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Research Unit: Phelma
Team(s): SICOM
Supervisor(s): Mauro Dalla Mura & Matthieu Muller

EEH

Image analysis project

Diop Babacar

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Abstract

The aim of this project is to recover a full RGB image from a raw acquisition of the image that is a grey-scale image produced by the Color Filters Array (CFA) technology. To do that we will do a demosaicing which is the method to re color an image from a raw CFA image.

Keywords: color recovering, demosaicing, interpolation

1 Introduction

To recover the RGB color of the ground truth image we will try to apply a method that I found on different scientific papers. In this report, I will try to explain the method that I have implement, with the different processing functions and present the results. I will conclude with an analyse of our method in comparison with the method that have been already implement in the project.

Figure 1 – Example of Ground truth vs raw image

2 Data comprehension

2.1 Initial images

For our initial dataset we have 4 images available to us. They are all RGB and have a dimension of (1024x1024), they are from the open dataset of the **National Gallery of Art**, USA.

2.2 CFA functions

To recover the color of the images we first need to have the raw images as acquired by the commercial RGB cameras. To be able to do that we need to use some functions to apply the CFA to those images. We then have two principal methods that are available to us in the project : the direct method that apply directly the CFA operation to the image and return the raw image. And the adjoint method that take the raw image as an input and give us the 3D RGB matrix of the raw image but with 0 value at all pixels of others layers. Those two cfa operations work with to different type of pattern the Bayer pattern which is the most common pattern for CFA and the Quad Bayer pattern.

2.3 Global Dataset

To resume, we then have 4 input images of size (1024x1024), that each can give two images : one direct (raw image) and one adjoint (3D RGB raw image) thanks to CFA functions. Each of this methods can be apply on a bayer and a quad bayer pattern. Finally what we want is a color recovering for the 4 images with each of the two patterns by using direct and/or adjoint matrix of the input images.

3 Demosaicing methods

We want here to explain the methods that we have seen during this project and the one that we have choose to demosaicing our images. For the theoretical part, we will only talk about the classical bayer pattern but it can also be extend to the quad bayer one.

3.1 Initial method of the project

As a hint to help us to start the project, a basic bilinear interpolation was available to us. The principle of this bilinear interpolation is to take for each missing pixel of a layer, the two or four nearest neighbours of this pixel and give to the missing pixel the value of the mean of the others pixels. This method is the easiest one and our objective was to improve it, by searching on different scientific papers on internet I found the High Quality linear interpolation (HQLI) method.

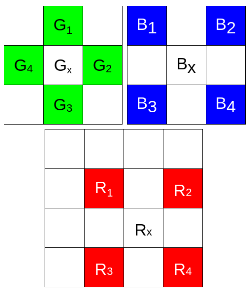

Figure 2 – Schema of bilinear interpolation form medium article

3.2 High Quality Linear Interpolation (HQLI)

HQLI is an improvement of the classical bilinear interpolation that we have seen before. I found this method on the article of Fard [2020] that have synthesized the article of Henrique S. Malvar and Cutler [2004]. The idea of the method is to extend the logic of the bilinear method to more neighbours than just the firsts ones and to extend this neighbourhood to others layers, not only the one of the pixel that we want to recover. The aim is then to take in account the firsts pixels of the current layer and then the firsts ones of the layer from which the current pixel originates. By computing the mean of those values with different weights we then obtain a more precise estimation of the value that the searched pixel should have. For bayer pattern we then have 8 possible configurations for applying a different mask, that can be reduce to four because the blue and red pixels have the same distribution.

