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Recursive group coding for image DCT compression efficiency

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Abstract. The problem of encoding information in order to eliminate its statistical redundancy has been considered. The most widespread techniques for lossless encoding are arithmetic and Huffman coding. One disadvantage of these methods is the lack of efficiency when encoding characters with extra-large alphabets. In this paper, the efficiency of image data compression with method of recursive group coding has been considered and compared to arithmetic and Huffman coding. It is shown that recursive group coding provides a sufficient gain in compression compared to aforementioned methods.

Keywords. Entropy coding, image compression, recursive group coding, arithmetic coding, Huffman coding

1. Introduction

Nowadays we can observe a significant increase in both Internet users and the number of network connections due to IOT devices and different web applications. All this leads to increase in the amount of data transmitted by telecommunication networks and stricter requirements to the bandwidth of data transmission channels. At the same time, data to be transmitted are often characterized by high homogeneity that allows improving compression performance.

Among the growing volume of traffic in modern networks, most of it are multimedia data [1]: video, images and sound. Thus, the need arises for designing new fast and efficient methods for such kind of data.

Modern researches in the field of data compression are progressing in parallel in several directions. First, new high-level compression techniques for images, video and audio are being developed [2]. Second, there is a permanent improvement in multipurpose high-level compression techniques such as dictionary compression methods and partial coincidence prediction compression. Third, researches continues in the field of low-level methods for eliminating statistical redundancy in data, such as arithmetic coding (AC) [3, 4] or Huffman coding (HC) [5], which are part of most high-level methods (for example, JPEG).

This article mainly addresses the field of low-level methods of compressing images. The problem of lossy image compression has been relevant over several decades. Essential attention has been paid to methods based on discrete cosine transform (DCT). Another direction in lossy image compression is to design methods that take into account the visual quality of images, in particular, compression without introducing visually noticeable distortions [6, 7]. These methods require the

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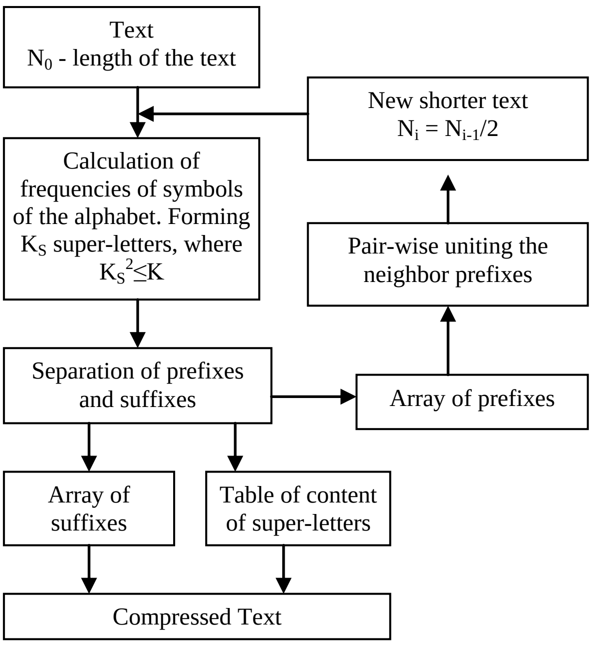
development and analysis of special metrics of visual quality of images [8]. In this sense, good results are shown by methods based on DCT [9-11].

Such methods are based on lossless encoding of quantized DCT coefficients. Efficiency attained at this stage sufficiently determines performance of image compression as a whole. Arrays of quantized DCT coefficients are characterized by a high degree of homogeneity that has to be exploited. To solve this problem, methods based on dictionary compression, compression with a prediction about partial coincidence, based on the Burroughs-Wheeler transformation [12] and others are mainly used. However, not all of these methods are effective enough for encoding characters of large alphabets, which are typical for the tasks of compressing multimedia information, for example images and video [13]. For such tasks, the size of one coded symbol can be up to 64 bytes and more. The disadvantage of Huffman coding is the insufficient efficiency of character coding for which less than one bit of memory can be sufficient. The drawback of arithmetic coding is the use of multiplication and division operations for coding which negatively affects the coding rate and significantly reducing the speed. Thus, one needs a fast and efficient coder able to compress data with a high degree of homogeneity.

2. Method

As an alternative to arithmetic coding and Huffman coding a faster and more efficient method of recursive group coding (RGC) has been developed recently [14]. This method implements the recursive application of the encoding procedure which is shown in Figure 1.

