Homework Assignment 1

Everyone will build your own version of a very basic image processing pipeline (without denoising and color transformsteps), to convert a RAW image into an image that can be displayed on a computer monitor or printed on paper.

1. Initials.

Load the image into Matlab.

Figure 1: One possible rendering of the RAW image provided with the assignment.

```
clc;
orgImg = imread('C:/Users/Amor/Desktop/assgn1/src/banana_slug.tiff')
```

```
orgImg = 2856×4290 uint16 ##
   2217    2391    2229    2456    2223    2481    2241    2474    2220    2448    2258 ···
   2407    2209    2467    2237    2440    2237    2501    2250    2428    2250    2482
   2239    2437    2244    2481    2235    2438    2240    2439    2262    2481    2239
   2409    2223    2453    2210    2426    2197    2439    2230    2429    2236    2479
   2197    2412    2204    2442    2225    2478    2261    2481    2265    2528    2233
   2399    2194    2427    2220    2484    2220    2486    2214    2470    2254    2540
   2203    2480    2215    2432    2276    2472    2275    2479    2225    2504    2226
   2374    2204    2430    2199    2462    2207    2465    2211    2471    2285    2494
   2227    2461    2241    2467    2251    2477    2228    2494    2255    2539    2218
   2415    2182    2400    2195    2444    2233    2478    2219    2464    2218    2458
     ⋮
```

display the size of orgImg

```
% displaly the height and width
size(orgImg)
```

```
ans = 1×2
        2856        4290
```

```
% convert the image into a double-precision array
doubleOrgImg = im2double(orgImg)
```

```
doubleOrgImg = 2856×4290
    0.0338    0.0365    0.0340    0.0375    0.0339    0.0379    0.0342    0.0378 ⋯
    0.0367    0.0337    0.0376    0.0341    0.0372    0.0341    0.0382    0.0343
    0.0342    0.0372    0.0342    0.0379    0.0341    0.0372    0.0342    0.0372
    0.0368    0.0339    0.0374    0.0337    0.0370    0.0335    0.0372    0.0340
    0.0335    0.0368    0.0336    0.0373    0.0340    0.0378    0.0345    0.0379
    0.0366    0.0335    0.0370    0.0339    0.0379    0.0339    0.0379    0.0338
    0.0336    0.0378    0.0338    0.0371    0.0347    0.0377    0.0347    0.0378
    0.0362    0.0336    0.0371    0.0336    0.0376    0.0337    0.0376    0.0337
    0.0340    0.0376    0.0342    0.0376    0.0343    0.0378    0.0340    0.0381
    0.0369    0.0333    0.0366    0.0335    0.0373    0.0341    0.0378    0.0339
      ⋮
```

2. Linearization.

```
% define the black and overexposed threshold.
black = 2047;
overexposed = 15000;
%change the value
linearImg=orgImg;
linearImg(linearImg<black)=black;
linearImg(linearImg>overexposed)=overexposed;
linearImg = linearImg - black
```

```
linearImg = 2856×4290 uint16 ##
   170   344   182   409   176   434   194   427   173   401   211   474   212 ⋯
   360   162   420   190   393   190   454   203   381   203   435   189   439
   192   390   197   434   188   391   193   392   215   434   192   444   217
   362   176   406   163   379   150   392   183   382   189   432   200   469
   150   365   157   395   178   431   214   434   218   481   186   474   188
   352   147   380   173   437   173   439   167   423   207   493   228   436
   156   433   168   385   229   425   228   432   178   457   179   436   207
   327   157   383   152   415   160   418   164   424   238   447   199   412
   180   414   194   420   204   430   181   447   208   492   171   483   180
   368   135   353   148   397   186   431   172   417   171   411   168   477
      ⋮
```

```
%normlization
normImg = linearImg* (1./(overexposed-black));
normImg = double(normImg);
```

3. Identifying the correct Bayer pattern

Think of a way for identifying which version of the Bayer patterns applies to our image file, and report which version you identified.

