

Project 2

Image Enhancement in Spatial Domain

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All four parts of this project have been solved.

Explanation of submission files (only .m files in alphabetical order)

File name	What it is---
part1_power_law_colorimage1.m	Power-law transformation code for the chosen color image 1
part1_power_law_colorimage2.m	Power-law transformation code for the chosen color image 2
part1_power_law_fig1.m	Power-law transformation code for figure 1
part1_power_law_fig2.m	Power-law transformation code for figure 2
part2_histo_equalization.m	Code for histogram equalization
part3_colortone_swap.m	Code for color tone swapping using histogram specification
part3_histo_spec_figure6.m	Code for histogram specification
part4_combined_enhance.m	Code for combined image enhancement

Part 1: Power-law Transformation

MATLAB Code



Figure 1 is dark. In order to make it brighter and thus visually more perceptible, power-law transformation with $\gamma < 1$ is required.

```
clc; clear; close all; font = 18;
I = imread("Figure1.tif"); I = im2double(I);
figure(1); subplot(251); imshow(I);
title("Original image", "fontsize", font);
c = 1; g = 0.9:-0.1:0.1;

gamma = g(1); Itr = c*(I.^gamma); subplot(252); imshow(Itr);
title("c = "+c+", \gamma = "+gamma, "fontsize", font);
gamma = g(2); Itr = c*(I.^gamma); subplot(253); imshow(Itr);
title("c = "+c+", \gamma = "+gamma, "fontsize", font);
gamma = g(3); Itr = c*(I.^gamma); subplot(254); imshow(Itr);
title("c = "+c+", \gamma = "+gamma, "fontsize", font);
gamma = g(4); Itr = c*(I.^gamma); subplot(255); imshow(Itr);
title("c = "+c+", \gamma = "+gamma, "fontsize", font);
gamma = g(5); Itr = c*(I.^gamma); subplot(256); imshow(Itr);
title("c = "+c+", \gamma = "+gamma, "fontsize", font);
gamma = g(6); Itr = c*(I.^gamma); subplot(257); imshow(Itr);
title("c = "+c+", \gamma = "+gamma, "fontsize", font);
gamma = g(7); Itr = c*(I.^gamma); subplot(258); imshow(Itr);
title("c = "+c+", \gamma = "+gamma, "fontsize", font);
gamma = g(8); Itr = c*(I.^gamma); subplot(259); imshow(Itr);
title("c = "+c+", \gamma = "+gamma, "fontsize", font);
gamma = g(9); Itr = c*(I.^gamma); subplot(2,5,10); imshow(Itr);
title("c = "+c+", \gamma = "+gamma, "fontsize", font);
```

Power-law Transformation Results for figure 1

Original image



$c = 1, \gamma = 0.9$



$c = 1, \gamma = 0.8$



$c = 1, \gamma = 0.7$



$c = 1, \gamma = 0.6$



$c = 1, \gamma = 0.5$



$c = 1, \gamma = 0.4$



$c = 1, \gamma = 0.3$



$c = 1, \gamma = 0.2$



$c = 1, \gamma = 0.1$



This one looks the best.



Power-law transformation results with Figure1

Comparison between the original image and transformed image

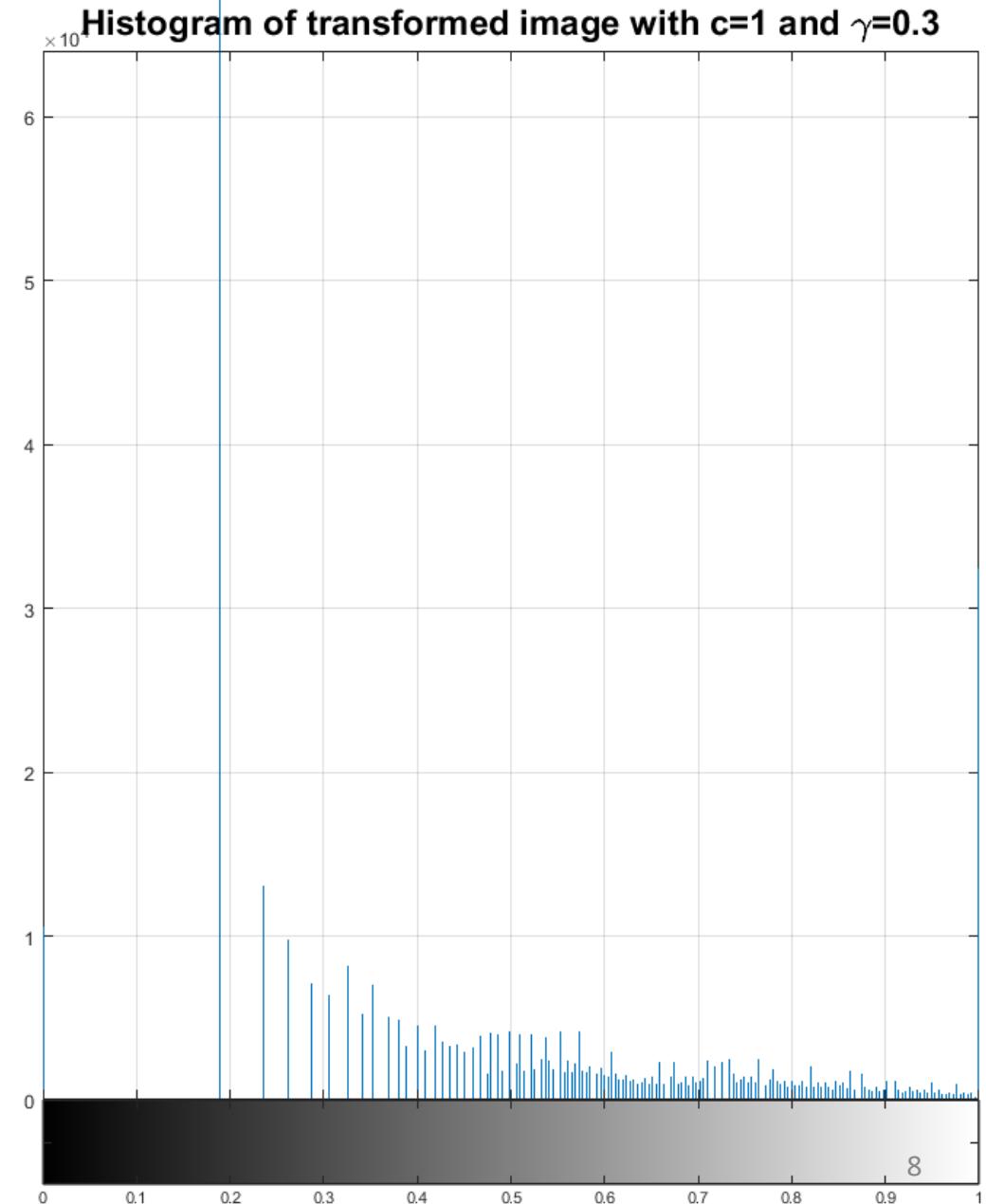
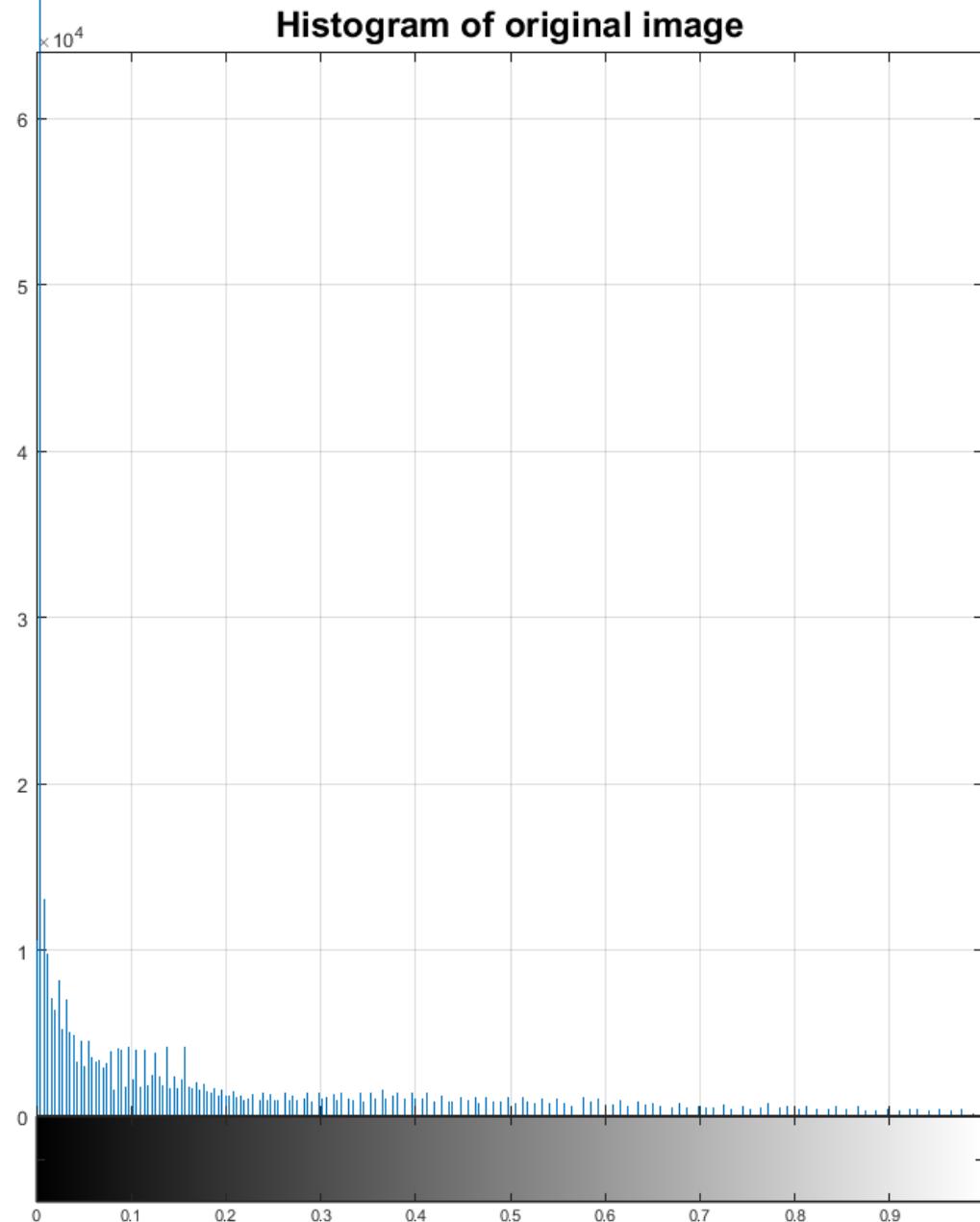
Original image



