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Masking Based Demosaicking for Image Enhancement Using Plenoptic Camera

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Abstract

This paper presents a demosaicking method by applying empty spaces between lenses of a plenoptic camera to the Hamilton-Adams (HA) method. Unlike standard cameras, plenoptic cameras have a structure where a circular micro lens array is placed between the main lens and the sensor for acquiring three-dimensional information of objects. However, due to the structure different from standard cameras, the conventional demosaicking techniques is not suitable for plenoptic cameras. Also, the standard demosaicking techniques degrade image quality by interpolating empty spaces between lenses, resulting in color artifacts. Thus, this paper presents a new demosaicking method utilizing the information on the empty spaces between lenses in a plenoptic camera. The proposed method introduces a masking method to generate a color image from CCD data. The proposed method can improve image quality of resulting images by the proposed masking method. To evaluate our method, we compare our method with the existing methods both objectively and subjectively. The experimental results indicate that the proposed method is superior to the existing methods.

Keywords: Demosiacking, Hamilton-Adams method, Light field coding, Plenoptic coding, Interpolation, CFA interpolation, Plenoptic interpolation

INTRODUCTION

The plenoptic camera has a structure in which an array of micro lens interpose in between the main lens and the image sensor. Thus, the plenoptic camera enables instantaneous capture of light fields with both angular and spatial information of the scene, in contrast to regular images with only 2D spatial coordinates. The acquired information about an image can be restored 3D images by applying integral techniques [1, 2].

The plenoptic camera is essentially a single-shot, multiview acquisition device. A high resolution sensor is generally used to acquire multiview in single-shot via the lenslet array. However the resulting images still have a low resolution. Image quality is a very important factor that determines the performance of the system in image systems. Therefore, research to enhance image quality is indispensable.

As with standard cameras, the plenoptic camera captures color information with a color filter array (CFA) covering the sensor pixels. Therefore, it is possible to improve the quality of the image by the demosaicking method. For each pixel there is only information on one color. So, demosaicking is essential to interpolate the missing colors at a pixel from the colors of the neighboring pixels. Many studies related to the demosaicking techniques have been discussed in different ways to improve image quality [3-12]. There are methods using general interpolation such as linear interpolation [3, 4], methods using edge direction [5-7], methods utilizing correlation between color plane [8, 9], Iteration interpolation [3, 10], interpolation based on noise removal technique [11] and frequency domain interpolation [12]. However, a raw image which is a set of element images has a structure different from the standard image, as depicted in Fig. 1. Therefore, unlike existing demosaicking methods, various demosaicking techniques using the features of plenoptic images have been studied recently [13-19]. Most methods overlook the pixels in the empty space caused by an array of circular lenses, which is the most important feature of plenoptic images.

Thus, in this paper, we provide an improved HA method in order to improve image quality of 3D imaging. The proposed method apply the information on empty space between the lenses to HA method. The HA is a simple but effective technique for improving the image resolution among existing demosaicking techniques. The mask data is set of pixels in the empty space obtained by a black and white image. This is applied to the HA method, omitting unnecessary processes and improving performance.

