A LOSSLESS COMPRESSION SCHEME FOR BAYER COLOR FILTER ARRAY IMAGES USING CONTEXT MATCHING BASED PREDICTION

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ABSTRACT

A color image requires at least three color samples at each pixel location. Computer images oftenuse red (R), green (G), and blue (B). A camera would need three separate sensors to completely measure the image. In a three-chip color camera, the light entering the camera is split and projected onto each spectral sensor. Each sensor requires its proper driving electronics, and the sensors have to be registered precisely. These additional requirements add a large expense to the system. Thus, many cameras use a single sensor covered with a color filter array (CFA). Several patterns exist for the filter array. The most common array is the Bayer CFA, The CFA allows only one color to be measured at each pixel. This means that the camera must estimate the missing two color values at each pixel. This estimation process is known as demosaicing. In most imaging systems, image compression is carried out after demosaicing process and compression algorithms usually have focused on compressing three channel color images. Recently, several image compression methods are proposed to directly handle CFA images, hence in this project a compression Method using the Context Matching Based Prediction (CMBP) scheme is implemented which is exclusively mend for Bayer's CFA images.

In context matching technique to rank the neighboring pixels when predicting a pixel, an adaptive color difference estimation scheme to remove the color spectral redundancy when handling red and blue samples, and an adaptive codeword generation technique to adjust the divisor of Rice code for encoding the prediction residues. Simulation results show that the implemented compression scheme can achieve a better compression performance than conventional lossless CFA image coding schemes. As the CFA blocks light selectively according to colour, meaning that the light loss depends on the colour of the scene, In addition to Bayers CFA an analysis is also made by changing the color filter arrays and the impact of them on various categories of images are compared with respect to the compression efficiency.

Keywords: Context Matching Based Prediction, Demosaicing Algorithms, Bilinear Interpolation

I. INTRODUCTION

Digital cameras have become popular, and many people are choosing to take their pic-tures with digital cameras instead of film cameras. When a digital image is recorded, the camera needs to perform a significant amount of processing to provide the user with a viewable image. An important part of this image processing chain is color filter array (CFA) interpolation or demosaicing. The digital color imaging systems generally use a single image sensor to capture full color images using a color filter array (CFA). A color filter array enables each pixel to capture the intensity of light with different color spectrum. The most common design of CFA is the Bayer pattern [10] which consists of two greens, one red, and one blue component. Since each pixel has only one color component, demosaic operation is performed to interpolate all three color components to estimate full color RGB images. Then, the demosaiced image can be sent to image display devices for display. When images are transmitted or stored from the image capture module, the connection between two systems is almost al-ways bandwidth-limited and becomes the bottleneck of whole system performance. Thus, efficient image compression methods are required to send less amount of data to the link and they are commonly applied after demosaicing operation [11], [12]

II. RELATED WORK

An early demosaicing method proposed in [8] uses derivatives of chrominance samples in initial green channel interpolation, and this idea is borrowed by many subsequent algorithms. Various demosaicing algorithms proposed directional interpolation with different decision rules [8]–[11]. For instance, Chung et al. [11] used variance of color differences to make a hard direction decision. On the other hand, the authors of [13] proposed a soft direction decision based on the Linear Minimum Mean Square Error Estimation (LMMSE) framework. Here, the directional color differences are considered as noisy observations of the actual color difference and they are combined optimally. Paliy et al. [14] improved this directional approach with scale adaptive filtering based on local polynomial approximation (LPA). Another interesting directional approach is to perform interpolation in both directions and then make a posteriori decision. Hirakawa et al. [15] used local homogeneity of the directional interpolation results and Menon et al. [16] used color gradients over a local window as the decision criteria. The demosaicing problem has been studied in the frequency domain as well. Gloztbach et al. proposed using high frequency components extracted from green channel to improve red and blue channel components that are more susceptible to aliasing [17]. In [18], Gunturk et al. proposed an alternating projections scheme using the strong inter-channel correlation in high frequency subbands. Since the method is iterative, it required a high number of calculations. Another method [19] proposed filtering the input mosaicked color components together to preserve the high frequency components better. Here, the luminance is estimated by a fixed 5 by 5 filter at green pixel locations and by an adaptive filter at red and blue channel locations. A comprehensive overview with objective comparison results can be found in a recent survey paper [20] by Li et. al. and the PhD thesis of Menon [22]. An overview of linear approaches to the problem can be found in [21]. Gradients are useful for extracting directional data from digital images. Several demosaicing methods including a recent integrated gradients method proposed in [23] made use of them. In [24], it is demonstrated that the gradients of color difference signals could be the valuable features to adaptively combine directional color difference estimates. In this method, the horizontal and vertical color difference estimates are blended based on the ratio of the total absolute values of vertical and horizontal color difference gradients over a local window.

