International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 3, Issue 05, March 2016
Available at http://internationaljournalofresearch.org

An Approach for Image Demosaicing Using Content based Strategy

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Abstract –

During an image capture process, a camera performs various including white balance adjustment, auto-focus, color interpolation, color correction, compression and more. In about 10 years, the camera market has grown rapidly to exceed film camera sales. Color images require multiple data samples for every pixel instead of grayscale images for which a pixel is represented by only 1 data sample. For the RGB image format, these data samples represent three color (red, green and blue) channels A typical digital camera captures only one of these simple channels at each pixel location and the other two must be estimated to generate the whole color information. This technique is known as color filter array (CFA) interpolation or demosaicing. The key objective of this paper is to study and analyze the existing techniques such as bilinear interpolation, constant hue based interpolation and the other ones and to provide the insufficiencies existing in these techniques. In this paper content adaptive strategy is implemented because this strategy contently classify the images, produces high quality images and utilizes the correlation between different planes. This strategy is simple not complicated.

Index Terms — Demosaicing; interpolation; ADRC; Color filter array; content clssification.

1. INTRODUCTION

Digital image sensors would be the vital part of one's digital camera. They are the light sensitive film that documents the image and enable you to have a picture. A digital camera sensor is in simple terms comprised of three different layers and these three different layers are:

A. Sensor Substrate

This is actually the silicon product, which steps the light intensity.

B. A Bayer Filter

This can be a colour filter that's bonded to the sensor substrate allowing color to be recorded. It can only just measure how many light photons it collects. It does not have any Means of determining the color of these Photons. As a result, the sensor itself can only just record in monochrome. The Bayer filter, often called the Colour Filter Array acts as a display, only enabling light Photons of a particular color to each pixel on the sensor. Due to the switching layout i.e Red/Green and Blue/Green, it could be named an RGBG filter.

C. Microlens

This tiny lens sits above the Bayer filter and helps each pixel capture just as much light as possible. The pixels don't remain effectively near to each other-there is a little space between them. Any Light that makes this space is wasted light, and won't be useful for the exposure. The microlens seeks to eliminate this light waste by directing the light that falls between two pixels into one or other of them.

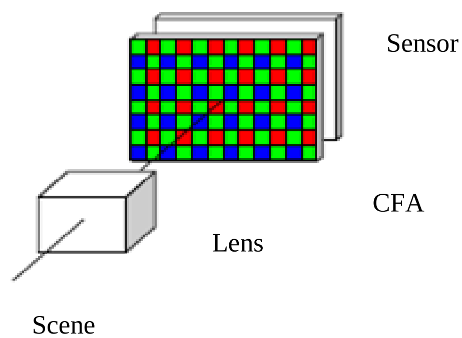

Fig. 1 Three different layer of digital camera

1.1 Full color image

In Bayer design filter, there are blue or red as there are double as many green squares filters. The reason behind double green filters in bayer design is human eye is significantly sensitive to green light than both red and blue. In bayer design image each pixel can only document a single colour of light. Demosaicing is the method of reconstructing the missing color channels of the pixels in the color filtered image using interpolation of neighboring pixels. The output of demosaicing process will be a full color image. The most commonly used method for the interpolation of missing values is to use the spatial invariant methods such as bilinear or bicubic interpolation but these methods may lead to the several kinds of artifacts such as: False color - is visible color errors which arise near the object limits, zipper impact artifacts- manifest as on-off design and are brought on by an incorrect interpolation across edges. Although there have been recent efforts to introduce generalized demosaicing algorithms, most demosaicing solutions are developed for the Bayer pattern. Ryo Kuroiwa et al. plan a novel structure for lossless/near- lossless color image code aided by an inverse demosaicing. CFA (Color filter array whose operator) could be stated as sqaure matrix. By utilizing the inverse matrix of a joint demosaicing and color-to-gray transformation, the planned decoder may recover the color image from its similar gray image information which is losslessly transmitted by the planned encoder. Hence LS/NLS color image reconstruction may be performed while keeping a bit rate significantly [1]. Hasan Azgin et al. proposed powerful Alternate Projection image demosaicing h/w. It is the first AP image demosaicing h/w in the literature. The planned hardware is executed applying Verilog HDL. The Verilog RTL rule is approved to function effectively in a Xilinx Virtex 6 FPGA [2]. Jing-Ming Guo et al. (2000) proposed a classified-based post-compensation algorithm for Color Filter Array demosaicing. Firstly, each pixel is categorized based on its neighborhood structure difference and angle. Various Least-Mean-Square filters are experienced to adopt for dealing pixels of several features. Xingyu Zhang et al. (2000) proposed a Joint Denoising and Demosaicing predicated on inter-Color -correlation (JDDC) scheme. A new platform that linearly mixes an extracted luminance image and a low-passed RGB images to acquire a full color image is proposed. Xiangdong Chen et al. (2000) proposed novel color image demosaicing algorithm. The algorithm present two steps are: An interpolation step, a refinement step. Ling Shao et al. (2000) proposed a content adaptive demosaicing strategy utilizing structure analysis and correlation between the red, green and blue planes. The offline training process optimizes the filter coefficient using pair of full resolution images and mosaic Bayer images. The classification of the pixel is performed by adaptive dynamic range coding. ADRC is computationally less complex as compared to the other strategies [3]. Ibrahim Pekkucuksen et al. planned a demosaicing process that uses multiscale color gradients to adaptively mix color huge difference estimates from various directions. The proposed option doesn’t involve any thresholds because it does not produce any difficult conclusion, and it is non iterative. Ting-Chun Wang et al. planned a self- validation structure for color demosaicking. Numerous methods will undoubtedly be executed to create numerous candidates. After that the final opinion of missing color sample likely to be determining by analyzing the neighbourhood consistency of each algorithm with double interpolation.

