An Efficient Two- Stage Block Coding Method for Compression Binary Images

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Abstract - *Efficient image compression without quality loss is one of important problems of the information theory. This problem has a wide practical application. It is known that any digital image can be represented by a sequence of messages. The only requirement for these methods is the possibility of restoring an exact copy of the original image from a sequence of messages [1]. One of the ways of choosing messages is that the adjacent picture elements are grouped into blocks. Then, these blocks are encoded according to the probabilities of their occurrence. Thus, short codewords are used for the most probable configurations of blocks, and long code words are used for less probable configurations. The result is an average ratio of data compression. The block coding method makes it possible to obtain efficient compression binaryimages without losing quality. This paper considers the solution of this problem. We consider any binary image as many adjacent rectangular blocks of a certain size. Using the optimal Huffman coding we can achieve the highest data compression. However, in blocks larger than 3×3 a set of messages is very large, and the Huffman code becomes inefficient. In addition, statistical analysis of binary images shows that a block consisting of white elements has high probability. Based on this observation and applying the known optimal code, this paper proposes an efficient two-stage block coding method for compression binary images. We found the optimal block size at the first stage of coding. We have also compared the experimental results of the compression ratio with the proposed algorithm and the block algorithm JPEG. The results have confirmed the efficiency of the proposed method.*

Keywords*: binary image , block coding , compression ratio.*

1. Introduction

Effective compression of images without loss of quality is one of the important problems of information theory, which has wide practical application. A number of studies have been devoted to its solution (for example [1-2-3]). Any digital image can be represented through a series of messages. There are numerous techniques to select such messages. The only requirement for them is to enable the restoration of an exact copy of the original image from the message sequence. Onlyaway for selecting messages is to grouping adjacent image components into blocks each block with size n × m, where n isthe number of elements in the horizontal direction and m is the number of element in the vertical direction [1]. Then the received blocks are coded depend on their probabilities of their appearance, and for the most probable blocks configuration, short code words are used, and for less likely ones, long code words, resulting in an average compression of data. This type of coding is called block coding and is considered in [4]. Block coding using adaptive methods was considered in [5, 6].

Any binary image will be considered as a set of n × m rectangular blocks adjacent to each other. Each image element can be either white (0) or black (1), so the total numbers of blocks configurations, that is, the possible element locations numbers in the blocks, is 2nm. These blocks form a collection of messages that characterize the image. Applying the optimal Huffman code [7] to the block set, you can achieve the greatest data compression. However, for blocks larger than 3 × 3, the aggregate of messages is very large, and the use of the Huffman code becomes unreasonable.

In this paper, I propose an effective two-stage block coding method for binary images. The optimum block sizes were found in the first stage of the coding, and the experimental compression results of the constructed algorithm were compared with the results of compression of the block JPEG algorithm [8], confirming the effectiveness of the proposed method.

2. Block Coding Method

Statistical analysis of block configurations for binary images shows that a block consisting of white elements has a rather high probability. Proceeding from this observation and the suboptimal code proposed in [7], we construct an effective method of block coding. Coding will be carried out in two stages.

Let's consider the first stage. The codeword for a block consisting of one zeros will be 0. The codewords for other block configurations are formed from nm binary bits corresponding to this blocksproceeding by the prefix 1. The probability distribution for the source at which this code is optimal is equal to

$$p(i,n,m) = \begin{cases} p(0,n,m) \text{ when } i = 1, \\ \frac{1-p(0,n,m)}{2^{nm}-1} \text{ when } i = 2..2^{nm}, \end{cases} (1)$$

Where P (0, n, m) is the probability of a completely white block.

Then the average length of the codeword is defined as

L = P (0, n, m) + (1 + nm) (1-P (0, n, m))

= nm (1-P (0, n, m)) + 1. (2) [1]

Now let y1y2 ... yt be the sequence obtained after the first coding stage, yi Î {0, 1}. Consider the second stage of the coding, carried out by the arithmetic code from [9]. We denote by p = p (1) and q = p (0) In this sequence, we select the series i = $\frac{1}{\sqrt{p}}$that follow after the occurrence of 1, and the special symbol 1 and 0 that do not belong to the blocks, that is, we represent the sequence y1y2 ... yt in the form

$$0\ldots0\ 1\ \underbrace{y_1 \ldots y_1}\ 0\ldots0\ 1\ \underbrace{y_1 \ldots y_1}$$

The coding of various yi is performed by the arithmetic code from [10] with the help of different encoder's tuned to different probability of occurrence of zeros and ones, and can be described as follows. The special symbols 0 and 1 are encoded using the encoder K0 with probabilities ql and 1 - ql for 0 and 1, respectively. Consider the encoding of symbols inside the block y1 ... yl of length l. Let y1 ... yi-1=$\underbrace{0 \ldots 0}_{i-1}$(i = 1, ..., l). Then the symbol yi, located in the i-th position after the appearance of i-1 zeros, is encoded with the help of the encoder Ki with probabilities pi and (1 - pi) for 0 and 1 respectively, where

From Table 1 it can be seen that the best values of the compression ratio give the sizes n = 4 and n = 5, which are the optimal block size.

$$\pi_1 = \frac{1-q}{1-q^{l-i+1}} = \frac{1}{1+p+p^2 \ldots +p^{i-1}}. (3)$$

The appearance of these probabilities is explained in [10]. Finally, the symbols in the block y1 ... yl, following the appearance in this block 1, are encoded using the encoder $\overline{K}$ with the initial probabilities q and p for 0 and 1, respectively. It is important to note that the probabilities pi are not stored in the encoder and decoder memory, but are calculated from the following recurrence formula:

$$\frac{1}{\pi_{i-1}} = \frac{1}{\pi_i} - q^{i-1}. (4)$$

Consequently, the calculation pi, defined by formula (3) can be arranged as follows:

$\bar{q} := \bar{q}/q\,, \bar{\pi}^{-1} := \bar{\pi}^{-1} - \bar{q}$with the initial data $\bar{q}:=q^i$, $\bar{\pi}^{-1}$:=1+q+…+q^{i-1}.