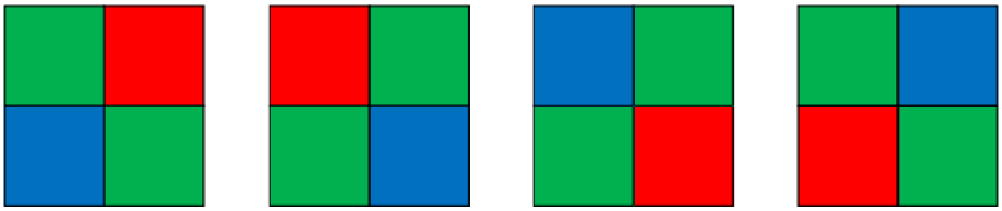
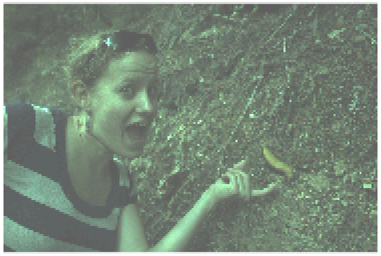


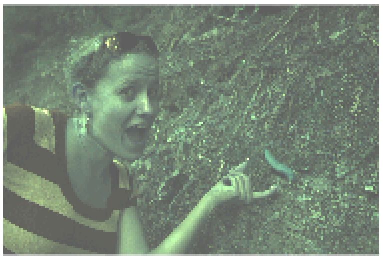
Figure 2: From left to right: 'grbg', 'rggb', 'bggr', 'gbrg'.

```
% using the demosaic function in matlab
Img_rggb = demosaic(orgImg,'rggb');
Img_bggr = demosaic(orgImg,'bggr');
Img_gbrg = demosaic(orgImg,'gbrg');
Img_grbg = demosaic(orgImg,'grbg');
%display the image with different bayer pattern
figure;
subplot(2,2,1);
imshow(Img_rggb*12);
title('rggb');
subplot(2,2,2);
imshow(Img_bggr*12);
title('bggr');
subplot(2,2,3);
imshow(Img_gbrg*12);
title('gbrg');
subplot(2,2,4);
imshow(Img_grbg*12);
title('grbg');
```

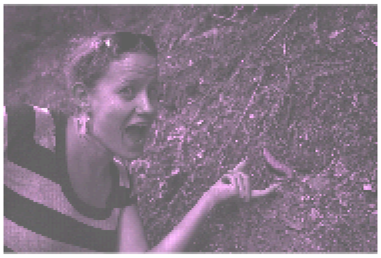
rggb



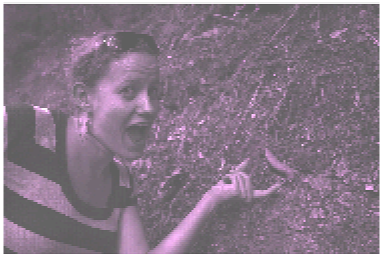
bggr



gbrg



grbg



4. White balancing

algorithm 1 : using mean of three channels .

```
% get the H and W
[orgH, orgW] = size(linearImg);
% get the data of R G B
R = linearImg(1:2:end,1:2:end);
B = linearImg(2:2:end,2:2:end);
G1 = linearImg(1:2:end,2:2:end);
G2 = linearImg(2:2:end,1:2:end);
G = [G1;G2];
% befor white balance. compute the mean of R G B channels
meanR = mean(mean(R))
```

```
meanR = 411.2180
```

```
meanB = mean(mean(B))
```

```
meanB = 431.1640
```

```
meanG = mean(mean(G))
```

```
meanG = 752.6595
```

```
meanG/meanR
```

```
ans = 1.8303
```

```
meanG/meanB
```

```
ans = 1.7456
```

```
wbImg = linearImg;
% white balancing
% do R channel data
for i = 1:2:orgH
    for j = 1:2:orgW
        wbImg(i,j)=wbImg(i,j)*(meanG/meanR);
    end

end
% do B channel data
for i = 2:2:orgH
    for j= 2:2:orgW
        wbImg(i,j)=wbImg(i,j)*(meanG/meanB);
    end
end

% the mean of R G B channel and ratio after white balance
wbR = wbImg(1:2:end,1:2:end);
wbB = wbImg(2:2:end,2:2:end);
wbwG1 = wbImg(1:2:end,2:2:end);
wbG2 = wbImg(2:2:end,1:2:end);
wbG = [G1;G2];
% compute the mean of R G B channels
meanR = mean(mean(wbR))
```

```
meanR = 752.6605
```

```
meanB = mean(mean(wbB))
```

```
meanB = 752.6589
```

```
meanG = mean(mean(wbG))
```

```
meanG = 752.6595
```

```
meanG/meanR
```

```
ans = 1.0000
```