Transformed image with $c = 1, \gamma = 0.3$



Histogram Plots – Figure 1



Power-law Transformation Results for figure 2

Original image

$c = 1, \gamma = 2.5$

$c = 1, \gamma = 3$

$c = 1, \gamma = 3.5$



This one looks the best.



$c = 1, \gamma = 4.5$

$c = 1, \gamma = 4.7$

$c = 1, \gamma = 5$

$c = 1, \gamma = 5.5$



Power-law transformation results with Figure2

Comparison between the original image and transformed image

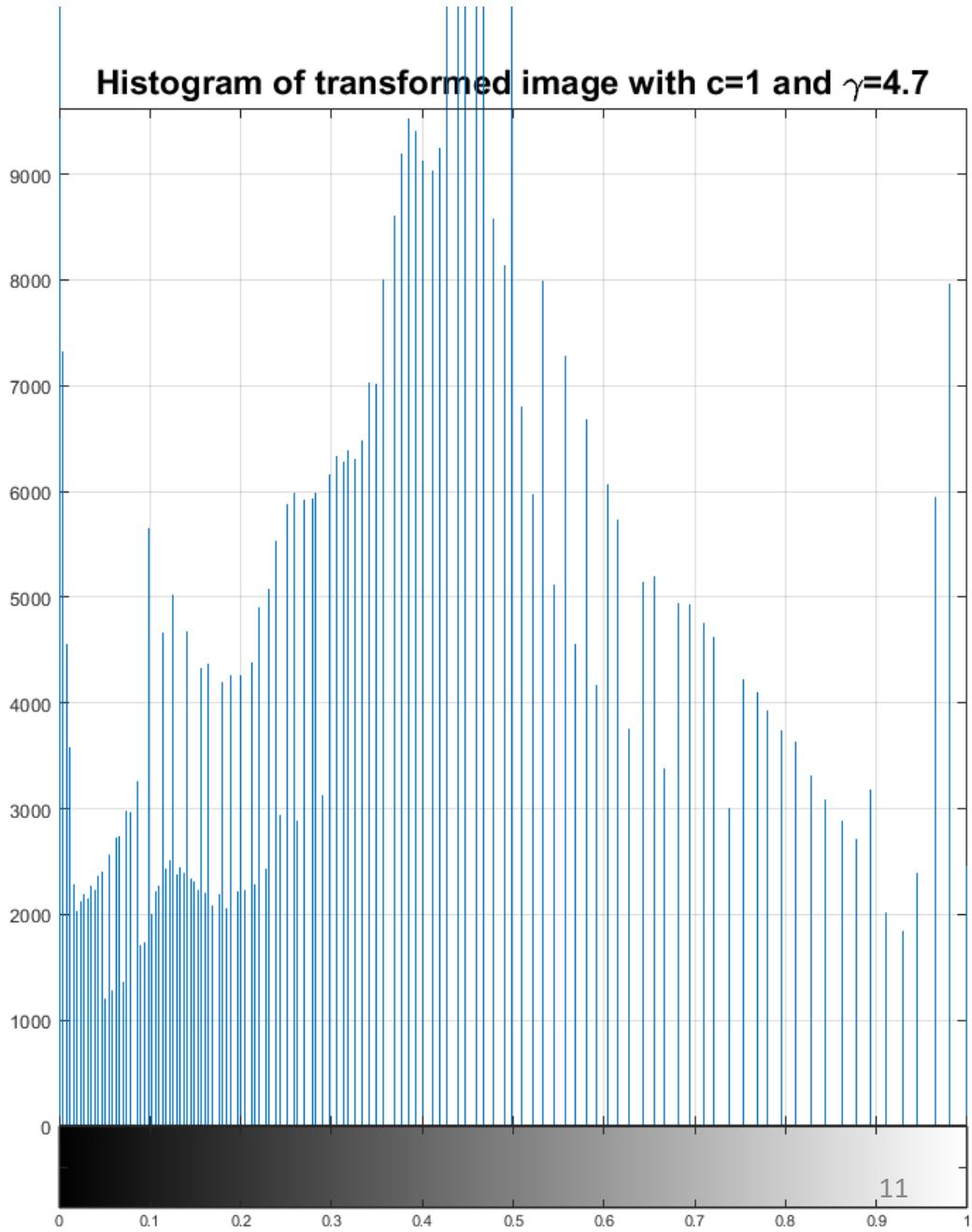
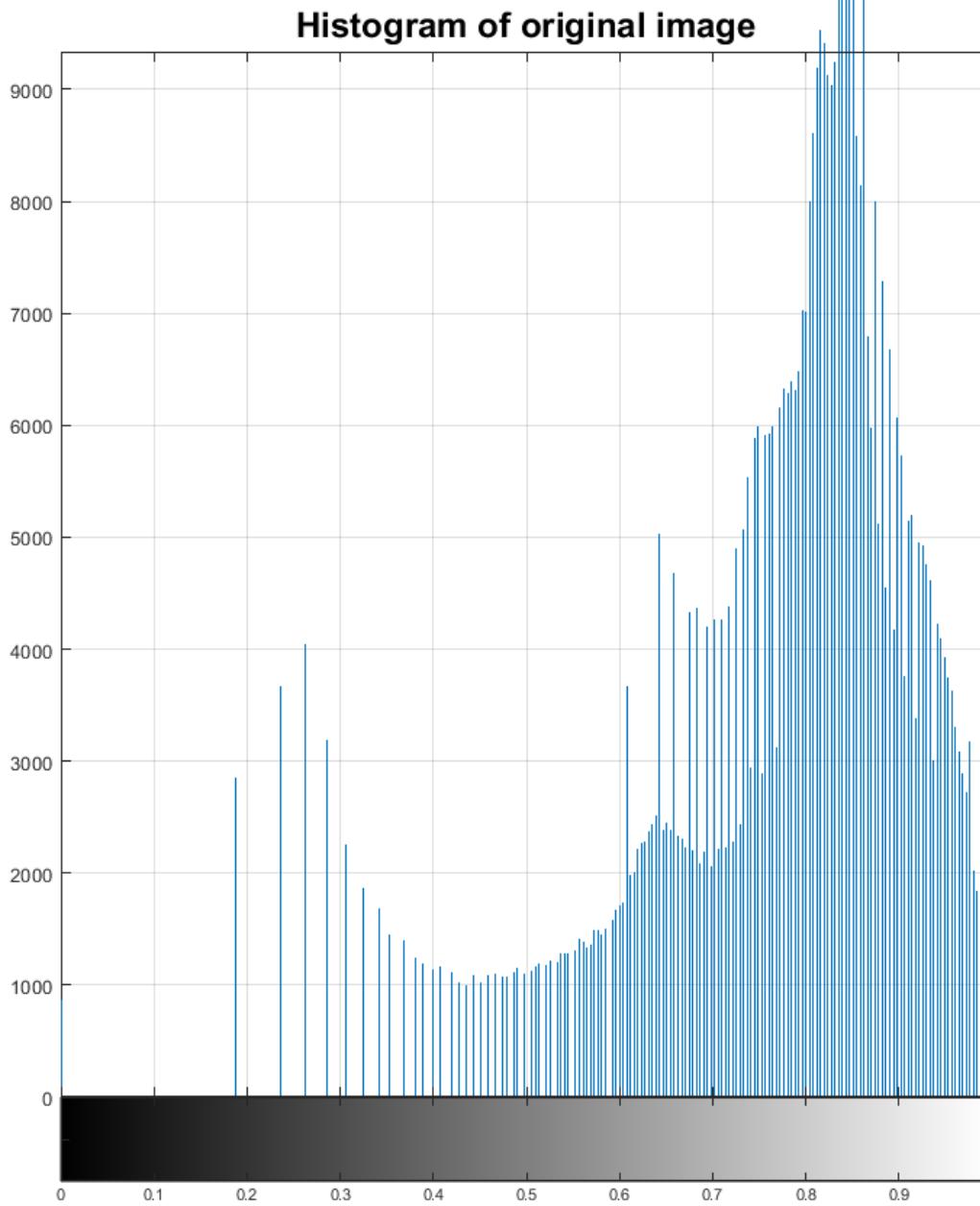
Original image



