's for video pixels in each category. And subsequently employed the Huffman coding scheme to generate codeword's for video pixels in each category. And subsequently employed the Huffman coding scheme to assign bit values to the codeword's. Finally they proposed a head code compression scheme to further reduce the size of the codeword bits. Experimental results show that the proposed algorithm achieves 22% more reduction than prior arts. Adina Arthur and V. Saravanan [7] had proposed a method which summarizes the different transformation methods used in compression. This paper outlined the comparison of transformation methods such as DPCM (Differential Pulse Code Modulation) and prediction improved DPCM transformation step of compression then introduced a transformation which is efficient in both entropy reduction and computational enhancing efficiency of Huffman coding using Lempel Ziv Coding for Image Compression. A novel algorithm named Swapped Huffman code Table (SHT algorithm) which has joined compression and encryption based on the Huffman coding. This technique was proposed in by Kuo-Kun Tseng, JunMin Jiang, Jeng-Shyang Pan, Ling Ling Tang, Chih-yu Hsu and Chih-Cheng Chen [8].

III. PROPOSED ALGORITHM

The proposed algorithm is improved version of Huffman coding algorithm by exploiting the differential property used to reduce number of intensity levels and increase the occurrence of them in an image. In the proposed algorithm an image is differentiated column wise first to reduce intensity levels and increase their occurrence before applying Huffman coding algorithm at encoder. The differentiated image can be used as reference and Huffman coding algorithm applied thereafter. At the decoder side, the received bit stream is decoded first using Huffman dictionary and integrated at last to retrieve original image. The proposed algorithm design steps are listed below:

3.1 Encoding

Step – I Let us take an image $I \in R^{MxN}$ which will be converted into differentiated image $I_1 \in R^{MxN}$ given by,

$$I_1(i,j) = I(i,j) - I(i,j-1) \text{ where } 1 \le i \le M \text{ and } 1 < j \le N \quad (1)$$

Step – II Determine all k intensity levels present in computed image I_1 where each intensity level is denoted as x_k.

Step – III Calculate occurrence (relative frequency) for k intensity levels x_k from image I_1 where each occurrence is denoted as a_k.

Step – IV Calculate probability of each intensity level of image I_1 using following formula:

$$p(x_k) = \frac{a_k}{MN} \quad (2)$$

Step – V Prepare Huffman dictionary based on already calculated p (x_k). With that determine average length per symbol given by following:

$$L_{avg} = \sum_{i=1}^{k} L(x_i)p(x_i) \quad (3)$$

Step – VI Encode the image I1 using Huffman Dictionary formulated as per previous step and send the bit stream to channel.

Step – VII Determine the compression ratio using the following formula:

$$CR = \frac{MN \log_2 k}{\sum_{i=1}^{k} L(x_i)a_i} \quad (4)$$

3.2 Decoding

Step – I Assuming the channel is lossless, the received bit stream can be decoded using Huffman Dictionary.

Step – II Arrange received vector using Huffman dictionary into Matrix form to represent in form of an image $I_2 \in R^{MxN}$.

Step – III Integrate the image extracted from Step – II such that we retrieve the image $I_{recover}$ using following formula:

$$I_{recover}(i,j) = I_{recover}(i,j-1) + I_2(i,j) \text{ where } 1 \le i \le M \text{ and } 1 < j \le N \quad (5)$$

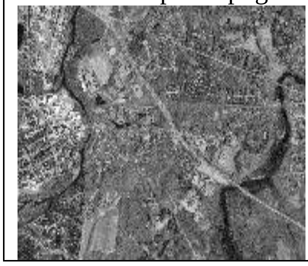
Note that the recovered image $I_{recover}$ in equation (5) will be exactly same as original image I.

