IMAGE ANALYSIS PROJECT REPORT

I. Introduction

In the field of digital photography, some commercial RGB cameras incorporate a technology known as "Colour Filters Array" (CFA). This technology can be likened to a matrix of coloured filters arranged in a mosaic on the photosites of the image sensor. These filters, either red, green, or blue, are arranged periodically on the sensor's surface, forming a predetermined CFA pattern. However, due to this configuration, each pixel captures only one colour, whether it be red, green, or blue. Hence, the output is not a RGB image but a grayscale image. The process of estimating the missing colour values to obtain a complete RGB image is then carried out through a technique called demosaicking.

II. Proposed solution

1. For Bayer pattern

After reviewing the document, you provided [1], I decided to implement a method based on residual calculation called minimized-Laplacian residual interpolation (MLRI) [2] for the Bayer pattern. This method relies on the fact that one channel has more information, which is the case here as green has twice as many occurrences as the other two colours, whether in the Bayer or Quad Bayer pattern. After estimating green (the interpolation method will be detailed later), the goal is to interpolate red and blue using spectral information from our green interpolation. Differences between observed and provisionally estimated pixel values are calculated, known as residuals. In the case of MLRI, this guided interpolation of red or blue is done using a modified guided filter algorithm (refer to [3] for implementation details), minimizing Laplacian energies, which is more precise than simple colour difference interpolation (see Figure 1)[2]. The residuals are then interpolated (in my case, using bilinear interpolation for better spectral information preservation) and added to our red or green estimation through the guided filter (see Figure 2).

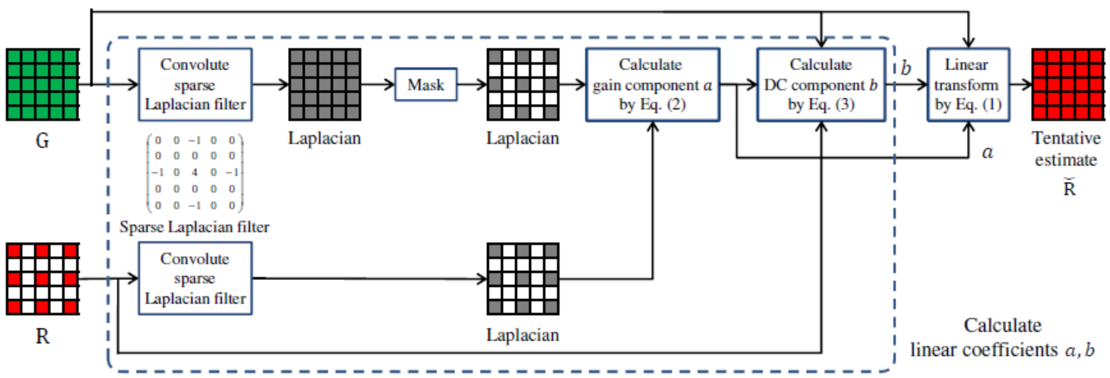

Figure 1: Operation of guided filtering to obtain the red or blue channel in MLRI (source: [2]*)*