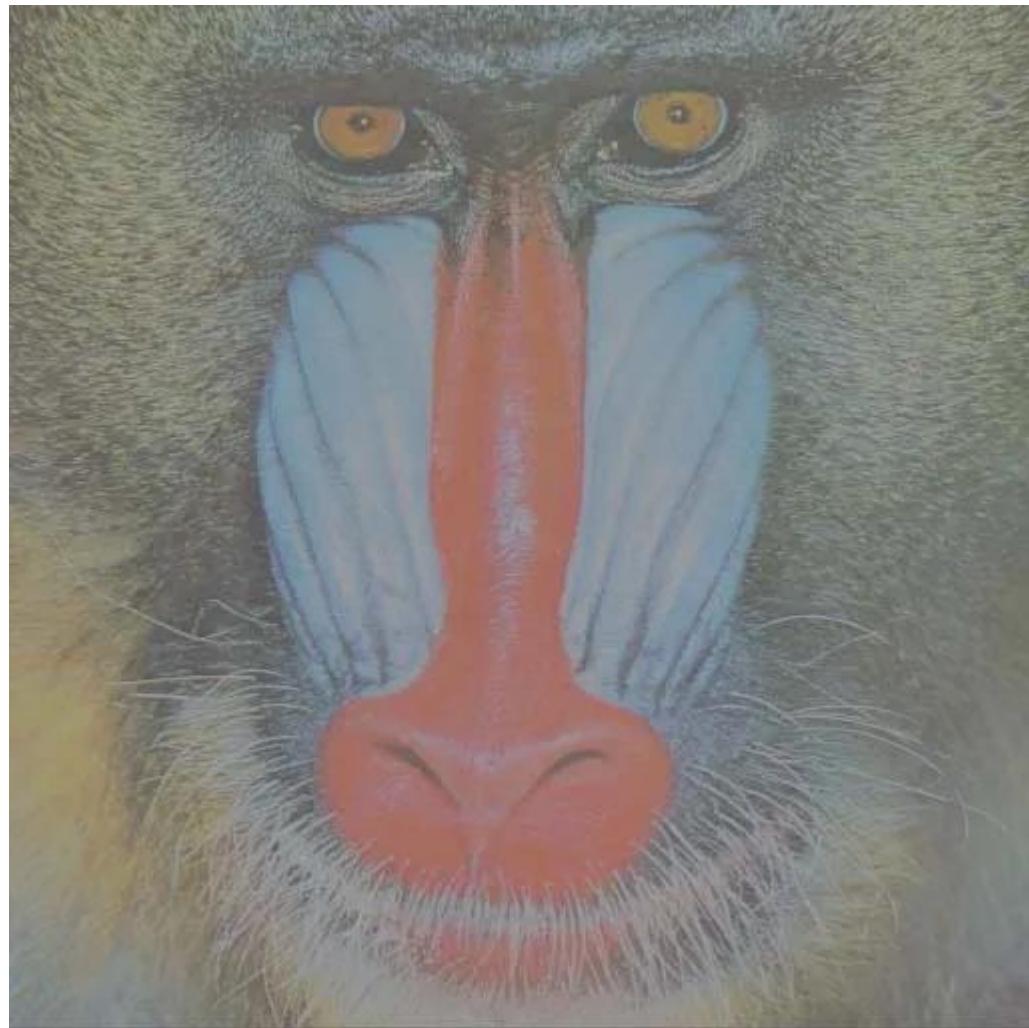
Transformed image with $c = 1$, $\gamma = 4.7$



Histogram Plots – Figure 2



These two low-contrast color images have been chosen



Colorimage1

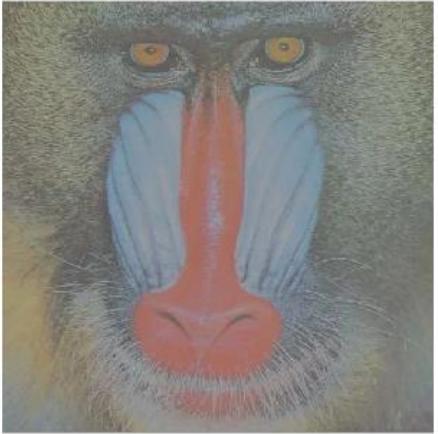


Colorimage2

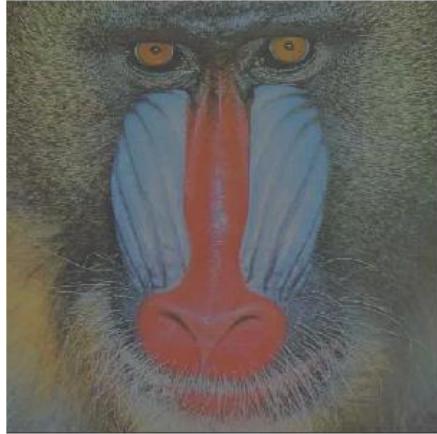
Power-law transformation with low contrast color image 1

C=1 is not giving good results for various $\gamma > 1$.