IV. RESULT ANALYSIS AND DISCUSSION

For analysis of proposed algorithm, various images with different classes available in MATLAB has been taken for testing in which is the amount of detail varies as per isopreference curve. As a part of experiment, various images have taken and for that average length and compression ratio have computed for both algorithms Huffman coding and Differential Huffman coding and shown in Table - I. As we can extract from Table – I, the average length of bits for Huffman coding are higher than Differential Huffman coding for various test images. This is due to the fact that using differential operator, we can increase the probability of occurrence for various intensities and hence number of average bits per symbol will be reduced. Therefore, we can have higher compression ratio in case of Differential Huffman coding with respect to Huffman coding algorithm.

Table I. Analysis Of Compression Ratio For Differential Huffman Coding

Input Image	Size (MxN)	L_{avg}	L_{1avg}	CR	CR1
Coins.png 	32x32	6.4375	5.8105	1.2427	1.3768
	64x64	6.3657	4.9431	1.2567	1.6184
	128x128	6.3350	4.5283	1.2628	1.7667
	256x256	6.3526	4.2655	1.2593	1.8755
cameraman.tif 	32x32	6.9922	5.8184	1.1441	1.3750
	64x64	7.0879	5.3486	1.1287	1.4957
	128x128	7.0746	5.0062	1.1308	1.5980
	256x256	7.0448	5.0787	1.1356	1.5752
autumn.tif 	32x32	6.8340	5.7598	1.1706	1.3889
	64x64	6.9956	5.3718	1.1436	1.4893
	128x128	7.0424	5.0175	1.1360	1.5944
	256x256	7.0527	4.6723	1.1343	1.7122
westconcordorthophoto.png 	32x32	7.2734	7.0635	1.0999	1.1326
	64x64	7.5486	7.0427	1.0598	1.1359
	128x128	7.6791	6.8129	1.0418	1.1742
	256x256	7.7446	6.4709	1.0330	1.2363
	366x364	7.7767	6.4822	1.0287	1.2341
peppers.png 	24x96	6.8403	4.9583	1.1695	1.6134
	48x192	6.9698	4.3630	1.1478	1.8336
	96x384	7.0043	3.8031	1.1422	2.1036
	192x768	7.0182	3.1218	1.1399	2.5627
	384x1536	7.0246	2.3455	1.1389	3.4107
Lenna.png 	32x32	7.2266	6.9141	1.1070	1.1571
	64x64	7.3816	6.4744	1.0838	1.2356
	128x128	7.4377	5.9083	1.0756	1.3540
	256x256	7.4559	5.3730	1.0730	1.4889
	512x512	7.4675	5.1009	1.0713	1.5684

concordorthophoto.png 	70x94	6.8426	6.4986	1.1692	1.2310
	140x186	7.0291	6.4874	1.1381	1.2332
	278x370	7.1724	6.3879	1.1154	1.2524
	554x740	7.2692	6.1764	1.1005	1.2953
	1108x1478	7.3313	5.9309	1.0912	1.3489

