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Prediction Based Lossless Compression Scheme for Bayer Color Filter Array Images

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***Abstract*—. In this paper, Bayer CFA images are captured and then demosaicing is carried out after compression. While performing it was found that compression schemes outperform the demosaicing schemes. So, this paper proposes a prediction based lossless compression scheme for Bayer CFA images. It employs context-matching technique to rank the neighboring pixels for predicting current pixel. In addition, an adaptive color difference estimation technique is also used to remove the color spectral redundancy. Based on this scheme, a comparison is made with the existing lossless CFA image and it is shown that the proposed scheme provides the best compression performance.**

***Index Terms*— Bayer pattern, color filter array (CFA), digital camera, Adaptive rice encoding, image compression, Demosaicing.**

I. INTRODUCTION

Most existing digital color cameras use a single sensor with a color filter array (CFA) to capture visual scenes in color. Since each sensor cell can record only one color value, the other two missing color components at each position need to be interpolated from the available CFA sensor readings to reconstruct the full-color image. Color demosaicing of charge-Coupled device sensor data holds a key to the quality of color images reconstructed from single-sensor digital still and video cameras. Such digital cameras capture an image with a single-sensor array. The full color image is reconstructed by interpolating the missing color samples. Color demosaicing has been extensively studied in spatial domain for still digital cameras. The earlier spatial demosaicing methods, such as nearest-neighbor replication and bilinear and bicubic interpolation can be easily implemented, but they suffer from many artifacts such as blocking, blurring and zipper effect at edges. Lately developed demosaicing methods exploited the correlation between color channels. Many CDM algorithms has been proposed and it is based on the undetermined assumption of noise-free CFA data. Many advanced denoising algorithms which are designed for monochrome images, are not directly applicable to CFA images due to underlying mosaic structure of CFAs.CFA (Color Filter Array) is a mosaic of tiny color filters placed over the pixel sensors of an image sensor to capture color information. Color filters are needed because the typical photo sensors detect light intensity with little or no wavelength specificity, and therefore cannot separate color information [3]. In the conventional processing chain of single-sensor digital still cameras [5], the images are captured with color filter arrays and CFA samples are demosaiced into a full color image before compression [1]. In order to overcome problem principle component analysis based denoising scheme which directly operates on the CFA domain of captured images. Two categories of CFA image compression schemes are carried out (i) lossy scheme that usually yield a higher compression ratio as compared with lossless scheme and another [7] (ii) lossless scheme. Lossless compression is necessary in such case where original CFA images are required for producing high quality full color image. In Demosaicing scheme, a CFA image is first interpolated [2], then demosaicing is performed to form full image before being compressed for storage [4]. An alternative processing chain has been proposed to move the compression process before the Demosaicing. As the compression process takes place before demosaicing, digital cameras can have simple design and low power consumption that motivates the demand of CFA image [1].In this missing green samples are first estimated based on the variances of the color differences along different edge. The missing red and blue components are then estimated based on the interpolated green plane. This algorithm can effectively preserve the details in texture regions and at the same time, it can significantly reduce the color artifacts [1]. This paper is based on Prediction-based lossless compression scheme and it proposes a lossless scheme with context matching techniques and an adaptive codeword generation technique to adjust the divisor of Rice code [6] for encoding the prediction residues.

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A. Image Processing

Image processing is any form of signal processing for which the input is an image, such as photographs or frames of video; the output of image processing can be either an image or a set of characteristics or parameters related to the image. Most image-processing techniques involve treating the image as a two-dimensional signal and applying standard signal-processing techniques to it. It usually refers to digital image processing, but optical and analog image processing are also possible.

B. Digital Image

Any image from a scanner, or from a digital camera, or in a computer, is a digital image. Computer images have been digitized, a process which converts the real world color picture to instead be numeric computer data consisting of rows and columns of millions of color samples measured from the original picture. The way a digital camera creates this copy of a color picture is with a CCD chip behind the lens, constructed with a grid of many tiny light-sensitive cells, or sensors, arranged to divide the total picture area into rows and columns of a huge number of very tiny sub areas.

