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Image Quality Comparison between 3CCD Pixel Shift Technology and Single-sensor CFA Demosaicking

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***Abstract*-- This paper investigates the performance differences in taking measure of the difference in total pixel count between the 1.5M-pixel 3CCD with pixel shift technology and the 2M-pixel single image sensor using CFA demosaicking for full HD video capture in terms of image quality and color artifacts.**

I. Introduction

For full HD video capture, it is apparent that the 3CCD with Pixel Shift Technology (PST) is emerging as the prevailing technology for the imaging systems, particularly for the domestic market. For the 3CCD with PST, the sensor for each color is only a quarter of the full resolution and hence the total pixel count required for the 3CCD sensors for full HD video capture is only 1.5M pixels, while the total pixel count for a single-sensor imaging system using Color Filter Array (CFA) demosaicking is 2M pixels i.e. 1920x1080. In other words, the 3CCD imaging system using PST has a smaller total pixel count. This paper investigates the performance differences due to the difference in total pixel count between the two imaging systems in terms of image quality and color artifacts.

II. Overview of HD Video Imaging Technology

The two mainstream technologies for HD video imaging acquisition mainly used in the domestic market, namely 3CCD with PST and single-sensor CFA demosaicking, will be compared in this paper. The true full HD 3CCD imaging system, without using PST, will obviously give the best image quality and will not be assessed here.

A. Pixel Shift Technology

3CCD with PST is an emerging technology for High-Definition video imaging, and it is expected that 3CCD video cameras will replace the current CCD based video cameras. In order to acquire higher resolution image than the effective number of pixels, a spatial half-pixel shift in the diagonal direction between the green channel and the red/blue channel is applied as shown Fig.1. The conventional PST method [10] first interpolates the RGB planes to four times of its original resolution to the size of a full HD image. The low frequency component of the luminance is then evaluated from the interpolated RGB planes. Using correlation between color pixels, the high frequency component of the luminance is determined. The HD luminance is obtained by adding the high and low frequency components together, and is then used to update the RGB pixel values to obtain a full HD color image output.

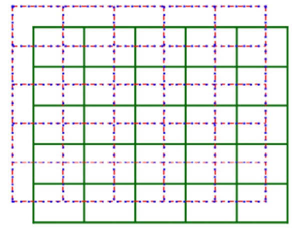

Fig.1 Pixel shift technology pattern

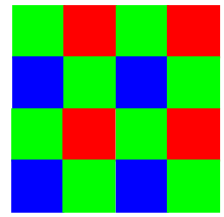

Fig.2 Bayer's pattern

B. Single-sensor CFA Demosaicking

Color filter array (CFA) demosaicking refers to the estimation of missing pixel color values when a single-sensor digital camera is used. A single image sensor does not allow the full red, green and blue color planes to be captured and the image color has to be captured in a sub-sampled pattern. The most common array used is the Bayer [1] color filter array as shown in Fig. 2, where the green color is sampled at twice the rate of the red and blue values.

One basic demosaicking method is bilinear interpolation, which fills missing color values with weighted averages of their neighboring pixel values. Although this method is simple, it introduces severe demosaicking artifacts and smears sharp color edges. For better performance, more sophisticated CFA demosaicking methods [2]-[7],[9],[11] have been developed to exploit the spectral and spatial correlations among neighboring pixels. Two CFA demosaicking methods [7],[9] have been selected for comparison in this paper based on their superior image quality performance.

III. Image Quality Assessment

Even though both imaging technologies have different total pixel count, they both maintain that they can produce full HD video images. The objective of this paper is to evaluate the difference of the two methods in image quality in terms of detail and color preservation.

To analyze the preservation of image details, the luminance component of the output image is assessed as the detail in an image from the eye's perspective is carried almost exclusively in the luminance component of the visual data [12].

PSNR [11] is the log ratio of the signal to noise in RGB color space. We apply PSNR to determine the log difference between the luminance component of the output image and that of the original image. A large PSNR value will indicate that image details are well preserved, and vice versa.