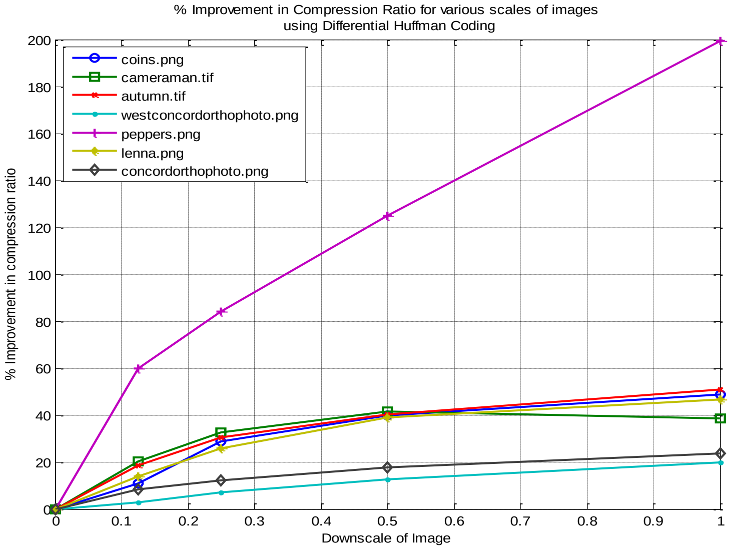


Figure 1. Improvement in compression ratio using Differential Huffman coding

The comparative analysis between conventional Huffman coding and proposed Differential Huffman coding has been done with respect to their compression ratios. As per that, each image is taken with different scaled versions and compression ratio is computed for each scale and for both the schemes simultaneously. The graph as shown in Figure 1 shows percentage improvement in compression ratio of Differential Huffman Coding with respect to Huffman coding for an image with different scales. For all the images, it is observed that percentage improvement in compression ratio reduces when the image is scaled down further. Interestingly, the maximum percentage improved compression ratio achieved for full scale image of peppers.png improved by 200%. While in case of other images, this ratio is improved by 20% - 50% for full scale image which shows significant improvement in proposed methodology. Apart from this, the different plots of various images proves that the dense informative image like concordorthophoto.png tends to achieve lower improved compression ratio whereas for less informative images like peppers.png yields towards higher improved compression ratio. Hence, empirically it is proved that proposed Differential Huffman Coding algorithm outperforms the conventional Huffman coding algorithms by means of compression ratio. In addition to that, more surprisingly results can be achieved in case of less informative images yield towards higher compression ratios using proposed Differential Huffman coding algorithm.

V. CONCLUSION AND FUTURE WORK

The empirical results shows that our proposed Differential Huffman coding algorithm outperforms the conventional Huffman coding algorithms by means of compression ratio. The results shows that the percentage improvement in compression ratio ranges from 20%-200% for different class of images. It has been observed that less informative image as per its isopreference curve achieves higher compression ratio than dense informative images. The JPEG codec can be equipped with our proposed algorithm to have higher amount of compression without loss of information. Although initial results are interesting for differential Huffman coding scheme, it can be extended for higher order differentiation in order to achieve higher compression ratio as future work. Since we have proved empirically that differential Huffman coding outperforms the Huffman coding scheme, theoretical proof can be derived for the future work.

REFERENCES

[1] D. A. Huffman, “A Method for the Construction of Minimum-Redundancy Codes,” *Proc. IRE*, vol. 40, no. 9, pp. 1098–1101, 1952.
[2] J. S. Vitter, “Design and analysis of dynamic Huffman codes,” *J. ACM*, vol. 34, no. 4, pp. 825–845, 1987.
[3] M. Buro, “On the maximum length of Huffman codes,” *Inf. Process. Lett.*, vol. 45, no. 5, pp. 219–223, 1993.
[4] M. Aggarwal and a. Narayan, “Efficient Huffman decoding,” *Proc. 2000 Int. Conf. Image Process. (Cat.*

No.00CH37101), vol. 1, pp. 936–939, 2000.

[5] Y. T. Pai, F. C. Cheng, S. P. Lu, and S. J. Ruan, "Sub-trees modification of huffman coding for stuffing bits reduction and efficient NRZI data transmission," *IEEE Trans. Broadcast.*, vol. 58, no. 2, pp. 221–227, 2012.

[6] H. C. Kuo and Y. L. Lin, "A hybrid algorithm for effective lossless compression of video display frames," *IEEE Trans. Multimed.*, vol. 14, no. 3 PART1, pp. 500–509, 2012.

[7] A. Arthur and V. Saravanan, "Efficient medical image compression technique for telemedicine considering online and offline application," in *2012 International Conference on Computing, Communication and Applications, ICCCA 2012*, 2012.

[8] K. K. Tseng, J. M. Jiang, J. S. Pan, L. L. Tang, C. Y. Hsu, and C. C. Chen, "Enhanced Huffman coding with encryption for wireless data broadcasting system," in *Proceedings - 2012 International Symposium on Computer, Consumer and Control, IS3C 2012*, 2012, pp. 622–625.