C. Pixel

A digital color image pixel is just a RGB data value (Red, Green, Blue). Each pixel's color sample has three numerical RGB components (Red, Green, Blue) to represent the color. These three RGB components are three 8-bit numbers for each pixel. Three 8-bit bytes (one byte for each of RGB) are called 24 bit color. Each 8 bit RGB component can have 256 possible values, ranging from 0 to 255. Larger numbers require multiple bytes, for example two bytes (16 bits) in the RGB system, it is know Red and Green makes Yellow. So, (255, 255, 0) means Red and Green, each fully saturated (255 is as bright as 8 bits can be), with no Blue (zero), with the resulting color being Yellow. Black is a RGB value of (0, 0, 0) and White is (255, 255, 255). Gray is interesting too, because it has the property of having equal RGB values. So (220, 220, 220) is a light gray (near white), and (40, 40, 40) is a dark gray (near black). Gray has no unbalanced color cast. Since gray has equal values in RGB, Black & White grayscale images only use one byte of 8 bit data per pixel instead of three. The byte still holds values 0 to 255, to represent 256 shades of gray.

D. Image File

The image file contains three color values for every RGB pixel, or location, in the image grid of rows and columns. The data is also organized in the file in rows and columns. Every location on one of the rows and one of the columns is color sample, which is called a pixel. The image data is just a series of RGB numeric color values in a grid of rows and columns.

II. OVERALL DESCRIPTION

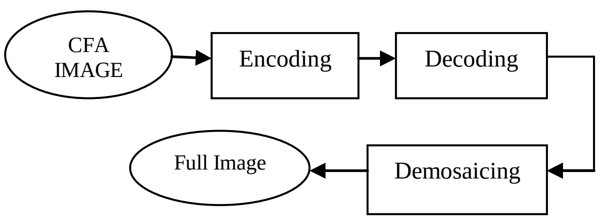

Fig 1. System Architecture

The architecture shown in Fig1 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 color difference estimation to remove the color 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.

III. PROPOSED METHOD

This paper proposes a Prediction-based lossless compression scheme for Bayer CFA images. It divides a CFA image into two sub images namely green sub image and non-green sub image. A green sub image contains all green samples of CFA image and a non-green sub image holds red and blue samples. Here, first green sub image is coded and besides to this follows non-green sub image as a reference. It is processed in the color difference domain so as to reduce the spectral redundancy. These images are then processed in the scan sequence and then prediction residue planes of these two images are then entropy encoded with rice code.

A. Structure of Proposed Compression Scheme

The Structure in Fig 2 shows the diagrammatic representation of proposed compression scheme with techniques such as context matching prediction to rank the neighboring pixels, adaptive color difference estimation to reduce the spectral redundancy and adaptive rice code used as entropy encoding for lossless compression.

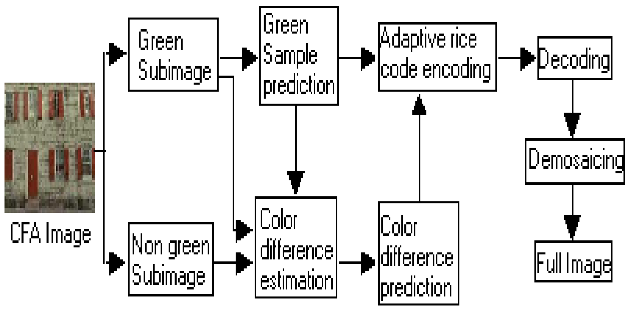

Fig 2. Structure of compression Scheme

B. 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 color difference of a red /blue sample when handling the non-green plane.

C. 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

$$\Phi_{g(i,j)} = \{g(i,j-2), g(i-1,j-1), g(i-2,j), g(i-1,j+1)\} \quad (1)$$

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

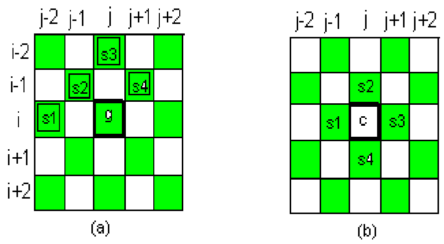

Fig 3.The support region of (a) a green sample and (b) a red/blue sample

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.

D. Non-Green plane prediction

In this method, when the sample being processed is a red or blue sample in the nongreen plane, the prediction is carried out in the color difference domain instead of intensity domain as in the green plane. This is done to remove the interchannel redundancy. Since the nongreen plane is processed after the green plane, all green samples in a CFA image are known and can be exploited when processing the nongreen plane.