2. RELATED WORK OF BAYER PATTERN IMAGE

2.1 Nearest Neighbor Replication

In this easy of color interpolation approach each missing color in a pixel is assigned by the value of the closed pixel of the exact same color in the input image. The closest neighbor can be any one of the upper, lower, left and right pixels. The only benefit of this approach is that computational requirement is really small and suited to applications where speed is very crucial but the significant color errors make it unacceptable for still imaging system, such as for instance high-resolution electronic cameras.

2.2 Initial Bilinear Interpolation

This interpolation strategy was planned in early eighties. They process each element plane individually and discover the missing levels by making use of linear interpolation on the available components in the plane, in both main directions of the image plane. Taking into account the GRG structure, at the middle pixel the missing blue and green values are interpolated by using following bilinear interpolation equations:

$$B = 1/4*(B_{-1,-1}+B_{1,-1}+B_{-1,1}+B_{1,1})$$
$$G = 1/4*(G_{0,-1}+G_{-1,0}+G_{1,0}+G_{0,1})$$

Similarly for RGR structure, missing values are interpolated by:

$$R = 1/2*(R_{-1,0}+R_{1,0})$$
$$B = 1/2*(B_{0,-1}+B_{1,0})$$

After performing the bilinear interpolation, sharpning spatial filter can be used to enhance the edges and remove associated noise. Convolution kernels are used to signify sharpning spatial filter. Big size of the kernel can create higher quality image but it will require more storage and hardware cost. The difficulty of 3x3 measurement kernel is changed by cross model kernel. Additionaly to reduce complexity and hardware cost T-modeled, inverse T-model modeled kernels are proposed for sharpning spatial filter.

2.3 Constant hue based interpolation

Constant hue based interpolation Hue is the property related to dominant (principal) wavelenght in the mixture of lightwaves. Hue provides principal color precieved by an observer. The artifacts occurred in bilinear interpolation due abrupt and unnatural change. In order to over come this, there's a need to maintain hue of colors means that no sudden jumps in hue except for edges. There are subsequent steps to make use of the inter channel correlation according to the color ratio rule as:

Step1:- interpolate green channel by bi-linear interpolation. Step2:- R and B channels are interpolated by averaging their neighbouring shade (color) ratios R/G and B/G and then multiplying the average color ratios by its green values.

R_{11}	G_{12}	R_{13}	G_{14}	R_{15}
G_{21}	B_{22}	G_{23}	B_{24}	G_{25}
R_{31}	G_{32}	R_{33}	G_{34}	R_{35}
G_{41}	B_{42}	G_{43}	B_{44}	G_{45}
R_{51}	G_{52}	R_{53}	G_{54}	R_{55}

Fig. 2 bayer pattern

Mathematically, Step1 is performed as

$$G_{22} = (G_{12} + G_{21} + G_{23} + G_{32}) / 4$$

Step 2:-

$$R_{44} = G_{44} * (\frac{R_{33}}{G_{33}} + \frac{R_{35}}{G_{35}} + \frac{R_{53}}{G_{53}} + \frac{R_{55}}{G_{55}}) / 4$$

$$B_{33} = G_{33} * (\frac{B_{22}}{G_{22}} + \frac{B_{24}}{G_{24}} + \frac{B_{42}}{G_{42}} + \frac{B_{44}}{G_{44}}) / 4$$

