

# An Improved Demosaicking Algorithm Based on Region-Dividing

Zheyuan Chen

Beijing 21st Century International School  
qietfy00@outlook.com

**ABSTRACT.** The Bayer Color Filter Array (CFA) is commonly used in such industries as digital cameras. However, due to the arrangement of color channels in the Bayer CFA, it becomes a problem to estimate the missed color information in each pixel. The algorithms that deal with this problem are named "demosaicking algorithms". There are many demosaicking algorithms, which show different efficiencies and image qualities for different images. This paper proposes an algorithm that combines two existing algorithms to reach better image qualities and acceptable computing complexities. The experimental results indicate effectiveness in terms of the balance between complexity and quality.

**KEYWORDS:** demosaicking algorithm, Bayer CFA, interpolation

## 1. Introduction

In the industry of cameras, for the sake of the balance between image quality and computing complexity, many manufacturers adopt the Color Filter Array (CFA). We generally adopt the Bayer CFA, where red, green, blue channels are included and arranged in a way that each pixel contains only one of the three colors, as shown in the Figure 1.

The arrangement of color channels triggers the need of interpolation and demosaicking, in that we need an algorithm to estimate and thus complete three colors in one pixel in order to obtain the final image. Many demosaicking algorithms have been proposed.

Generally, demosaicking algorithms based on linear interpolation use the colors of neighboring pixels to recover missing color information on each pixel. However, the inaccuracy of estimate causes a variety of problems, such as Zipper Effect and Color Moire Effect.

The algorithm proposed by Cok [1], based on color ratios, successfully utilizing the correlation of different color channels. This algorithm provided great ideas to later algorithms. However, the color ratios interpolation has its flaw in that if the color information is low in the picture, the final result will lose accuracy.

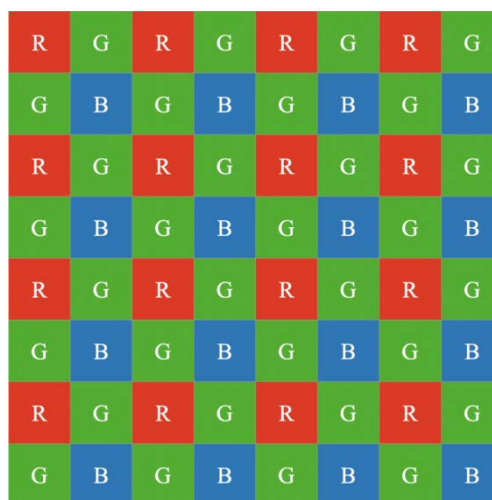


Figure. 1 Illustration of a Bayer CFA

In the algorithm proposed by Ron Kimmel [2], which was inspired by Cok's [1] algorithm, the weighting coefficient computed by differential along eight directions is first proposed. Besides, the color ratio rule is used in this algorithm. The algorithm improves the image quality with low computational complexity, but also brings a problem when the green components are low or incomplete, since the green components are used as denominators.

In the algorithm proposed by Menon et al [3], the color difference rule is used after the green information being interpolated by bilinear method. Similarly, Lei et al [4] proposed the demosaicking algorithm. The algorithm estimates the color difference gradient in local area and then interpolate along two directions (vertical and horizontal). This algorithm provides good image quality with relatively low computational complexity, but the Zipper Effect and Color Moire Effect still exist.

T. Saito and T. Komatsu proposed total-variance (TV) based algorithm [5] and then introduced TV regularization of color differences and color sums [6] in order to reduce the color artifacts. This algorithm significantly enhances the image quality and is robust to noise.

As for the self-similarity driven demosaicking (SDD) algorithm by Antoni Buades et al [7], the algorithm searches similar pixels in within a given window in the whole raw images. Aside from other conventional algorithms, this algorithm uses the nonlocal information. The algorithm has great advantage in natural images, and effectively reduces or avoids the Zipper Effect and restores highly repeated parts.

In the algorithm proposed by Zhang et al [8], the original green information is used to estimate the interpolational direction, and then the color difference is used to compute coefficient which is used to interpolate. This algorithm effectively improves the image quality. Meanwhile, the computational complexity is decreased.

Aside from the simple color difference model, Chen et al [9] proposed color covariance-based adaptive demosaicking (CCAD) algorithm, using geometric duality to estimate color covariance. Compared with other classic algorithms, CCAD estimates all the missing colors at the same time. As a result, the green component won't affect the overall interpolation to significant extent. Furthermore, this algorithm divides raw images to two regions: complex region, where CCAD algorithm is used, and smooth region, where conventional algorithm is applied. Therefore, the overall computational complexity is significantly reduced and the speed is improved.

