A demosaicing technique for optimized color transform in the reconstruction of red , green and blue colors to impose higher smoothness using color filter array (CFA)

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ABSTRACT

An optimal approach to color image using demosaicing is introduced in this paper. Accordingly, an efficient algorithm for color image coding is proposed. In the encoder, mosaic of the primary colors is encoded instead of the full color image. This mosaic is considered as four different color channels that are compressed using sub band transform coders. In the decoder, a demosaicing algorithm is applied to the decompressed channels to reconstruct the full image. Optimized color transforms are used both in the encoding stage and in the decoding stage. The experimental results show that the proposed method outperforms currently available techniques with regard to visual and quantitative measures and is efficient for color image coding.

Index terms: Demosaicing, Color transforms, Mosaic, Sub band transform

I. INTRODUCTION

In this work, a new approach to color images based on the naturally high inter-color correlations of the RGB primaries is introduced. Various methods have been proposed in order to reduce the amount of data that is actually encoded, such as transforming the RGB primaries into a new color space such as YUV, and then encoding the new color components at different rates according to their energy concentration or visual significance. Here, a new image compression approach based on image demosaicing and a coding algorithm introduced recently. A Bayer pattern of a given color image is used . It consists of a mosaic of the pixels of the primary colors, so that the green occupies half of the pattern while the red and the blue occupy a quarter each is shown in Figure 1.

A. Interpolation

It is a fundamental problem in image processing to re-sample the image size. Due to the physical limitation of imaging hardware, image interpolation techniques are often employed to reconstruct a higher resolution (HR) image from its low resolution (LR) counterpart. Image interpolation is widely used in digital photographs, medical imaging and remote sensing etc., and many interpolation algorithms have been proposed, including the simple but fast linear interpolators and those more complex non-linear interpolators. Most of the existing interpolation schemes assume that the original image is noise free. This assumption, however, is invalid in practice because noise will be inevitably introduced in the image acquisition process.

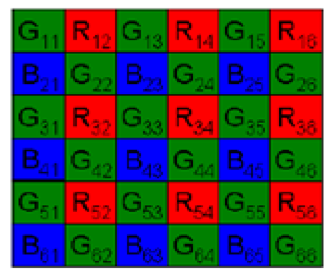

Figure 1. The Bayer Pattern

B. Denoising

Denoising is to estimate the original pixels from the noisy measurements, while interpolation is to estimate the missing sample from its local neighbors. Usually denoising and interpolation are treated as two different problems and they are performed separately. However, this may not be able to yield satisfying result because the denoising process may destroy the edge structure and introduce artifacts, which can be further amplified in the interpolation stage.

An iterated total variation refinement scheme was developed and the iterative regularization method was generalized to nonlinear inverse scale space and applied to wavelet based denoising.

C. Interpolation Technique

The traditional linear interpolation methods, such as bi-linear and bi-cubic interpolation, are simple and fast. Demosaicing method has to be used to reconstruct the full color image from its mosaic. These algorithms often reconstruct the green first, followed by reconstruction of the red and blue colors using the differences from the interpolated green. As different method, using an optimized color space for the reconstruction of the red and the blue is proposed. According to this approach, the coding is performed by considering the Bayer pattern as made of four components according to color: RR for the red, BB for the blue and GR and GB for the green as shown in Figure 2.

These components are encoded and reconstruction of the image is done by decoding each of the four components and then running a demosaicing algorithm.

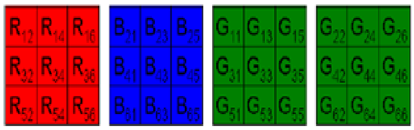

Figure 2. The Bayer pattern components: RR, BB, GR and GB

II RELATED WORK

To minimize cost and size, most commercial digital cameras acquire imagery using a single electronic sensor (CCD or CMOS) overlaid with a color filter array (CFA) such that each sensor pixel only samples one of the three primary color values [1].Image demosaicing algorithms are used to reconstruct a full color image from the incomplete color samples output (RAW data) of an image sensor overlaid with a Color Filter Array (CFA). Better demosaicing algorithms are superior in terms of acuity, dynamic range, signal to noise ratio, and artifact suppression, which make them suitable for high quality delivery such as the atrical broadcast [2]. A rate distortion model for color image compression can be employed to find the optimal color components and optimal bit allocation (optimal rates) for the compression[3]. Most commercial digital cameras use color filter arrays to sample red, green, and blue colors according to a specific pattern [4]. At the location of each pixel only one color sample is taken, and the values of the other colors must be interpolated using neighboring samples. This color plane interpolation is known as demosaicing; it is one of the important tasks in a digital camera pipeline.