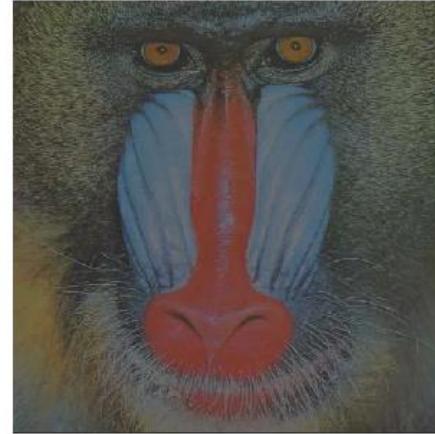
Original image



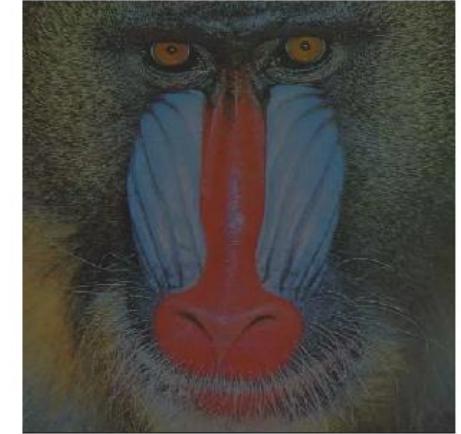
$c = 1, \gamma = 1.4$



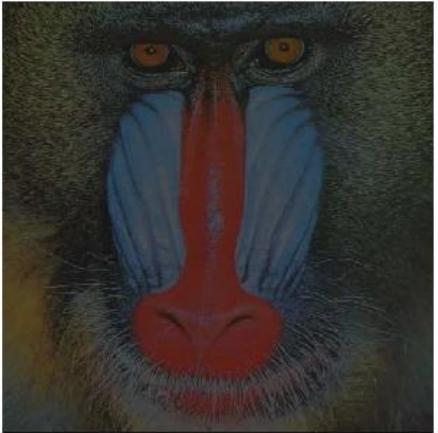
$c = 1, \gamma = 1.7$



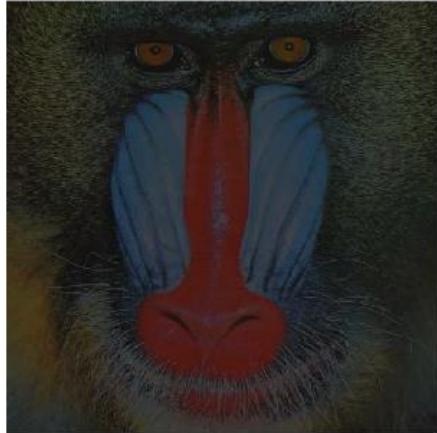
$c = 1, \gamma = 2$



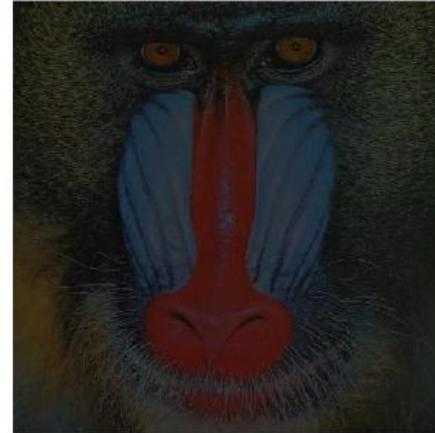
$c = 1, \gamma = 2.4$



$c = 1, \gamma = 2.7$



$c = 1, \gamma = 3$



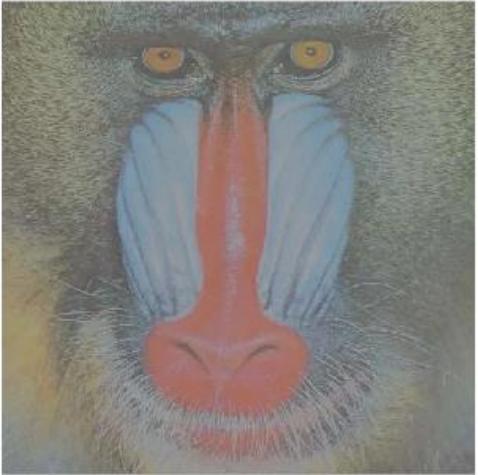
$c = 1, \gamma = 3.4$



Power-law transformation with low contrast color image 1

C=3, $\gamma=2.7$ gives the best result (found by trial and error)

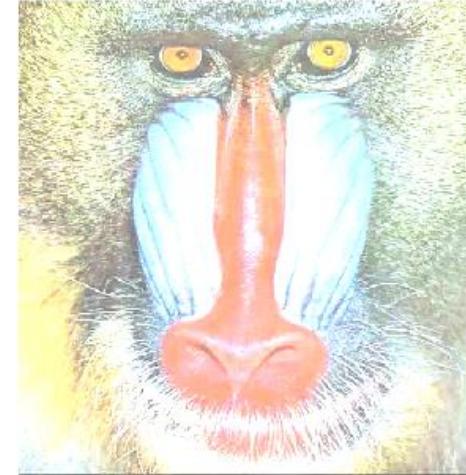
Original image



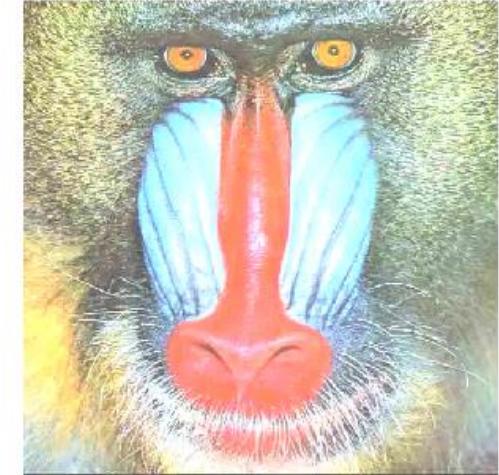
$c = 3, \gamma = 1.4$



$c = 3, \gamma = 1.7$

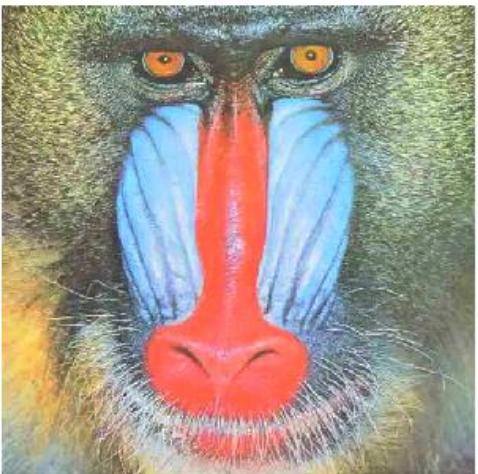


$c = 3, \gamma = 2$

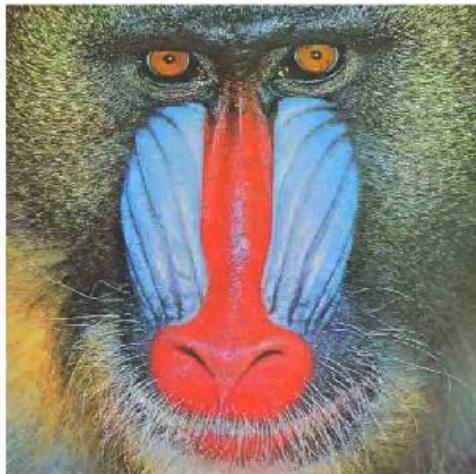


This one looks the best.