Considering all the algorithms mentioned, we find that each algorithm has its own advantages and disadvantages. Based on this, a new algorithm has been proposed, which combines several different algorithms for the sake of better demosaicking effect. In practice, the algorithms proposed by Hibbard [10] and Zhang et al [8] are selected to be the base algorithms for the new one. The proposed algorithm divides the whole image into several regions, then detects certain characteristics of the region, and thus chooses the optimal algorithm for each region.

The proposed algorithm has three main advantages. Firstly, it shows better image quality than the other two algorithms which it bases on, in the perspective of both experimental analysis and subjective evaluation. Secondly, the complexity of the proposed algorithm is within the acceptable range and is much lower than that of the Zhang et al algorithm [8] it utilizes. This indicates that the approach to combining several simple and complex algorithms for the sake of relatively low complexity and high image quality is reachable. Thirdly, this algorithm provides applicable ideas for further work, which may focus on incorporating more effective algorithms and enhancing the region-dividing process.

In the second part of this paper, the process of the proposed algorithm, from dividing regions and detecting certain characteristics to choosing the corresponding algorithms, has been specifically stated. The third part of the paper focuses on the experimental results, which compare the algorithm proposed by Hibbard [10], Zhang et al [8], and the author of this paper. In the fourth part of the paper, the conclusion and the potential future work are listed.

## 2. Proposed Algorithm

To make sure the demosaicking methods are practical and efficient, the balance between computational complexity and the quality of result must be taken into account. Since images are complicated, including both smooth region and complex region, each algorithm can not perform perfectly for the whole image overall. Therefore, the new algorithm combines two previous algorithms proposed by Hibbard [10] and Zhang et al [8]. This proposed algorithm divides the holistic Bayer CFA into different regions and examines the characteristics, thus choosing the optimal algorithm for each region in terms of quality and complexity. Figure 2 shows the overall process of the algorithm.

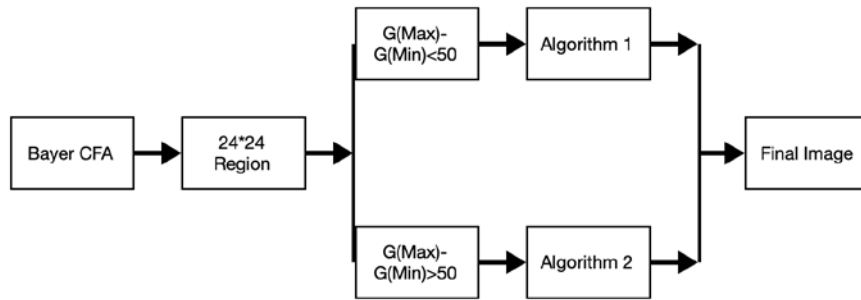


Figure. 2 Overall process of the proposed algorithm

### 2.1 Dividing regions

Compared with the blue or red channel information, green channel information doubles in Bayer Array, as shown in Figure 1. Furthermore, the edge in an image generally embodies in all three color channels. Therefore, green channel alone can be used to estimate the existence of edge. Admittedly, there are some special cases in which green information cannot perfectly represent the existence of edge. Nevertheless, by only using green channel information to estimate edge, we can reduce the complexity of the algorithm and thus the computing time. Besides, this means is effective in most images. According to many experiments, the difference between the maximum and minimum value of green component in a small region can reflect the existence of an edge to a great degree.

By experiments, it can be concluded that the Hibbard algorithm shows superiority, in both the final quality and the computing time, when dealing with the region where an edge is not likely to exist or the edge is slight, compared to the algorithm proposed by Zhang et al. When dealing with the region where the edge is likely to exist, the algorithm proposed by Zhang et al shows greater final image quality than Hibbard Algorithm, since this algorithm considers the color channel in nearby area, uses the gradient information to calculate a weighting coefficient, and has a self-correcting process. Therefore, we propose that in each region, when the difference between the maximum and minimum value of green components exceeds certain value, the algorithm proposed by Zhang et al [8] is chosen. Otherwise, we choose the algorithm proposed by Hibbard [10].

According to experiments, it is optimal to divide the whole picture into several 24\*24 regions. For each region, the maximum of Green pixel is compared with the minimum value. If the difference does not exceed 50, the demosaicking 1 based on the Hibbard algorithm [10] is used for the region. Otherwise, the algorithm 2 based on the algorithm proposed by Zhang et al [8] is used.

### 2.2 Algorithm 1

This algorithm is based on the algorithm proposed by Hibbard [10].

