

AN ENLARGEMENT AND REDUCTION OF DIGITAL IMAGES WITH MINIMUM LOSS OF INFORMATION

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Abstract— Color demosaicing is a key image processing step aiming to reconstruct the missing pixels from a recorded raw image. Without reconstruction the image is with a poor quality and produce strong visible artifacts. In current digital era, the image interpolation technique is based on multiresolution technique are being discovered and developed. The most important aspect of image processing is the ways in which the quality of an image is improved using various techniques. Image interpolation is one such technique. Interpolation technique determine the values of function at position lying between samples. The interpolation techniques are nearest neighbour, bilinear, bicubic interpolation. My work presents demosaicing using alternating projection with better performance with minimum loss of information than bilinear interpolation.

Index Terms—Bayer pattern, color filter array, demosaicing

I. INTRODUCTION

SINGLE-CHIP digital cameras use color filter arrays to sample different spectral components, such as red, green, and blue. At the location of each pixel only one color sample is taken, and the other colors must be interpolated from neighboring samples. This color plane interpolation is known as *demosaicing*, and it is one of the important tasks in a digital camera pipeline. If demosaicing is not performed appropriately, images suffer from highly-visible color artifacts. The most commonly used color pattern is the “Bayer” pattern. As seen in Fig. 1, in a Bayer pattern, green samples are obtained on a quincunx lattice (checkerboard pattern), and red and blue samples are obtained on rectangular lattices. The density of the red and blue samples is one-half that of the green ones.

Demosaicing methods can be grouped into two distinct classes. The first class applies well-known interpolation techniques to each color channel separately. These techniques include nearest-neighbor replication, bilinear interpolation, and cubic spline interpolation. Although these single-channel algorithms can provide satisfactory results in smooth regions of an image, they usually fail in high-frequency regions, especially along edges. For natural images better performance is possible than is achieved by these techniques because of the high cross-correlation between color channels. The second class of algorithms exploits this inter-channel correlation, and has significantly better performance than the first class.

One approach in this class is *smooth hue transition*. Smooth hue transition algorithms are based on the assumption that hue does not change abruptly between neighboring pixel locations. As a first step, these algorithms interpolate the luminance (green) channel, which is usually done using bilinear interpolation.

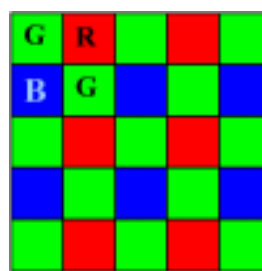


Fig. 1. Bayer pattern.

The chrominance channels (red and blue) are estimated from the bilinearly interpolated “red hue” (red-to-green ratio) and “blue hue” (blue-to-green ratio). To be more explicit, the interpolated “red hue” and “blue hue” values are multiplied by the green value to determine the missing red and blue values at a particular pixel location. Instead of interpolating the hue, it is also possible to interpolate the logarithm of the hue.

Another approach that exploits inter-channel correlation is *edge-directed interpolation*. The main difference between this approach and the previous one is that the bilinear interpolation of the green channel is replaced by adaptive interpolation to prevent interpolating across edges. In first-order horizontal and vertical gradients are computed at each missing green location on the Bayer pattern. If the horizontal gradient is greater and the vertical gradient is less than a predetermined threshold, suggesting a possible edge in the horizontal direction, interpolation is performed along the vertical direction. If the vertical gradient is larger and the horizontal gradient is less than the threshold, interpolation is performed only in the horizontal direction. When the horizontal and vertical gradients are nearly equal, (that is, both gradients are less than or greater than the threshold), the green value is obtained by averaging its four neighbors. Interpolation of the red and blue channels can be done by either interpolating color ratios (as in smooth hue transition) or by interpolating the color differences instead of the color ratios.



Fig. 2. Images used in the experiment

In this paper, we present a very effective means of using inter-channel correlation in demosaicing. The algorithm defines constraint sets based on the observed color samples and prior knowledge about the correlation between the channels. It reconstructs the color channels by projecting the initial estimates onto these constraint sets. We have compared our algorithm with the various other techniques that we have outlined above, and it outperforms them both visually and in terms of its mean square error. Section II presents the motivation and details of this algorithm. Its experimental performance and comparisons with other techniques are given in Section III. A complexity analysis is provided in Section IV.