2.4 Gradient Based Interpolation

Gradient Based Interpolation this method take the advantage of human eye is more sensitive toward green channel. In this method to do interpolation there are three steps: firstly being the interpolation of green (luminance channel) and second and third being interpolation of color difference i.e. red-green and blue-green. In this method classifiers are being utilized to determine if a pixel belongs to a horozontal or verticle edge. Reference to figure 2 green channels is interpolated by defining classifier α and β as follow

$$\alpha = \text{abs}\ [\ (B_{42} + B_{46.}) / 2 - B_{44}\ ]$$

$$\beta = \text{abs}\ [\ (B_{24} + B_{64}) / 2 - B_{44}\ ]$$

The classifiers are the second derivatives with the sign inverted and halved in magnitude. Following are utilized for estimates the green pixel values

$$G_{44} = \begin{cases} \frac{G_{43} + G_{45}}{2}\ IF \alpha < \beta \\ \frac{G_{34} + G_{54}}{2}\ IF \alpha > \beta \\ \frac{G_{43} + G_{45} + G_{34} + G_{54}}{4}\ IF \alpha = \beta \end{cases}$$

After the interpolation of luninance channels, chrominance channels are interpolated from the difference between the color and luminance signals.

3. RESULT AND DISCUSSION

Todays most of the algorithms and approaches have utilized in order to improve the performance of the demosaicing process out of which one is content adaptive demosaicing strategy. This strategy uses the content and color correlation analysis between the red, green and blue planes to reconstruct a high quality demosaicing image from a bayer pattern in a color filter array. It depends on the two phases; one is training phase and second is testing phase. During the training phase set of image patches are collected randomly from the Kodak image suit. All image patches are classified via fast effective coding technique and look table is utilized for storing the class code and corresponding filter cofficient. Adaptive dynamic range coding (ADRC) is used to contently classification of an image.

Offline procedure provides the training to the different filter and stores the result of different fiters according to class code into lookup table. It takes the target image first and generates its bayer pattern after that the classification is to be performed by using ADRC in order to generate the class code. Corresponding target plan is to be extracted and filter coefficient to be generated by using least square optimization which is further stored into lookup table. Working of offline training process is shown below:

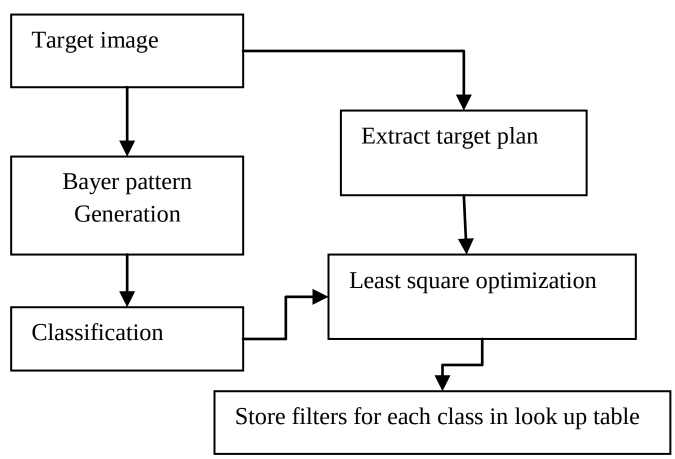

Fig. 3 offline training procecure

Mean square erroe is minimized with the first order derivatives and further equation will be solved by gaussian elimination. Mean square error is evaluated with the equation

After that the trained filter is used in online process to generate full color image. ADRC is the adaptive dynamic range coding which are used to take the average of all the pixels present into the filter of an image. After that the value

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present at every pixel is compared with this average and if the present pixel value is less then this average than it will put 0 at that pixel otherwise it will put 1.