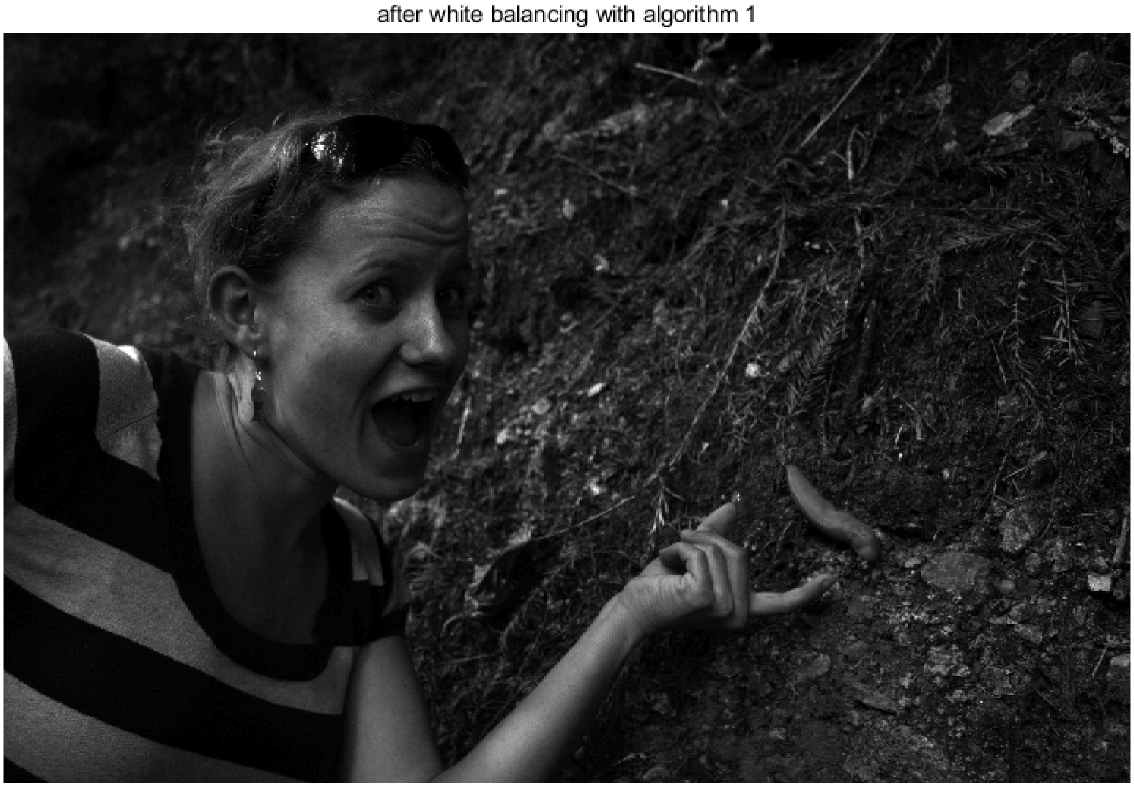
```
meanG/meanB
```

```
ans = 1.0000
```

```
figure;
imshow(wbImg*12);
```