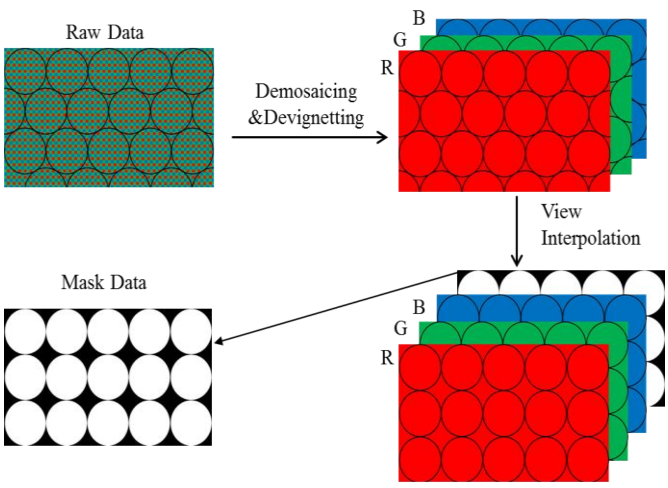


Figure 1. Basic architecture from a raw data to RGB images and a mask image

RELATED WORK

1. BILINEAR INTERPOLATION

Bilinear interpolation interpolates the missing pixel with the average of neighboring pixels. Demosaicking based on bilinear interpolation is the easiest method. Bilinear interpolation's hardware implementation is easy at low cost, but it have a blurring phenomenon in areas of uniform color. Also it generates zipper effect along the edges and color noise in high-frequency areas. These problems degrade the resolution of images.

2. HAMILTON-ADAMS (HA)

The HA algorithm detects the high frequency of surrounding pixels and reconstructs the image along the direction of that. This method uses the Laplacian equation of neighboring pixels along the direction to detect high frequencies along the edge direction. It uses other planar pixels as well as coplanar pixels. Therefore, the high frequency can be detected more accurately. In the calculation process for predicting interpolated pixels, we perform a low-pass filter of pixels in the same plane and perform a high-pass filter of pixels in the other plane. The missing pixel interpolates by including both low frequency and high frequency so that increase the accuracy of the predicted value. The HA uses a sequential method of interpolating the G-plane which has many pixels of the CFA and then restoring the R/B-plane using the fully interpolated G-plane.

2.1 G-plane Interpolation

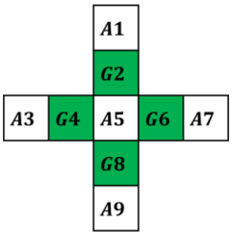


Figure 2. Pixels for reconstruction of G-plane in HA method

The G-plane has a quincunx form in the CFA. The pixel value similarly does not exist in the diagonal and reverse diagonal directions around the point where there is no pixel value but there are pixel values in the horizontal and vertical directions. Therefore, the direction of the edge is set in both the vertical and horizontal directions in the luminance region reconstruction to execute restoration along the edge direction.

The G-plane first calculates gradient for the direction of vertical and horizontal edges, and then restores the interpolated pixel along each direction. The value to be interpolated is determined based on the comparison of two gradient values calculated previously. The pixels used for interpolation are shown in Fig. 2. For example, in an application that interpolates the position of G5, the horizontal gradient (DH) and the vertical gradient (DV) can be obtained as follows.

$$\mathrm{DH} = |-A3 + 2A5 - A7| + |G4 - G6| \quad (1)$$

$$\mathrm{DV} = |-A1 + 2A5 - A9| + |G2 - G8| \quad (2)$$

The values H and V interpolated along the direction are defined as follows.

$$\mathrm{H} = (\mathrm{G4} + \mathrm{G6})/2 + (-\mathrm{A3} + 2\mathrm{A5} - \mathrm{A7})/\,4 \quad (3)$$

$$\mathrm{V} = (\mathrm{G2} + \mathrm{G8})/2 + (-\mathrm{A1} + 2\mathrm{A5} - \mathrm{A9})/\,4 \quad (4)$$

The G5 is estimated to H if it is interpolated horizontally and estimated to V if interpolated vertically through the comparison of the determined DH and DV result values.

2.2 R/B-plane interpolation

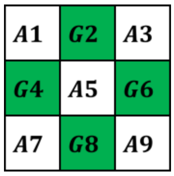


Figure 3. Pixels for reconstruction of R/B-plane in HA method

R / B color is only one pixel value among 2 × 2 size repetitions of the CFA. Therefore, interpolation of the remaining three places is necessary. R/B-plane interpolation uses the color of the same plane and the value of the pre-reconstructed G-plane. Pixels of Fig. 3 is necessary to restore one color plane in this process. Since R/B-plane has the same shape, they are expressed as A-plane. Based on Fig. 3, interpolation method divided into two cases when reconstructing the A-plane. There are pixels in the same plane present on the left and right of the restored position or present up and down of the restored position. For example, restoring the position of A2 as in Eq. (5) is the case where the same plane pixels are present on the left and right, restoring the position of A4 as in Eq. (6) is the case where the same plane pixels are present on top and bottom. If pixels in the same plane exist on the left and right so as to interpolate the position of A2, it is interpolated using the left and right pixels and the high frequency of the restored G-plane of that position. If the same plane pixels are present top and bottom so as to interpolate the position of A4, interpolation is performed by using the top and bottom pixel values and the high frequency of the G-plane recovered to that place.

