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Report image analysis project

This report sums up my approach to the project image analysis. From the problem statement, the choices that I made, the analysis made to finally the conclusion that I drew.

I. Problem statement

In many RGB cameras, there is a layer of filter in front of the sensor for the color red, green and blue. It is called Color Filter Array (CFA). In this projects we will study two configuration of CFA :

- bayer pattern
- quad bayer pattern

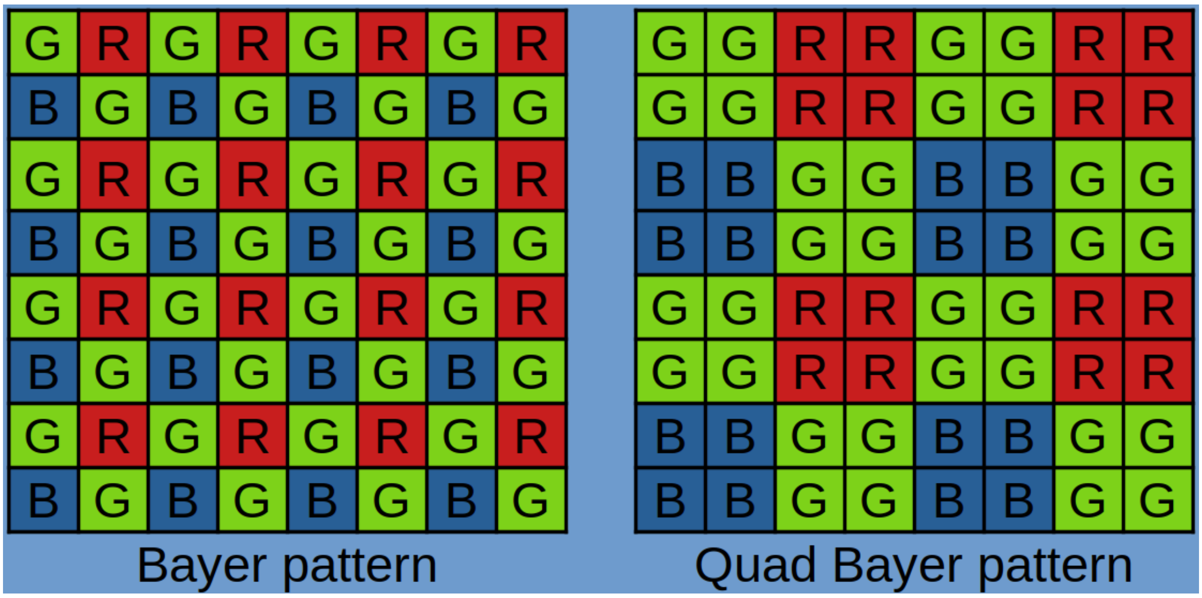

Figure 1 : Illustration of bayer and quad bayer pattern

The raw acquisition outputted by the sensor is a gray scaled image. The goal of this project is to recover a full RGB color image by a demosaicing method.

II. Solution : Spectral difference method

To solve this problem, I implemented a spectral difference method described by Picone [1]. This method is based on injecting complementary spectral information into a naive interpolation of the raw output.

This naive interpolation $\widetilde{\mathbf{y}}^{\boxdot}_{:l}$ is done by convoluting each missing pixel from each channel by a weighted average of its neighborhood pixels.
Here are the 3 kernel used respectively fro channel red, green and blue:

$$\mathbf{U}^{[b]}_{::1} = \frac{1}{4}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}, \quad \mathbf{U}^{[b]}_{::2} = \frac{1}{2}\begin{bmatrix} 0 & 1 & 0 \\ 1 & 2 & 1 \\ 0 & 1 & 0 \end{bmatrix}, \quad \mathbf{U}^{[b]}_{::3} = \frac{1}{4}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

We need then to compute the spectral difference between each bands

$$\mathbf{d}^{[l]}_{:k} = \mathbf{y}^{\boxdot}_{:k} - \widetilde{\mathbf{y}}^{\boxdot}_{:l} \odot \mathbf{h}_{:k} \, ,$$

Finally we interpolate the difference with the same kernel as before to compute our estimated image.

$$\widehat{\mathbf{x}}_{:k} = \sum_{l=1}^{N_b} \left(\mathbf{y}^{\boxdot}_{:l} + \widetilde{\mathbf{d}}^{[l]}_{:k} \odot \mathbf{h}_{:l} \right) \, .$$

This method works for the classical bayer pattern but doesn't with the quad bayer pattern. To tackle this issue, it is common to convert the quad bayer pattern into a bayer pattern. The method is to swap pixels from each row and column to obtain a bayer pattern, Pyxalis [2].