警告：图像太大，无法在屏幕上显示；将以 17% 显示

```
title('after white balancing with algorithm 1');
```



algorithm 2 : using max value of three channels

```
% get the H and W
[orgH, orgW] = size(linearImg);
% get the data of R G B
R = linearImg(1:2:end,1:2:end);
B = linearImg(2:2:end,2:2:end);
G1 = linearImg(1:2:end,2:2:end);
G2 = linearImg(2:2:end,1:2:end);
G = [G1;G2];
% befor white balance. compute the max value of R G B channels
maxR = max(max(R))
```

```
maxR = uint16

4912
```

```
maxB = max(max(B))
```

```
maxB = uint16

8489
```

```
maxG = max(max(G))
```

```
maxG = uint16

12953
```

```
maxG/maxR
```

```
ans = uint16

3
```

```
maxG/maxB
```

```
ans = uint16

2
```

```
wbImg2 = linearImg;
% white balancing
% do R channel data
for i = 1:2:orgH
    for j = 1:2:orgW
        wbImg2(i,j)=wbImg2(i,j)*(maxG/maxR);
    end
end
% do B channel data
for i = 2:2:orgH
    for j= 2:2:orgW
        wbImg2(i,j)=wbImg2(i,j)*(maxG/maxB);
    end
end

% the mean of R G B channel and ratio after white balance
wbR = wbImg2(1:2:end,1:2:end);
wbB = wbImg2(2:2:end,2:2:end);
wbwG1 = wbImg2(1:2:end,2:2:end);
wbG2 = wbImg2(2:2:end,1:2:end);
wbG = [G1;G2];
% compute the max value of R G B channels
maxR = max(max(wbR))
```

```
maxR = uint16

14736
```

```
maxB = max(max(wbB))
```

```
maxB = uint16

16978
```

```
maxG = max(mean(wbG))
maxG = 1.0459e+03
```

```
maxG/maxR
```

```
ans = uint16

0
```

```
maxG/maxB
```

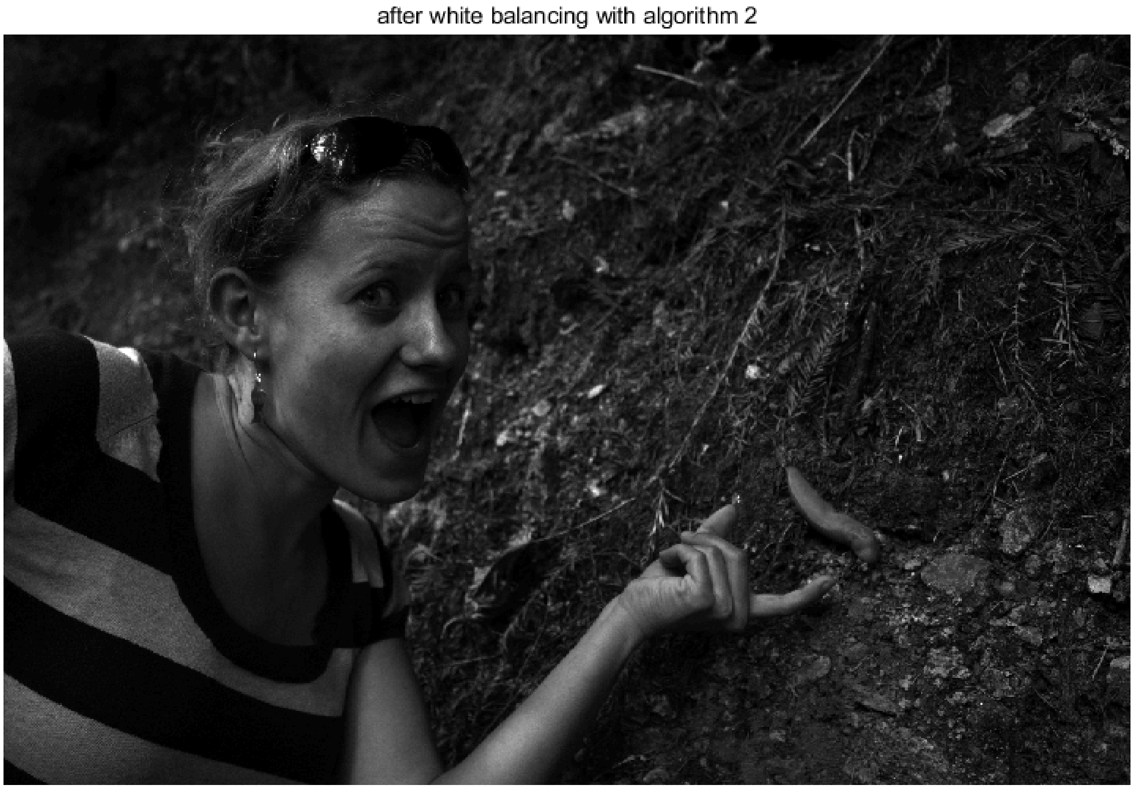
```
ans = uint16

0
```

```
figure;
imshow(wbImg2*12);
```

```
警告：图像太大，无法在屏幕上显示；将以 17% 显示
```

```
title('after white balancing with algorithm 2');
```



