Academic Year 2023 – 2024
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EEH

Image Analysis course SICOM 3A - Project

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January 30, 2024

Abstract

In this report, we will test and analyse different color demosaicing methods using multiple instanciate images with a classic Bayer mask. We will use two methods of interpolation. We will also try out different filters. Analysis of the quantitative results will show that we can obtain a very accurate reconstruction.

Keywords: Image Analysis, image processing, RGB, demosaicing methods

1 Introduction

The goal of this project is to delve into the intricate process of demosaicking, aiming to recover all the missing colors for each pixel to reconstruct the full RGB image. By exploring and implementing three distinct demosaicing methods compare the efficacy and outcomes of each method. The two methods we'll be using will then be compared with a conventional bilinear interpolation method. They will be based on articles by Malvar et al. [2004] and Menon et al. [2007]. This comparison will provide a comprehensive understanding of how different approaches tackle the complex task of color reconstruction.

2 Methods of demosaicing of bayer-patterned color

2.1 Improved linear interpolation - Malvar method

In this section, I'm going to present the method described in the article : Malvar et al. [2004]. This method is a process of reconstructing a complete colour image from incomplete colour samples. Unlike traditional methods, which are often based on a constant or near-constant hue approach, this method introduces a new criterion based on the observation that the edges of an image generally show more marked changes in luminance. Firstly, the method does not reject the existing colour value in a pixel (e.g. red in a green pixel location) as it provides valuable information and evaluates the existing colour value against its estimation by bilinear interpolation based on nearby samples of the same colour. Then, if there is a significant difference from the bilinear estimate, this indicates a net change in luminance. The method then adjusts the bilinearly interpolated green value by adding part of this estimated change in luminance. For example, to interpolate G values (green) to R locations (red), the method involves the gradient of R and a correction factor (α) :

$$P_{est} = P_{blue} + \alpha * Grad_{Red} \tag{1}$$

Similar formulas are applied to interpolate G to blue pixels , R to green pixels, and R to blue pixels , with respective gain factors. Similarly, we obtain for values of B, by symmetry.

To determine the appropriate values of the gain parameters, the authors of the study used a Wiener approach. This means that they calculated the values leading to an interpolation with the minimum mean square error, based on second-order statistics computed from a dataset of quality. Finally, we obtain the following masks :

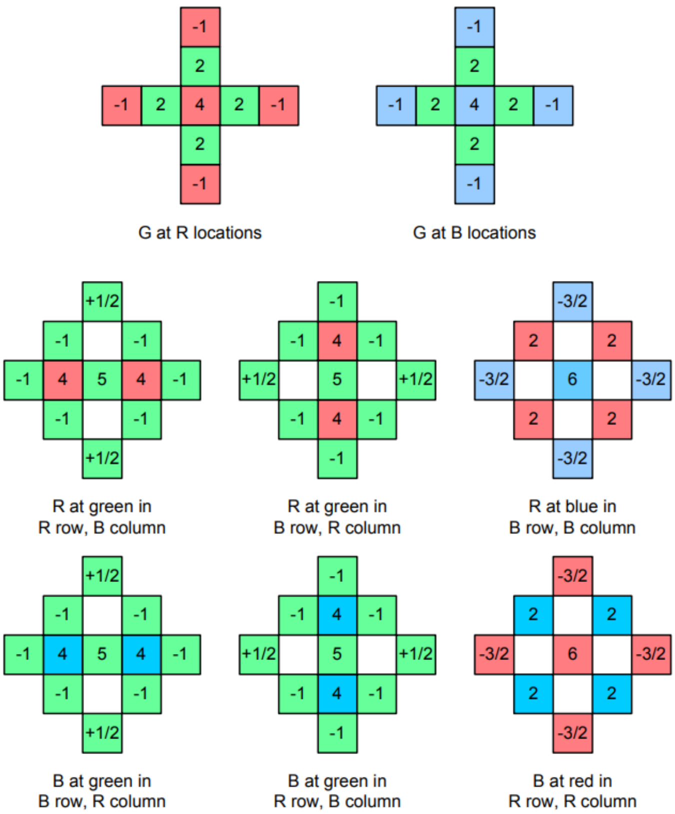

Figure 1 – . Filter coefficients for a proposed linear - image taken from Malvar et al. [2004]

