EE569: Homework #1

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Information

1. All codes are written in Matlab R2019b.
2. The 8-bites raw images used or generated by my code are all arranged in the form of Bayer array.
3. The 24-bites raw images used or generated by my code are all arranged with the order of Red, Green and Blue.
4. *readraw.m* is provided by prof. C.C. Jay Kuo and modified based on input image pixels.
5. *writeraw.m* is provided by prof. C.C. Jay Kuo.

1 Image Demosaicing and Histogram Manipulation

1.1 Demosaicing

The images captured by digital cameras are always in form of color filter array (CFA), thus, each pixel in the captured raw image only contains monochrome value. Demosaicing is a process to reconstruct RGB values of each pixel from the raw images. In the following I will implement bilinear demosaicing and Malvar-He-Cutler (MHC) Demosaicing.

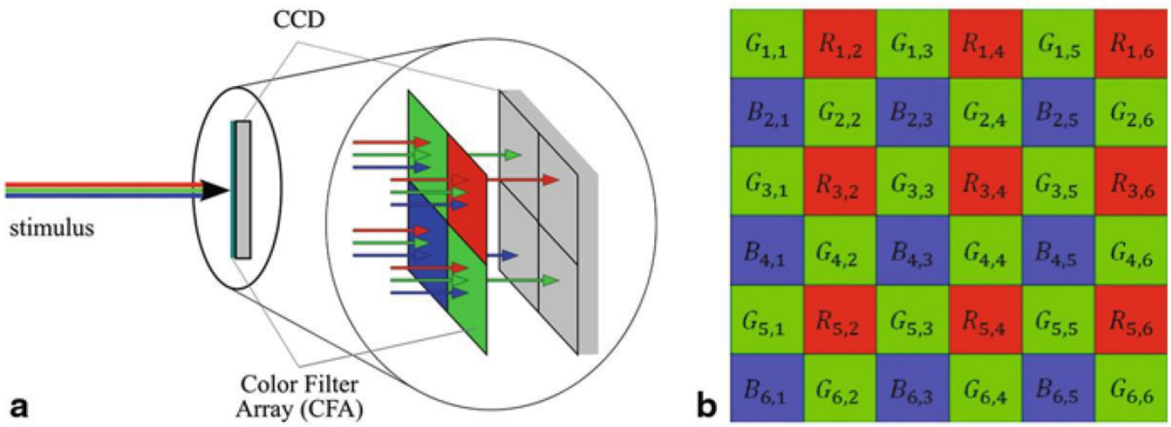


Figure 1: CFA

1.1.1 Bilinear demosaicing

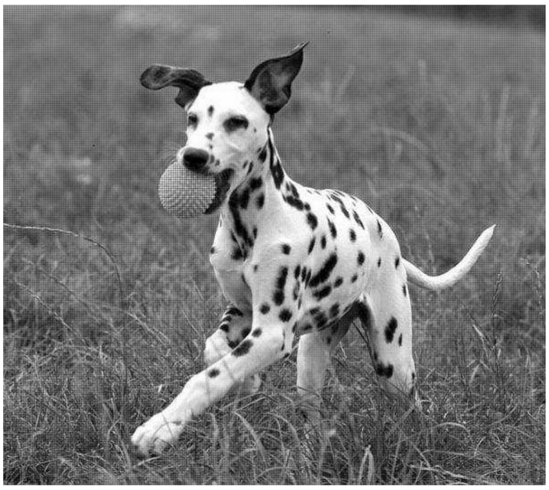
1.1.1.1 Approach and Procedure

The missing color channel values are calculated based on their 1^{st} -order pixel values (realized in *main.m*). And the original image has been mirror padded so that we can have a better convolution result. The algorithm for bilinear demosaicing is shown below.