$$\mathrm{A2} = (\mathrm{A1} + \mathrm{A3})/2 + (-\mathrm{G1} + 2\mathrm{G2} - \mathrm{G3})/2 \quad (5)$$

$$\mathrm{A4} = (\mathrm{A1} + \mathrm{A7})/2 + (-\mathrm{G1} + 2\mathrm{G4} - \mathrm{G7})/2 \quad (6)$$

Finally, the same plane pixel sometimes exists diagonally and reverse diagonally when interpolating the A-plane. For example, it is the case of restoring the position of A5 as in Eq. (7). In this case, interpolation can be performed along both directions, so gradients in each direction are obtained and pixels are interpolated to that value is determined. The diagonal gradient value DN and the reverse diagonal gradient value DP are as follows.

$$DN = |-G1 + 2G5 - G9| + |A1 + A9| \quad (7)$$

$$DP = |-G3 + 2G5 - G7| + |A3 + A7| \quad (8)$$

Similarly, the value of A5 restored is determined based on the comparison of the gradient value, and the interpolated values N and P are as follows.

$$N = (A1 + A9)/2 \;+\; (-G1 + 2G5 - G9)/2 \quad (9)$$

$$P = (A3 + A7)/2 \;+\; (-G3 + 2G5 - G7)/2 \quad (10)$$

PROPOSED SYSTEM

In this chapter, we propose the improved HA method by applying mask information. The characteristic of plenoptic images are that there is an empty space in images because of the circular lens arrangement. The empty space of the image has no information about the image, rather it interrupts the image processing. Therefore, the proposed method omits unnecessary arithmetic processing of the empty space to improve accuracy.

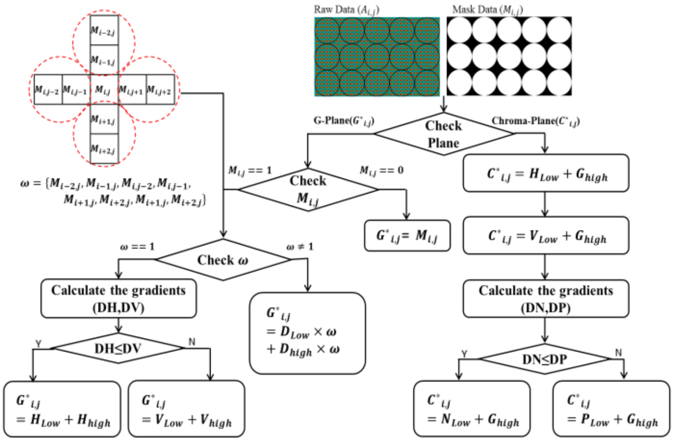
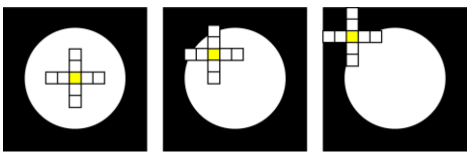


Figure 4. Block diagram of the proposed method

The proposed demosaicking method is as shown in the Fig. 4. Mask data is extracted from the raw image of the plenoptic image. The missing color information is interpolated only the pixels in the mask data except for the pixels of the empty space through the acquired mask data. Frequency components in R/B-plane are restored by discrimination between high frequency and low frequency based on HA method. The mask data is used only in the G-plane interpolation process. The G-plane interpolation is divided into three cases as shown in the Fig 5.