2.2 Demosaicing With Directional Filtering and a posteriori Decision - Menon Method

I will now present the method described in the article: Menon et al. [2007]. In this paper, an improved directional interpolation method is introduced. The distinguishing feature of this method is that the choice of the ideal interpolation direction is based exclusively on the reconstructed green component of the image. Once the appropriate direction has been determined, the red and blue components of the image are then interpolated. The major advantage of this technique is that it applies to just one colour component, rather than all three channels. In addition, it requires a decision to be made for only half of the pixels in the image, specifically where the green samples have not been captured by the sensor. This method has the added advantage of providing a more accurate estimate of the green component after decision making, enabling more efficient reconstruction of the red and blue components.

The first step in the algorithm is to reconstruct the green image in both horizontal and vertical directions. To interpolate the Bayer pattern samples, a five-coefficient FIR (finite impulse response) filter is used. The authors avoid the use of a longer filter to prevent edge effect; to reduce aliasing and improve mid-frequency response, information from the high bands of the red and blue signals is used, given the high-frequency correlation of the color channels.

The second sted, after interpolating the green component in the horizontal and vertical directions, thus producing two green images, is to take a decision has to be made as to which filtering direction performs best. This decision is based on the natural property of images, where color differences vary slowly and show abrupt changes only at the edges. Then, for reconstruction in green locations, bilinear interpolation of color differences is applied. For red values in blue pixels (and vice versa) edge-directed interpolation is used, using the estimated red samples in green locations, with a preference for cardinal rather than diagonal directions, based on the higher frequency of cardinal edges in natural images. The classifiers already used for green reconstruction and decision, are employed to decide on the best interpolation direction

Finally, to reduce the artifacts caused by interpolation, we perform a refinement step that involves filtering the green components and then updating the R and B components in all possible configurations.

2.3 Quality indexes

We will use two quantitative factors to assess the effectiveness of our pansharpening. We will use the SSIM (Structural Similarity Index Measure) and the PSNR (Peak Signal-to-Noise Ratio), two measures commonly used to assess image quality in the field of image processing. They are used to quantify the similarity between two images, often an original image and a processed image (such as a compressed, restored or pansharpened image).

PSNR is a measure that evaluates the ratio between the maximum possible power of a signal (in this case, the values of the pixels in the image) and the power of the noise that affects its representation. Higher PSNR values generally indicate better quality. However, PSNR does not always take into account human perception of image quality.

SSIM is a metric that measures the similarity between two images in terms of brightness, contrast and structure, ranging from -1 to 1, where 1 indicates a perfect match. Unlike PSNR, SSIM is designed to be more consistent with human visual perception, taking into account the texture, brightness and contrast of images.We will conclude our results with these indicators.

-	PSNR	SSIM
Bilinear naive method	31.55	0.89
Malvar method	35.31	0.9515
Menon method	36.10	0.9595

Table 1 – Table of qualitative values according to the method used - based on original image.

3 Results and Analysis

We will evaluate performance on the following image:

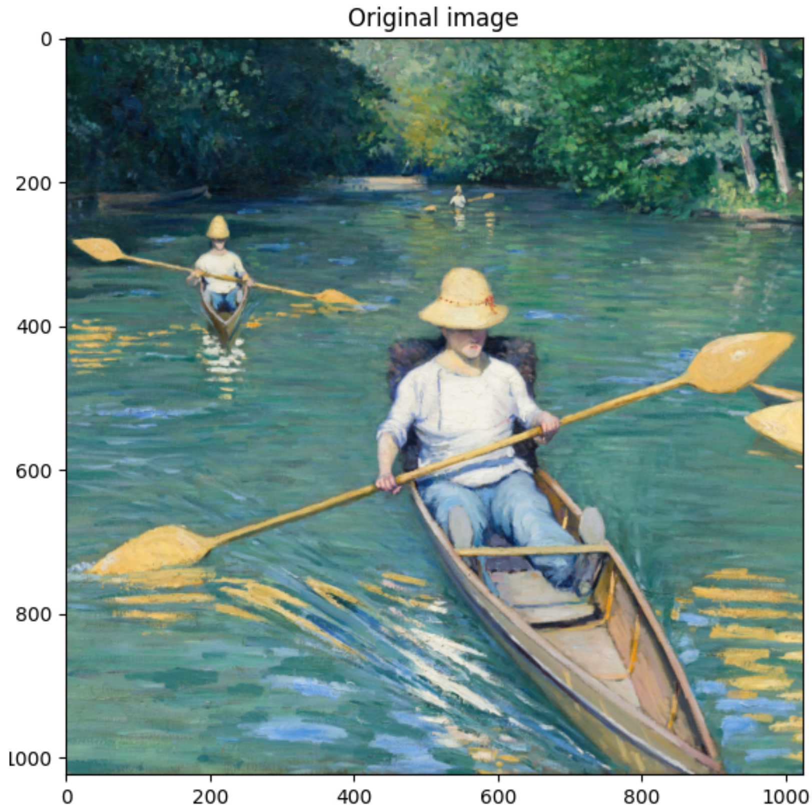

Figure 2 – Example image used - Périssoires (Caillebotte, Washington)

We can then evaluate the quantitative performance of the different methods. We then obtain satisfactory and comparable results.

Overall, the image is well reconstructed. The Malvar and Menon method gives good results both qualitatively and quantitatively compared with the bilinear method. Otherwise, it may be noted that the Menon method offers the best compromise between detail reconstruction and absence of edge effects without being too demanding in terms of calculation. The best reconstruction is obtained with this method. In the zoomed-in image, you'll notice that some artifacts are particularly noticeable in areas of high contrast (the paddle and the black background in the example below) and in areas of color gradation. There's still room for improvement.

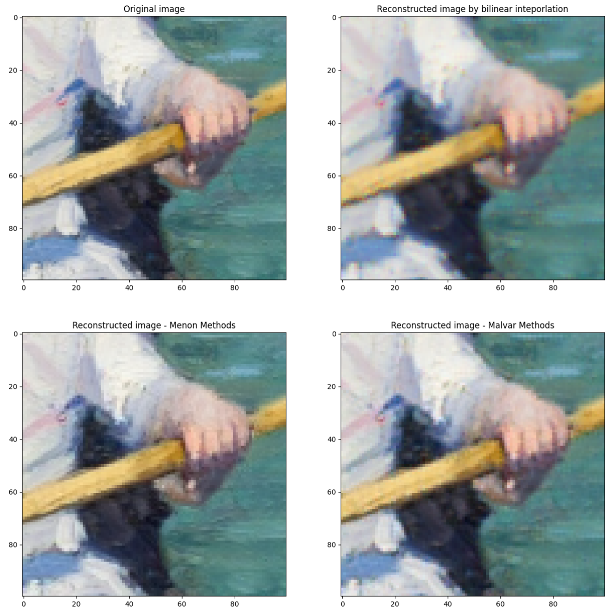

Figure 3 – Zoom in on the image and the images reconstructed by the various methods

4 Conclusion

In conclusion, this project effectively compared three demosaicing methods, including a conventional bilinear approach and advanced techniques based on Malvar's and Menon's research. The findings confirmed Menon's method as the most effective, offering superior color reconstruction. However, there's potential for further refinement, perhaps through integrating advanced algorithms or new research insights. This study not only underscores the effectiveness of demosaicing techniques.

References

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