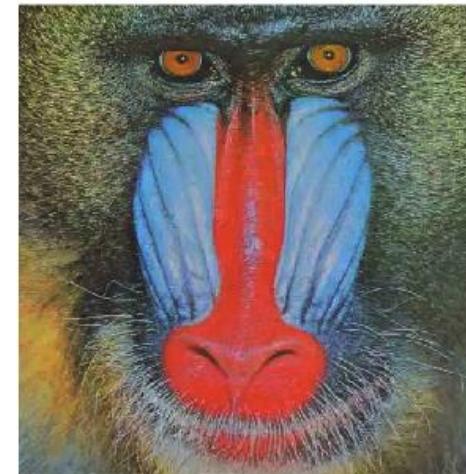
$c = 3, \gamma = 2.4$



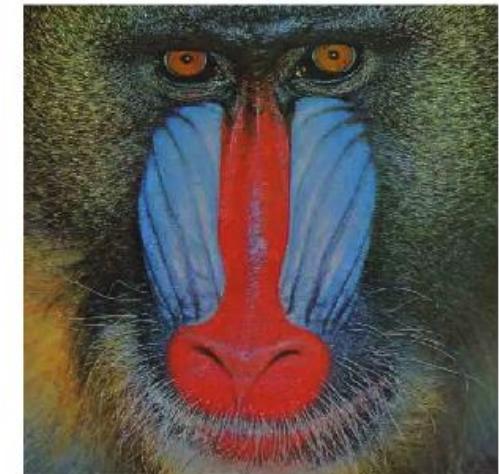
$c = 3, \gamma = 2.7$



$c = 3, \gamma = 3$



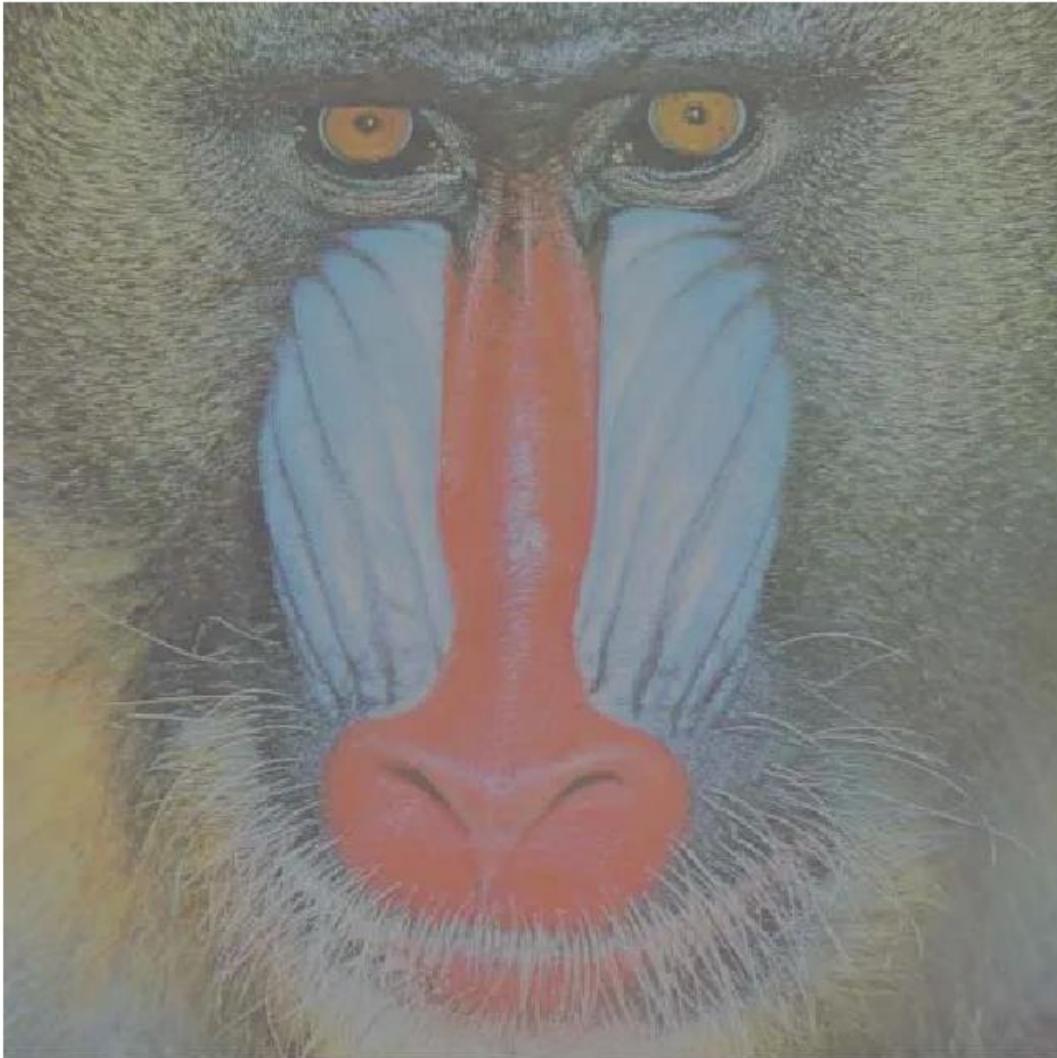
$c = 3, \gamma = 3.4$



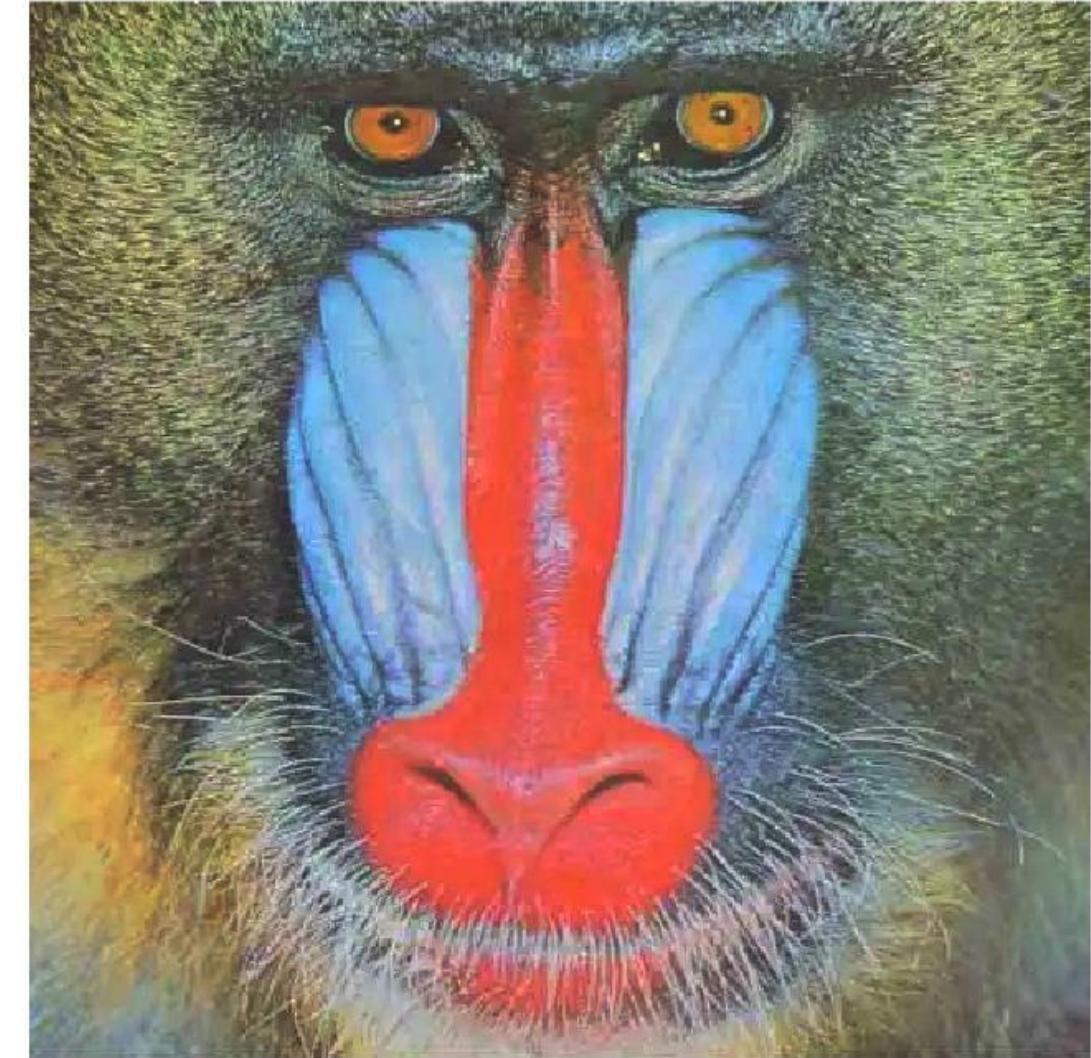
Power-law transformation with low contrast color image 1