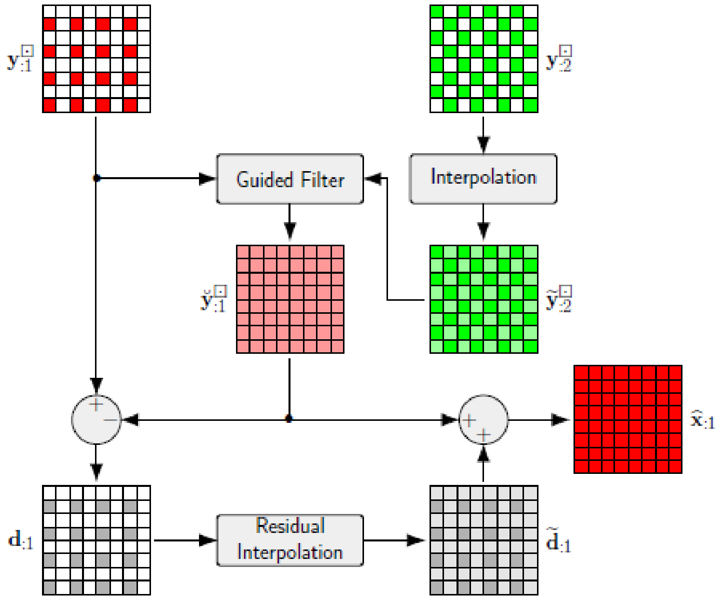

Figure 2: Operation of the algorithm for estimating red or blue colour using residuals (source: [1])

For green interpolation, I based it on the gradient-based threshold-free algorithm (GBTF) [4]. (I won't detail the algorithm equations in this report due to length, but everything is explained in [4]). It involves interpolating green values considering the values of neighbouring blue and red pixels. This is done by calculating vertical and horizontal colour differences using interpolations from the Hamilton and Adams' algorithm [5]. Horizontal and vertical colour differences are estimated using original and interpolated pixel values in each direction. Two arrays of differences are obtained, one for horizontal estimates and the other for vertical estimates.

These directional colour differences are combined, considering values within a 5*5 window weighted by the importance of each cardinal point on the central pixel. This forms the final estimation. The target green pixel value is then calculated by adding the estimated colour difference in the final estimation to the available target pixel (red or blue).

2. For Quad Bayer Pattern

For the Quad Bayer pattern, I assumed that within a 2*2 square of one colour, the differences between pixels after averaging would be generally the same for the other channels once interpolated. Based on this assumption, I calculated the average for each 2*2 cube and subtracted it from our pattern to obtain a difference mask in the 2*2 neighbourhood. A Bayer pattern is then calculated using our quad Bayer pattern, replacing each 2*2 cube with a pixel representing the average of those four pixels. We can then apply our previous method to this new pattern. To obtain the final image, we sum, for each colour, our interpolated pixel representing the average in the 2*2 neighbourhood and each pixel in our difference mask in that neighbourhood.

III. Visual Comparisons

1. For Bayer pattern

My method has the advantage, thanks to the residuals, of retaining high-frequency values lost with the initially proposed kernel methods in the project. As seen in Figure 3, even when zooming into the image, the result is very similar to the original image, unlike the initial method, which blurs because no information from other channels is used to estimate colour, and no spectral information is used to try to preserve high frequencies.

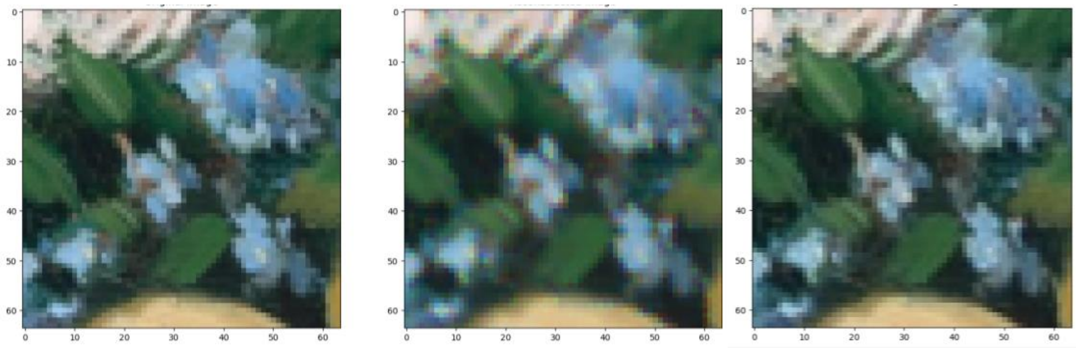

Figure 3: Visual comparison between the original image, the image reconstructed with your method, and my image for the Bayer pattern (left to right)

2. For Quad Bayer pattern

A similar phenomenon is observed on the Figure 4 with the Quad Bayer pattern. Our method is closer to reality, but it seems to suffer from the loss of high frequencies this time, with a beginning of blurring around the edges. This can be explained by the employed method of subsampling and then oversampling, which inevitably loses information on the edges despite calculating differences to the average.