Conventional single - chip digital cameras use color filter arrays (CFA) to sample different spectral components [5] use demosaicing algorithms.A single sensor equipped with a color filter array (CFA) is used in many digital still cameras to capture any of the three primary color components, R(red), G(green) or B(blue) on each pixel location, in order to reduce the hardware cost[7]. Most signal processing applications are based on discrete-time signals although the origin of many sources of information is analog [6]. A fast and high-performance algorithm for color filter array (CFA) demosaicing[8] . Most digital still cameras acquire imagery with a color filter array (CFA), sampling only one color value for each pixel and interpolating the other two color values afterwards [10] . The interpolation process is commonly known as demosaicking.The statistical dependence (redundancy) between three differentially coded color components of a video-telephone signal are explored by means of an entropy study[9].

In 1996, the JPEG committee began to investigate possibilities for a new still image compression standard to serve current and future applications[11] .This initiative, which was named as JPEG 2000. The embedded zero tree wavelet algorithm (EZW) is a simple , yet remarkably effective , image compression algorithm , having the property that the bits in the bit stream are generated in order of importance, yielding a fully embedded code[12].The most image compression algorithms deal today with color images, the theory behind the compression process is based mainly on monochrome tools[13].The common approach to color imag ecoding is to decrease the high inter-color correlations in the RGB domain by transforming the color primaries into a de-correlated color space prior to coding. The encoding of colored pictures in components has attracted a lot of attention. In this paper, for their efficient transmission in the 2-3 bit/per range, the direct encodingof the red (R), green (G), and blue (B) primaries is investigated [5].Digital cameras sample scenes using a color filter array of mosaic pattern (e.g., the Bayer pattern). The demosaicing of the color samples is critical to the image quality [15].

III. THE PROPOSED METHOD

The block diagram of the proposed method is shown in Figure 3.The color image is given as an input. The input image is first converted into binary image for analysis (i.e., 0 to 255 color value is changed to 0's and 1's binary image). The next step is to perform image enhancement, it corrects color hue and brightness imbalances as well as other image editing features, such as red eye removal, sharpness adjustments, zoom features and automatic cropping to improve the quality of images.

Then the image enters RGB pattern analysis and red pattern, blue pattern and green pattern are obtained separately. Next, the color segmentation process is carried out to divide the color image into multiple segments or super pixels and used to locate objects and boundaries. The next step is to filter the images to apply various effects on the photos; it is mainly used to remove noise from the images by using Weiner filter.

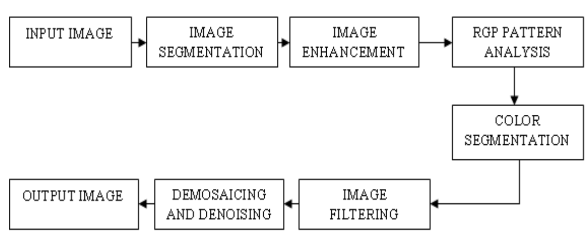

Figure 3. Block diagram

The final step is to undergo denoising and demosaicing by using bilinear interpolation is applied to the decompressed channels to reconstruct a full color image from the incomplete color samples to get the output image with improved quality. The reconstructed image is typically accurate in uniform-colored areas.

A. The Encoding Algorithm

First a Bayer pattern is created for a given image. This is done by sampling the image keeping only the RGB pixels at the locations. Then a compression method is applied to this pattern as follows.