Let d(p,q) be the green-red (or green-blue) color difference value of a non-green sample c(p,q). For any non-green sample c(i,j), its candidate set is

$$\Phi_{c(i,j)} = \{d(i,j-2), d(i-2,j-2), d(i-2,j), d(i-2,j+2)\} \quad (2)$$

And its support region is defined as

$$S_{c(I,j)} = \{(I,j-1),(i-1,j),(I,j+1),(i+1,j)\} \quad (3)$$

The prediction error is then obtained with $d(i,j)-d^{\wedge}(i,j)$.

Steps involved in scanning the image on non-green plane**:**

a) Estimate color 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 nongreen plane.

E. Adaptive Color Difference Estimation

In this method when compressing the nongreen color plane, color difference information is exploited to remove the color spectral dependency. This shows that the color 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 color sample (either red or blue) at a nongreen sampling position (m,n).The green-red (green-blue) color difference of pixel is obtained by

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

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).

$$\hat{g}(m,n) = \text{round}[(\delta H * G_V + \delta V * G_H)/(\delta H + \delta V)] \quad (5)$$

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 color 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) $d(m,n) = \hat{g}(m,n) - c(m,n)$.

IV. SIMULATION

Prediction based lossless compression scheme for Bayer CFA image is implemented using the MATLAB which is a scientific computational tool and basic entity is Matrix. Twenty-four bit color images were sampled according to the Bayer pattern to form a set of 8-bit testing CFA images. Out of these images one image is chosen and is evaluated for prediction. Here GUI component is used to show the operation involved in predicting an image. In Fig 4, Fig 5, Fig 6 and Fig 7 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 color difference estimation is carried out and direction is mapped. In future, the obtained image is encoded with rice code, decoded and finally in Table I different demosaicing method is compared. Demosaicing algorithm is applied to get a high-qualified image.

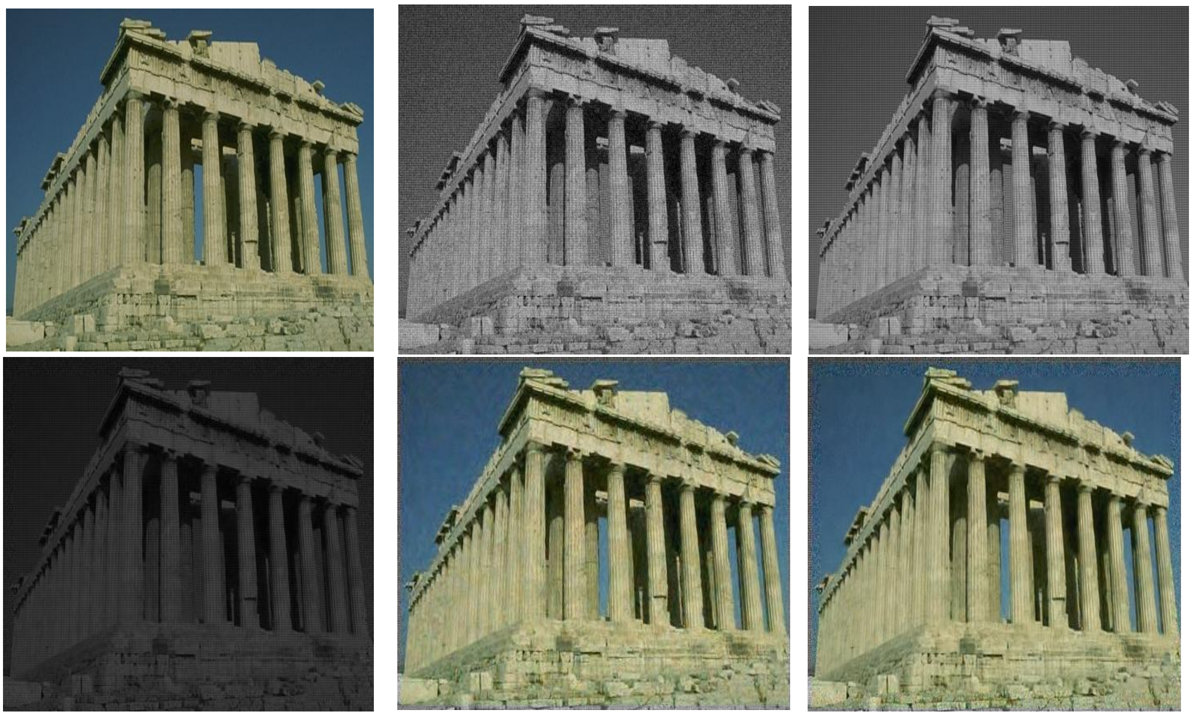

Fig 4.Denoising results of CFA image "*Parthenon*" (a) Original CFA image; (b) Noisy CFA image (c) Difference between the denoised and original CFA images by using methods (d) CDM Method (e) Adaptive PCA-based CFA denoising method (f) Proposed Method