III.PROPOSED METHOD

We propose a Context Matching Based Prediction based JPEG-LS (lossless) compression standard for Bayer pattern. It is used to select the best patterns or pixels among the set of available patterns or pixels in the Bayer pattern Image. It also achieves better compression ratio and Less Elapsed time.

Proposed Module

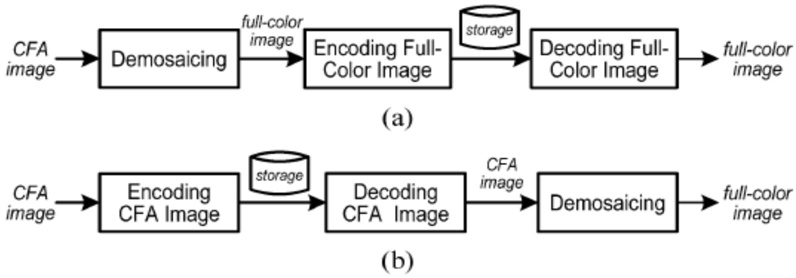

Fig.2: Single Sensor Camera Imaging Chain:

(A) The Demosaicing – First Scheme (B) The Compression – First Scheme

3.1. Context Matching Based Prediction:

CMBP population should be initialized with randomly created cluster centers. From the initial population by subsequent iterations the new populations are created by operations of selection, cross-over and mutation. For every solution in population, fitness value is calculated according to the specific fitness function. The Solutions with high fitness values come into mating pool. The process is repeated until termination criteria are met. Below some implementation details are given.

Chromosomes

Chromosomes represent solutions consisting of centers of k clusters. Each cluster center is a d dimensional vector of values in the range between 0 and 255 representing intensity of gray or color component.

Population initialization and fitness computation

The clusters centers are initialized randomly to k d dimensional points with values in the range 0 – 255. Fitness value is calculated for each chromosome in the population according to the rules.

Selection

Selection operation tries to choose best suited chromosomes from parent population that come into mating pool and after cross-over and mutation operation create child chromosomes of child population. Most frequently genetic algorithms make use of tournament selection that selects into mating pool the best individual from predefined number of randomly chosen population chromosomes. This process is repeated for each parental chromosome.

Crossover

The crossover operation presents probabilistic process of exchanging information between two parent chromosomes during formation of two child chromosomes. Typically, one-point or two-point crossover operation is used. According to [5] crossover rate 0.9 - 1.0 yields the best results.

Mutation

Mutation operation is applied to each created child chromosome with a given probability *pm*. After crossover operation children chromosomes that undergo mutation operation flip the value of the chosen bit or change the value of the chosen byte to other in the range from 0 to 255. Typically mutation probability rate is set in the range 0.05 - 0.1 [5].

Termination criterion

Termination criterion determines when the algorithm completes execution and final results are to be presented to the user. Termination criterion should take into account specific requirements. Most often termination criterion is that algorithm terminates after predefined number of iterations. Other possible conditions for termination of the *k*-means algorithms depend on degree of population diversity or situation when no further cluster reassignment takes place.