Figure 1. RGC method



In the source text (with the number of characters equal to K), the frequencies of appearance of characters are counted p_k and then they are sorted in ascending order. Next, super letters Ks (groups of characters) are formed by combining alphabet characters with close frequencies of their o appearance in the text into a super-letter.

By concatenating the characters of the alphabet into a super-letter, the length of the code for those characters is increased. In this case, a super-letter can be formed only if this increase in the code length does not exceed a given acceptable threshold.

The increase in code length due to the concatenation of characters into a super letter in relative units is expressed as:

$$\Delta = -p_E(-\log_2 p_E + \log_2 M)/\sum_{k=1}^{M}(p_k \log_2 p_k), \tag{1}$$

where M is a number of symbols united in the super-letter, p_E - denotes a sum of probabilities of these symbols determined as $\sum_{k=1}^{M} p_k$.

The value of Δ depends on homogeneity (in the statistical sense) of symbols united into a super-letter: more homogeneous - less a value of Δ is.

Then prefixes (group numbers) and suffixes (number of a character within a group) are extracted.

Suffixes are numbered and, together with the tables of super letters, are stored in a compressed file (to ensure further decoding). In this case, coding is not applied to the prefixes but the adjacent prefixes (2 or more prefixes) are combined and a new text Ni is formed which is several times smaller than the original one. Further, the method is applied to the formed shorter text that is the actions are recursively repeated until the size of this text is less than the specified threshold.

The use of this recursive group coding can significantly increase the data compression rate. This is achieved due to the computational simplicity of the encoding and decoding process (only simple addition, logical "or" and offset operations are used).

The use of recursion allows efficient encoding the characters of extra-large alphabets that are inherent in multimedia data. The compression ratio remains comparable and even exceeds the compression ratio for arithmetic and Huffman coding.

3. Result

RGC shows efficiency close to AC [15] in the worst case. Meanwhile, for compression of homogeneous data with large alphabets, RGC provides significantly higher compression ratios [15, 16] with very good computational coding efficiency. Examples of such homogeneous data are just the quantized DCT values in image blocks using lossy compression [17]. In this case, the size of the alphabet characters can reach 128 bytes [18, 19] while, in other cases, even 2048 bytes or more are possible.

In this paper, we study the efficiency of using RGC for compression of DCT of image coefficients in comparison to other low-level method for eliminating statistical redundancy in data - AC.

To be efficient and universal, a lossless method should perform well for different images and different quantization steps. Because of this, for a comparative analysis of the RGC efficiency, we have used a set of test grayscale images from the TID 2013 database [8] shown in Figure 2.

All images were saved in the bmp format; without compression, the original size of each file is 197686 bytes. Typical multimedia data that can be additionally compressed while transmitting through communication channels are quantized coefficients of DCT in blocks of images or in blocks of video frames. The size of these blocks varies from 8x8 pixels (for JPEG) to 16x16 pixels (for video coding standards) [16]. For each image DCT values were calculated (size of blocks 8x8) with their further quantization. The calculations used quantization steps (QS) of 10, 30, 50.

Due to the fact that the quantized DCT coefficients are statistically inhomogeneous, the use of AC and HC for their compression is inherently ineffective and requires additional solutions. One such solution for example in the JPEG standard is to use ZigZag scanning to obtain a one-dimensional sequence, as well as RLE (Run Length Encoding) to encode a large number of identical characters (zeros).

