Joint Denoising and Demosaicking of Noisy Bayer sampled Color Images with LSLCD and Noise Level Estimation

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Abstract: Demosaicking and zooming are important for the quality of digital images in resource-constrained single chip devices such as wireless camera phones and vision-based portable devices. During Demosaicking process color artifacts are introduced which can be magnified during zooming process and vice versa. This paper represents a joint demosaicking–zooming scheme by exploiting the fact that red/green and blue/green color difference signals are much smoother than the red, green and blue original signals. Using the high spectral–spatial correlations in the color filter array (CFA) image the color difference signals are computed. The computed color difference signals are used to recover the green channel. This green channel is enlarged using an edge guided zooming scheme. By adding the correspondingly enlarged red/green and blue/green color difference images to the enlarged green channel the enlarged red and blue channels can be found. The proposed joint demosaicking–zooming scheme performs well in both visual perception and Peak Signal to Noise Ratio (PSNR) measurement, reducing much color artifacts arising from demosaicking as well zippers and rings arising from zooming.

Index Terms – Demosaicking, Peak Signal to Noise Ratio (PSNR)

I.INTRODUCTION

Most digital still/video cameras capture images using a single chip and a color filter array (CFA) known as the Bayer color filter array (CFA) pattern. The process to reproduce the color components and enlarge the images while maintaining image quality is crucial to many resource-constrained digital imaging devices such vision-based pocket devices, camera phones and low-cost color value video cameras.

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The enlarged image quality depends on two image processing operations: demosaicking (spectral interpolation) and zooming Spatial interpolation). A single chip camera sample only one of the three primary color components (red, green and blue), a full color image is created through a process called demosaicking, which is used to bring out the other two missing color (components at each pixel location. The input image is been enlarged using zooming and spatial interpolation sequentially. The full color is obtained by, enlarged image from a CFA image, i.e. To increase the spatial and spectral resolution of a CFA image, there are three strategies: the CFA image is first demosaicked and then enlarged; second the CFA image is first enlarged and then demosaicked; the demosaicking and zooming are implemented simultaneously. The first two strategies, the quality of the resulted image depends on the demosaicking and zooming algorithms used and their application order to the CFA image. However, errors in the form of color artifacts are usually introduced into the final image.

II.METHODOLOGY

The Fig.1 shows the flowchart of the proposed joint demosaicking–zooming scheme. Because of the high spectral correlation between color channels, the R–G and B–G color difference signals are much smoother than the original color signals G, R and B. Based on this observation, the R–G and B–G color difference images are estimated and they heavily affect the demosaicking–zooming results, as enlarging the color difference images instead of R and B images significantly reduces the demosaicking and interpolation errors. Once the R–G and B–G values at the red and blue sample positions are estimated, the fully populate R–G and B– G images are used to demosaick the green channel. Since the sampling frequency of green channel is as twice as that of red or blue channel, it can be demosaicked and interpolated more accurately than red and blue channels. The green channel contains the most of the details of an image and then the green channel should serve as an anchor for recovering red and blue channels.

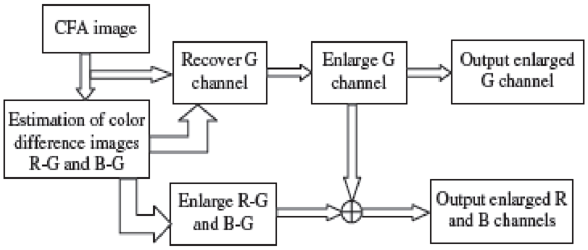

Fig. 1. Flowchart of the proposed joint demosaicking–zooming scheme.

The demosaicked Green image is first enlarged to improve the resolution. The interpolation based on linear convolution methods are simple but suffer from artifacts such as block effects, blurred details and edge ringing effects. Some nonlinear interpolation methods yield better results but suffer from high computation load [3,7,10,12,13]. Here, we will employ an edge sensitive interpolator with a reasonable complexity. The R–G and B–G color difference images are then interpolated and added to the already interpolated Green channel to obtain the enlarged R and B channels. The anchor function of green channel ensures the preservation of edge structures in red and blue channels. The Fig. 2 shows an example, of RGB model and the difference image between G and R channels and finally the difference image between G and B images, where we see that the edge structures in the chromatic channels are removed or significantly smoothed in the color difference images.