Comparison between the original image and transformed image

Original image

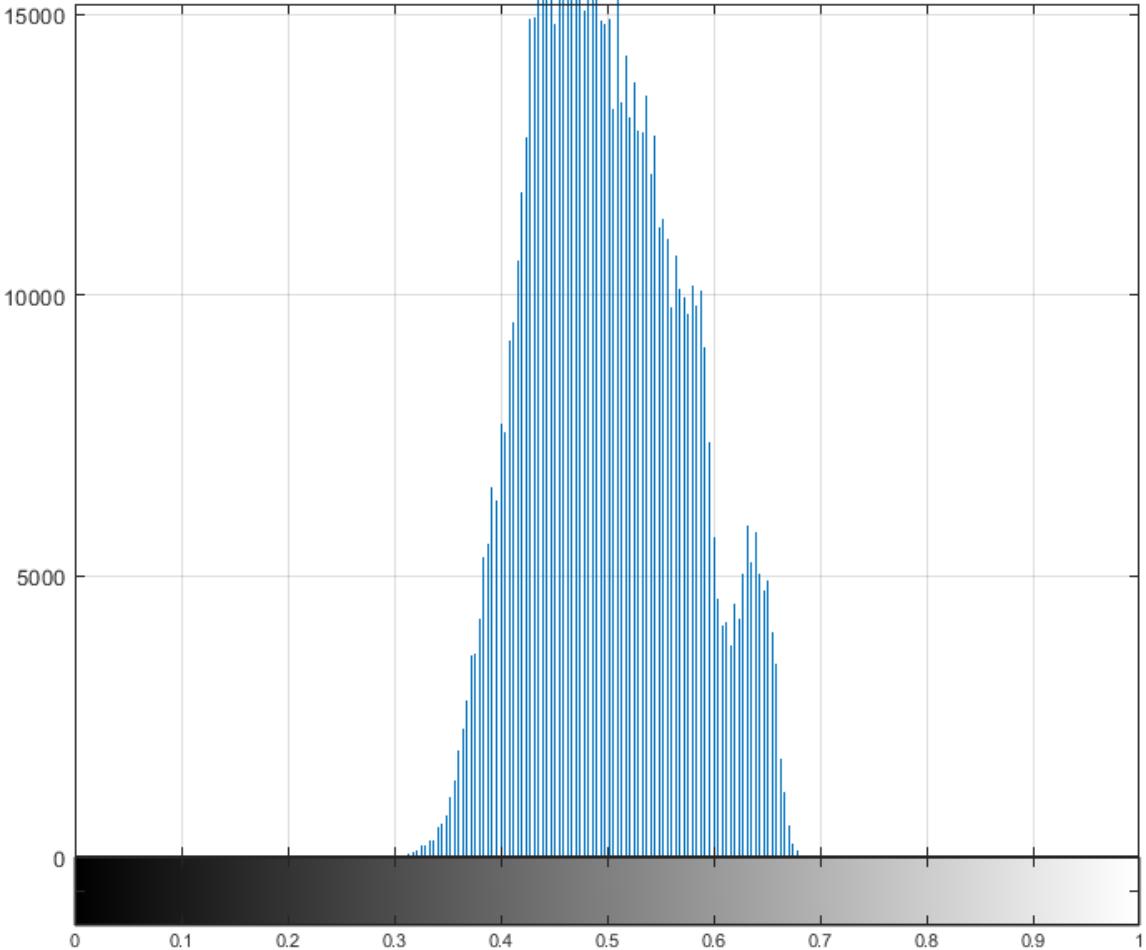


$c = 3, \gamma = 2.7$

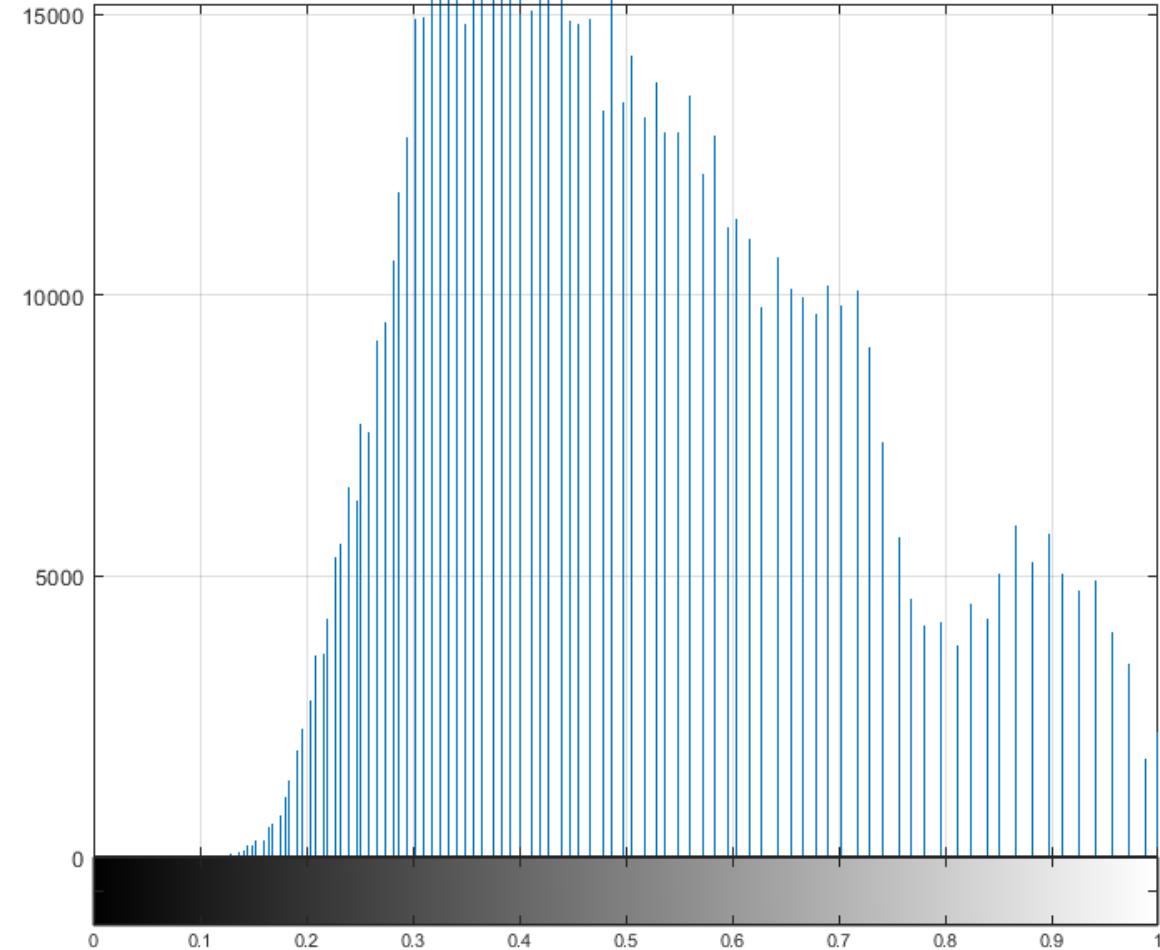


Histogram Plots – Colorimage1

Histogram of original image



Histogram of transformed image with $c=3$ and $\gamma=2.7$



Power-law transformation with low contrast color image 2

- $C=2, \gamma=1.6$ gives the best result (found by trial and error)

Original image



$c = 2, \gamma = 1.4$



$c = 2, \gamma = 1.6$



This one looks the best.