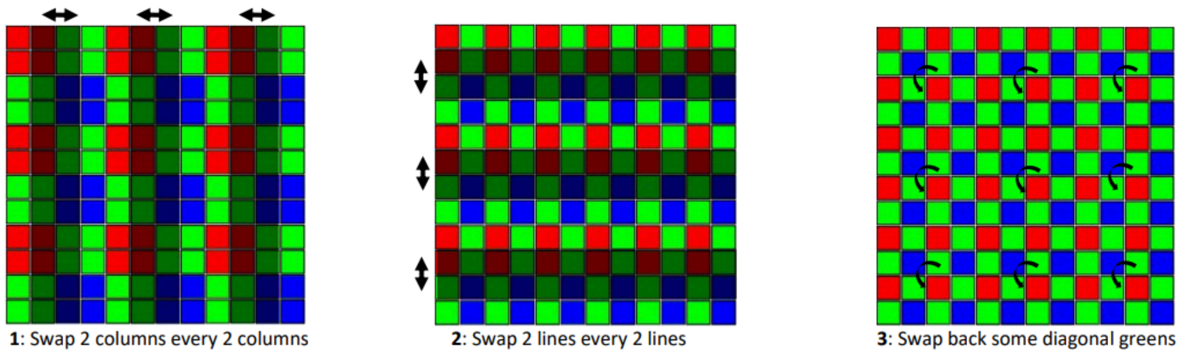

Figure 2 : Algorithm used to convert quad bayer to bayer pattern

III. Results

To evaluate the result, we compute two metrics on images from the [National Gallery of Art, USA]() dataset :

- PSNR : Power Signal to Noise Ratio
- SSIM: Structural Similarity Index Measure

	Naive interpolation		Spectral difference	
	PSNR	**SSIM**	**PSNR**	**SSIM**
Image 1	**34.63**	**0.9502**	**38.43**	**0.9786**
Image 2	**30.31**	**0.8430**	**33.95**	**0.9443**
Image 3	**31.98**	**0.8941**	**34.84**	**0.9499**
Image 4	**29.88**	**0.8145**	**33.22**	**0.9242**

Figure 3: Metrics compared between different images and different methods with bayer pattern

	Naive interpolation		Spectral difference	
	PSNR	**SSIM**	**PSNR**	**SSIM**
Image 1	**30.98**	**0.9108**	**28.98**	**0.8709**
Image 2	**26.96**	**0.7577**	**26.86**	**0.7033**
Image 3	**28.61**	**0.8280**	**27.5**	**0.7704**
Image 4	**26.65**	**0.7230**	**26.85**	**0.6730**

Figure 4: Metrics compared between different images and different methods with quad bayer pattern

According to the metrics, the spectral difference method is better to reconstruct the original image with a bayer pattern. However the results are worse for the quad bayer pattern. This may be caused by my implementation of the conversion between quad bayer to bayer.

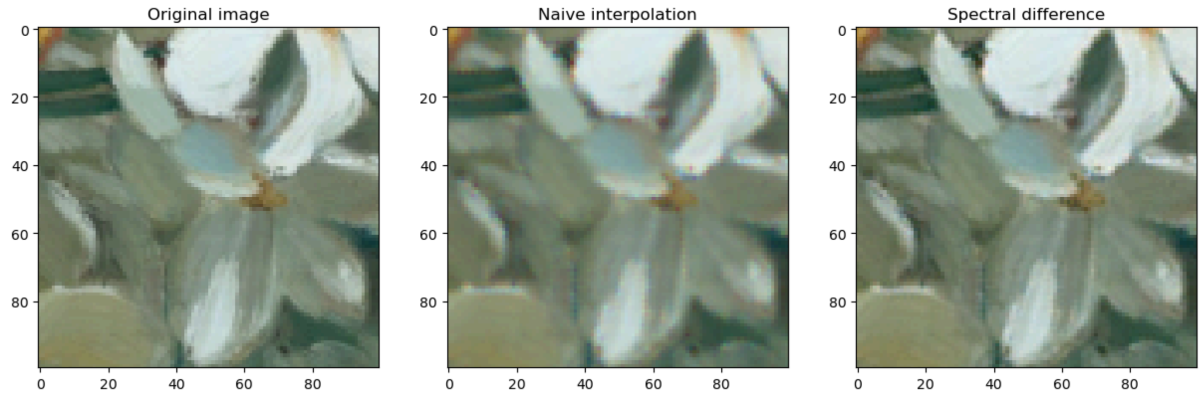

Figure 4 : Visual comparison between the naive interpolation and spectral difference method for bayer pattern

Visually, we can see that there are less color artifacts around the edge for the spectral difference method compared to the naive interpolation but there are still some artifacts present .

IV. Conclusion

To conclude, the results are satisfying but can be improved. The kernel used to interpolate the image doesn't preserve the edges well. One way to do that is to use a bilateral filter instead. The conversion between quad bayer to bayer may not be correctly implemented. That would explain the result.

V. Reference

[1] Daniele Picone. Model Based Signal Processing Techniques for Nonconventional Optical Imaging Systems. Signal and Image processing. Université Grenoble Alpes [2020-..], 2021. English. ⟨NNT : 2021GRALT080⟩. ⟨tel-03596486⟩: https://theses.hal.science/tel-03596486

[2] Pyxalis image Viewer-User guide
https://pyxalis.com/wp-content/uploads/2021/12/PYX-ImageViewer-User_Guide.pdf