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Enhancement of CFA in Single Sensor Camera using Laplacian Projection Technique.

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ABSTRACT

This project is to enhance images using laplacian projection technique. A digital camera uses a sensor array of millions of tiny pixels in order to produce the final image. The proposed work implements demosaicing process for restoring full color images from incomplete color samples acquired by single sensor digital cameras. In the demosaicing process red, green and blue components of the image are acquired and interpolated to reconstruct the image. To restore the full color image from its samples of CFA, the two missing color values at each pixels are usually estimated from their neighboring CFA samples. This process is commonly referred as CFA demosaicing and it has a substantial impact on the quality of the color images produced by a single sensor digital cameras. It gives better performance with less computational cost.

Keywords: CFA- Color Filter Array, CPSNR-Color Peak Signal to noise Ratio, MSE-Mean Square Error .

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INTRODUCTION

In recent years a massive research and development effort has been witnessed in color imaging technologies in both the industry and the ordinary life. Color is commonly used in media and printing industry. In all the applications, the perception of color is paramount for the correct understanding and dissemination of the visual content. Recent technological advancement have reduced the complexity and the cost of color devices, such as scanners, printers, monitors and copiers, thus allowing their use in the office and home environment. However, it is still increasing popularity of the consumer, single-sensor digital cameras which boosts today's research activities in the field of digital color image acquisition, processing and storage. Single-sensor camera image processing methods are becoming increasingly important due to the development and proliferation of emerging digital camera-based applications and commercial devices, such as mobile phones and sensor networks, surveillance and automotive devices.

In a systematic and comprehensive manner demosaicking, demosaicked image postprocessing and camera image zooming solutions which utilize data-adaptive and spectral modeling principles to produce camera images with an enhanced visual quality. The existence of realistic and efficient design procedures and the variety of processing solutions developed through the presented data-adaptive, spectral model-based processing framework make this family of processing methodologies an indispensable tool for single-sensor imaging.

EXISTING METHODOLOGIES

There are a variety of method available, with the simplest being the nearest neighbor interpolation but it does not maintain the color information and edges as well. More complicated and advanced methods provide better reconstruction of the color-filtered image. If the calculated image is divided by measured color into three separate images, this problem looks as a typical image interpolation problem. Since the three color images are generally highly correlated, common image interpolation techniques failed to give good results. So specialized algorithm need to be used for Demosaicing problem.

The Demosaicing algorithms can be classified as Adaptive algorithm and Non-adaptive algorithms. Non-adaptive algorithms does interpolation in affixed pattern for each pixel. While adaptive algorithms can detect local spatial features present in the neighbourhood of the pixel to create effective choices of predictors to use the right predictor for that neighbourhood.

The Non-adaptive algorithms are

- Nearest neighbour interpolation
- Smooth hue transition

The adaptive algorithms are

- Edge sense interpolation
- Variable number offset method

Another classification is non-iterative and iterative algorithms. Non-iterative demosaicing techniques mainly rely on the idea of edge directed interpolation to improve the reconstruction performance. The exploitation of intra-plane correlation can be done by estimating either local offsets or local covariance information. The exploitation of inter-plane correlation can be performed based on either the color ratio rule or the color difference rule. Iterative Demosaicing techniques, update the green, red/blue channels iteratively by enforcing the color ratio rule. Iterative Demosaicing techniques are capable of achieving higher quality in the reconstructed images than non-iterative ones at the price of increased computational cost.

Like other color image processing problems, correlation modelling among three color channels plays the critical role in Demosaicing. All color channels have very similar characteristics such as texture and edge location. Ignoring such inter-plane dependency often renders the Demosaiced image suffering from annoying artifacts caused by color mis-registration. To restore more accurate and visually appealing results, many sophisticated Demosaicing methods have been proposed exploiting image spatial or spectral correlation or both. Image spatial correlation refers to the fact that within a homogeneous image region, neighboring pixels share similar values of color, while spectral correlation dictates that there is a high correlation between the red, green and blue planes, resulting in that the difference (or ratio) between two color planes is likely to be a constant within a local image neighborhood. Various techniques have been proposed to obtain a more faithful and higher quality reproduction of color images by exploiting the inter-plane correlation. The challenge is to find the best tradeoff between image quality and computational cost.