Compression

In the compression method, the four channels RR, BB, GR and GB of the Bayer pattern are jointly coded using sub band transform coders . The stages of the coding algorithm are:

1) Apply a color transform to the input channels to improve the energy concentration. If we denote the channels at some pixel by x = [RR GR GB BB] T and the color transform matrix by M, then this stage is given by the equation (1).

$$\_x = M_x \quad (1)$$

Where x = [C1 C2 C3 C4] is the vector of the new color components at the same pixel. Since it can be shown that the Discrete Cosine Transform (DCT) can be used as the color transform in this stage, apply the DCT color transform to the [BB RR GB] T vector of channels is proposed. The fourth color component can be taken simply as GR – GB.

2) Apply the Discrete Wavelet Transform (DWT) to each of the new color components.

3) Quantize the DWT coefficients of each color component using quantization steps derived from optimal subband rates allocation. The quantization steps are part of the output bit stream.

4) Use a lossless coding technique as a post-quantization stage such as in the Embedded Zero tree Wavelet algorithm (EZW) to encode the quantized DWT coefficients using the intra-subband and inter-subband correlations.

B. The Decoding Algorithm

The decoder has to decompress the four color channels RR, BB, GR and GB, to arrange them in a Bayer pattern and then to apply a demosaicing algorithm to reconstruct the full image.

The decompression technique and the proposed demosaicing method is discussed in the following subsections.

Decompression

To decode the four color channels, the following stages are performed.

1) Inverse post-quantization coding, corresponding to the one used in Step 4 of the compression method.

2) Inverse quantization of the Discrete wavelet transform (DWT) coefficients of the four color components.

3) Inverse DWT applied to the coefficients of each of the color channels.

4) Inverse color transform, which can be described.

$$x = M-1\_x \quad (2)$$

Where _x and x are the vectors of the reconstructed color components before and after the inverse color transform respectively. This can be shown in equation (2).

Noise will be inevitably introduced in the image acquisition process and denoising is an essential step to improve the image quality. As a primary low-level image processing procedure, noise removal has been extensively studied and many denoising schemes have been proposed, from the earlier smoothing filters and frequency domain denoising methods to the lately developed wavelet, curvelet and ridgelet based methods, sparse representation and K-SVD methods, shape-adaptive transform , bilateral filtering , non-local mean based methods and non-local collaborative filtering .

With the rapid development of modern digital imaging devices and their increasingly wide applications in our daily life and in every technologies there are increasing requirements of new denoising and demosaicing algorithms for higher image quality.

C. Wavelet Transform

Wavelet transform (WT) has proved to be effective in noise removal . It decomposes the input signal into multiple scales, which represent different time-frequency components of the original signal. At each scale, some operations, such as thresholding and statistical modeling, can be performed to suppress noise. Denoising is accomplished by transforming back the processed wavelet coefficients into spatial domain.

D. Demosaicing

Once the four color channels RR, BB, GR and GB have been decoded and arranged in a Bayer pattern, a demosaicing algorithm is performed. In this work a basic demosaicing algorithm has been choosen consisting of the following stages:

1)The green color component is interpolated using edge preserving filtering. It consists of filtering the Bayer pattern horizontally and vertically, then choosing the direction of interpolation corresponding to the smaller estimated gradient to avoid interpolation across edges: horizontal or vertical.

2) The interpolated green component G is used in the reconstruction of the red and blue colors. The linear combinations are shown in equations (3) and (4).

$$C_{RG} = a_1R + a_2G \quad (3)$$

$$C_{BG} = d_1B + d_2G \quad (4)$$

are calculated at the known pixels of the red and the blue colors, respectively. There are different choices of a_1, a_2, d_1 and d_2 that are better than the common choice: $a_1 = d_1 = 1$, $a_2 = d_2 = -1$. In this work we have taken the choice that provides minimal gradient energy of C_{RG} and C_{BG} (summed up for the whole image),The coefficients corresponding to this choice are shown in equation (5).

$$a_1=1 \text{ , } a_2= \frac{-\sum_i \sum_j (\nabla R)^T_{ij} (\nabla \hat{G})_{ij}}{\sum_i \sum_j \left\| (\nabla \hat{G})_{ij} \right\|^2} \quad (5)$$

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R and G at pixel (i, j), respectively. The solution for d_1 and d_2 is similar, with B replacing R everywhere. Then the red-green combination is interpolated at the locations of the known blue samples, and the blue-green combination is interpolated at the locations of the known red samples using a local polynomial approximation (LPA) filter.