3.2. Demosaicing Algorithms

A. Bilinear Interpolation

In this technique, the missing color value is estimated by calculating the average value of the four neighboring samples in each color plane. Consider the array of pixels as shown in Fig.2, at the blue center B_{44}, we need to estimate the green and red components. G_{44} can be calculated as

$$G_{4,4} = \frac{(G_{3,4} + G_{4,3} + G_{4,5} + G_{5,4})}{4}$$

& similarly R_{44} can be calculated as

$$R_{4,4} = \frac{(R_{3,3} + R_{3,5} + R_{5,3} + R_{5,5})}{4}$$

Performing this operation at each pixel in each color plane, we can obtain three-color planes for the image, which would give us one possible demosaicked form of the image.

B. Design of Bayer Mosaic Filter

The Bayer Mosaic Filter comprises an RGB filter mask applied to standard grey sensor. As figure shows, the green and blue pixels alternate in one line, and the red and green pixels in the next line. For the following model calculations, the pixels have been numbered consecutively with p(x, y)

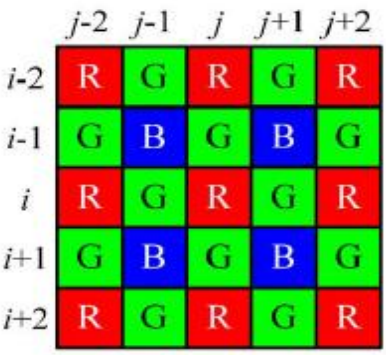

Fig.3 : Bayer Mosaic Filter

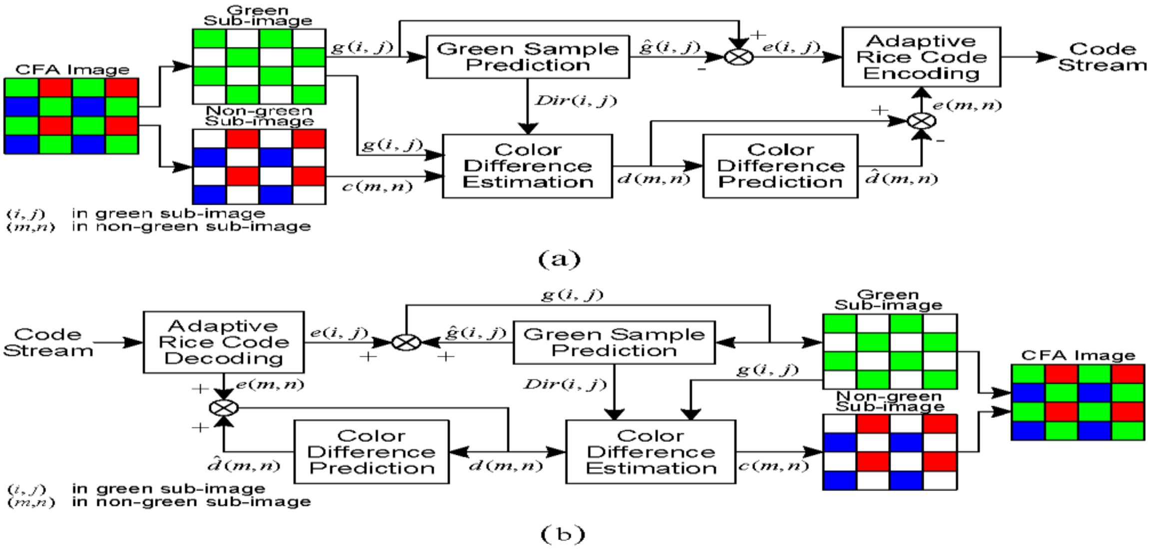

Fig 4: Block diagram of (a) Encoder and (b)Decoder

The proposed prediction technique handles the green plane and the nongreen plane separately in a raster scan manner. It weights the neighbouring samples such that the one has higher context similarity to that of the current sample contributes more to the *current* prediction. Accordingly, this prediction technique is referred to as context matching based prediction (CMBP) in this paper the green plane (green subimage) is handled first as a CFA image contains double number of green samples to that of red/blue samples and the correlation among green samples can be exploited easily as compared with that among red or blue samples .Accordingly, the green plane can be used as a good reference to estimate the colour difference of a red or blue sample when handling the nongreen plane (nongreen subimage).