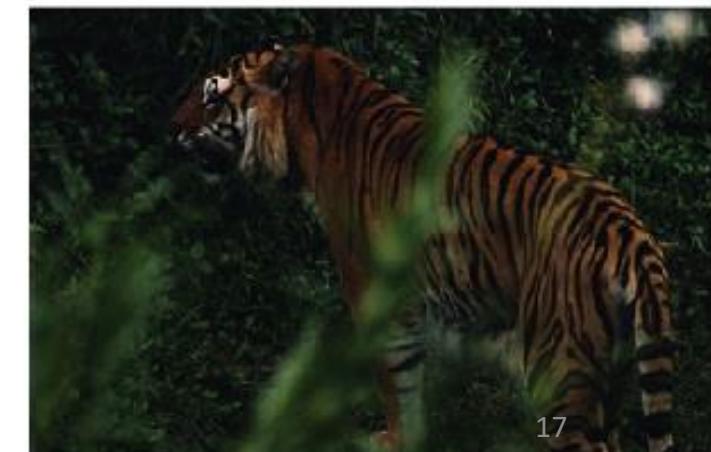
$c = 2, \gamma = 2.4$



$c = 2, \gamma = 2.7$



$c = 2, \gamma = 3$



Power-law transformation with low contrast color image 2

Comparison between the original image and transformed image

Original image

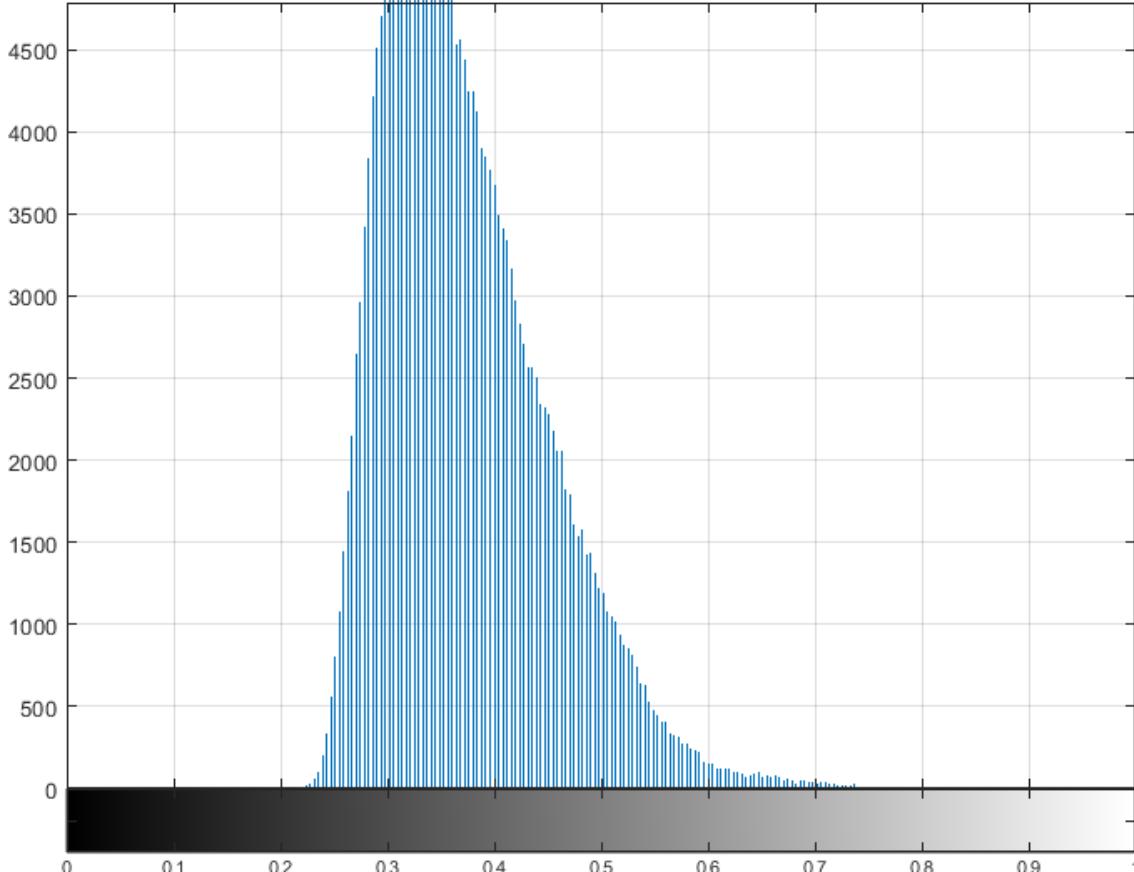


$c = 2, \gamma = 1.6$

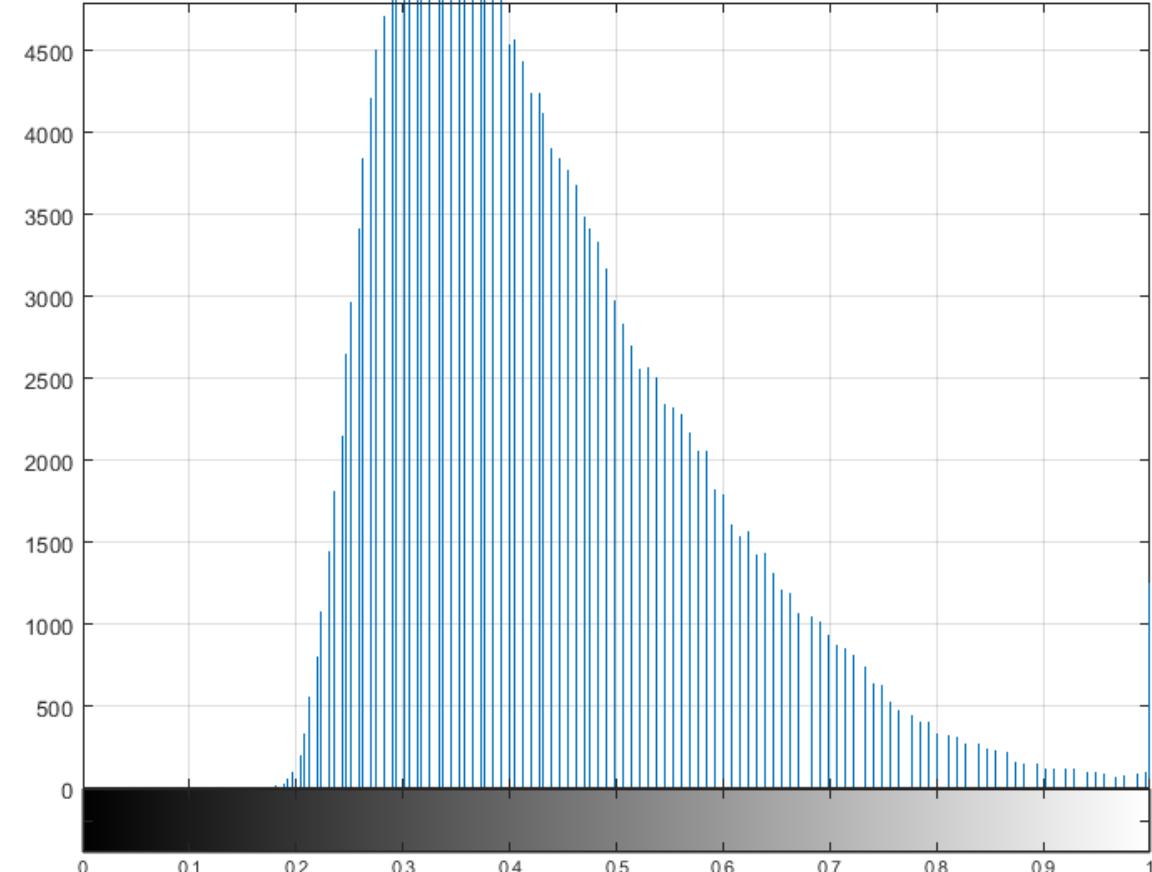


Histogram Plots – Colorimage2

Histogram of original image



Histogram of transformed image with $c=2$ and $\gamma=1.6$



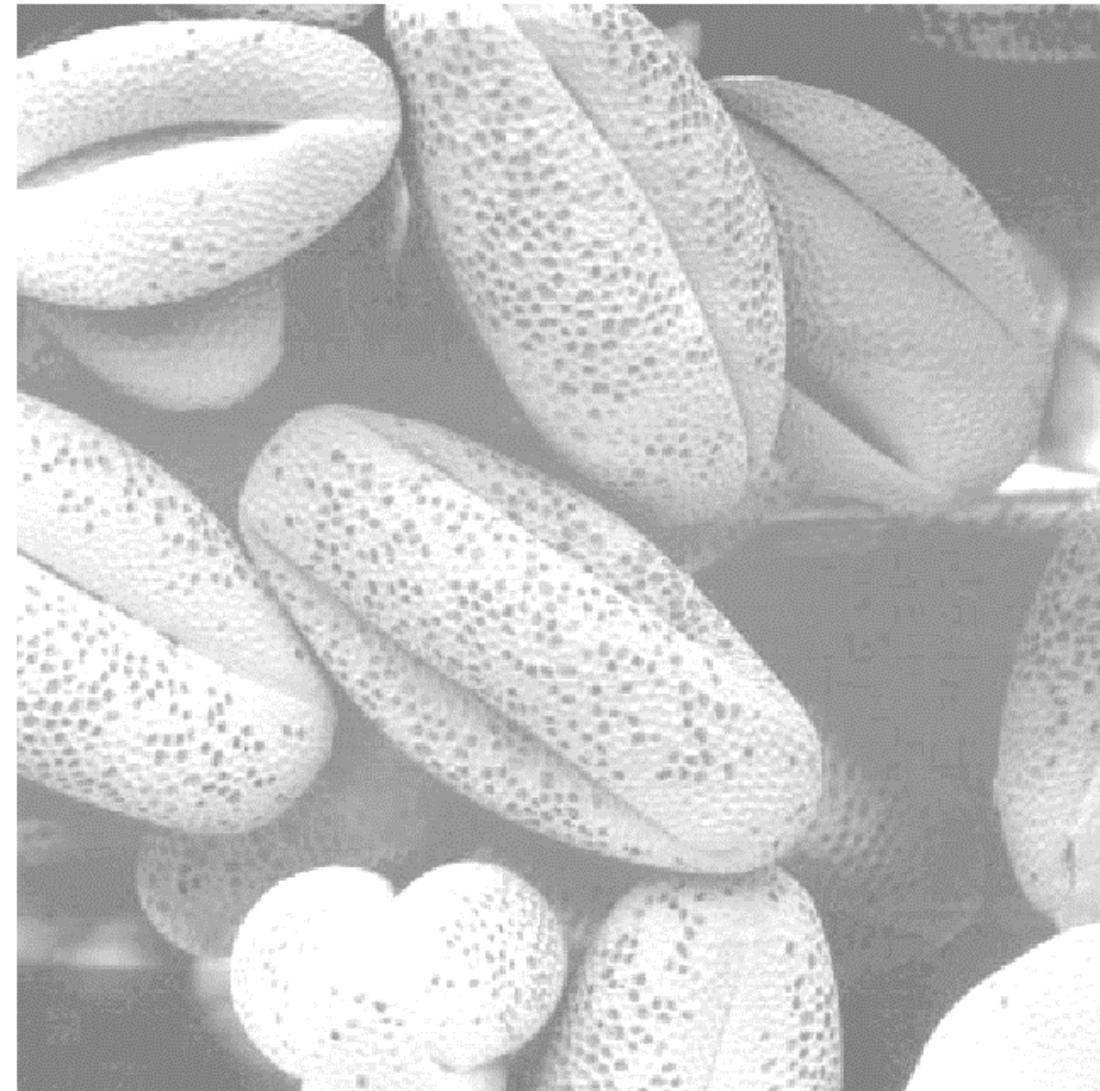
Part 2: Histogram Equalization

MATLAB Code for Histogram Equalization and Plotting

```
clc; clear; close all; font = 18;
I = imread("Figure3.tif");
figure(1); subplot(121); imshow(I);
title("Original image","fontsize",font);
[pr, r]=imhist(I); pr = pr/sum(pr);
figure(2); subplot(131); stem(r,pr); grid on;
title("Histogram (PMF) of the original image","fontsize",font-3);
cdf = cumsum(pr);
L = 256;
s = (L-1).*cdf;
figure(2); subplot(132); plot(r,s,"linewidth",1.7); grid on;
xlabel("r_k","fontsize",font); ylabel("s_k","fontsize",font);
title("The transformation function","fontsize",font);
I_tr= uint8(round(s(I+1)));
figure(1); subplot(122); imshow(I_tr);
title("Transformed image (through histogram equalization)",...
"fontsize",font-3);
[pr_tr, r_tr]=imhist(I_tr);
figure(2); subplot(133); pr_tr = pr_tr/sum(pr_tr); stem(r,pr_tr); grid on;
title("Histogram of the transformed image after equalization",...
"fontsize",font-5);
```

Figure 3 (Original and Transformed)

Original image



Transformed image (through histogram equalization)