3) The missing pixels in the red and blue - those at the locations of the known green pixels are interpolated by averaging their two vertical and two horizontal neighbors (bilinear interpolation). The interpolation is performed once again for the CRG and CBG combinations, resulting in full images CRG and CBG

4) The final red and blue components are calculated according to the reconstructed red, green and blue components of the image are the output of the decoder as in equations (6) and (7)

$$\hat{C}_{RG} - a_2 \hat{G}\hat{R} = a_1 \quad (6)$$

$$\hat{B} = \hat{C}_{BG} - d_2 \hat{G} d_1 \quad (7)$$

E. Post Processing

The result of the demosaicing algorithm is refined using post processing. This way provides further utilization of the inter-color and intra-color correlations of the image components and improves the performance.

F.Modules

1) Upload image
2) RGB pattern analysis
3) Color segmentation
4) Image filtering
5) Demosaicing

IV. Performance Evaluation

A. PSNR and Deblurring

The performance of the proposed coding algorithm to JPEG 2000 is proposed. The common objective measure of PSNR (Peak Signal to Noise Ratio) given by equation (8).

$$\text{PSNR} \triangleq 10\log_{10}\frac{(255)^2}{MSE} \quad (8)$$

Where MSE is the mean square error between the reconstructed image I and the original image I. It is calculated according to equation (9).

$$\text{MSE} \triangleq 1/3 \sum_{k\in\{R,G,B\}} \sum_i \sum_j (I_k(i,j) - \hat{I}_k(i,j))^2 \quad (9)$$

I_k(i, j) and $\hat{I}_k$(i, j) are the k^{th} color components of I and J, respectively. The algorithms are compared using the subjective PSPNR (Peak Signal to Perceptible Noise Ratio) measure, given by equation (10).

$$\text{PSPNR} \triangleq 10\log_{10}\frac{(255)^2}{WMSE} \quad (10)$$

Where WMSE is the weighted mean square error. The results in term of PSNR and PSPNR for the new algorithm and JPEG2000 are summarized for the test images shown in Figure 4. As can be seen, the proposed method outperforms JPEG2000 for all the images with a gain of more than 1dB PSNR, and more than 1dB PSPNR on average. Visual comparison is shown in Figure 5. Once again the new algorithm provides better performance. Note the color artifacts and blur introduced by JPEG2000, especially in the regions marked by a frame.

The deblurring results by the competing methods are then compared in Figure 4 & /Figure 5. One can see that there are many noise residuals and artifacts around edges in the deblurred images by the iterated wavelet shrink age method. The TV-based methods in and are effective in suppressing the noises as shown in Figure 5.

Figure 4. Test Image Of Camera Man

Figure 5. Test Image Of A Girl

Figure 6. Test Image of Parrot

The BM3D method is very competitive in recovering the image structures. However, it tends to generate some “ghost” artifacts around the edges as shown in Figure 4. The proposed method leads to the best visual quality. It can not only remove the blurring effects and noise, but also reconstruct more and sharper image edges than other methods.

Experimental results of single image super-resolution are presented. Again test the robustness of the proposed method to the training dataset. Figure 6. shows the reconstructed HR Parrot images by the proposed methods. The proposed method with the two different training datasets produces almost the same HR images.

Gaussian white noise (with standard deviation) to the LR images is added, and the reconstructed HR images are showed. It is seen that the method is sensitive to noise and there are serious noise-caused artifacts around the edges. The TV-regularization based method also generates many noise-caused artifacts in the neighborhood of edges. The Soft cuts method results in over-smoothed HR images.