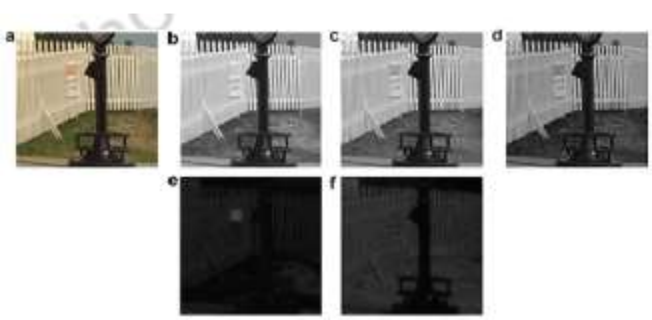

Fig. 2. (a) A full color test image; the (b) red, (c) green and (d) blue channel of the test image; (e) the difference image between green and red channels; (f) the difference image between green and blue channels.

III. DOWNSAMPLED IMAGE

A pixel is defined as a complete set of color data for a point in an image. A pixel is said to complete only when the red, green and blue values are known for the unique location of that particular pixel. A special Bayer interpolation algorithm is then used to create separate R, G and B values for every pixel location. Remember that before this interpolation that each location only had a R or G or B value; not a R value and a G value and a B value for each location. The algorithm creates values for each of the three colors at every location by smearing (interpolating) each set of partial R, G and B values to have values at every location. Conventionally, digital color images are represented by setting specific values of the color space coordinates for each pixel. The color spaces with decoupled chrominance and luminance coordinates (YUV type) allow the number of bits required for acceptable color description of an image to be reduced, and is based on greater sensitivity of the human eye to changes in luminance than to changes in chrominance.

Fig. 3.Downsampled input image

The idea behind this approach is to set individual value of luminance component to each pixel, while assigning the same color (chrominance components) to certain groups of pixels sometimes called macropixels) in accordance with some specific rules. This process is called downsampling which is as shown in Fig.3 and there are different sampling formats depending on the underlying scheme.In signal processing, downsampling (or "subsampling") is the process where the sampling rate of the original signal is reduced. This is usually done to reduce the size of the data. The downsampling factor (commonly denoted by M) is usually an integer or a rational fraction greater than unity. This factor multiplies the sampling time or, equivalently, divides the sampling rate. For example, a 16-bit compact disc audio (sampled at 66,100 Hz) is downsampled to 33,050 Hz, the audio is said to be downsampled by 2 factor and bit rate from one to half.

IV.RGB PATCHING

Finding the noise level in the three channels of the CFA signal we can select the appropriate set of trained filters, although there are many methods developed for noise level estimation in single-channel images, little work has been done on this problem for CFA signals. We have experimented with various techniques for noise level estimation and found that the method of Amer and Dubois [1] is most suitable for our problem. The section shows how the method of [1] has been adapted for CFA images. The Fig.4 depicts the RGB patched image. Thus, the assumption of the equation is given as,

$$f_{CFAN}[n1,n2] = F_{CFA}[n1,n1] + v[n1,n2] \quad (1)$$

Where v [n1, n2] is independent white Gaussian noise with variance σ2 i in the i th channel ([n1, n2] ∈Ψi). We have tested our noise estimation methods on two standard image data sets with added noise: the 768×512 Kodak images (KO), and the data set of 720 × 540 images made available by L. Condat [7] (LC).