II. DEMOSAICING USING ALTERNATING PROJECTIONS

There are two observations that are important for the demosaicing problem. The first is that for natural images there is a high correlation between the red, green, and blue channels. All three channels are very likely to have the same texture and edge locations. The second observation is that digital cameras use a color filter array (CFA) in which the luminance (green) channel is sampled at a higher rate than the chrominance (red and blue) channels. Therefore, the green channel is less likely to be aliased, and details are preserved better in the green channel than in the red and blue channels. In demosaicing, it is the interpolation of the red and blue channels that is the limiting factor in

performance. Color artifacts, which become severe in high-frequency regions such as edges, are caused primarily by aliasing in the red and blue channels. Although this fact is acknowledged by the authors of most demosaicing algorithm that does remove aliasing in these channels using an alternating-projections scheme. It defines constraint sets using both the inter-channel correlation and the observed data, and reconstructs the red and blue channels by projecting initial estimates onto these constraint sets.

Section II-A quantifies the degree of cross-correlation between the color channels. Section II-B illustrates the aliasing that results from CFA sampling and motivates a detail-retrieving interpolation scheme. Section II-C derives the constraint sets used by the proposed demosaicing scheme. Section II-D presents the details of the implementation and Section II-E describes some extensions.

A. Inter-Channel Correlation

In natural images the color channels are highly mutually correlated. Since all three channels are very likely to have the same edge content, we expect this inter-channel correlation to be even higher when it is measured between the high frequency components. (The reason for investigating correlation in the high-frequency components will become evident in Section II-B.) In order to illustrate this we decomposed the three color channels of 20 natural images (Fig. 2) into sub-bands. We used two-dimensional separable filters constructed from a low-pass filter and a high-pass filter to decompose each image into its four subbands: (LL) both rows and columns are low-pass filtered, (LH) rows are low-pass filtered, columns are high-pass filtered, (HL) rows are high-pass filtered, columns are low-pass filtered, (HH) both rows and columns are high-pass filtered.

B. Color Plane Sampling

As seen in Fig. 1, in a Bayer pattern the green channel, sampled with a quincunx lattice, is less likely to be aliased than the red and blue channels, which are sampled with less dense rectangular lattices. This can easily be illustrated in the frequency domain. Fig. 3(a) depicts the Fourier spectrum of an image with f_m being the maximum observable frequency. When this image is captured with a digital camera, the color planes are

sampled according to a CFA, which is generally the Bayer pattern. As illustrated in Fig. 3(b) and (c), while there is no aliasing in the green channel, the red and blue channels are aliased.

C. Constraint Sets

Set-theoretic reconstruction techniques produce solutions that are consistent with the information arising from observed data or prior knowledge about the solution. Each piece of information is associated with a constraint set in the solution space, and the intersection of these sets represents the space of acceptable solutions [19]. For the demosaicing problem, we define two types of constraint sets, one coming from the observed data, and the other based on the prior knowledge of the inter-channel correlation.

A very effective means of using inter-channel correlation in demosaicing is alternating projection. The algorithm defines constraint sets based on the observed color samples and prior knowledge about the correlation between the channels. It reconstructs the color channels by projecting the initial estimates onto these constraint sets. This is compared with bilinear interpolation and it outperforms them both visually and in terms of its mean square error. There are two observations that are important for the demosaicing problem. The first is that for natural images there is a high correlation between the red, green, and blue channels. All three channels are very likely to have the same texture and edge locations. The second observation is that digital cameras use a color filter array (CFA) in which the luminance (green) channel is sampled at a higher rate than the chrominance (red and blue) channels. Therefore, the green channel is less likely to be aliased, and details are preserved better in the green channel than in the red and blue channels. It defines constraint sets using both the inter-channel correlation and the observed data, and reconstructs the red and blue channels by projecting initial estimates onto these constraint sets.

III. ALTERNATING PROJECTIONS ALGORITHM

1) Projection Operators: The first constraint set that is used in the reconstruction is the "observation" constraint set given in P_o (2). Referring to that equation, we can write the projection onto the "observation" constraint set as follows:

$$P_o[S(n1,n2)] = \begin{cases} O(n1, n2), & (n1, n2) \in \Lambda_S \\ S(n1, n2), & \text{otherwise} \end{cases}$$

where S is the color channel which can be the red, green or blue channel.

2) Convergence: An initial estimate converges to a solution in the feasibility set by projecting it onto these constraint sets iteratively. The initial estimates for the red and blue channels were obtained by bilinear interpolation.

3) Updating the Green Channel: This algorithm reconstructs the high-frequency information of the red and blue channels. The performance of this reconstruction directly depends on the accuracy of the green channel interpolation.

IV. UPDATE GREEN CHANNEL

1) Interpolate the green channel to get an initial estimate. Either bilinear or edge-directed interpolation methods can be used for this step.

2) Use the observed samples of the blue channel to form a downsampled version of the blue channel.

3) Use the interpolated green samples at the corresponding (blue) locations to form a downsampled version of the green channel.

4) Decompose these blue and green downsampled channels into their subbands

5) Replace the high-frequency subbands of the green channel with those of the blue channel.