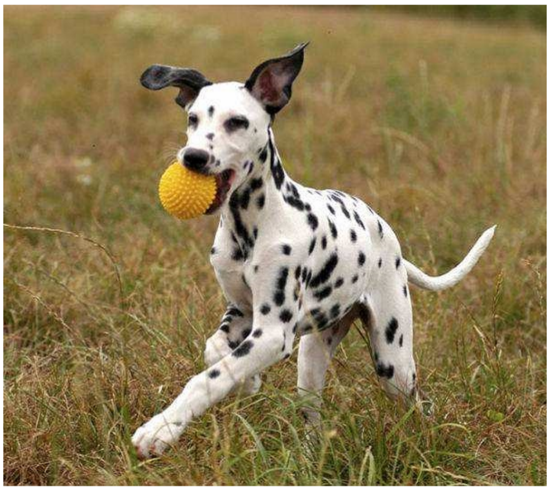
$$\hat{B}_{3,4} = \frac{1}{4}(B_{2,3} + B_{2,5} + B_{4,3} + B_{4,5})$$
$$\hat{G}_{3,4} = \frac{1}{4}(G_{3,3} + G_{2,4} + G_{3,5} + G_{4,4})$$

$$\hat{R}_{3,3} = \frac{1}{2}(R_{3,2} + R_{3,4})$$
$$\hat{B}_{3,3} = \frac{1}{2}(B_{2,3} + B_{4,3})$$

1.1.1.2 Results



(a) CFA sensor input.



(b) ground truth color image

(C) image after bilinear demosaicing

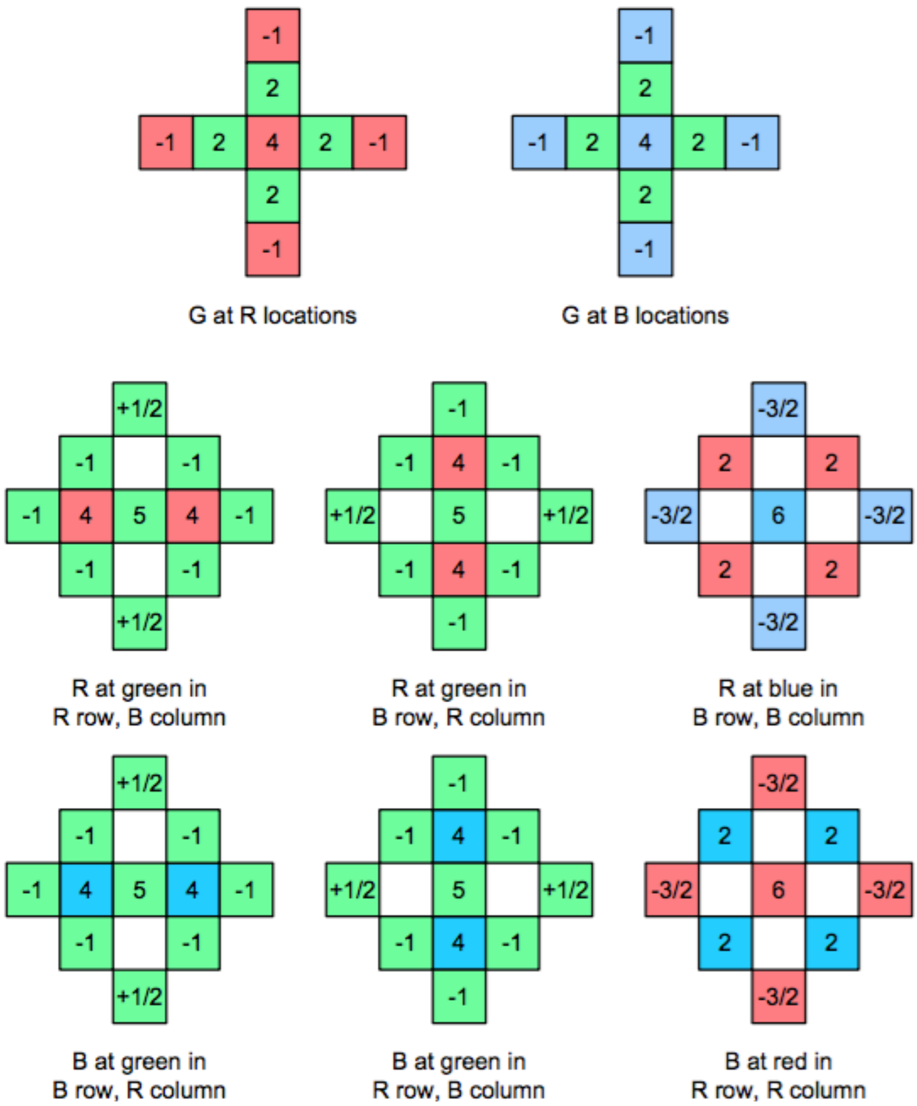
1.1.1.3 Discussion of results

The demosaicing image is similar to the original image, though it has some artifacts comparing to the ground truth color image. The resulting image has more blurry edges than the ground truth color image. This may be due to the adoption of the mean value of the surrounding values. Maybe we can take the gradient change of surrounding pixels into calculation to improve its result.