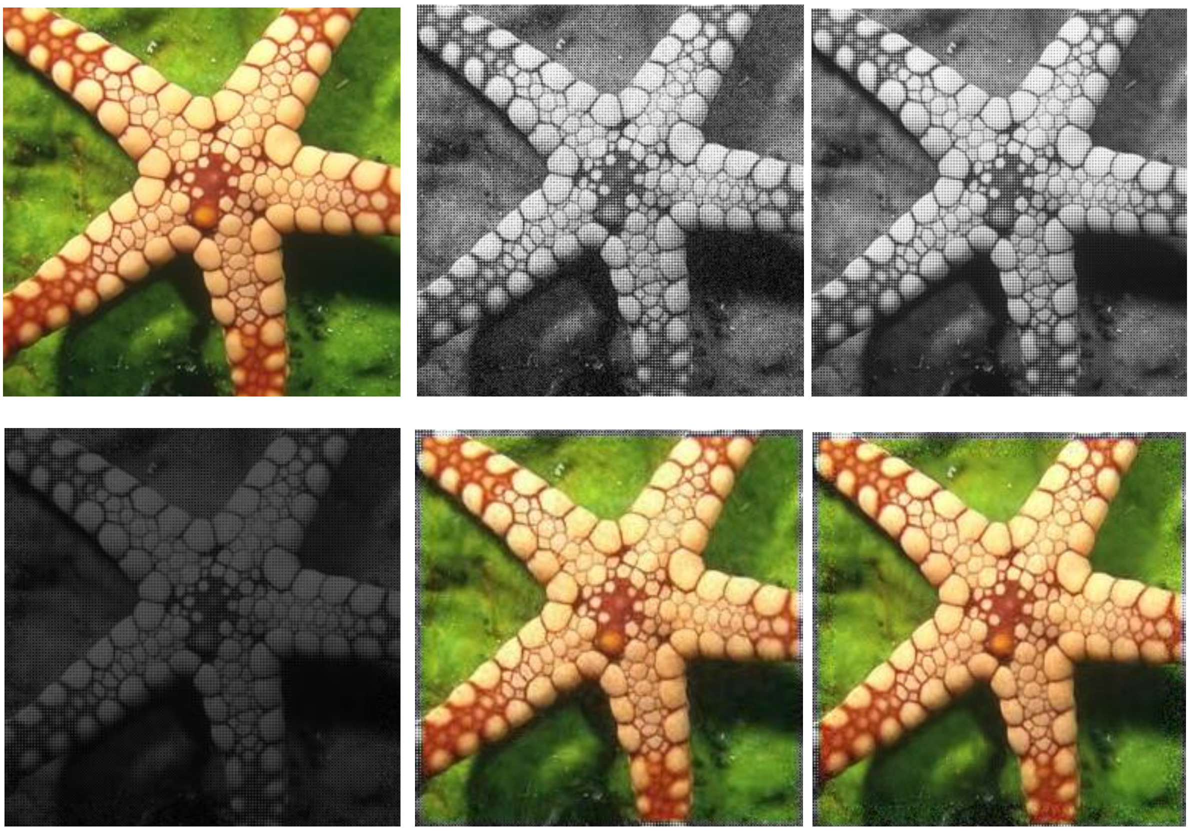

Fig 5.Denoising results of CFA image "*Starfish*." (a) Original CFA image; (b) Noisy CFA image (c) Difference between the denoised and original CFA images by using methods (d) CDM Method (e) Adaptive PCA-based CFA denoising method (f) Proposed Method

TABLE I
PSNR (DB) RESULTS OF THE CFA IMAGES BY DIFFERENT DEMOSAICING METHODS

Images	Demosaicing Methods	**PSNR(dB)**		
		R	G	B
Patheron	Adaptive PCA-based CFA	29.4136	30.1288	29.5041
	Proposed Method	**29.4163**	**30.1282**	**29.7418**
Starfish	Adaptive PCA-based CFA	29.5333	29.7664	29.1352
	Proposed Method	**29.9705**	**30.1248**	**29.7508**
Butterfly	Adaptive PCA-based CFA	28.9792	29.6587	28.1532
	Proposed Method	**29.5431**	**30.0434**	**28.9923**
Fence	Adaptive PCA-based CFA	29.5370	30.1719	29.4746
	Proposed Method	**30.3325**	**30.7160**	**30.3978**