6) Reconstruct the downsampled green channel, and insert the pixels in their corresponding locations in the initial green channel estimate.

7) Repeat the same procedure for the pixels at the red samples.

V. PSEUDOCODE

1) Initial interpolation: Interpolate the red, green, and blue channels to obtain initial estimates. Bilinear is used for this initial interpolation.

2) Update the green channel: Update the green channel using the scheme explained in 4.4.1

3) "Detail" projection: Decompose all three channels with a filter bank. At each level of decomposition, there will be four subbands. Update the detail subbands of the red and blue channels and reconstruct these channels.

4) "Observation" projection: Compare the samples of the reconstructed red and blue channels with the original samples.

5) Iteration: Go to Step 3, and repeat the procedure until a stopping criterion is achieved.

The result of demosaicing using alternating projection is then compared with the bilinear interpolation. Finally, the quality in terms of PSNR is

calculated for both demosaicing using alternating projection and bilinear interpolation. It is observed that the PSNR value of the alternating projection algorithm outcomes the bilinear interpolation technique.

VI. DEMOSAICING USING BILINEAR INTERPOLATION-RESULTS

Fig shows the input of flowers and sill used for bilinear interpolation.

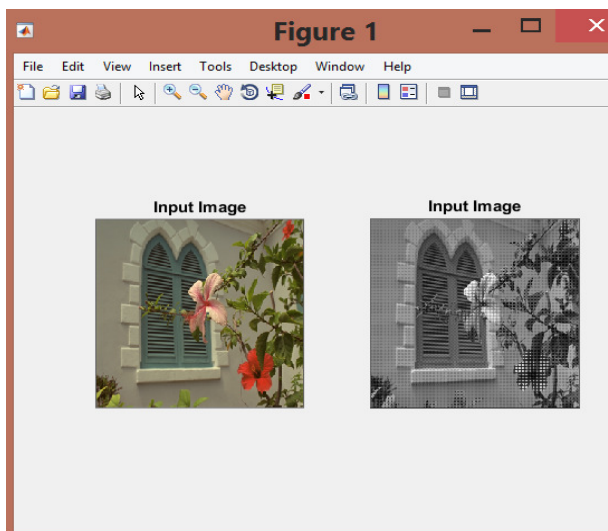