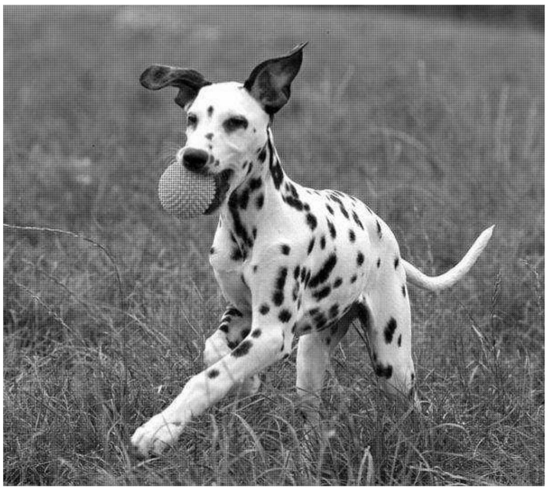
1.1.2 Malvar-He-Cutler (MHC) Demosaicing

1.1.2.1 Approach and Procedure

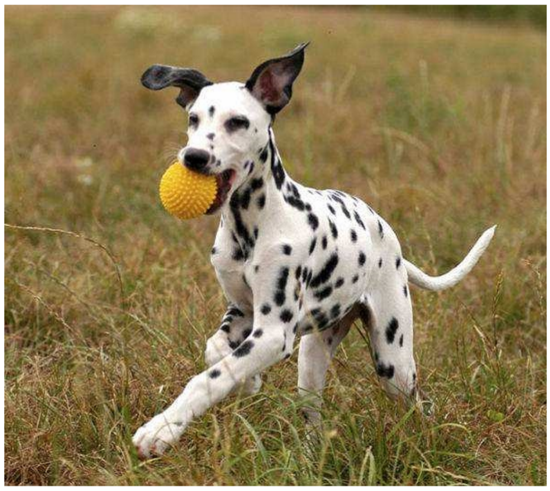
Comparing to bilinear demosaicing, MHC demosaicing has made some improvements which takes 2nd-order cross-channel pixel values into calculation (realized in *main.m*). The formula of MHC is given in Homework 1, so I'm not going to repeat it here. And the original image has been mirror padded so that we can have a better convolution result. The coefficients of filters are given below.



1.1.2.2 Results



(a) CFA sensor input.



(b) ground truth color image

(c) Image after MHC

1.1.2.3 Discussion of results

MHC has a better performance over the algorithm of bilinear demosaicing. The grass edges of the MHC image are more pronounced. In the following, I will compare the PSNR values of the different color channels of the two images to the color channels of ground truth color image.

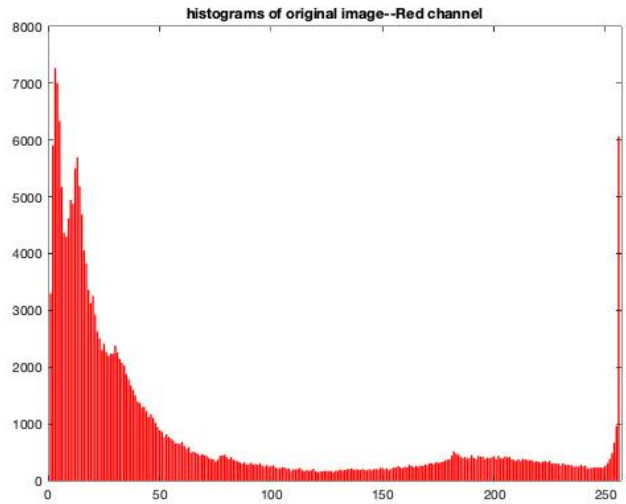
PSNR	Red Channel	Green Channel	Blue Channel
Bilinear	27.0976	30.8537	27.3169
MHC	33.1227	37.0513	33.3926