5. Demosaicing

```
% demosaicing
wbImg = double(wbImg)/255/255; % using white balance algo 1
```

```
%wbImg = double(wbImg2)/255/255; % using white balance algo 2
R = wbImg(1:2:end,1:2:end);
B = wbImg(2:2:end,2:2:end);
G1 = wbImg(1:2:end,2:2:end);
G2 = wbImg(2:2:end,1:2:end);
x=1:2:orgW;
y=1:2:orgH;
[x,y]=meshgrid(x,y);
xq=1:orgW;
yq=1:orgH;
[xq,yq]=meshgrid(xq,yq);
demoImgR = interp2(x,y,R,xq,yq)
```

```
demoImgR = 2856×4290
    0.0048    0.0050    0.0051    0.0050    0.0050    0.0052    0.0055    0.0052 ⋯
    0.0051    0.0052    0.0053    0.0052    0.0051    0.0053    0.0054    0.0055
    0.0054    0.0055    0.0056    0.0054    0.0053    0.0054    0.0054    0.0057
    0.0048    0.0049    0.0050    0.0051    0.0052    0.0054    0.0057    0.0059
    0.0042    0.0043    0.0044    0.0047    0.0050    0.0055    0.0060    0.0061
    0.0043    0.0044    0.0046    0.0051    0.0057    0.0060    0.0062    0.0059
    0.0044    0.0046    0.0047    0.0056    0.0064    0.0064    0.0064    0.0057
    0.0047    0.0049    0.0051    0.0056    0.0061    0.0059    0.0058    0.0056
    0.0051    0.0053    0.0055    0.0056    0.0057    0.0054    0.0051    0.0055
    0.0051    0.0050    0.0049    0.0052    0.0055    0.0056    0.0056    0.0056
      ⋮
```

```
[bh,bw]=size(B);
B1 = zeros(bh+1,bw+1);
B1(2:bh+1,2:bw+1)=B;
x=1:2:orgW+1;
y=1:2:orgH+1;
[x,y]=meshgrid(x,y);
xq=2:orgW+1;
yq=2:orgH+1;
[xq,yq]=meshgrid(xq,yq);
demoImgB = interp2(x,y,B1,xq,yq)
```

```
demoImgB = 2856×4290
    0.0011    0.0022    0.0024    0.0026    0.0026    0.0026    0.0026    0.0027 ⋯
    0.0022    0.0044    0.0047    0.0051    0.0051    0.0051    0.0053    0.0054
    0.0023    0.0045    0.0046    0.0047    0.0047    0.0046    0.0049    0.0052
    0.0024    0.0047    0.0046    0.0044    0.0042    0.0040    0.0045    0.0049
    0.0022    0.0043    0.0044    0.0045    0.0044    0.0043    0.0045    0.0047
    0.0020    0.0040    0.0043    0.0046    0.0046    0.0046    0.0046    0.0045
    0.0020    0.0041    0.0042    0.0044    0.0044    0.0045    0.0045    0.0044
    0.0021    0.0042    0.0041    0.0041    0.0042    0.0043    0.0043    0.0044
    0.0020    0.0039    0.0040    0.0040    0.0043    0.0046    0.0046    0.0045
    0.0018    0.0036    0.0038    0.0040    0.0045    0.0050    0.0048    0.0046
      ⋮
```

```
% interp G1 channel
[bh,bw]=size(G1);
G11 = zeros(bh+1,bw+1);
G11(2:bh+1,2:bw+1)=G1;
x=1:2:orgW+1;
```

```
y=1:2:orgH+1;
[x,y]=meshgrid(x,y);
xq=2:orgW+1;
yq=2:orgH+1;
[xq,yq]=meshgrid(xq,yq);
demoImgG1 = interp2(x,y,G11,xq,yq)
```

```
demoImgG1 = 2856×4290
    0.0013    0.0026    0.0029    0.0031    0.0032    0.0033    0.0033    0.0033 ⋯
    0.0026    0.0053    0.0058    0.0063    0.0065    0.0067    0.0066    0.0066
    0.0028    0.0056    0.0061    0.0065    0.0064    0.0063    0.0063    0.0063
    0.0030    0.0060    0.0063    0.0067    0.0063    0.0060    0.0060    0.0060
    0.0029    0.0058    0.0061    0.0064    0.0063    0.0063    0.0063    0.0064
    0.0028    0.0056    0.0058    0.0061    0.0064    0.0066    0.0067    0.0067
    0.0031    0.0061    0.0061    0.0060    0.0063    0.0066    0.0066    0.0067
    0.0033    0.0067    0.0063    0.0059    0.0062    0.0065    0.0066    0.0066
    0.0033    0.0065    0.0064    0.0062    0.0064    0.0066    0.0067    0.0068
    0.0032    0.0064    0.0064    0.0065    0.0065    0.0066    0.0067    0.0069
       ⋮
```