The algorithm first uses gradient information to estimate possible edge direction, then interpolating G channel along the direction. After interpolating all green information, the algorithm uses G-R and G-B color difference to inter the red or blue information in each pixel.

### 2.3 Algorithm 2

This algorithm is mainly based on the algorithm proposed by Zhang et al [8].

This algorithm first uses gradient and nearby color channel to calculate G-R and G-B color difference in G position. Next, the algorithm interpolates G information in R and B position, using gradient information to determine the coefficient and color difference to confirm the result of G. After that, the algorithm computes G-R and G-B information in B and R position, respectively. By using the new computing color difference, the algorithm corrects and improves the accuracy of color difference in G position. Finally, the algorithm uses the eventual color difference to interpolate R and B values in each pixel.

### 3. Experimental result

The effect of the proposed algorithm, which is named Region-Dividing Demosaicking (RDD) algorithm, is analyzed experimentally. Generally, the proposed algorithm and the algorithm proposed by Hibbard and Zhang et al, the base of the new algorithm, are compared.

The Peak Signal to Noise Ratio (PSNR) is an effective means to examine the quality of reconstructed image. Generally, the higher the value of PSNR, the higher the quality of the reconstructed image.

The Structural Similarity Index (SSIM) measures the similarity between two images. SSIM is used here to examine the similarity between images reconstructed by each algorithm and the original images. SSIM gives a value between 0 and 1. The higher the value of SSIM, the higher the similarity between the two images and thus the greater the quality of reconstructed image is.

The computing time is an indicator of the complexity of the algorithm. In terms of the practicality, the computing time of one algorithm should not exceed certain limit. The computing time of the three algorithms mentioned above is compared.

Overall, four images are tested, which are listed in Figure 3. Table 2 and 3 show the results. Additionally, the comparison of the reconstructed images and the original image for one of the tested image is provided in Figure 4.

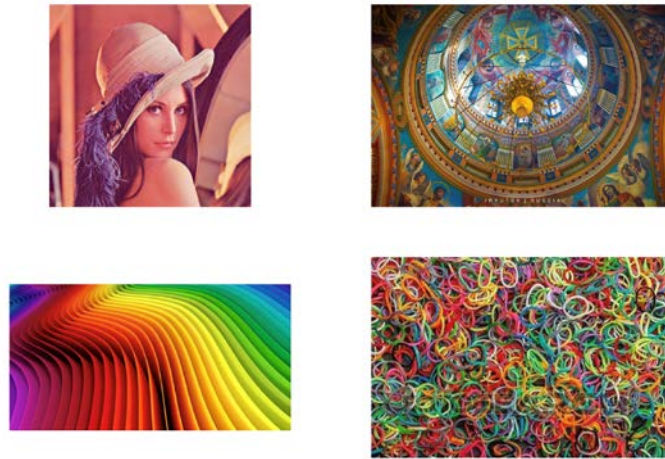


Figure. 3 The set of tested images. The order is from left to right and up to down

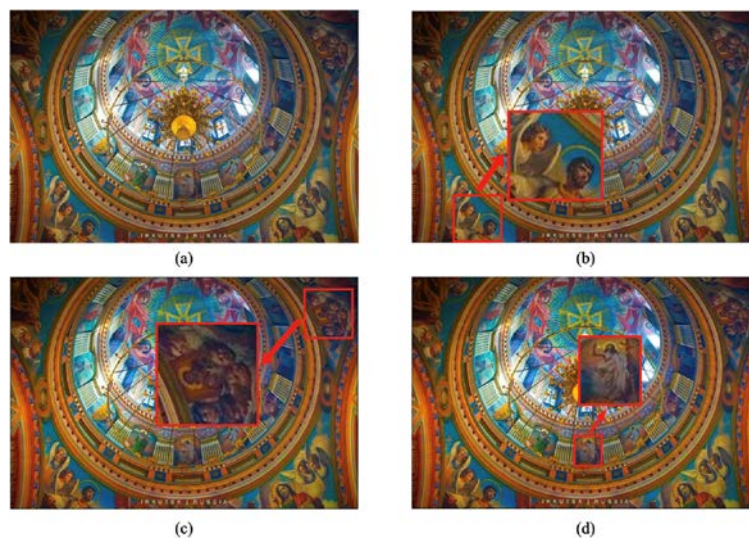


Figure. 4 (a) shows the original image, (b) (c) (d) show the image reconstructed by Hibbard, Zhang et al, and proposed algorithm, respectively

It turns out that most figures, the PSNR and SSIM values for the proposed algorithm (RDD) are the highest among the three. This indicates that the quality of demosaiced figures is the highest for the proposed algorithm, illustrating the effectiveness of it. Moreover, the computing time of the proposed algorithm is significantly lower than that of the Zhang et al's algorithm, which means that the complexity of the proposed one is greatly lower than that of Zhang et al's. When compared with Hibbard's algorithm, the computing time for proposed algorithm is higher but with a small magnitude. Therefore, the complexity of the proposed algorithm is acceptable, compared with Hibbard's algorithm.