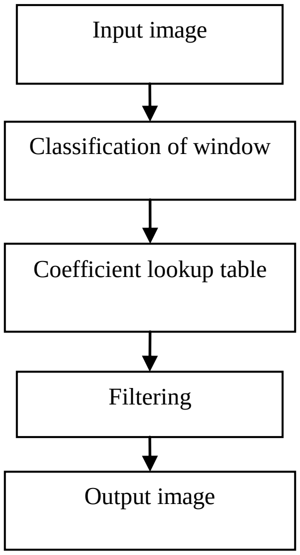


Fig. 4 online procedur

1 2 3

4 5 6

7

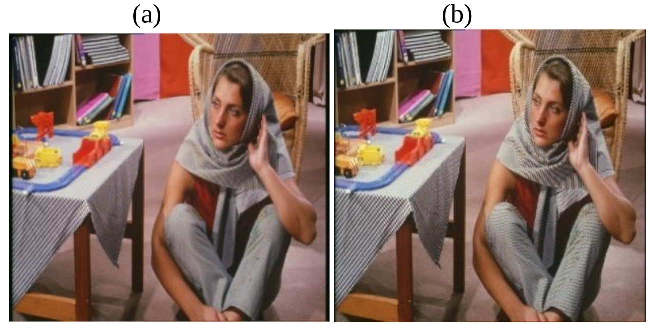
Fig. 5 Kodak set of images

Fig. 5 show the Kodak set of images that are being used for online offline training procedure. Firstly take a target image and generate the bayer pattern, after that ckeck the PSNR of the original image and the image generated by this strategy.PSNR is calculated as

PSNR=10*log (255*255/MSE)/log (10)

This strategy provides the good results for the image quality as comaperd to the others. It is also used to eliminate the false color artifacts and provide the more information to the corresponding image.

(a) (b)



(c) (d)

Result1 (a) input image (b) bayer pattern genetration of input image (c) Demosaicing using bilinear (d) original image by content based color correlation analysis

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(a) (b)

(c) (d)

Result2 (a) input image (b) bayer pattern genetration of input image (c) Demosaicing using bilinear (d) original image by content based color correlation analysis

As compared to the original image demosaicised image is high quality image. Table that is shown below shows the PSNR results of the original images and the demosaicised images.

Table1
Comparison of results (PSNR)

Image No.	Bilinear	Using content based color filter array
1.	26.9	31.8
2.	22.1	26.6
3.	29.9	34.3
4.	37.7	39
5.	29.8	32.5
6.	29	31.8
7.	34.9	38.8
Avg	**30.04**	**33.54**

Results images shown in result 1 and result 2 shows that firstly preprocessing operations has been performed on the input image and after that full color images has been recovered by using interpolation strategies. In this paper, bilinear interpolation and content based CFA strategies has been utilized and their performance is shown in table 1 based on PSNR analysis.

Table2
Comparison of results (MSE)

Image No.	Bilinear	Using content based color filter array
1.	130	42
2.	395	141
3.	14	412
4.	66	24
5.	67	36
6.	81	42
7.	21	10
Avg	**110.57**	**101**

From the above table results of content based strategy as compared to bilinear interpolation are much better on the basis of MSE analysis.

3.1 Parameter Analysis

On the basis of following parameters results of the images has been evaluated:

- PSNR (Peak Signal to Noise Ratio)

The term peak signal-to-noise ratio (PSNR) is an expression for the ratio between the maximum possible value (power) of a signal and the power of distorting noise that affects the quality of its representation. PSNR is evaluated by

$$PSNR = 10 * \log(255 * 255 / MSE) / \log(10)$$

Where, 255 is the maximum power of the signal.

- MSE (Mean Square Error)

In this research $M \times N$ represent the size of the each image. Where M represents the no. of rows and N represents the no. of columns. The original image is represented by the function $f(i, j)$ at location i, j and the filtered image i.e. full color image is represented at location i, j by $\hat{f}(i, j)$. mean square error between original image and demosaicised image is evaluated by using following equation:

$$MSE = \frac{1}{MN} \sum_{i=1}^{M} \sum_{J=1}^{N} (f(i, j) - \hat{f}(i, j))^2$$

4. CONCLUSION AND FUTURE SCOPE

There are several demosaicing stratgies in order to generate full colr image from bayer patteren. But some strategies produces the color arefacts like false color generation, poor contrast etc. The content based color correlation strategy has proven to be quite effective because in it images are classified via adaptive dynamic range coding and filter coefficient are generated by least square optimization. In the online process same classification is performed and full color image is generated by demosaicing. This paper has shown that the strategy is simple, not complicate, produces a high quality image and utilizes the correlation between different planes. Overall this technique produces high resolution and quality of the image but still there are some limitations of this strategy such as take more memory while providing the training to the different samples. Further the working of this strategy can be improved by using fuzzy logic or other soft computing tool to reduce the color artifacts in more optimistic manner. Fuzzy will use multivalent logic to produce the interpolated color in more optimistic manner.

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