The next block is coded in the same way, and the initial data is updated before each new block. To find the optimal block sizes in the first stage of coding, we find the theoretical compression coefficient obtained after the first stage. By the compression ratio C, we will understand the ratio of the number of bits needed to represent a given image before encoding to the number of bits after encoding [1]. Taking (2) into account, we obtain

$$C = \frac{nm}{\bar{L}} = \frac{nm}{nm\,(1-p(0,n,m))+1}\ (5).$$

We confine ourselves to the consideration of the square blocks n 'n. Table 1 shows the results of the dependence of the compression coefficient, obtained theoretically from the theoretical point of view and experimentally, on the size of the square block for different binary images of A1-A5. Note that for theoretical and experimental results, the size n was taken in the range from 2 to 6. This is because the compression ratio begins to decrease for n> 6, so further increase in the block size becomes impractical.

TABLE 1. DEPENDENCE OF THEORETICAL AND EXPERIMENTAL RESULTS OF THE COMPRESSION RATIO ON THE SIZE OF A SQUARE BLOCK.

Picture	Coefficient of compression	Block size, n				
		2	3	4	5	6th
A1	Theor	3.01	5.22	6.91	7.15	6.87
	Exp	3.26	5.54	7.13	7.44	7.08
A2	Theor	3.25	5.19	6.26	6.61	6.30
	Exp	3.15	5.06	6.11	6.54	6.19
A3	Theor	3.21	5.15	5.68	5.60	5.24
	Exp	3.06	4.89	5.53	5.48	5.07
A4	Theor	2.99	3.68	3.91	3.81	3.57
	Exp	2.83	3.56	3.81	3.66	3.48
A5	Theor	2.52	3.23	3.31	3.14	2.95
	Exp	2.45	3.14	3.19	3.03	2.87

3. COMPARISON OF EXPERIMENTAL COMPRESSION RESULTS

To confirm the effectiveness of the proposed method, the experimental compression results were compared with the constructed algorithm with the results of the most common and known image compression standard - the block JPEG method. As test images, the above binary images A1-A5 were taken. The comparison was carried out by the compression ratio. By the compression ratio in this case, we mean the number of bits that a single byte (8 bits) of the original (uncompressed) image is represented in the compressed file. The results of the compression ratio for the proposed kNEW method and for the block JPEG method - kJPEG are presented in Table 2.

It can be seen from the table that the compression ratio of kNEW is approximately 22-24% better than the compression ratio by the block method of JPEG, which confirms the effectiveness of the proposed method.

TABLE 2. THE RESULTS OF THE COMPRESSION RATIOS OF THE VARIOUS BINARY IMAGES FOR THE PROPOSED ALGORITHM AND THE KNOWN BLOCK JPEG METHOD.

Picture	kNEW	kJPEG
A1	2.94	3.16
A2	4.58	4.81
A3	3.53	3.77
A4	4.91	5.14
A5	5.15	5.39

4. CONCLUSIONS

The obtained experimental data show the effectiveness of the method of block coding of binary images proposed in this paper: it compresses such images by 22-24% better than the known and widely used JPEG method. It is shown that the optimal block sizes for the proposed method are 4 × 4 or 5 × 5. The constructed coding algorithm can be used in practice for effective compression of cartographic and facsimile images, satellite images of the earth's surface, etc.

REFERENCE

[1] Mridul K. M., Seema L., Dr. Dheeraj S. "Lossless Huffman Coding Technique For Image Compression And Reconstruction Using Binary Trees," IJCTA, pp. 76-79, 2012.

[2] Vasudev B., Konstantinos K. Image and Video Compression Standards: Algorithms and Architectures ,II edition ,kiuwer Academic Publisher , 2012,pp.319-389

[3] Babu P., Sathappan S. Efficient lossless image compression using modified hierarchical prediction and context adaptive coding. Indian Jour. of Sc. and Tech., 2015, vol. 8, pp. 1-6.

[4] WatanabeT.,Sugawara K., Sugihara H., A new pattern representation scheme using data compression, 2002, IEEE Transactions on Pattern Analysis and Machine Intelligence Volume: 24, Issue: 5.

[5] Coulon F., Jonsen O. Adaptive block scheme for source coding of black-and-white facsimile. Electron. Lett., 1976, vol. 12, no. 3, pp. 61-62.

[6] Bhavna P, Reena S, Mitul M, Tutorial review on existing image compression techniques, International Journal Of Engineering And Computer Science . 2014. Volume 3 Issue 8 pp. 7882-7889

[7] Mamta S., Compression Using Huffman Coding,2010, International Journal of Computer Science and Network Security, VOL.10 No.5.

[8] Weinberger MJ, Seroussi G., Sapiro G. The LOCO-I lossless image compression algorithm: Principles and standartization into JPEG-LS. IEEE Trans. Image Process, 2000, vol. 9, no. 8, pp. 1310-1324.

[9] RyabkoB.Ya., Fionov A.N; Homophonic coding with logarithmic memory size. Algorithms and Computation, Springer, Berlin, 1997, pp. 253-262.

[10] Trofimov V. K., Efficiency of Output-Uniform Coding of Bernoulli Sources for Unknown Message Statistics, 2010, Avtometriya 46(6), 32–39 .