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RESEARCH ARTICLE

An Improved Method of Image Compression with GPPM Tree and Haar Wavelet

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Abstract—Compression of image is done to reduce the size of the image, which reduces the size of the memory needed to store the image and the time required to transmit the image trough a network. There are two types of compression called the lossless compression and the lossy compression. Many works have been done in lossless compression. GPPM tree along with PPM tree are used in compression of RGB image in [1].This is a lossless compression. A small change is made in the steps involved in this existing algorithm. This step increases the compression ratio and decreases the bits per pixel. Haar wavelet is taken for the image and rounded values of the coefficients are taken and the algorithm in [1] is applied only on the LL component. For the other coefficients a mapping is done to convert the positive and negative coefficients into positive integer symbols. This is a one to one function. The Huffman coding is done for all the other three coefficients (LH, HL, and HH). Then all the compressed strings are combined into one file using a particular format. The testing is done with grayscale images. The original algorithm was implemented and checked for the performance of the compression algorithm in this paper. The metrics used for compression is compression ratio, PSNR, and SSIM and bits per pixel. Improved values are found for the compression ratio and bits per pixel.

Keyworks— CFA image compression; Image compression; lossless compression; GPPM tree; PPM tree; SSIM.

I. INTRODUCTION

A compression method is introduced by the authors for RGB colour images by using GPPM and PPM trees [1]. Image compression is a method to decrease the size of the, image to reduce the redundant information present in the image. There are three kinds of redundancy present in the images. They are coding redundancy, interpixel redundancy and pshycovisual redundancy. There are different kinds of compression methods and standards. To give an improvement to the compression method given in the [1], Haar wavelet is taken as the first step. An improvement in compression ratio, and bits per pixel are recorded in the experiments done. This algorithm is tested for the CFA images also.

CFA (colour filter array) image is an image which is a single array of R,G and B colours. One particular CFA array is the Bayer pattern. It contains 25% of the pixels as red components, 25% of pixels as blue components and 50% of the pixels as green components[2],[3]. These three components are arranged in a single array. Modern digital cameras use the colour filter array to capture the images. To get the full colour image an interpolation method should be used to get the missing values in each pixel position. This method is called demosicing [4]. In older works compression of CFA image was done after demosicing. This introduced redundancy in the compressed file. Now-a-days the compression of CFA image is done directly and demosicing is done after decompression [5]. Many works have been done on CFA image compression in transform domain [6], [7].

The following sections are organized as follows: section II discusses the original existing algorithm [1] and the proposed algorithm. Section III discusses the experimental results and comparison of the proposed algorithm with the existing algorithm. The conclusion is discussed in section IV.

II. MODIFICATION IN THE ALGORITHM

A. *Existing Algorithm (Algorithm I)*

The existing algorithm [1] is discussed here.

1. Read the image.
2. Divide the image into bitplanes $I_0(i,j), I_1(i,j), \ldots, I_7(i,j)$, where (i,j) is the position of the image pixel and $I_k(i,j) = 0\ or\ 1$.
3. Repeat the following step for all the bitplanes.
   Construct the PPM tree, GPPM tree and have the raw data. Find the one which has the least size and consider that as the string to encode the particular bitplane. Also construct another string which stores two bits for each bitplane to show what method is used to store the string. 00 represents PPM tree, 01 represents GPPM tree and 10 represents raw image data.
4. Then, the compressed file is constructed for the image in the following format.

TABLE I
THE FORMAT OF THE FILE IN EXISTING ALGORITHM

S. No	Byte No	Description
1	1	Length of the original image as a power of 2
2	2,3	Bit representing which segments are stored in raw or compressed form [8x2=16]
3	3 onwards(variable size)	Data for the interleaved or de-interleaved CFA image.

B. *Proposed Algorithm (Algorithm II)*

The proposed algorithm is discussed here.

1. Read the image.
2. Apply Haar wavelet. Haar wavelet coefficients are real numbers and they must be converted into positive integers so that they can be divided into bitplanes or Huffman coding can be done. So, the wavelet coefficients are rounded first.
   The following equation is used for taking the Haar wavelet for a 1D signal.
   Low frequency coefficients: $l_{\frac{i}{2}} = \frac{(a_i + a_{i-1})}{2}$
   High frequency coefficients: $l_{(n+i)/2} = \frac{(a_i + a_{i-1})}{2} \forall i = 0,1,\ldots,n-1$

   $l_{i/2}=(a_i+a_{i-1})/2,$
   $h_{n/2+i/2}=(a_i-a_{i-1})/2, \quad i=0,1,2,\ldots,n-1$

   For an image, the above Haar wavelet is taken row wise and then column wise. Thus the image will be divided into four frequency coefficients (LL, LH, HL,and HH).
3. Divide the LL component of the image into bitplanes.
4. Repeat the following step for all the bitplanes.

Construct the PPM tree, GPPM tree or have the raw data for the bitplanes. Find the one which has the minimum size and consider that as the string to encode the particular bitplane. Also construct another string which stores two bits for each bitplane to show what method is used to store the string.