(a) (b) (c)

Figure 5. Cases of the G-plane interpolation

First the case in Fig.5 (a) is that the missing pixel exists in the mask and all eight neighboring pixels necessary for restoration are present in the mask. In this case, since there is no unnecessary data, the HA method is applied. The second case as shown in Fig.5 (b) is when the pixel to be restored exists in the mask and only a part of the adjacent eight pixels exist in the mask. For example, restoration of A5 in Fig. 2 is the same as Eq. (11). The mask data is denoted by M and has a value of 1 if it is in the mask, and a value of 0 otherwise.

$$\left(\sum_{k=1}^{4} A_{2k} \cdot M_{2k} \Big/ \sum_{k=1}^{4} M_{2k}\right) + \quad (11)$$
$$\left\{\left(\sum_{k=1}^{4} M_{2k-1} \times A5 - \sum_{k=1}^{4} A_{2k-1} \cdot M_{2k-1}\right) \Big/ \left(2 \times \sum_{k=1}^{4} M_{2k-1}\right)\right\}$$

Finally, for the case in Fig. 5 (c) is that the missing pixel does not exist in the mask. It means that the pixel to be restored corresponds to a blank. Therefore, it is reconstructed as a background color without complicated operation.

SIMULATION

To evaluate our method, we compare our method with the existing methods both objectively and subjectively. Experimental images are shown in Fig. 6. These images are eight plenoptic raw images of 7560 x 5250 sizes taken with the Lytro Illum camera. These images provides the results of objective, subjective experiments. For comparison, two existing demosaicking algorithms, including LI [20] and HA [3], were implemented. We measured the peak signal to noise ratio (PSNR) of the interpolated G-planes of experimental methods.

Figure 6. Plenoptic raw images

Table 1. PSNR results for plenoptic raw data set

	LI	HA	Proposed Method
Bike	25.27	29.27	44.16
Building	27.84	31.63	45.89
Car	25.08	28.86	43.31
Flower	24.06	28.10	42.29
Fruit	25.62	29.58	52.79
General	24.68	28.80	42.69
People	26.28	30.56	42.5
Reflective	23.30	28.97	43.69
AVE	25.27	29.47	**44.67**

Table 1 shows the PSNR values of the results of the respective methods. Simulation results show that the proposed method is superior to the lasted demosaicking algorithms for all images. The proposed method improved on average by 15.2dB compared with HA method and showed a maximum improvement of 23.21dB according to an image. The advantage of the proposed method comes from the introduction of information on the empty space which is a value that disturbs during the image process. There are enlarged images of an original image and the result of each methods as shown in Fig. 7. The proposed method has no zipper effects near the lens's edge at all than existing methods. Thus, the proposed method is superior to the existing methods both objectively and subjectively.

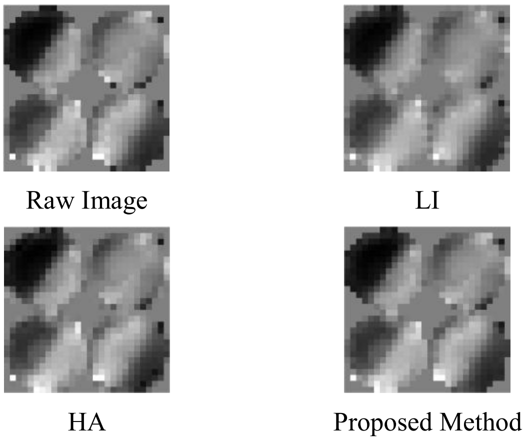


Figure 7. Resulting images from plenoptic raw images at "Flower"

CONCLUSION

In this paper, we proposed a demosaicking algorithm to apply the empty space between lenses from plenoptic image to HA method. The empty space generated due to the circular lens shape does not have any image information. So unnecessary image process of empty space are removed. In the objective performance evaluation using PSNR with the conventional method and the proposed method showed remarkably excellent performance. Also, subjective performance evaluation confirmed that image restoration is performed better than the conventional method. These results are expected to improve the imaging quality with the extension of the demosaicking technique of plenoptic images. We are going to further optimize the research of demosaicking technology further expanded in this paper applying R/ B-plane restoration mask information and the imaging technology of plenoptic video in the future.

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