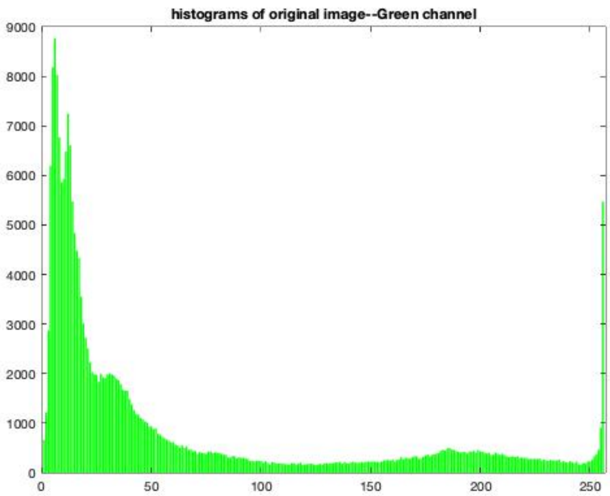
MHC restored the original image better.

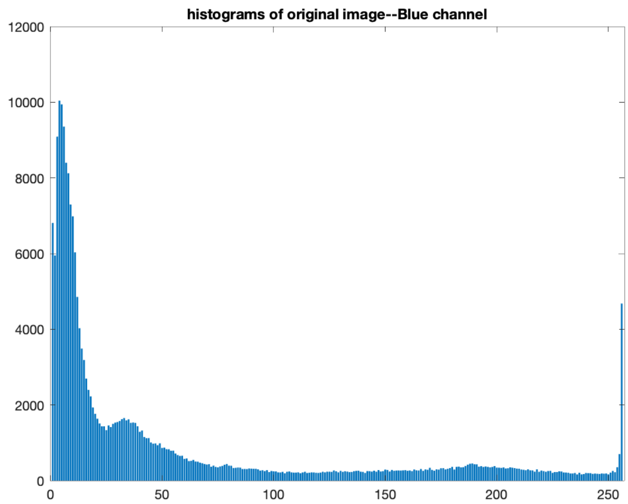
1.2Histogram Manipulation

When the image histogram is distributed completely evenly, the entropy of the image reaches its maximum, and the image contrast is maximum. Histogram equalization is more conducive to image observation.

1.2.1 Original image and its histograms of RGB channels





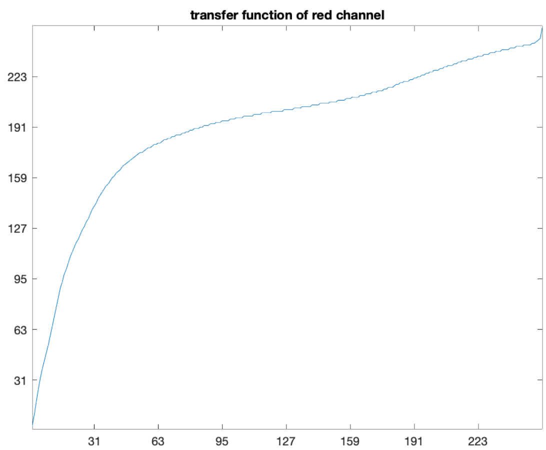


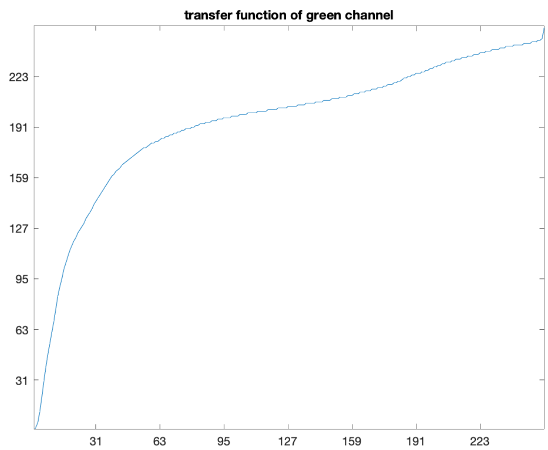
1.2.2 The transfer-function-based histogram equalization

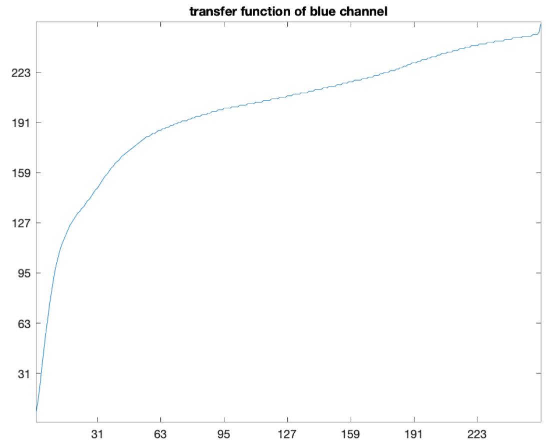
The method of transfer-function-based histogram equalization is to calculate the transfer equation to each color channel. The formula for calculation is $round(\frac{n}{M} * 255)$. Where n is of pixels whose brightness less than or equal to n, and M is the total number of image pixels. Then transfer color channels separately to generate the new image.