Since the sparse representation based method is followed by a back-projection process to remove the blurring effect, it is sensitive to noise and the performance degrades much in the noisy case. In contrast, the proposed method shows good robustness to noise. Not only the noise is effectively suppressed, but also the image fine edges are well reconstructed. It is seen that the average PSNR gains of ASDS-AR-NL-TD2 over the second best methods (for the noiseless case) and (for the noisy case) are 1.13 dB and 0.77 dB, respectively.

Another important issue of the proposed method is the size of image patch. To evaluate the effects of the patch size on IR results, the sub-dictionaries and AR models are trained with different patch sizes, i.e., 3×3, 5×5 and 7×7. Then applied these sub-dictionaries and AR models to the 10 test images and the constructed 1000-image database. The experimental results of deblurring and super-resolution are presented.

B. Results of demosaicing

The original image and other output images are shown from Figure 7. to Figure 19.

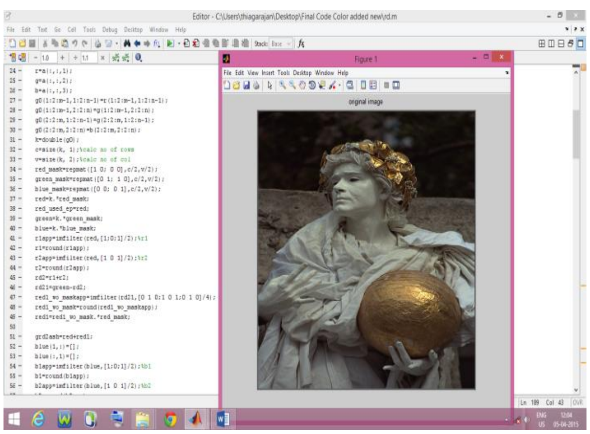

Figure 7.The original image

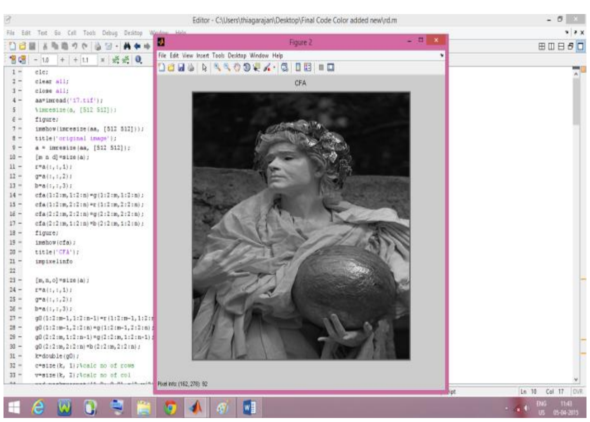

Figure 8. The CFA Image

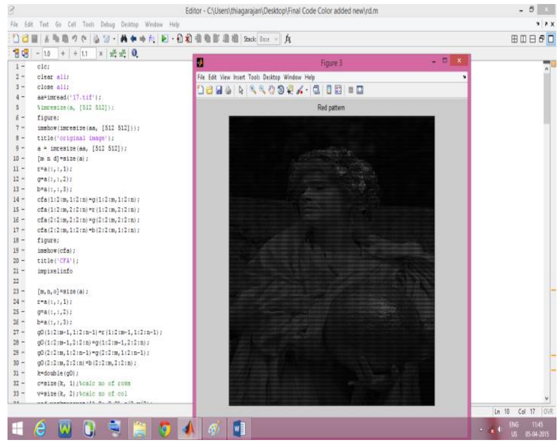

Figure 9. Red Pattern

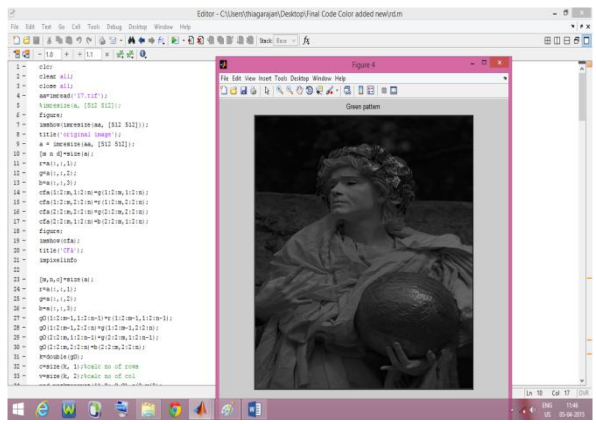

Figure 10. Green Pattern

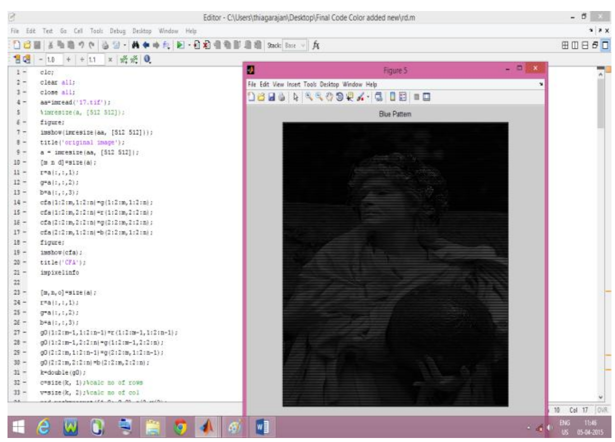

Figure 11. Blue Pattern

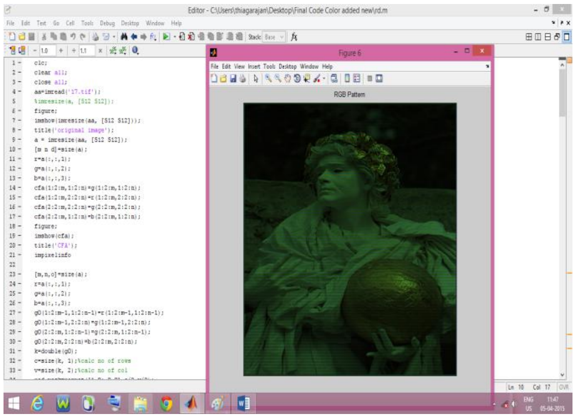

Figure 12. RGB Pattern

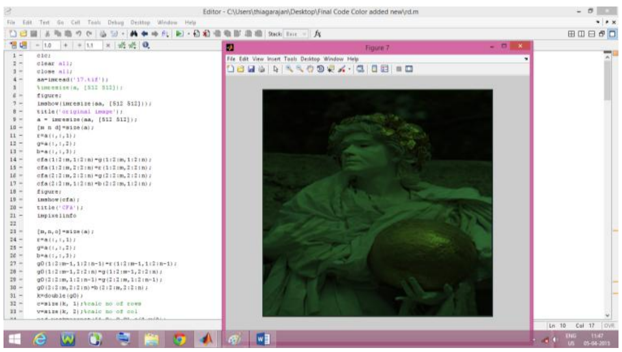

Figure 13. Interpolated Image

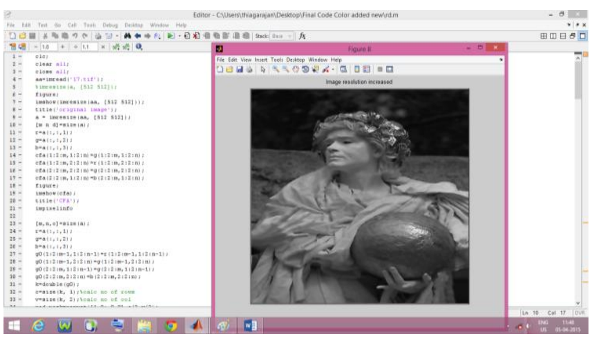

Figure 14. Image Resolution Increased

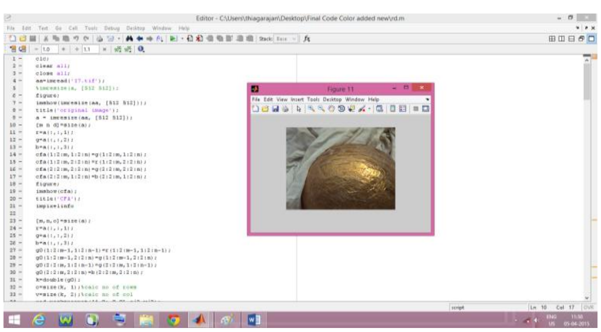

Figure 15. Enlarged Image

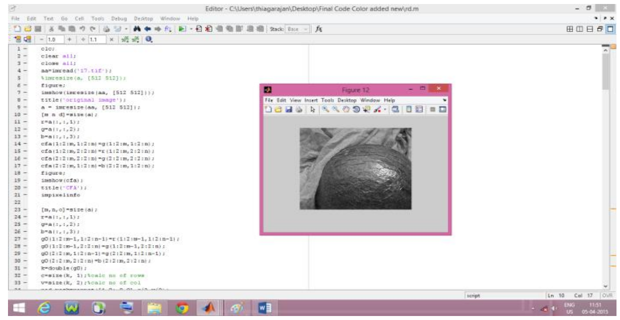

Figure 16.Gray Image

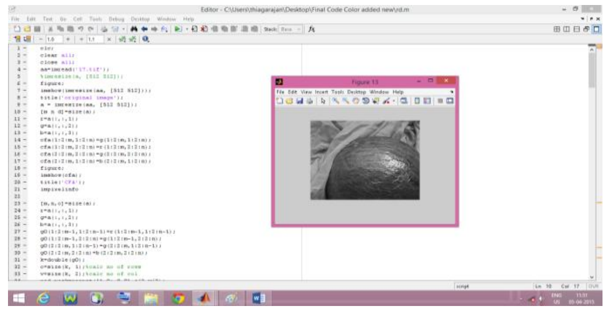

Figure 17. Gray Image With Noise

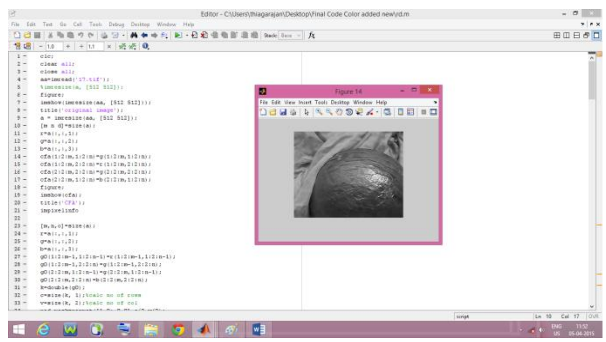

Figure 18. Gray Image With Increased Resolution

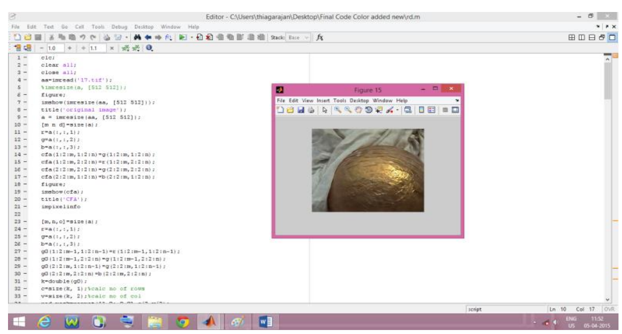

Figure 19. Reconstructed Color Image

VI. Conclusion

A new approach to color image compression based on image demosaicing is presented in this paper. . Both the image encoding technique (at the encoder) and the demosaicing method (at the decoder) are based on optimized color processing. The coding fits the Rate-Distortion model of from which optimal sub band rate allocation can be derived. A color transform based on the DCT for the coded channels is proposed. The demosaicing technique employs an optimized color transform in the reconstruction of the red and the blue colors to impose higher smoothness in the new color space in terms of minimal gradient energy.

This aids the reconstruction process and improves its performance. The proposed algorithm to JPEG2000 is compared and shown superior performance of the algorithm in terms of quantitative distortion measures, as well as visual quality. Hence the proposed method can be efficient for applications of color image communication. The Shared memory is used for further optimization. The codes are integrated with proper interface to import image data and export pixel data. High resolution can be done by using additional filters.

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