*Table 1 Experimental Result of the top two test images*

Algorithm	Image 1		Image 2		Image 3		Image 4	
	PSNR	SSIM	Computing Time		PSNR	SSIM	Computing Time	
Algorithm Proposed by Hibbard	<b>41.222</b>	<b>0.966</b>	<b>0.118</b>	34.953	0.927	0.039	0.098	41.356
Algorithm Proposed by Zhang et al	35.314	0.847	0.415	34.960	0.940	0.124	0.327	35.668
RDD	37.243	0.903	0.240	<b>36.234</b>	<b>0.956</b>	0.295	<b>43.784</b>	<b>0.985</b>
			0.058	<b>35.282</b>	<b>0.958</b>	<b>0.036</b>		

*Table 2 Experimental Result of the top two test images*

Algorithm	Image 3		Image 4		Image 3		Image 4	
	PSNR	SSIM	Computing Time		PSNR	SSIM	Computing Time	
Algorithm Proposed by Hibbard	<b>41.356</b>	<b>0.976</b>	<b>0.047</b>	32.982	0.927	0.039	0.039	41.356
Algorithm Proposed by Zhang et al	35.668	0.870	0.153	33.037	0.945	0.124	0.124	35.668
RDD	43.784	0.985	0.058	<b>35.282</b>	<b>0.958</b>	0.036	<b>43.784</b>	<b>0.985</b>
			0.058	<b>35.282</b>	<b>0.958</b>	<b>0.036</b>		

#### 4. Conclusion

This paper proposes an on region-dividing demosaicking algorithm. Generally, it divides the whole Bayer CFA into several regions and detects certain characteristics in the region. Finally, it chooses corresponding algorithms to conduct the interpolation process.

The proposed algorithm shows its effectiveness in terms of the image quality and the computing complexity, compared with the other two algorithms it bases on.

Further work may focus on combining more sophisticated and efficient demosaicking algorithms referring to the frame provided by this paper. The standard used to divide regions and find the optimal algorithm for each region may be a possible direction of study.

#### References

- [1] David Cok. "Reconstruction of CCD images using template matching". In: (Jan. 1994).
- [2] R Kimmel. "Demosaicing: image reconstruction from color ccd samples". In: Image Processing IEEE Transactions on 8.9 (1999), pp. 1221-1228.
- [3] M. A. Eskelinen and J. Hamalainen. "Dangers of Demosaicing: Confusion. From Correlation". In: 2018 9th Workshop on Hyperspectral Image and Signal Processing: Evolution in Remote Sensing (WHISPERS). 2018, pp. 1-5.
- [4] Lei Hua, Lei Xie, and Huifang Chen. "A color interpolation algorithm for Bayer pattern digital cameras based on green components and color difference space". In: 2010 IEEE International Conference on Progress in Informatics and Computing. Vol. 2. 2010, pp. 791-795.

- [5] T. Saito and T. Komatsu. "Demosaicing approach based on extended color total-variation regularization". In: 2008 15th IEEE International Conference on Image Processing. 2008, pp. 885-888.
- [6] Takashi Komatsu. "Sharpening-demosaicking method with a total-variationbasedsuperresolution technique". In: Proceedings of Spie the International Society for Optical Engineering 5678 (2005), pp. 177-188.
- [7] A. Buades et al. "Self-Similarity Driven Color Demosaicking". In: IEEE Transactions on Image Processing 18.6 (2009), pp. 1192-1202.
- [8] Zhang Qigui and Zhao Lijuan. "Implementation of bayer image interpolation based on FPGA". In: 2012 6th International Conference on New Trends in Information Science, Service Science and Data Mining (ISSDM2012). 2012, pp. 45-49.
- [9] Xiangdong Chen, Qi Wang, and Youngsup Lee. "Real-time demosaicking method based on mixed color channel correlation". In: Journal of Real-time Image Processing 16.1 (2019), pp. 61-69.
- [10] Robert H Hibbard. Apparatus and method for adaptively interpolating a full color image utilizing luminance gradients. 1995.