1.2.2.1 Result

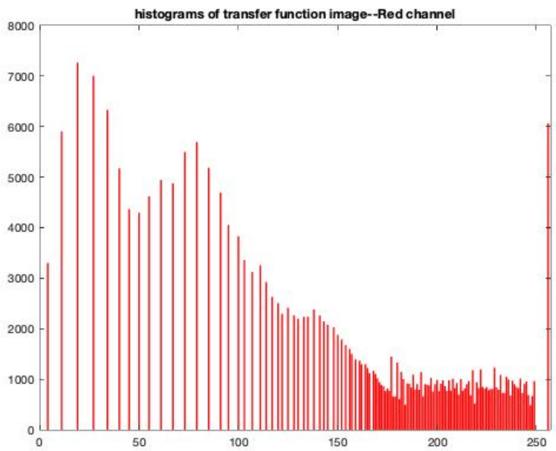
1.2.2.2 Transfer functions

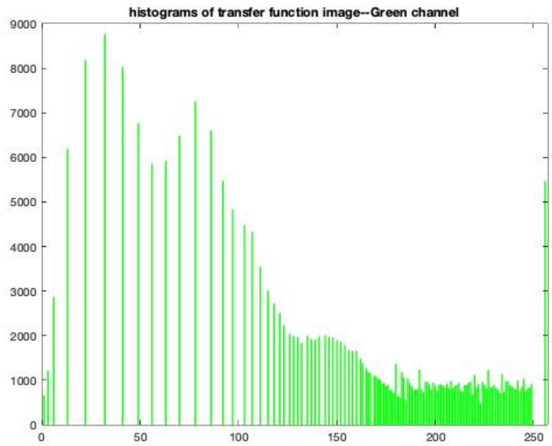


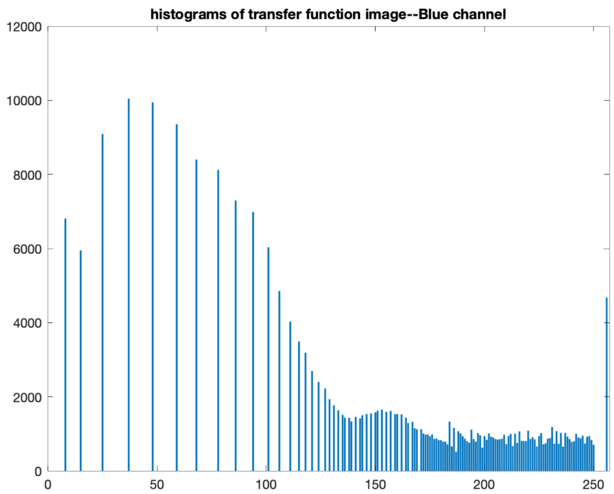




1.2.2.3 Histograms of each channel





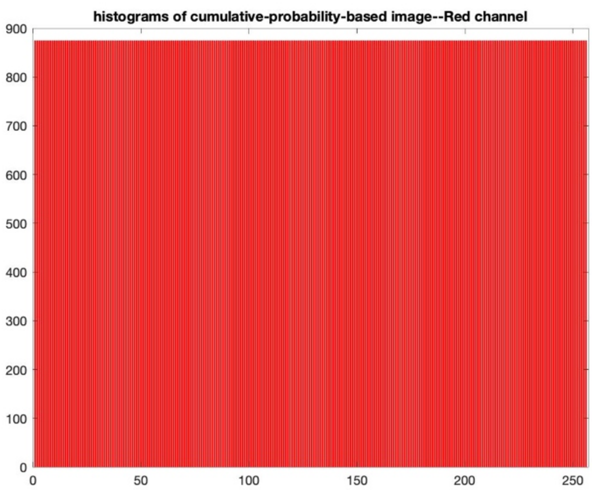


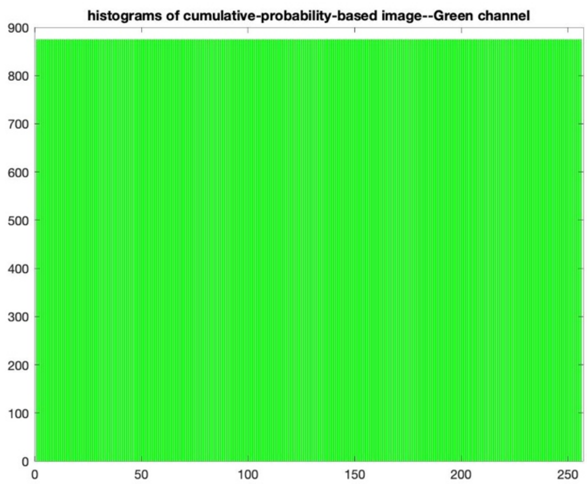
1.2.3 the cumulative-probability-based histogram equalization method

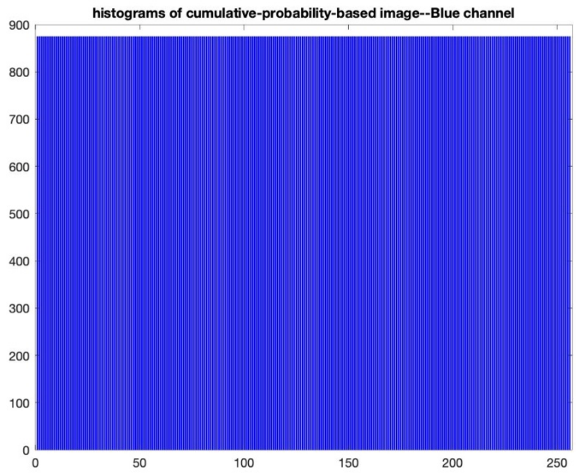
All the pixels are sorted according to the brightness of the single channel, and then cut into 256 segments. After this adjust the brightness value of each pixel based on the number of segments. The relationship between the new luminance value L and the segment number N is $L = N - 1$.