5. Then concatenate the strings.
6. The coefficients in the other components (LH, HL, and HH) are converted into positive valued symbols by using the mapping given below.

$$\boldsymbol{F(x,y) = 2f(x,y) \qquad \forall f(x,y) \geq 0}$$
$$\boldsymbol{F(x,y) = -2f(x,y) - 1 \qquad \forall f(x,y) < 0}$$

7. Huffman coding is done for these coefficients.
8. A file is constructed by the following structure.

TABLE II
THE FORMAT OF THE FILE IN PROPOSED ALGORITHM

S. No	Byte No	Description
1	1	Length of the LL component of the image as a power of 2
2	2,3	Bit representing which segments are stored in raw or compressed form [8x2=16]
3	3 onwards(variable size)	Data for the interleaved or de-interleaved CFA image.
4	variable size	Data for the Huffman compressed LH, HL, and HH coefficients.

Taking wavelet is itself a compression. Here the most significant information is packed in the average coefficients. The other coefficients (LH, HL, and HH) have smaller values. So when they are divided into the bitplanes there is more scope for compression.

III. EXPERIMENTAL RESULTS AND COMPARISON

Two sets of results are taken for this paper. First the results are taken for the grayscale values of different test images for existing, and proposed algorithm. Similarly, the same way results are taken for different interleaved and de-interleaved CFA images for the proposed. The test images are lena, baboon, baby and peppers. Raw CFA images are not used; instead the color images were converted into CFA images and used in the experiments. The metrics used to measure the efficiency of compression are PSNR, compression ratio, BPP and SSIM.

TABLE III
THE METRICS FOR DIFFERENT IMAGES FOR EXISTING ALGORITHM IN GRAYSCALE IMAGES

Image	PSNR	Compression Ratio	BPP	SSIM
Lena	Inf	1.2544	6.3775	1
baboon	Inf	1.1465	6.9778	1
Baby	Inf	1.5029	5.3230	1
Peppers	Inf	1.3386	5.9764	1

TABLE IV
THE METRICS FOR DIFFERENT IMAGES FOR PROPOSED ALGORITHM IN GRAYSCALE IMAGES

Image	PSNR	Compression Ratio	BPP	SSIM
Lena	56.7210	1.8498	4.3248	0.9999
baboon	56.7290	1.6755	4.7747	0.9999
Baby	58.1948	2.3536	3.3990	0.9999
Peppers	57.1573	2.0110	3.9781	0.9999

Table III and IV compares the results for the grayscale images given in the existing and proposed algorithm. There are many inferences drawn from the tables given above. First of all, the algorithm I is a lossless image compression algorithm. So the PSNR of the decompressed image is infinite. But the algorithm II is a lossy compression, since Haar wavelet is taken and rounding is done before compression. But the PSNR of the decompressed images are good enough because they are very much greater than 30. Secondly, when the compression ratio and bits per pixel are seen they give an improvement. For more smooth images the compression ratio is greater and relatively less for images which have high variation. For this, the example of pepper and baboon can be taken. Bits per pixel and compression ratio are inversely proportion, and so as the compression ratio increases the bits per pixel decreases. Thirdly, the SSIM has the value one in existing algorithm and slightly lesser value in the proposed algorithm because of lossy compression.

TABLE V
THE METRICS FOR DIFFERENT IMAGES FOR PROPOSED ALGORITHM IN INTERLEAVED CFA IMAGE

Image	PSNR	Compression Ratio	BPP	SSIM
Lena	56.6159	1.4463	5.5313	0.9999
baboon	56.6538	1.2568	6.3654	0.9999
Baby	56.6049	1.4894	5.3711	0.9999
Peppers	56.6511	1.2749	6.2751	1

TABLE VI
THE METRICS FOR DIFFERENT IMAGES FOR ALGORITHM IN DE-INTERLEAVED CFA IMAGE

Image	PSNR	Compression Ratio	BPP	SSIM
Lena	56.6428	1.6855	4.7465	0.9999
baboon	56.6413	1.5133	5.2863	0.9999
Baby	57.4704	1.9096	4.1895	0.9999
Peppers	56.7676	1.7208	4.6489	1

By comparing the different values for the interleaved and de-interleaved CFA images, for the proposed algorithm the PSNR and SSIM are almost the same from Table V and VI. The compression ratio is slightly greater for the de-interleaved CFA images than the interleaved CFA images. While comparing the proposed algorithm for grayscale and the interleaved and the de-interleaved images the compression ratio for interleaved and de-interleaved CFA images are in between the values of the grayscale image for the existing and proposed algorithm. Otherwise, the PSNR for the grayscale images, interleaved and de-interleaved CFA images are almost the same. The bits per pixel have the effect from the compression ratio, that bits per pixel decrease as the compression ratio increases.

IV. CONCLUSION

From the discussion above there are few conclusions taken. First of all, the compression achieved by the proposed algorithm for grayscale images are greater than the ones obtained for the grayscale images in the existing algorithm and the interleaved and CFA images in proposed algorithm. Thus it can be concluded that the proposed algorithm is better than existing algorithm for grayscale images. Also, the proposed algorithm is best suited for grayscale images than CFA images. Even when it is used for CFA images the proposed algorithm gives greater compression ratio and thus smaller bits per pixel. Also, this method has greater compression ratio for images with less variations and lesser compression ratio for images having lesser variations. The proposed algorithm has very good PSNR ratio and SSIM which says that there is very small loss in the decompressed image.

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