Fig.4. RGB Patching

V.NOISE ESTIMATION

To adapt the noise estimation of [1] to CFA images, we partition the image into four rectangular sampled sub images R, G1, G2, and B, corresponding to the four phases of the Bayer pattern. Actual proposed method estimates the global image noise variance from the variances of a set of blocks within the sub images classified as the most Intensity Homogeneous Blocks (IHB).This method selects IHBs in a sub image by rejecting blocks with line structure, using the masks of [1] to detect line structures. The noise level estimation method consists of two parts: (1) detecting IHBs, (2) calculation of σi =√αiσA for color i ∈ {R, G, B} of the selected blocks. For each sub image, we define square ω × ω blocks B(j)kl , centered at each location (k, l) in the sub image, j ∈ {R, G1, G2, B}. The sample mean and sample variance for each block is denoted by μB(j)kl and σ2B(j)kl . The assumption is that for the most homogeneous blocks of the image, μB(j)kl represents the signal value and the variance σ2B(j)kl can be attributed to the noise in the corresponding channel, and a good estimate of the noise variance in that channel. Calculation of homogeneity measure, ξB(j)kl is needed to determine if a block can be classified as an IHB, we need to calculate a homogeneity measure, ξB(j)kl. Assuming we have eight directional homogeneity measures from eight edge directions, where ζ (m)B(j)kl is the absolute value of the output of a one dimensional high pass filter applied on mask contour m , evaluated at the center of the block. We assume that blocks with the smallest sum of all directional homogeneity measures, ξB(j)kl=1≤m≤8 ζ (m)B(j)kl , may be identified as IHBs. Multiple combinations of configurations can be made for determining IHBs.

Estimating color differences R–G and B–G: Most demosaicking methods exploits the correlation between red, green and blue channels. Two assumptions on the relation between red and green components and the relation between blue and green components used in color demosaicking literature are constant ratio [6] and equal difference [1,2] in the localized image area. In [11], Zhang and Wu showed that the differences between the red and green channels and between the blue and green channels, which are referred to as primary difference signals (PDS), are low-pass signals. Based on this assumption, they presented an adaptive demosaicking method which is optimal in the sense of LMMSE. However, the computation load of this method may be heavy for resource-constrained devices. In this paper, the rationale of [11] is employed in estimating the PDS signals but the complexity is reduced greatly by sacrificing the optimality of LMMSE. Except, the PDS estimation performance is only slightly sacrificed. We denote the two PDS signals by DR;G ¼ R _ G; DB;G ¼ B _ G ð2-1Þ Under the assumption that DR,G and DB,G are smooth signals [11], which mostly are smoother than the original R, G and B color channels, PDS signals can be more accurately estimated than the individual color channels.

Estimating DR,G and DB,G, the green channel is demosaicked and then used to reconstruct the other two red and blue channels. Because of the symmetry between the red and blue channel locations in the Bayer pattern, we only discuss the estimation of DR,G and the estimation of DB,G can be derived in the same way. DR,G is computed in three steps. The first and most important step is to estimate the DR,G values at the positions of red samples. We then estimate the DR,G values at the positions of blue samples and finally the other values. The red sample at the centerFig.2.It is seen that the color difference images are much smoother than the original channels. (For Experimental results The proposed joint demosaicking–zooming method is compared against The first three schemes are ‘‘demosaicking-first and zooming-later’’ methods. The three demosaicking algorithms used are the SOLC by Hamilton and Adams [4], the successive approximation based demosaicking by Li [8] and the adaptive homogeneity- directed demosaicking by Hirakawa and Parks [5] four schemes. The zooming algorithm used is the nonlinear edge-directed interpolator proposed by Li and Orchard [7]. The fourth scheme used in comparison is a ‘‘CFA-zooming-first and demosaicking-later’’method. In this scheme, the CFA zooming algorithm proposed by Lukac et al. [9] is used to enlarge the CFA image first and the adaptive homogeneity- directed demosaicking by Hirakawa and Parks [5] is employed to generate the full color image.

Fig.5. Fully generated color image

VI. CONCLUSION

This paper presented here shows joint demosaicking–zooming scheme for single-chip digital color imaging devices. The proposed method well exploits the high spectral correlation existed in the images of natural scenes. The R–G and B–G color difference images are first estimated and they are used to recover the green channel. As an visual to reconstruct the red/blue channel, the green image is enlarged by using an edge direction guided interpolation scheme. Instead of enlarging the red/blue channels directly, the R–G and B–G images are interpolated because they are much smoother than the original color images. Adding the interpolated color difference images to the already enlarged green channel produces the red and blue images. The proposed joint demosaicking– zooming scheme was compared with other methods and the experimental results showed that it proves well in both visual perception and PSNR measurement.

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