1.2.3.1 Result

1.2.3.2 Cumulative histogram for each channel



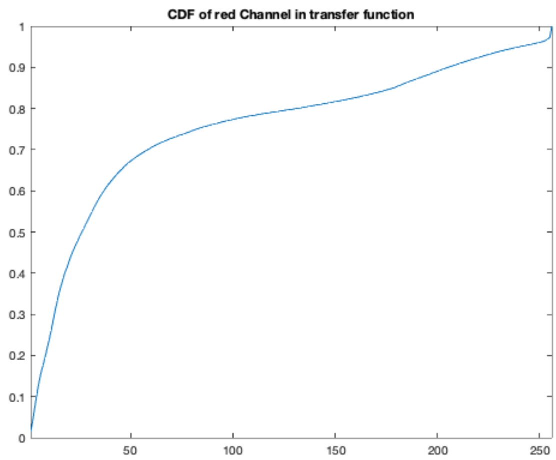


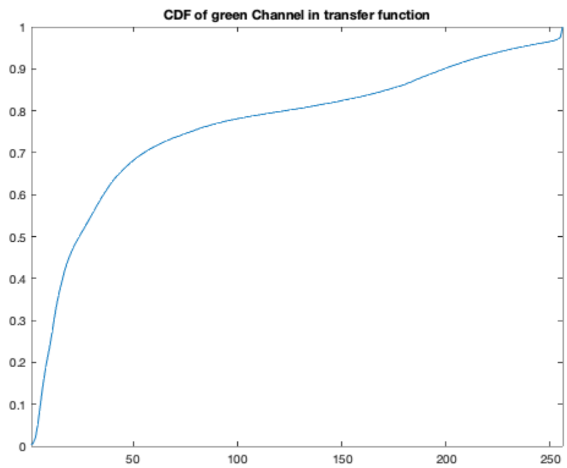


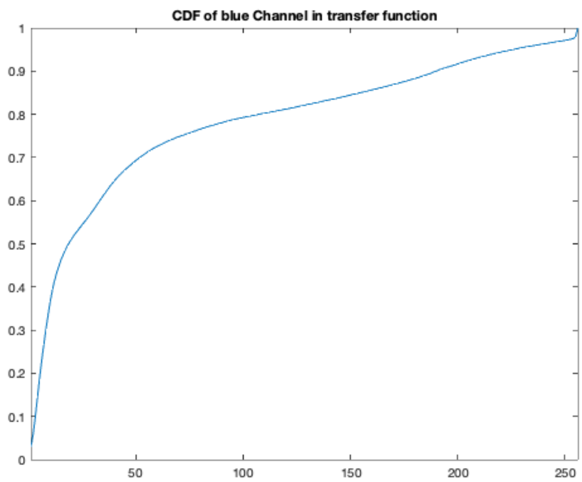
1.2.3.3 Discussion of results

Comparing to the original image, both images generates by the two algorithms have a higher contrast. At here I will calculate the CDF to evaluate these two algorithms.

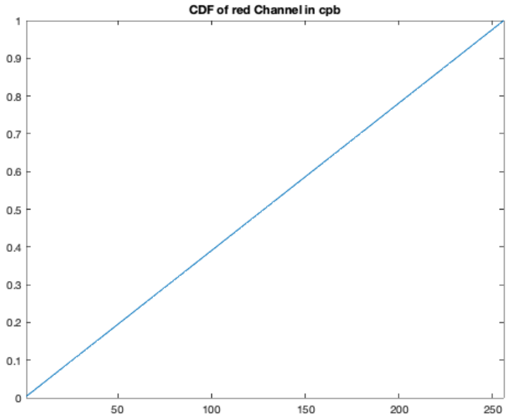
1.2.3.3.1 For transfer-function-based histogram equalization

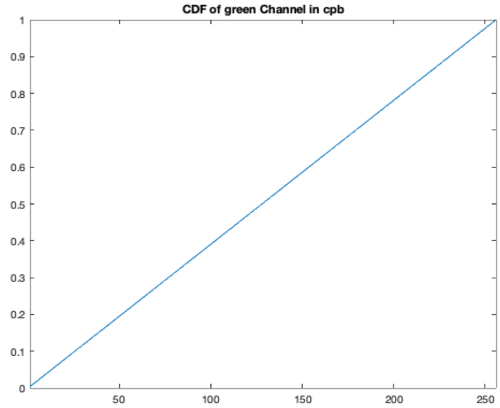


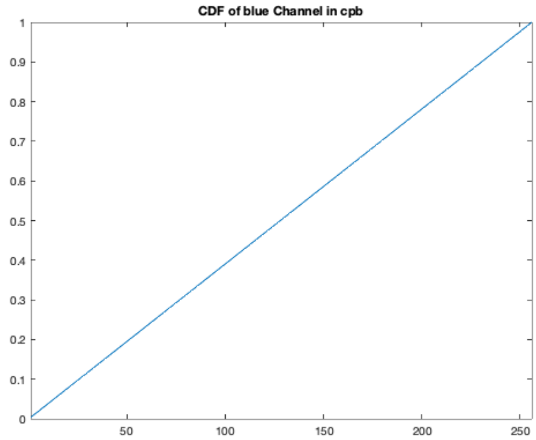




1.2.2.3.2 For cumulative-probability-based histogram equalization method







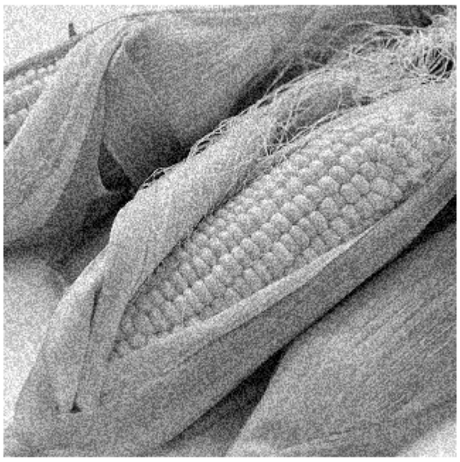
According to CDF characteristics, cumulative-probability-based histogram equalization method has better histogram equalization results. These two algorithms have good histogram equalization ability, but they are easy to produce color block and color distortion. Histogram equalization based on gray scale may be useful to avoid the occurrence of the phenomenon above.

2 Image Denoising

Image noise is unavoidable. If the noise is too large, it will affect the image observation, so image denoising is needed.

