PREDICTION BASED LOSSLESS COMPRESSION SCHEME FOR BAYER COLOUR FILTER ARRAY IMAGES USING DIFFERENT ENCODING AND DECODING TECHNIQUES

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ABSTRACT

This paper presents an experimental evaluation of the effectiveness of various techniques for lossless compression of CFA images. A colour image requires at least three colour samples at each pixel location. A digital camera would need three separate sensors to completely measure the image. In a three chip colour 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 most commercial digital cameras use colour filterarrays to sample red, green, and blue colours according to a specificpattern. At the location of each pixel only one colour sample istaken and the values of the other colours must be interpolated usingneighbouring samples. This colour plane interpolation is knownas demosaicing.Demosaicing is generally carried out before compression.Recently, it was found that compression first schemes outperform the conventional demosaicing first schemes in terms of output image quality.An efficient prediction based lossless compression scheme for Bayer CFA images is proposed in this paper. It exploits a context matching technique to rank the neighboring pixels when predicting a pixel, an adaptive colour difference estimation scheme to remove the colour spectral redundancy when handling red and blue samples, and an adaptive code word generation technique.
Simulation results show the comparison of different coding scheme in terms of compression ratio.

INDEX TERMS – Bayer pattern, CFA, Bilinear Interpolation, Context Matching Based Prediction.

INTRODUCTION

Digital cameras have become popular, and many people are choosing to take their pictures 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. Most digital cameras use a single image sensor to capturescene images. In these cameras, Bayer colour filter array(CFA) [1], as shown in Fig. 1, is usually coated over a sensorto record only one of the three chromatic components at eachpixel location. The most common design of CFA is the Bayer pattern [1] which consists of two greens, one red, and one blue component. Since each pixel has only one colour component, demosaic operation is performed to interpolate all three colour components to estimate full colour 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 always bandwidth limited and becomes the bottleneck of whole system performance. Thus, efficient image compression methods are required to send fewer amounts of data to the link and they are commonly applied after demosaicing operation [8], [9]

Fig1. Bayer pattern having a red sample as its centre

Recently, some reports [6,7] indicated that such a demosaicing first scheme was inefficient as the demosaicing processintroduced redundancy which should eventually be removedin the compression step. As a result, an alternativeapproach [6,7] which carries out compression before demosaicingas shown in Fig. 2 has been proposed lately. Underthis new strategy, digital camera can have a simpler designand lower power consumption as the computationally heavyprocesses like demosaicing can be carried out in an offlinepowerful personal computer.

In this paper, a simple predictionbased lossless CFAcompression scheme is presented. It employs context matchingtechnique to rank the neighbouring pixels for predictingthe current pixel. In addition, an adaptive colour differenceestimation technique is also used to remove the colour spectralredundancy.
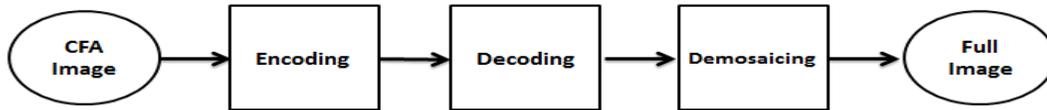
OVERALL DESCRIPTION

Fig2.System Architecture

The architecture shown in Fig2 consists of an input image, a process and an output image. The process includes encoding and decoding. The encoding involves techniques such as Context matching based prediction that handles the green plane and the non-green plane separately and then weights the neighboring samples, adaptive colour difference estimation to remove the colour spectral dependency and adaptive rice coding used as an entropy encoding for lossless compression scheme. The decoding process is just the reverse process of encoding where original CFA image is reconstructed by combining the two sub images. Here an image that we want to compress is a CFA image. It is then followed by compression process and then image got from compression process is then applied to a technique called as Demosaicing. The image then is demosaiced and a full high quality image is obtained.

PROPOSED METHOD

We propose a Context Matching Based Prediction based losslesscompression 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.