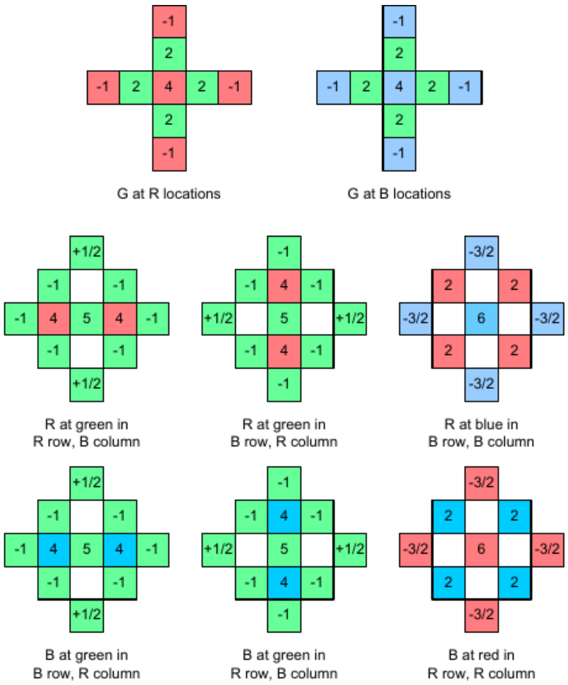

Figure 3 – Schema of HQLI from medium article

3.3 Implementation

For the implementation of the HQLI method we have done a function that do two different process if it's a bayer or a quad bayer pattern. I will try to explain the methodology for each in this section.

3.3.1 Bayer pattern

For the bayer pattern the aim is to implement the theoretical method presented before in python. The principle is that we have an image of (1024x1024) pixels and we want to recover a (1024x1024x3) image with the interpolate value of each zero value of each layers. To do that, we want to convolve by a (5x5) mask each sub matrix (5x5) of the image. Like all masks need the value of pixels from two layers we decided to use the direct image to have access to them. We then need to have conditions to use one or an other mask in function of : the pixel's layer, the layer we want to recover and the neighbours of this pixel. We then can browse all the pixels of the image and compute the value of the missing pixels by a convolution of the (5x5) pixels around it and the chosen mask, in function of the previous conditions. We finally recover a RGB image from the direct image with the HQLI method.

3.3.2 Quad Bayer pattern

For the quad bayer pattern the masks have to be modified, indeed the pattern is now the same but with 4 pixel of same color against one previously. My first intuition was to apply the same filters but with 4 pixels instead of 1 for each value, we then have a (10x10) mask that work the same way as previously. The problematic is that with this implementation, for each (2x2) missing color pixels we have the same value, which isn't something suitable to be able to reconstruct well the RGB image.
The solution that I have found is then to compute the value of each pixel of the (2x2) missing pixels independently. But to be able to do that we need four different masks (for each position of the pixels in the (2x2) matrix) for each of the four different possible configurations. After having instantiate all the 16 (10x10) masks we create the final RGB image by the same process as previously.

Remark : Notice that before being processed the images have to be padded to be able to do a convolution on the pixels on the edge of the image.

3.4 Metrics for results analyse

After having recover our RGB images by using the HQLI method, we want to be able to compare this process with the naive interpolation provide in the project, in order to evaluate the improvement of our method. As suggested in the project, we are going to use two metrics to analyse our results (in addition to the visual result).
The SSIM (Structural Similarity Index Measure) and the PSNR (Peak Signal-to-Noise Ratio) that are often used metrics to compare different images. For the experimental part it's important to notice that two function have been already implement to compute those two metrics.

4 Experimentation and results

4.1 Bayer pattern

We will first observe the results for the bayer pattern. We recover our RGB image, and compute the two metrics. We then compare it with the bilinear interpolation.

Figure 4 – Original, bilinear interpolation and HQLI

Methods	PSNR	SSIM
Bilinear	29.88	0.8145
HQLI	33.06	0.9214

Table 1 – Metrics of two methods

We can observe that we significantly improve the results on the two metrics which is a good thing, we also see that in comparison with the original image the two reconstructed images are less light and more contrast. But we see that we steel have a big marge of improvement, particularly on the edges of the image where we can see that the color of the pixels is not really accurate, probably because of our zero-padding.

4.2 Quad Bayer pattern

We now observe the results with the quad bayer pattern.

Figure 5 – Original, bilinear interpolation and HQLI

Methods	PSNR	SSIM
Bilinear	26.65	0.7230
HQLI	24.81	0.5578

Table 2 – Metrics of two methods

We see that we have not improve the results on the two metrics comparatively to the naive interpolation, even if visually it seems to be good. We steel have the edges problem which is even worth. It makes sense because by convolve with bigger masks we then have the zero padding problem that is more propagated in the center of the image.

5 Conclusion

As a conclusion, we have understand and study the method that was already in place and try to improve it with a new method : the high quality linear interpolation. The results are quite good for both the bayer and quad bayer pattern, but with an improvement in comparison with the bilinear methiod for the first one and not for the second. We also have a common problem with the zero-padding of the images because we always find some artefacts on the edges of the images. This could be an area for improvement to be explored. We could also try to implement more complex demosaicing algorithm, for the quad bayer pattern, that use machine learning but it was to short to try it.

References

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