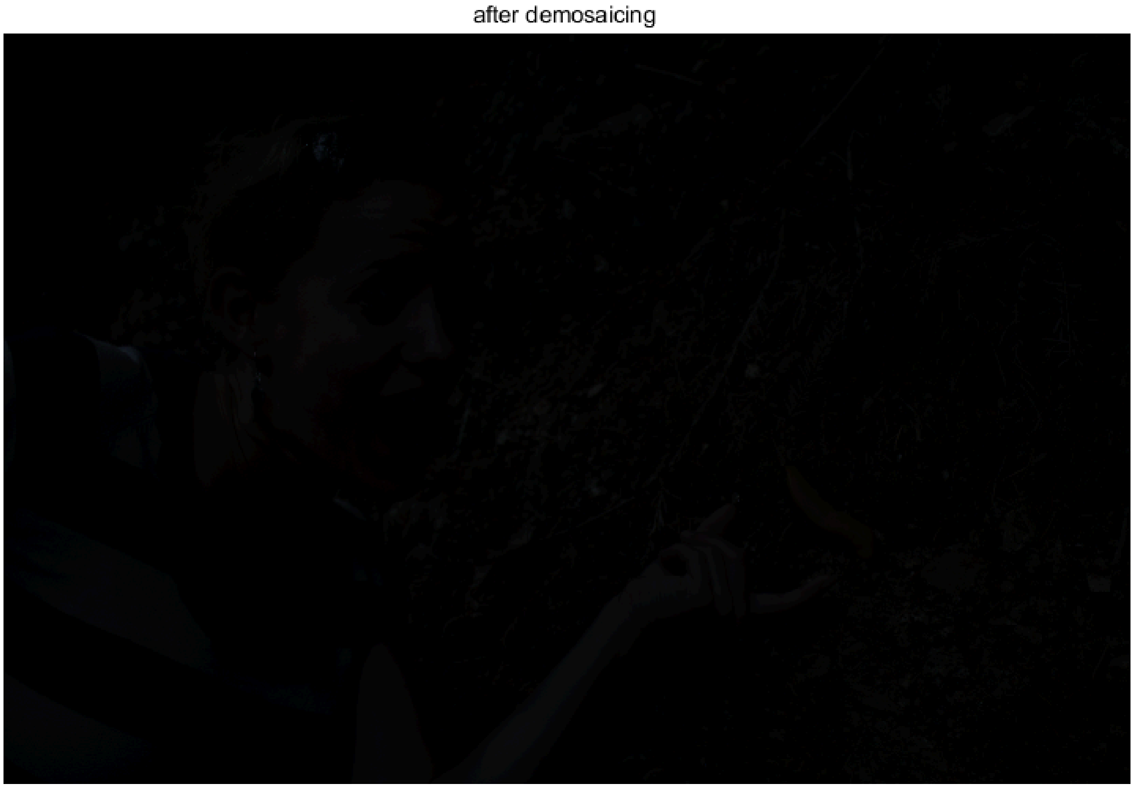
```
% interp G2 channel
[bh,bw]=size(G2);
G21 = zeros(bh+1,bw+1);
G21(2:bh+1,2:bw+1)=G2;
x=1:2:orgW+1;
y=1:2:orgH+1;
[x,y]=meshgrid(x,y);
xq=2:orgW+1;
yq=2:orgH+1;
[xq,yq]=meshgrid(xq,yq);
demoImgG2 = interp2(x,y,G21,xq,yq)
```

```
demoImgG2 = 2856×4290
    0.0014    0.0028    0.0030    0.0032    0.0031    0.0030    0.0033    0.0035 ⋯
    0.0028    0.0055    0.0060    0.0065    0.0063    0.0060    0.0065    0.0070
    0.0028    0.0056    0.0060    0.0064    0.0061    0.0059    0.0062    0.0065
    0.0028    0.0056    0.0059    0.0062    0.0060    0.0058    0.0059    0.0060
    0.0027    0.0055    0.0058    0.0060    0.0062    0.0063    0.0063    0.0064
    0.0027    0.0054    0.0056    0.0058    0.0063    0.0067    0.0067    0.0068
    0.0026    0.0052    0.0055    0.0059    0.0062    0.0066    0.0066    0.0066
    0.0025    0.0050    0.0055    0.0059    0.0061    0.0064    0.0064    0.0064
    0.0027    0.0053    0.0055    0.0057    0.0060    0.0062    0.0064    0.0065
    0.0028    0.0057    0.0055    0.0054    0.0058    0.0061    0.0064    0.0066
       ⋮
```

```
% merge the G1 and G2
demoImgG = (demoImgG1+demoImgG2)*0.5;
rgbImg = cat(3,demoImgR,demoImgG,demoImgB);
figure;
imshow(rgbImg);
```

```
警告: 图像太大，无法在屏幕上显示；将以 17% 显示
```