PROPOSED METHODOLOGY

As discussed in existing methods to enhance color filter array images using laplacian projection technique. A digital camera uses a sensor array of millions of tiny pixels in order to produce the final image. The proposed work uses demosaicing process for restoring full color images from incomplete color samples acquired by single sensor digital cameras. In the demosaicing process red, green, and blue components of the image are acquired and interpolated to reconstruct the image. To restore a full color image from its CFA samples, the two missing color values at each pixel are usually estimated from their neighboring CFA samples. This process is commonly referred to as CFA demosaicing and it has a substantial impact on the quality of the color images produced by a single sensor digital cameras. It provides better performance with low computational cost.

The most popular CFA pattern was introduced by Bayer, which uses the three additive primary colors Red, Green and Blue for the Filter elements. It samples the green band using a quincunx grid, while red and blue are derived by a rectangular grid. The color representation of the full image is reconstructed from the mosaic image using interpolation. In this process of Demosaicing, avoiding the introduction of visible artifacts, such as aliasing and zippering is desirable.

Algorithm

A digital camera uses a sensor array of millions of tiny pixels in order to produce the final image. Color imaging with a single detector the use of a Color Filter Array (CFA), which covers the detector array. The recovery of full-color images from a CFA-based detector requires a method of calculating values of the other color separations at each pixel. These methods are commonly called as color interpolation or color Demosaicing algorithms.

The most popular CFA pattern was introduced by Bayer, which uses the three additive primary colors Red, Green and Blue (RGB) for the filter elements. It samples the green band using a quincunx grid, while red and blue are derived by a rectangular grid. The full color representation of the image is reconstructed from the mosaic image using interpolation. In this process of Demosaicing, avoiding the introduction of visible artifacts, such as aliasing and zippering is desirable.

A Demosaicing algorithm is a digital image processing which is used to reconstruct a full color image from the incomplete color samples output from an image sensor overlaid with a color filter array (CFA) also known as CFA interpolation or color reconstruction, Demosaicing. Most modern digital cameras acquire images using a single image sensor overlaid by CFA, so Demosaicing part of the pipeline processing required to render these images as a viewable format. However, a Bayer image can also be seen as a grayscale image. Many digital cameras can save images in a raw format allowing the user to do the demosaic it using software, rather than using the camera's firmware.

The aim of a Demosaicing algorithm is to reconstruct a full color image (with full set of color triples) from the spatially under sampled color channels output from the single sensor camera. The algorithm should have the following traits:

- Avoiding of the introduction of false color artifacts such as chromatic aliases, zippering and purple fringing
- Preservation of the image resolution to the maximum.
- Less computational complexity for fast processing or efficient hardware implementation for the camera.
- Amenability to analyses for accurate noise reduction.

Flow Chart

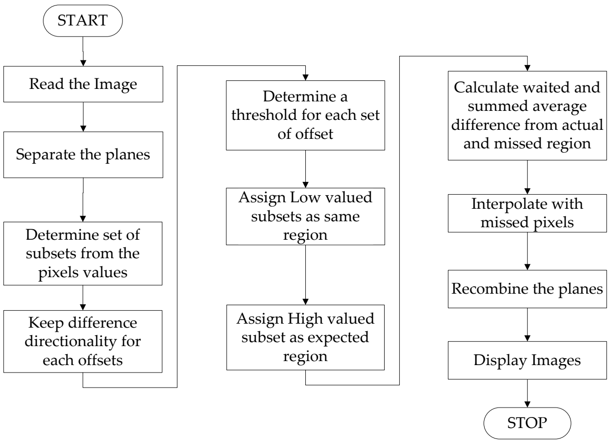

Figure 1: Flow chart for projection algorithm

Variable Number Offsets Method

In this method multiple offsets are considered and interpolated accordingly. The basic procedure is explained below: The set of offsets is determined from the color values in the 5x5 neighborhood centered at the pixel under consideration. Each offset corresponds to a different direction. For each set of offsets, a threshold value is determined and the threshold is used to select a subset of offsets. Low valued offsets indicate pixels having similar color value whereas high value offsets would be expected in the regions of the image where there are many fine details and sharp edges. The subset of offsets is used to locate regions of pixels that are most like the pixel under consideration. The pixels in these regions are then waited and summed to determine the average difference between the color of the actual measured central pixel value and the missing color. To interpolate the missing pixel, consider to estimate G13 and B13 at R13,