D. Lossless Compression

JPEG-LS is a lossless/near-lossless compression standard for continuous-tone images. Its official designation is ISO-14495-1/ITU-T.87. JPEG-LS were developed with the aim of providing a low-complexity lossless and near-lossless image compression standard that could offer better compression efficiency than lossless JPEG. JPEG-LS mainly consist of context modeling, pixel prediction, and prediction error encoding. In the run mode of JPEG-LS, a run length coding scheme with low computational cost is used to encode constant regions when a zero prediction error occurs. A small compression gain with respect to the static JPEG-LS coding, applied on a frame by frame basis, is obtained at the price of significant increase of computational complexity, delay time, and memory cost. It is a simple and efficient baseline algorithm which consists of two independent and distinct stages called modeling and encoding. It was developed because at the time, the Huffman coding-based JPEG lossless standard and other standards were limited in their compression performance.

IV. SIMULATION RESULTS

The input image was selected from the current directory for the compression using CMBP

Fig 5.1: Original Image

2. The RGB image was converted into CFA image and separated into Green Image and Non_Green Image.

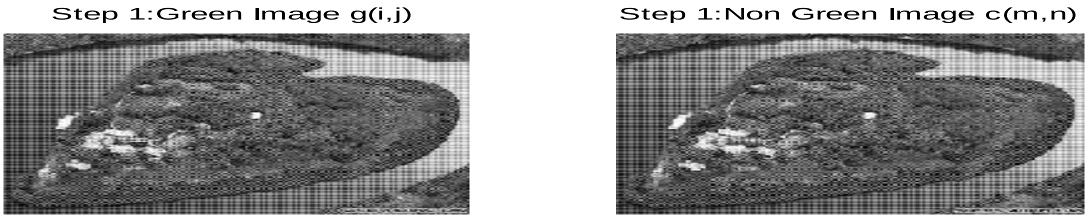

Fig 5.2: Conversion of RGB to CFA and Separation of Green and Non-Green Image

3. The direction of the each pixel was predicted. Based on the direction the green plane prediction error was found.

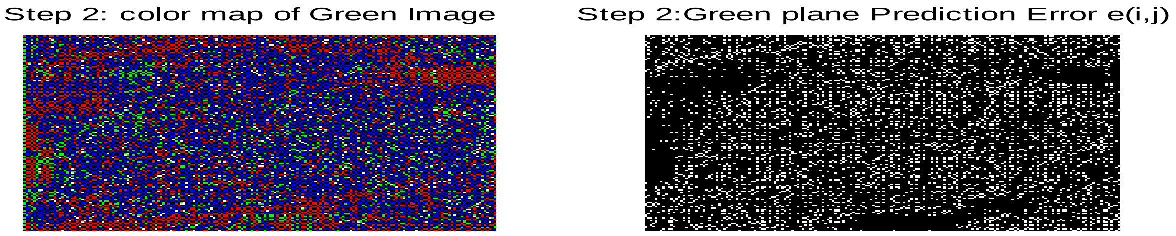

Fig 5.3: Green plane prediction

4. The color difference estimated image was found for the non green plane prediction based on the directions of the green plane pixels.