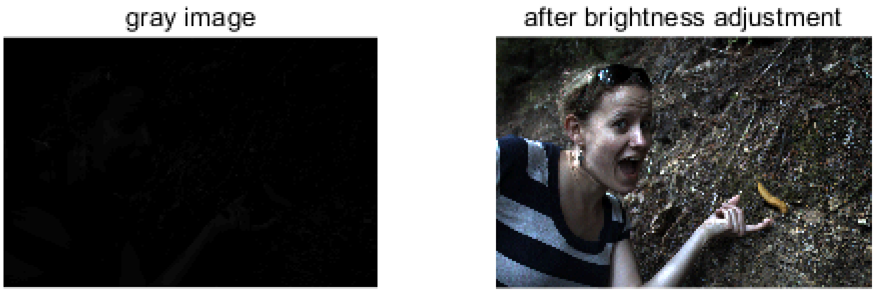
```
title('after demosaicing ');
```



after demosaicing

6.1 Brightness adjustment and gamma correction

```
% convert to gray image
grayImg = rgb2gray(rgbImg);
maxValue = max(max(grayImg));
rgbImg = rgbImg * (1/maxValue)*3;
figure;
subplot(1,2,1);
imshow(grayImg);
title('gray image');
subplot(1,2,2);
imshow(rgbImg);
title('after brightness adjustment');
```