According to the image given in homework. The embedded noise in Figure 7(b) is

Gaussian Noise



Original image and embedded noise image

2.1Basic denoising method

2.1.1 Approach and procedure

This method uses a low pass filter to do denoising. It is assumed that the useful information of the image is concentrated in the low-frequency part. Therefore, low-pass filtering window is adopted to convolve with noisy image to achieve noise reduction. In this question I will apply two different low pass filters to do denoising.

2.1.2 Result

Result of uniform weight function

N =3,PSNR= 19.4307

Result of gaussian weight function

N=3, PSNR= 19.5363

2.1.3 Describe of results

In this denoising, I have tried uniform weight functions from 1*1 to 11*11, and gaussian weight function from 3*3 to 7*7. The PSNR obtains from the process above is listed as following.

PSNR of different uniform weight function

N*N	1*1	3*3	5*5	7*7	9*9	11*11
PSNR	17.7062	19.4307	19.2023	18.9563	18.7478	18.5751

PSNR of different gaussian weight function

N*N	3*3	5*5	7*7
PSNR	19.5363	19.5145	19.5238

As the table above, when N = 3, both uniform weight function and gaussian weight function achieve their best denoising performance. And gaussian uniform weight function is better than the uniform one.

2.2 Bilateral Filtering

2.2.1 Motivation

In most Low-pass filter, no matter how the low-pass filter has been designed, the edge often been blurred. Using nonlinear filters could modify this circumstance.

2.2.2 Approach and procedure

Bilateral filtering takes neighborhood pixels into calculation, which will preserve edges.

2.2.3 Result

Result of bilateral filtering

PSNR = 19.7218

2.2.4 Discussion of result:

σ_c and σ_s are the two values correspond to the influence of distance and brightness of the neighborhood pixels' weight. The higher of σ_c and σ_s, the more pixels with larger difference of distance or brightness will be considered. The bigger the first one, the blurrier the image, and the bigger the second one, the better the edges of the image will be preserved.

Compared with the first two denoising results, this method retains more edges. But it loses more image texture.

2.3 Nonlocal Mean

2.3.1 Motivation

The noise of the image is gaussian noise. If a low pass filter is used, the image will be blurred. If multiple images are superimposed, gaussian noise can be effectively reduced

2.3.2 Approach and procedure

Pick up one pixel from the original image and set it as the center of a small and a large rectangular (search window and similarity window). The search window is the searching region and be cut into blocks based on the size of the similarity window. After this calculate the weight of each block and then add them together based on the weight. Replace the similarity window with the result.

The matlab code is obtained from this address: [csdn-nonlocal-mean]

2.3.3 Result

Search window=10 similarity window=8 degree of filtering=15

PSNR=19.9470

2.3.4 Discussion of results

Search window contribute to the searching area. The bigger searching window and similarity window the better output PSNR will be. However, larger these two winds will lead to more time to run this program. As for filtering degree, the larger number will lead to the looser of image texture. According to my test, if it is larger than 15 the PSNR will go down.

So according to the thing above I choose search window=10, similarity window=8, degree of filtering=15.

Comparing to (a) and (b), NLM preserve more texture and reduce more noise.

2.4 BM3D

The matlab code is obtained from http://www.cs.tut.fi/~foi/GCF-BM3D

2.4.1 Explain of BM3D

BM3D first grouping the blocks which are similar to each other to build a 3-D matrix. Then doing BIOR 1.5 on to each 2-D blocks and then operate Hadamard on to the second dimension. After this compare the 3-D matrix with threshold value. After that, doing One dimensional inverse transformation and two-dimensional inverse transformation at the second dimension and apply aggregation.

The next, doing another grouping and collaborative filtering and aggregation to get the final image.

2.4.2 Result

Denoised External i, PSNR: 19.911 dB

2.4.3 Question answers

BM3D has a much better result comparing to the result of (a), since it has more texture preserved and less noise remain. In addition, BM3D preserve the edge of original image much better than (a).

2.5 Mixed noise in color image

2.5.1 There are gaussian noise and salt and pepper noise.

2.5.2 We should utilize filters separately. On filter specific to gaussian noise and one specific to the salt and pepper noise.

2.5.3 We are supposed to remove the salt and pepper noise first and then remove the gaussian noise. If not, after the removement of the gaussian noise, some of the salt and pepper noise may not can’t be recognized.