STRUCTURE OF PROPOSED COMPRESSION SCHEME

The Structure in Fig 3 shows the diagrammatic representation of proposed compression scheme with techniques such as context matching prediction to rank the neighboring pixels, adaptive colour difference estimation to reduce the spectral redundancy and adaptive rice code used as entropy encoding for lossless compression.
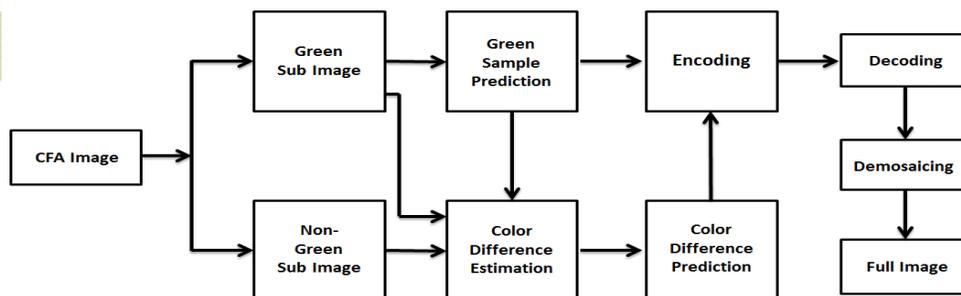

Fig3. Structure of compression Scheme

i.   Context Matching Based Prediction

This technique handles the green plane and the non-green plane separately in a scanning sequence. It exploits the neighboring samples when predicting a pixel. The green plane is handled first as a CFA image contains double number of green samples to that of red/blue samples. Green plane can be used as a good reference to estimate the colour difference of a red /blue sample when handling the non-green plane.

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 colour 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 [10] 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 [10].

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.

ii.   Green plane prediction

This technique involves scanning of green plane. In prediction on green plane, the plane is raster scanned and all prediction errors are recorded. During processing, all processed green samples are known and can be exploited in the prediction of the pixels. Here a particular green sample $g(i,j)$ is processed. The four nearest processed neighboring green samples of $g(i,j)$ form a candidate set

$$\Phi g(i,j) = \{g(i,j-2),g(i-1,j-1),g(i-2,j),g(i-1,j+1)\} \qquad (1)$$

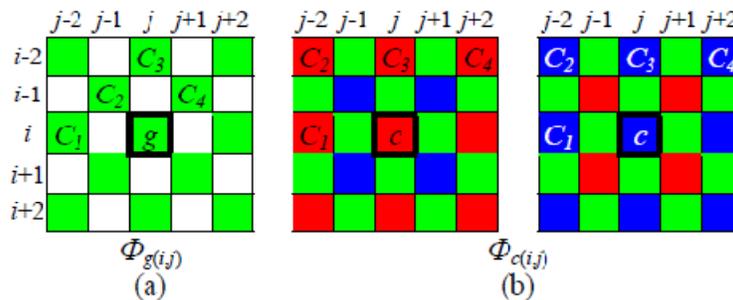The candidates are ranked by comparing their support regions with that of $g(i,j)$.

Fig4. The support region of (a) a green sample and (b) a red/blue sample

Steps involved in scanning the image on green plane:
a) Determine context difference and sort all candidates by their context differences
b) Determine Dir (i, j).
c) If the direction belongs to the sorted candidates then (i, j) is in a homogeneous region else (i, j) is in a heterogeneous region.
d) Then green planes are generated.

iii.   Non-Green plane prediction

In this method, when the sample being processed is a red or blue sample in the non-green plane, the prediction is carried out in the colour difference domain instead of intensity domain as in the green plane. This is done to remove the interchannel redundancy. Since the non-green plane is processed after the green plane, all green samples in a CFA image are known and can be exploited when processing the non-green plane. Let $d(p,q)$ be the green-red (or green-blue) colour difference value of a non-green sample $c(p,q)$. For any non-green sample $c(i,j)$, its candidate set is

$$\Phi c(i,j) = \{d(i,j-2),d(i-2,j-2),d(i-2,j),d(i-2,j+2)\} \qquad (2)$$

And its support region is defined as

$$Sc(I,j)= \{(I,j-1),(i-1,j),(I,j+1),(i+1,j)\} \qquad (3)$$

The prediction error is then obtained with d(i,j)-d^(i,j). Steps involved in scanning the image on non-green plane:
a) Estimate colour difference d (i, j).
b) Determine context difference and sort all candidates by their context difference.
c) Then after sorting predict with prediction filter in order to remove noise and redundancy.
d) Generate the non-green plane.