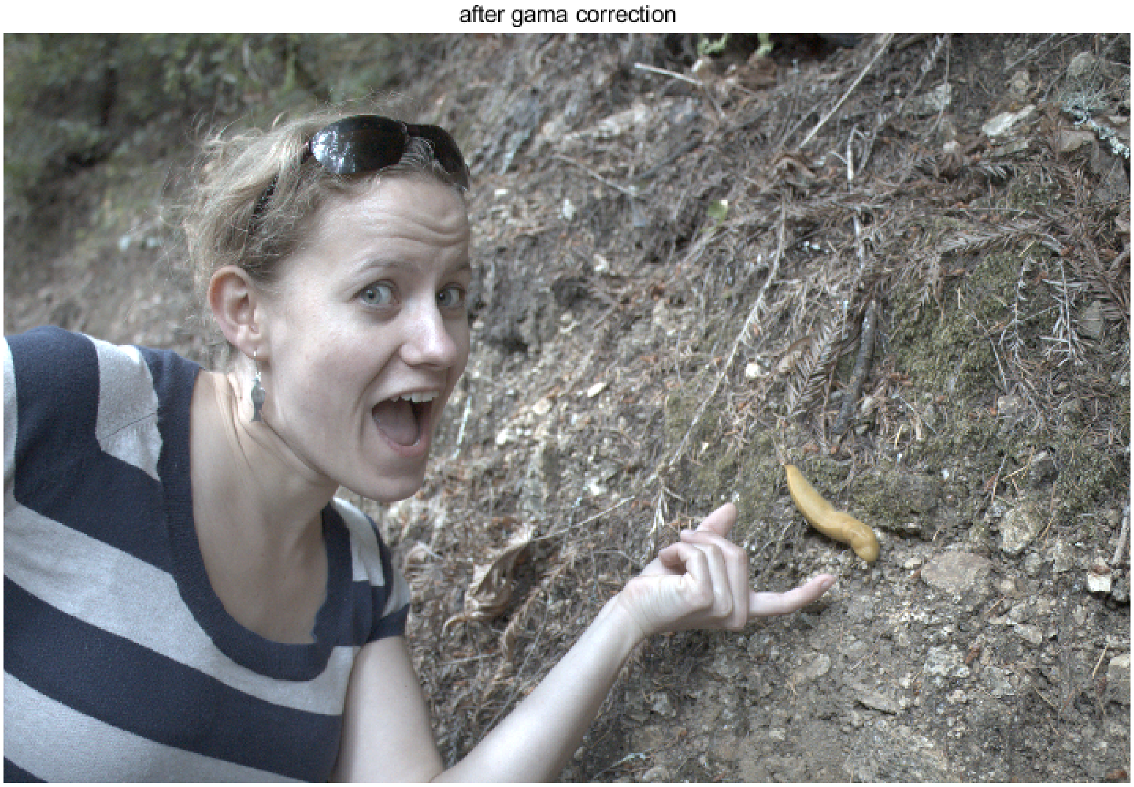
6.2 gamma correction

$$C_{\text{non}-\text{linear}} = \begin{cases} 12.92 \cdot C_{\text{linear}}, & C_{\text{linear}} \leq 0.0031308 \\ (1+0.055)*C_{\text{linear}}^{\frac{1}{2.4}} - 0.055, & C_{\text{linear}} \geq 0.0031308 \end{cases}$$

```
% build the loop up table
lut = 0:255;
norLut = lut./255;
% compute the gama correction para
for i=1:256
    if(norLut(i)<0.0031308)
        norLut(i)=norLut(i)*12.92;
    else
        norLut(i)=(1+0.055)*norLut(i)^(1/2.4)-0.055;
    end
end
% mapping the norLut to rgbImg
intRgbImg = im2uint8(rgbImg);
intRgbImg = intRgbImg +1;
intNorLut = norLut*255;
gamaImg = intNorLut(intRgbImg);
gamaImg = gamaImg /255;
figure;
imshow(gamaImg);
```

警告: 图像太大，无法在屏幕上显示；将以 17% 显示

```
title('after gama correction');
```



7. Compression

Use the imwrite command to store the image in .PNG format (no compression), and also in .JPEG format with quality setting 95.

ratio = bytes_after_compression / bytes_before_compression

difference between .PNG format and .JPEG format:

gamaCorrect.png = 16.2 M

gamaCorrect.jpg = 3.17 M

```
% PNG format
imwrite(gamaImg,'.\gamaCorrect.png');
% JPG format with quality 95
%imwrite(gamaImg,'.\gamaCorrect.jpg','Quality',95);
```