Fig 6. Denoising results of CFA image "*Butterfly*." (a) Original CFA image; (b) Noisy CFA image (c) Difference between the denoised and original CFA images by using methods (d) CDM Method (e) Adaptive PCA-based CFA denoising method (f) Proposed Method

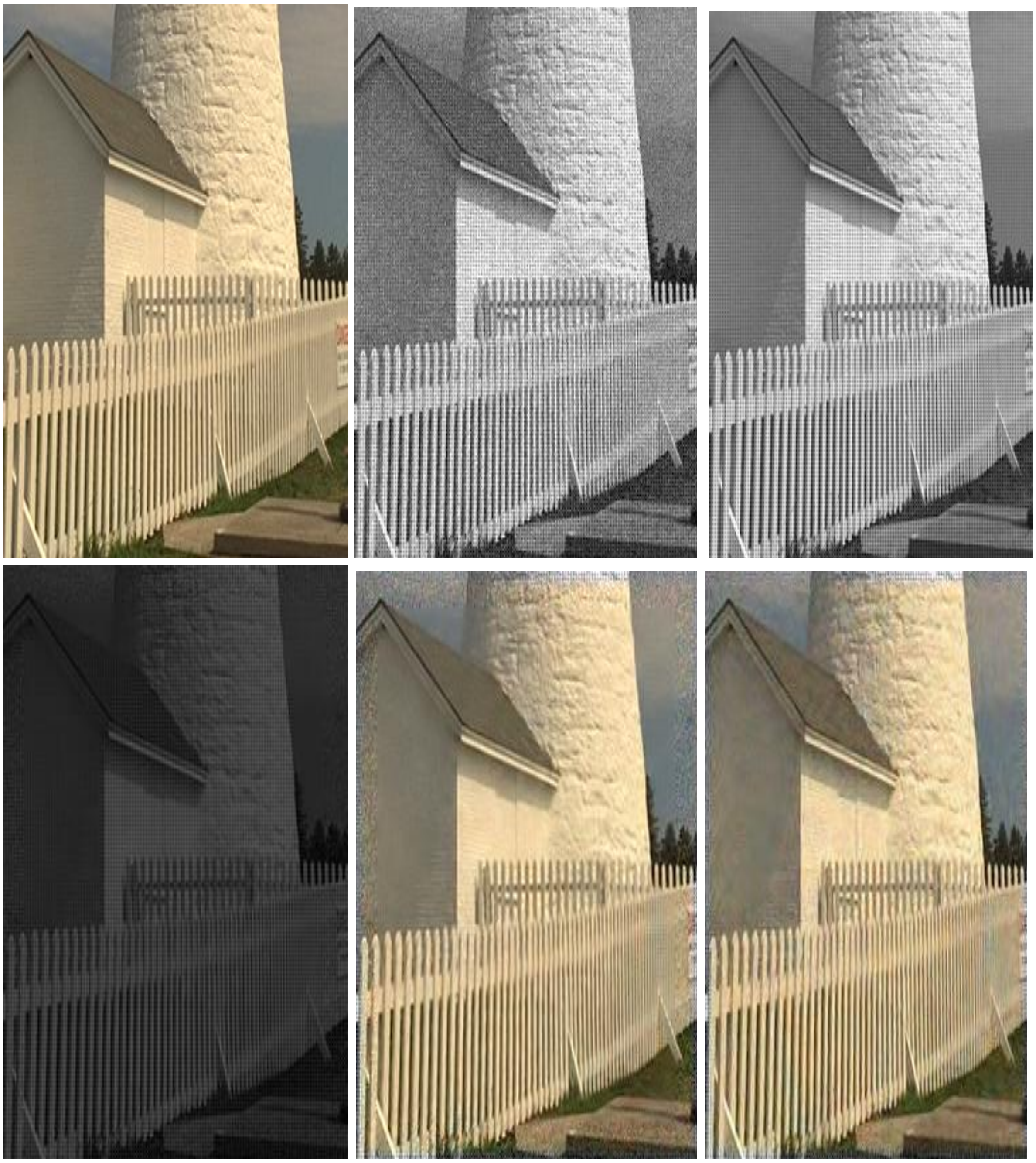

Fig 7. Denoising results of CFA image "*Butterfly*." (a) Original CFA image; (b) Noisy CFA image (c) Difference between the denoised and original CFA images by using methods (d) CDM Method (e) Adaptive PCA-based CFA denoising method (f) Proposed Method