In order to assess the degree of color artifacts in the output image, we apply NCD [8], Normalized Color Difference, for comparison. A smaller NCD value will indicate a better color preservation.

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IV. RESULTS

To assess the output image quality of the methods, we apply the image as shown in Fig 3(a) to the following methods: 3CCD with PST [10], CFA demosaicking using bilinear interpolation, CFA demosaicking using Gunturk's method [9] and CFA demosaicking using Li&Randhawa's Cubic Spline Interpolation (CSI) method [7].

The PSNR results of the luminance component of the output images are tabulated in Table 1. Since the luminance indicates the amount of image details retained in the image, this shows that the CFA demosaicking methods outperforms the 3CCD with PST in this case.

The degree of color artifacts produced in the output image can be determined through the NCD values in Table 1. It is apparent that while the 3CCD with PST outperforms the simple CFA bilinear demosaicking method, it is not as good as the other more sophisticated CFA demosaicking methods.

Both the PSNR and NCD results in Table 1 can be confirmed visually by the output images in Fig. 3. It is clear that the CFA demosaicking methods produce sharper images in general. On the other hand, the 3CCD with PST is able to reproduce color faithfully with less color artifacts than the CFA bilinear demosaicking method. However, it is noticeable that the more sophisticated CFA demosaicking methods produce less color artifacts.

TABLE 1 IMAGE QUALITY PERFORMANCE MEASURES

	3CCD with PST	Single image sensor using CFA demosaicking		
Fence	Conventional	Bilinear	Gunturk[9]	CSI[7]
PSNR	24.90	25.72	43.37	45.55
NCD	0.0854	0.1655	0.0263	0.0215

V. CONCLUSION

In general, 3CCD with pixel shift technology has a lower computational cost than the single-sensor CFA demosaicking methods. On the other hand, the 3CCD sensor technique requires a more sophisticated optical system. However, from the point of view of the user, besides cost, image quality is of main concern. From our investigation, it appears that the 2M-pixel single image sensor using state-of-the-art CFA demosaicking techniques can give an image with more details and less color artifacts when compared with the 1.5M-pixel 3CCD with pixel shift technology.

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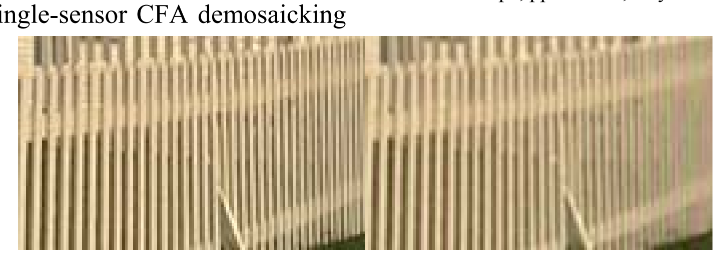
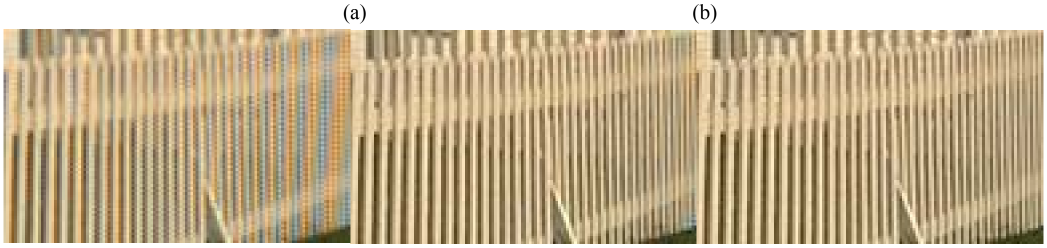


(a) (b)



(c) (d) (e)

Fig. 3 Picket fence region of (a) the original Lighthouse image, output images using (b) 3CCD with conventional PST, (c) CFA demosaicking using bilinear interpolation (d) CFA demosaicking using Gunturk's method [9] and (e) CFA demosaicking using Li&Randhawa's Cubic Spline Interpolation (CSI) method [7].