iv. Adaptive Colour Difference Estimation

In this method when compressing the non-greencolour plane, colour difference information is exploited to remove the colour spectral dependency. This shows that the colour difference value of a pixel without having a known green sample of the pixel. Let c(m,n) be the intensity value of the available colour sample (either red or blue) at a non-green sampling position (m,n).The green-red (green-blue) colour difference of pixel is obtained by

$$d(m,n) = \hat{g}(m,n)-c(m,n) \qquad (4)$$

Where$\hat{g}$(m,n) represents the estimated intensity value of the missing green component at position (m,n).In the proposed estimation, and $\hat{g}$(m,n) is adaptively determined according to the horizontal gradient δH and the vertical gradient δV at (m,n).

$$\hat{g}(m,n)=round[(\delta H*GV+\delta V*GH)/(\delta H+\delta V)] \qquad (5)$$

From the above equation it is noted that, the missing green value is determined in such a way that a preliminary estimate contributes less if the gradient in the corresponding direction is larger. Steps involved in estimating colour difference for non-green sample:
a) Determine the horizontal and vertical gradient.
b) Check whether (i,j) is in a heterogeneous region or homogeneous region.
c) Then estimate the missing green sample by using $\hat{g}$(i,j).
d) Estimate the difference using
e) d(m,n) = $\hat{g}$(m,n)-c(m,n).

Simulation

Prediction based lossless compression scheme for Bayer CFA image is implemented using the MATLAB. The performance of the proposed method is evaluated on five CFA images. Thumbnails of the test images are shown in Figure 5. First a CFA image is taken as the input and is processed with context matching prediction. After image has been processed with context matching, green sub image is predicted with green sample. Then Adaptive colour difference estimation is carried out and direction is mapped. In future, the obtained image is encoded with rice code & arithmetic code separately, decoded and finally in Table 1 different coding method is compared in terms of compression ratio.
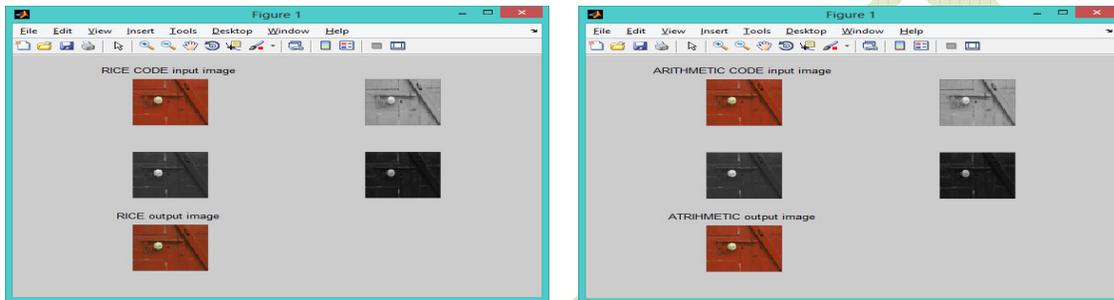
Fig5. Thumbnails of the test images

Fig6. Simulation results using Adaptive Rice code and Arithmetic coding methods

Table 1 Achieved Results of various coding schemes in terms of Compression Ratio

IMAGE NO.	PARAMETERS	ADAPTIVE RICE	ARITHMETIC
01	CR_GREEN	0.1431	0.3952
	CR_RED	0.1614	0.4297
	CR_BLUE	0.1221	0.3982
	Compression Ratio	0.8928	0.4077
02	CR_GREEN	0.1133	0.4548
	CR_RED	0.1204	0.4411
	CR_BLUE	0.157	0.507
	Compression Ratio	0.8913	0.4676
03	CR_GREEN	0.3523	0.547
	CR_RED	0.248	0.4571
	CR_BLUE	0.3345	0.53
	Compression Ratio	0.914	0.5113
04	CR_GREEN	0.1514	0.3471
	CR_RED	0.1887	0.3852
	CR_BLUE	0.1711	0.3714
	Compression Ratio	0.8963	0.3679
05	CR_GREEN	0.0813	0.1797
	CR_RED	0.0911	0.2024
	CR_BLUE	0.116	0.2264
	Compression Ratio	0.8870	0.2028

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 non-greensubimage and then encodes them separately with predictive coding. The prediction was carried out in the intensity domain for the green subimage while in the colour difference domain for the non-greensubimage. 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 colour 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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