V. CONCLUSION AND FUTURE WORK

A Prediction based lossless compression for Bayer CFA image is proposed and based on the proposed compression scheme architecture, we also propose a context matching technique to rank the neighboring pixels for predicting values of the pixel then color difference is estimated to reduce the spectral redundancy. The prediction residues are then separately encoded. Our future work would be to encode image with adaptive rice coding, then decoded. This decoded image is then introduced to an algorithm known as Demosaicing algorithm used to interpolate a complete image from the partial raw data received from the color-filtered image.

REFERENCES

[1] King-Hong Chung and Yuk-Hee Chan,"A Lossless Compression Scheme for Bayer Color Filter Array Images," IEEE Trans on Image Processing, Vol.17, No.2, February 2008.

[2] B. K. Gunturk, Y. Altunbasak, and R. M. Mersereau, "Color plane interpolation using alternating projections," *IEEE Trans. Image Process.*, vol. 11, no. 9, pp. 997–1013, Sep. 2002.

[3] R. Lukac and K. N. Plataniotis, "Color filter arrays: Design and performance analysis," *IEEE Trans. Consum. Electron*, vol. 51, no. 4, pp. 1260–1267, Apr. 2005.

[4] K. H. Chung and Y. H. Chan, "Color demosaicing using variance of color differences," *IEEE Trans. Image Process.*, vol. 15, no. 10, pp. 2944–2955, Oct. 2006.

[5] C. C. Koh, J. Mukherjee, and S. K. Mitra, "New efficient methods of image compression in digital cameras with color filter array," *IEEE Trans. Consum. Electron.*, vol. 49, no. 4, pp. 1448–1456, Nov. 2003.

[6] S. Battiato *et al.*, "Coding techniques for CFA data images," in *Proc. Int. Conf. Image Analysis and Processing*, Mantova, Italy, 2003, pp. 418–423.

[7] X. Xie *et al.*, "A novel method of lossy image compression for digital image sensors with Bayer color filter arrays," in *Proc. IEEE Int. Symp. Circuits and Systems*, Kobe, Japan, 2005, pp. 4995–4998.

[8] L. Zhang, X. Wu, and D. Zhang, "Color reproduction from noisy CFA data of single sensor digital cameras," *IEEE Trans. Image Process.*, vol.16, no. 9, pp. 2184–2197, Sep. 2007.

[9] D. Paliy, V. Katkovnik, R. Bilcu, S. Alenius, and K. Egiazarian, "Spatially adaptive color filter array interpolation for noiseless and noisy data," Int. J. Imaging Systems and Technology, Special Issue on Applied Color Image Processing, vol. 17, pp. 105–122, 2007.

[10] D. Paliy, M. Trimeche, V. Katkovnik, and S. Alenius, "Demosaicing of noisy data: spatially adaptive approach," *Proc. SPIE*, vol. 6497, pp. 64970K–64970K, 2007.

[11] K. Hirakawa and T. W. Parks, "Joint demosaicking and denoising,"*IEEE Trans. Image Process.*, vol. 15, no. 8, pp. 2146–2157, Aug.2006.

[12] R. Zeyde, M. Elad, and M. Protter, "On single image scale-up using sparse representation," in *Curves & Surfaces,* Avignon-France, pp. 711-730, June 2010.

[13] L. Zhang, L. Zhang, X. Mou, and D. Zhang, "FSIM: A Feature Similarity Index for Image Quality Assessment," *IEEE Trans. on Image Process.,* vol. 20, no. 8, pp. 2378-2386, Aug. 2011.

[14] R. Chartrand and W. Yin, "Iteratively reweighted algorithms for compressive sensing," *IEEE Int. Conf.on Acoustics, Speech and Signal Process.(ICASSP),* pp. 3869-3872, Apr. 2008.

[15] E. J. Candes and M. B. Wakin, "An introduction to compressive sampling," *IEEE Signal Processing Magazine*, pp. 21-30, Mar. 2008