Fig 3 Input image for bilinear interpolation

Fig shows the bilinear green plane for the above figure

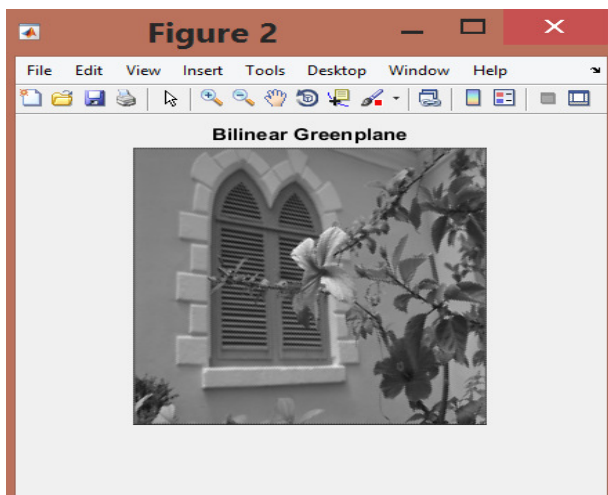


Fig 4 Bilinear Greenplane

Fig shows the bilinear redplane for the input image

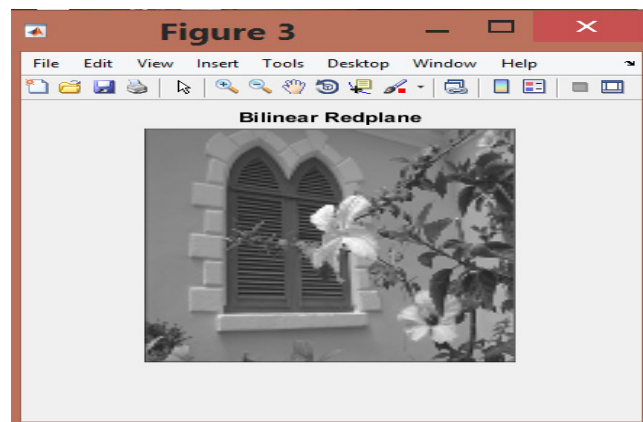


Fig 5 Bilinear Redplane

Fig shows the bilinear blueplane for the input image

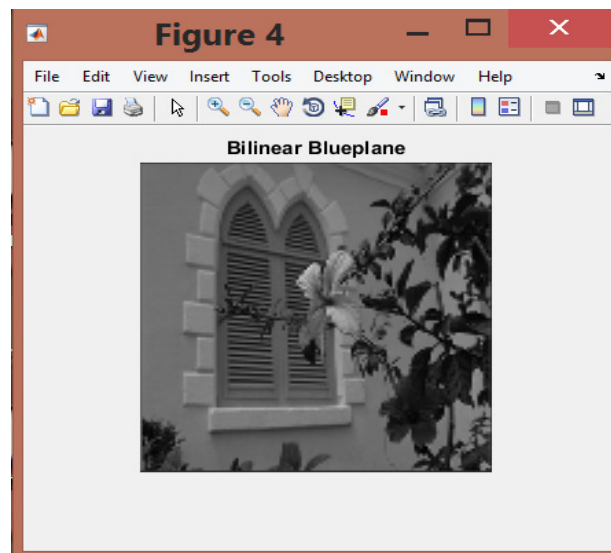


Fig 6 Bilinear Blueplane

Fig shows the output image obtained using bilinear interpolation technique

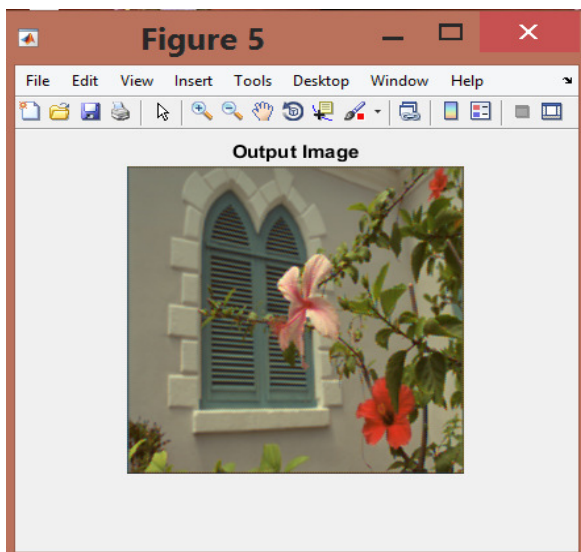


Fig 7 Output of bilinear interpolation

The proposed PSNR performance is 36.00 dB.

VII. DEMOSAICING USING ALTERNATING PROJECTIONS- RESULTS

Fig shows the input image for alternating projections.

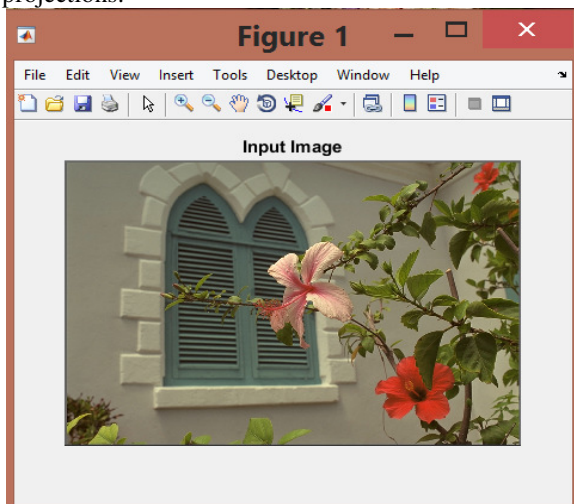


Fig 8 Input image for alternating projections

Fig shows the output image obtained using alternating projections.

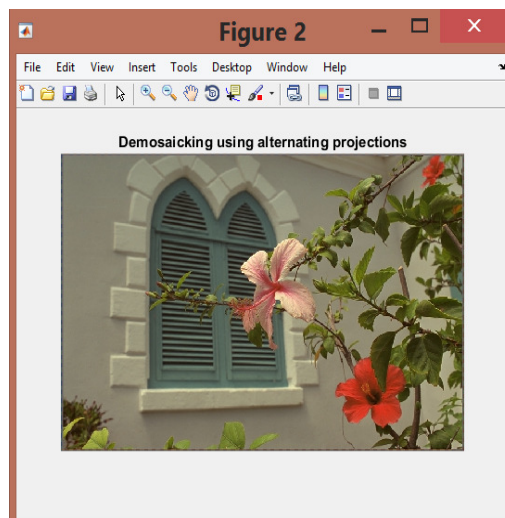


Fig 9 Output image for alternating projection

The proposed PSNR performance is 43.9888 dB.

VIII. CONCLUSION AND FUTURE WORK

Thus the proposed algorithm was compared with the well known demosaicing algorithm such as bilinear interpolation and it showed an outstanding performance both visually and in terms of PSNR at a reasonable computational complexity. The extension of this work is to use bicubic interpolation for pixel accuracy and better quality.

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