R1	G2	R3	G4	R5
G6	B7	G8	B9	G10
R11	G12	R13	G14	R15
G16	B17	G18	B19	G20
R21	G22	R23	G24	R25

Figure 2: Reference Bayer CFA

The formulae for offsets are as follows:

Offset N = G8-G18|+|R3-R13|+|B7-B17|/2+|B9-B19|/2+|G2-G12|/2+|G4-G14|/2 (1)
Offset E=G14-G12|+|R15-R13|+|B9-B7|/2 +|B19-B17|/2+|G10-G8|/2+|G20-G18|/2 (2)
Offset S=|G18-G8|+|R23-R13|+|B19-B9|/2+|B17-B7|/2+|G24-G14|/2+|G22-G12|/2 (3)
Offset W=|G12-G14|+|R11-R13|+|B17-B9|/2+|B17-B7|/2+|G24-G14|/2+|G22-G12|/2 (4)
Offset NE=|B9-B17|+|R5-R13|+|G8-G12|/2+|G14-G18|/2+|G4-G8|/2+|GG8|/2+|G10-G14|/2 (5)
Offset SE= |B19-B7|+|B25-R13|+|G14-G8|/2+|G18-G12|/2+|G20-G14|/2+|G24-G18|/2 (6)
Offset NW= |B7-B19|+|R1-R13|+|G12-G18|/2+|G8-G14|/2+|G6-G12|/2+|G2-G8|/2 (7)
Offset SW= |B17-B9|+|R21-R13|+|G18-G14|/2+|G12-G8|/2+|G22-G18|/2+|G16-G12|/2 (8)

The threshold is determined by

$$dd\ T=k_1 *\text{Min}+k_2*(\text{Max-Min}),$$

where the Min is the minimum offset value and Max is the maximum offset value k1and k2 are determined as 1.5 and 0.5, respectively. k1* Min accounts for the case in which the offsets are all very similar, so that all of them need to be included by setting a threshold that exceeds them. Also k2*(Max-Min) accounts for the case in which there is a significant difference between the maximum and minimum offset values. Locate the pixels in the regions corresponding to the subset of offsets and to use those pixels to determine a color difference between the center pixel color and the color to be recovered. Determine the average green, blue and red values in the offset subset regions from the average color values in the laplacian subset regions to get Gsum, Bsum and Rsum.

Gsum=*G18+G12+ (G4+G8+G2+G14)/4+ (G14+G18+G20+G24)/4* (9)
Bsum = (B17+B19)/2+ (B7+B17)/2+B9+B19 (10)
Rsum = (R13+R23)/2+(R11+R13)/2+(R13+R5)/2+ (R13+R25)/2 (11)

Find the normalized color difference by dividing the difference of two sums by the number of offsets in the threshold subset and add this normalized color difference to the pixel value under consideration to form the other two missing color components.

G13 = R13 + (Gsum-Rsum)/4 (12)
B13 = R13 + (Bsum-Rsum)/4 (13)

To interpolate the missing blue/red pixel value at the green pixel to estimator R13 and B13 at G13
The formulae for finding offsets are as follows:

Offset N= |G3-G13|+|B8-B18|+|G7-G17|/2+|G9-G19|/2+|R2-R12|/2+|R4-R14|/2 (14)
Offset E = |R14-R12|+|G15-G13|+|G9-G7|/2 +|G19-G17|/2+|B10-B8|/2+|B20-B18|/2 (15)
Offset S= |B18-B8|+|G23-G13|+|G19-G9|/2+|G17-G7|/2+|R24-R14|/2+|R22-R12|/2 (16)
Offset W= R12-R14|+|G11-G13|+|G17-G9|/2+|G17-G7|/2+|B24-B14|/2+|B22-B12|/2 (17)
Offset NE= |G9-G17|+|G5-G13|+|R4-R12|+|B10-B18| (18)
Offset SE=|G19-G7|+|G25-G13|+|B20-B8|+|R24-R12| (19)
Offset NW= |G7-G19|+|G1-G13|+|B6-B18|+|R2-R14| (20)
Offset SW= |G17-G9|+|G21-G13|+|R22-R1|+|B16-B8| (21)

Determine a threshold and select a subset offset.

T=k1* Min+k2*(Max-Min), (22)

Where k1=1.5 and k2=0.5

Locate pixels in the selected regions and use those pixels to determine a color difference between center pixel color and the color to be recovered, finally add this color difference to produce an estimate for the missing color value.

RESULTS AND DISCUSSION

Color Peak Signal to noise Ratio (CPSNR)

The phrase color peak signal-to-noise ratio, often abbreviated CPSNR is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. The CPSNR was used as a measure to qualify the performance of the Demosaicing methods. It can be defined as

CPSNR = 10 log 10(2552/CMSE) (23)

Where,

Color Mean Square Error (CMSE),
CMSE = (1/3HW) ∑ (I0(x, y, i)-Ir(x, y, i)) 2 (24)

I0 and Ir represent the original and the reconstructed images of size H x W each.

Simulation Results

The Bayerized image of single sensor camera has been taken as an input to this method. Missed samples which missing are reconstructed at the output image. The simulated results of the proposed method shown in Figure 3.

Figure 3: Bayerized image and its reconstructed image

PSNR –MSE Comparison

Below Figure 4 shows the comparison between the original and reconstructed image using PSNR and MSE as a parameter.

Table 1: PSNR and MSE comparison

Image	PSNR	MSE
1	0.4667	28.7
2	0.4490	28.79
3	0.1725	29.5
4	0.4374	28.85
5	0.4521	28.73
6	0.3863	29

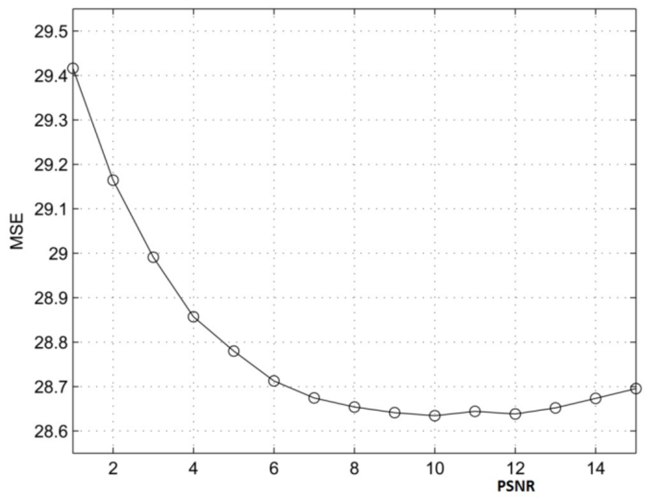

Figure 4: PSNR and MSE comparison

CONCLUSION

The digital image processing operations support digital cameras equipped with a color filter array placed on top of a single image sensor. These consumer-grade cameras capture the natural scene first by producing the mosaic-like image and then by using extensive calculations based on the concept of image interpolation to output the full-color, visually pleasing image.

Since the edges and fine details are essential for image understanding, color plays a significant role in the perception of edges or boundaries between two surfaces. The demosaicing algorithm can be used to enhance the visual quality of the demosaicked image and to increase the spatial resolution of the captured images. Therefore, it is not difficult to see that single-sensor camera image processing techniques have an extremely valuable position in digital color imaging and will be also essential for new-generation imaging-enabled consumer electronics as well as novel multimedia applications.

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