Figure 2. Test images from the TID 2013

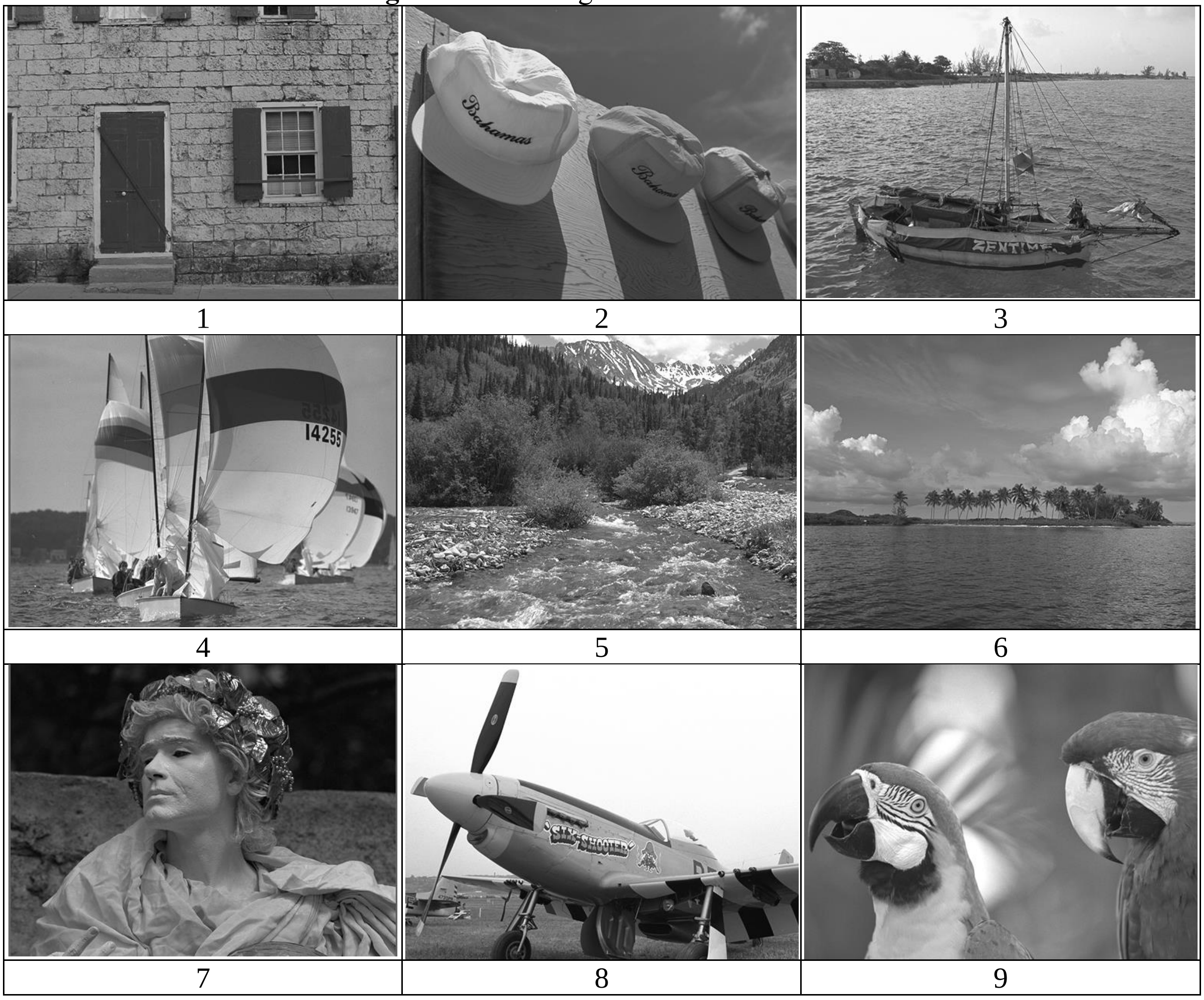


Table 1 shows the results of compression of test images by the RGC, AC and HC (for DCT with a quantization step of 10, 30, 50).

Table 1. Results of compression of test images

	Compression ratio								
QS	10			30			50		
№ image	RGC	AC	HC	RGC	AC	HC	RGC	AC	HC
1	2.65	2.01	1.92	4.31	3.41	3.26	6.85	5.30	5.30
2	2.65	1.87	1.66	4.26	3.23	2.97	6.77	5.20	5.14
3	2.21	1.67	1.56	3.71	2.96	2.78	5.88	5.11	5.04
4	2.19	1.76	1.76	3.68	3.12	3.16	6.21	5.31	5.30
5	2.29	1.77	1.60	3.89	3.07	2.76	6.32	5.29	5.22
6	2.75	1.84	1.74	4.30	3.52	3.43	6.92	5.64	5.54
7	2.52	1.82	1.80	3.79	3.34	3.32	6.19	5.55	5.49
8	2.62	1.90	1.78	3.98	3.38	3.22	6.49	5.78	5.70
9	2.30	1.73	1.71	3.77	3.05	3.03	6.35	5.28	5.26
Average	2.46	1.82	1.72	3.96	3.23	3.10	6.44	5.38	5.33

It can be seen from the data in Table that RGC due to its ability to work with symbols of large alphabets (to take into account the correlation between large groups of symbols) provides a gain in comparison to AC by an average of 20% and by 23% with respect to HC.

4. Conclusion

The paper analyzes the effectiveness of using the RGC method to eliminate statistical redundancy which. due to its recursiveness, is able to efficiently encode symbols of large alphabets. Analysis has been carried out for compressing DCT coefficients for a set of test images, RGC is compared to AC and HC. Obvious advantages of RCG are demonstrated.

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