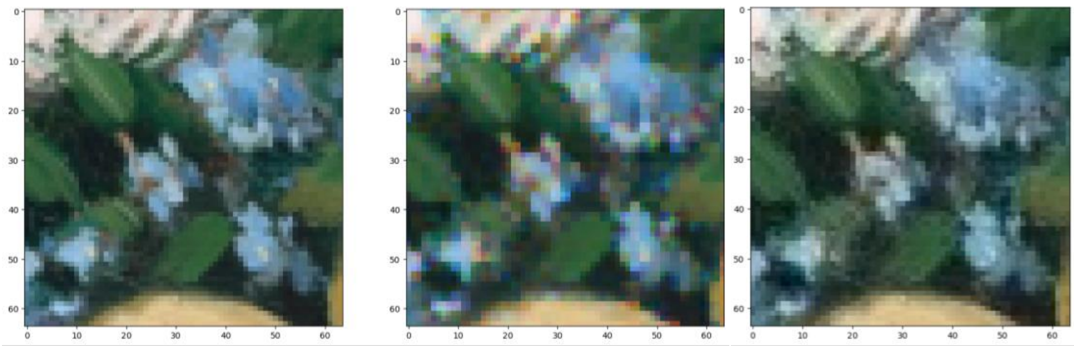

Figure 4: Visual comparison between the original image, the image reconstructed with your method, and my image for the Quad Bayer pattern (left to right)

IV. Results

The results confirm what was already observed visually. My methods provide both better overall results with a higher PSNR and structurally better SSIM closer to 1 than the initial method (see Table 1 and Table 2).

1. For Bayer pattern

Results for the Bayer pattern show that our method averages a PSNR of 37.4dB, a gain of 5.7dB compared to the baseline method. We also significantly improve SSIM, going from an average SSIM of 0.875 to 0.964.

	Img_1		*Img_2*		*Img_3*		*Img_3*	
algo	baseline	MLRI	baseline	MLRI	baseline	MLRI	baseline	MLRI
PSNR	34,63	41,23	30,31	36,16	31,98	37,21	29,88	34,98
SSIM	0,9502	0,987	0,843	0,9614	0,8941	0,9669	0,8145	0,9424

Table 1: Comparison of results on the set of four images between the baseline algorithm and my algorithm for the Bayer pattern

2. For Quad Bayer pattern

Results for the quad Bayer pattern show that our method averages a PSNR of 33.8dB, a gain of 5.5dB compared to the baseline method. We also significantly improve SSIM, going from an average SSIM of 0.805 to 0.940.

	Img_1		*Img_2*		*Img_3*		*Img_3*	
Algo	baseline	MLRI	baseline	MLRI	baseline	MLRI	baseline	MLRI
PSNR	30,98	36,41	26,96	32,78	28,61	32,82	26,65	33,02
SSIM	0,9108	0,9697	0,7577	0,9322	0,828	0,9306	0,723	0,9262

Table 2: Comparison of results on the set of four images between the baseline algorithm and my algorithm for the quad Bayer pattern

V. Conclusion

In conclusion, the implemented solution works well and provides satisfactory results on the project dataset. A more in-depth study is needed to determine the solution's robustness with more unconventional image types, such as those with marked vertical or horizontal patterns or abrupt colour changes, as seen in an Andy Warhol painting. Additionally, it should be compared to other more advanced algorithms to evaluate its position relative to algorithms stronger than the one proposed in the initial project. As for improvements, there might be a way to enhance the quad Bayer method I proposed to better preserve contours. It's also necessary to investigate whether the parameters chosen in the MLRI method are truly optimal (window size in GBTF analysis, standard deviation of the Gaussian filter, choice of epsilon in the guided filter, etc.).

VI. REFERENCES

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