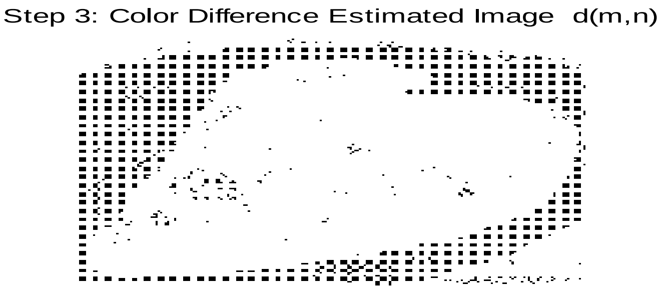

Fig 5.4: Color difference estimation

5. The Non – Nreen plane prediction error was found. The Green and Non_Green plane prediction errors were added and shown in below figure.

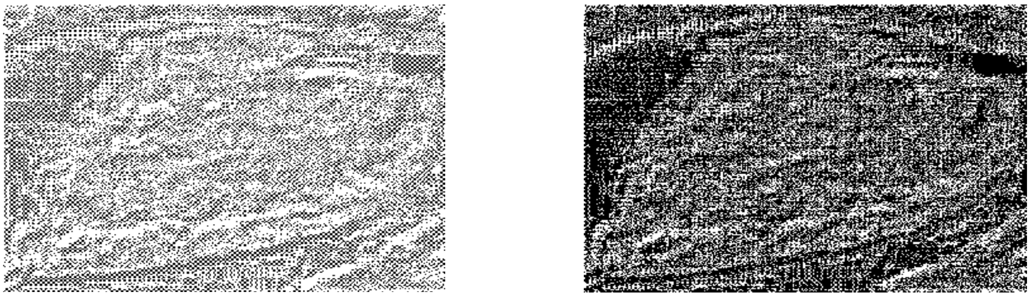

Fig 5.5: Non Green plane prediction

6. The CFA image was reconstructed and the CFA is converted back into original image.

Fig 5.6: Reconstruction of CFA image and Original image

Table 3. 1: Compression Efficiencies of Various Lossless Compression Schemes in terms of Bits Per Pixel

IMAGE	JPEG – LS	JPEG 2000	LCMI	IMPLEMENTED METHOD
1	6.403	5.816	5.824	5.328
2	6.787	5.134	4.629	3.979
3	5.871	5.210	5.139	4.701
4	6.295	5.899	5.966	5.940
5	5.074	4.391	4.319	3.964
6	5.395	4.556	4.415	4.304
7	5.370	4.986	4.952	4.448
8	5.628	4.485	4.307	3.813

9	6.747	6.372	6.503	5.736
10	6.289	5.555	5.487	5.207
11	6.317	4.656	4.396	4.372
12	5.289	4.552	4.521	4.216
13	6.184	5.570	5.538	5.141
14	5.470	4.909	4.898	4.561
15	5.467	5.039	4.983	4.539
16	6.188	5.218	5.060	4.637

V. CONCLUSION

In this work, Context Matching Based Prediction (CMBP) scheme, a lossless compression scheme for Bayer image is presented. This scheme separates a CFA image into a green subimage and a nongreen subimage and then encodes them separately with predictive coding. The prediction was carried out in the intensity domain for the green subimage while in the color difference domain for the nongreen subimage. In both cases, a context matching technique was used to rank the neighboring pixels of a pixel for predicting the existing sample value of the pixel. The prediction residues originated from the red, the green, and the blue samples of the CFA images were then separately encoded.

The value distribution of the prediction residue can be modeled as an exponential distribution, and, hence, the Rice code was used to encode the residues. Assuming the prediction residue as a local variable and estimated the mean of its value distribution adaptively. The divisor used to generate the Rice code was then adjusted accordingly so as to improve the efficiency of Rice code. Experimental results show that the implemented compression scheme could efficiently and effectively de-correlate the data dependency in both spatial and color spectral domains. Consequently, it was proved to be the best average compression ratio as compared with the latest lossless Bayer image compression scheme.

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