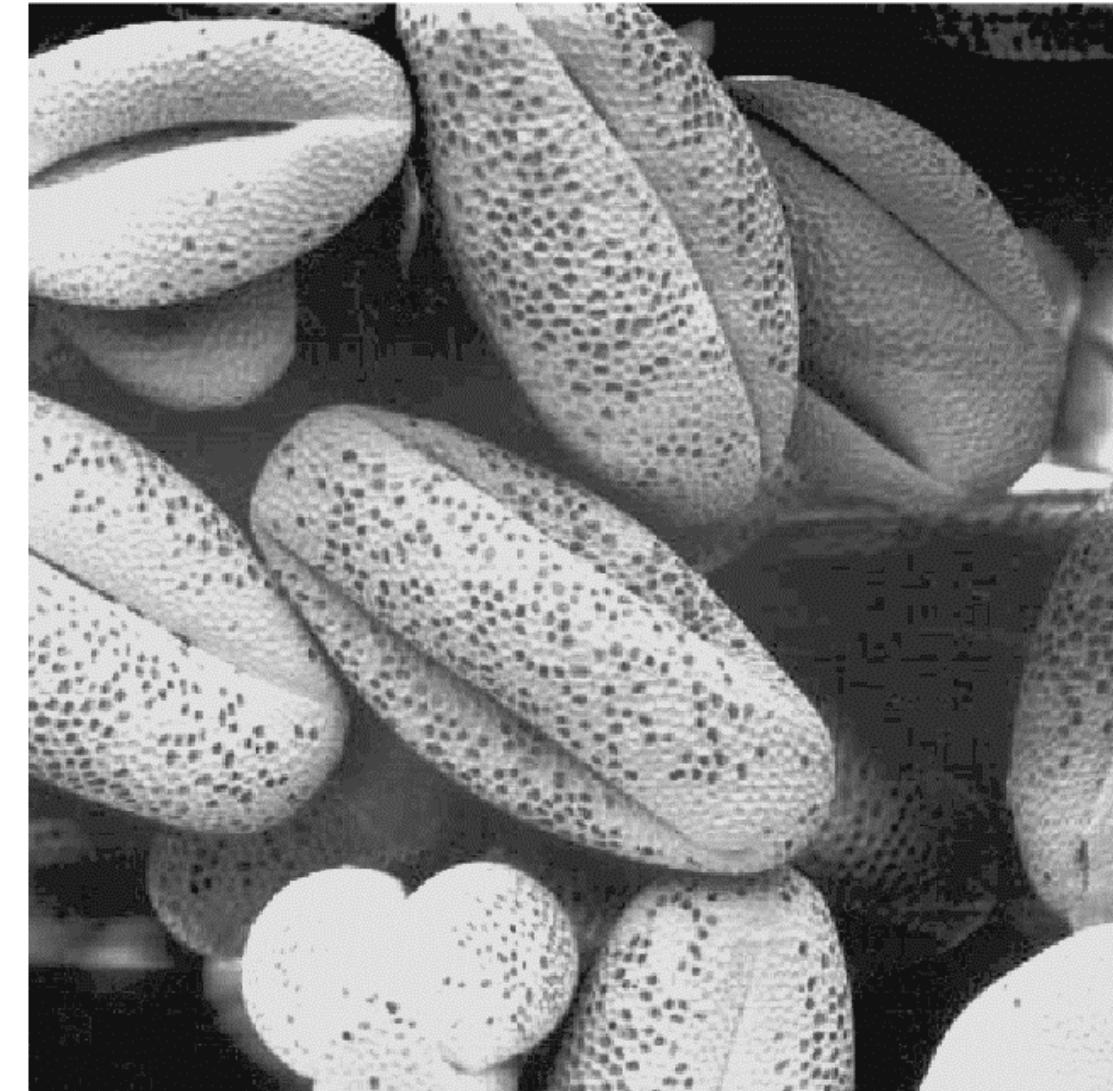
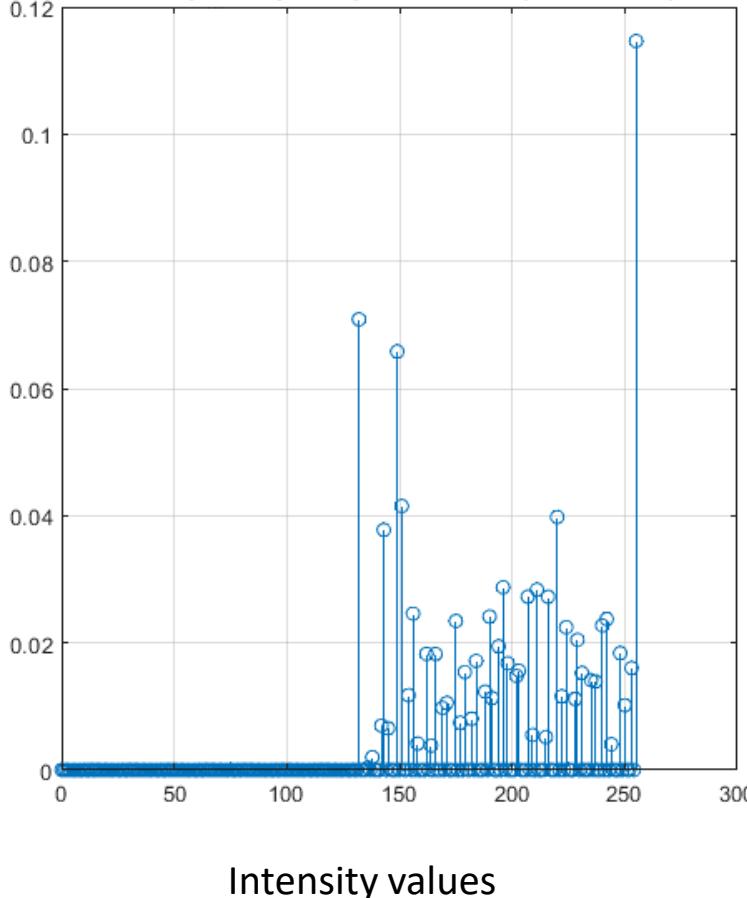
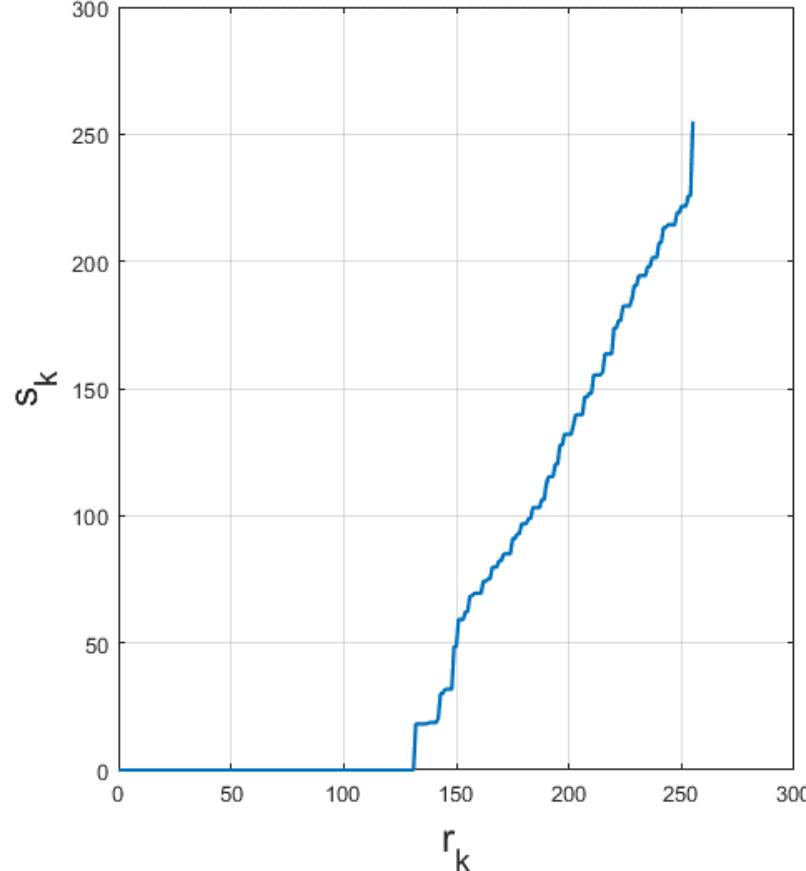


Figure3 - Original and Equalized Histograms

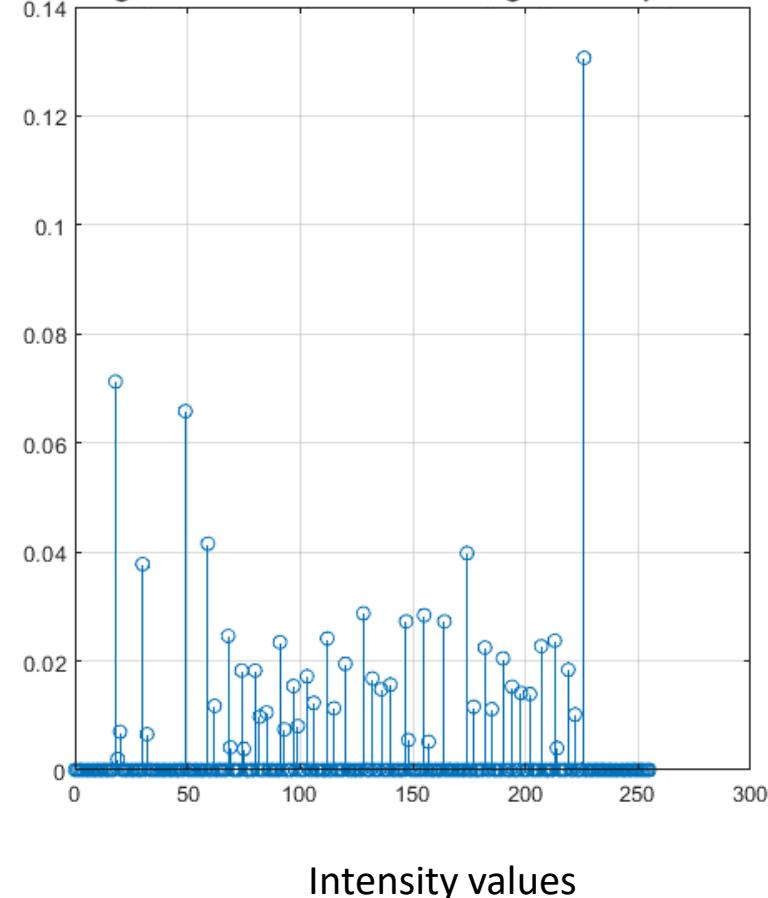
Histogram (PMF) of the original image



The transformation function



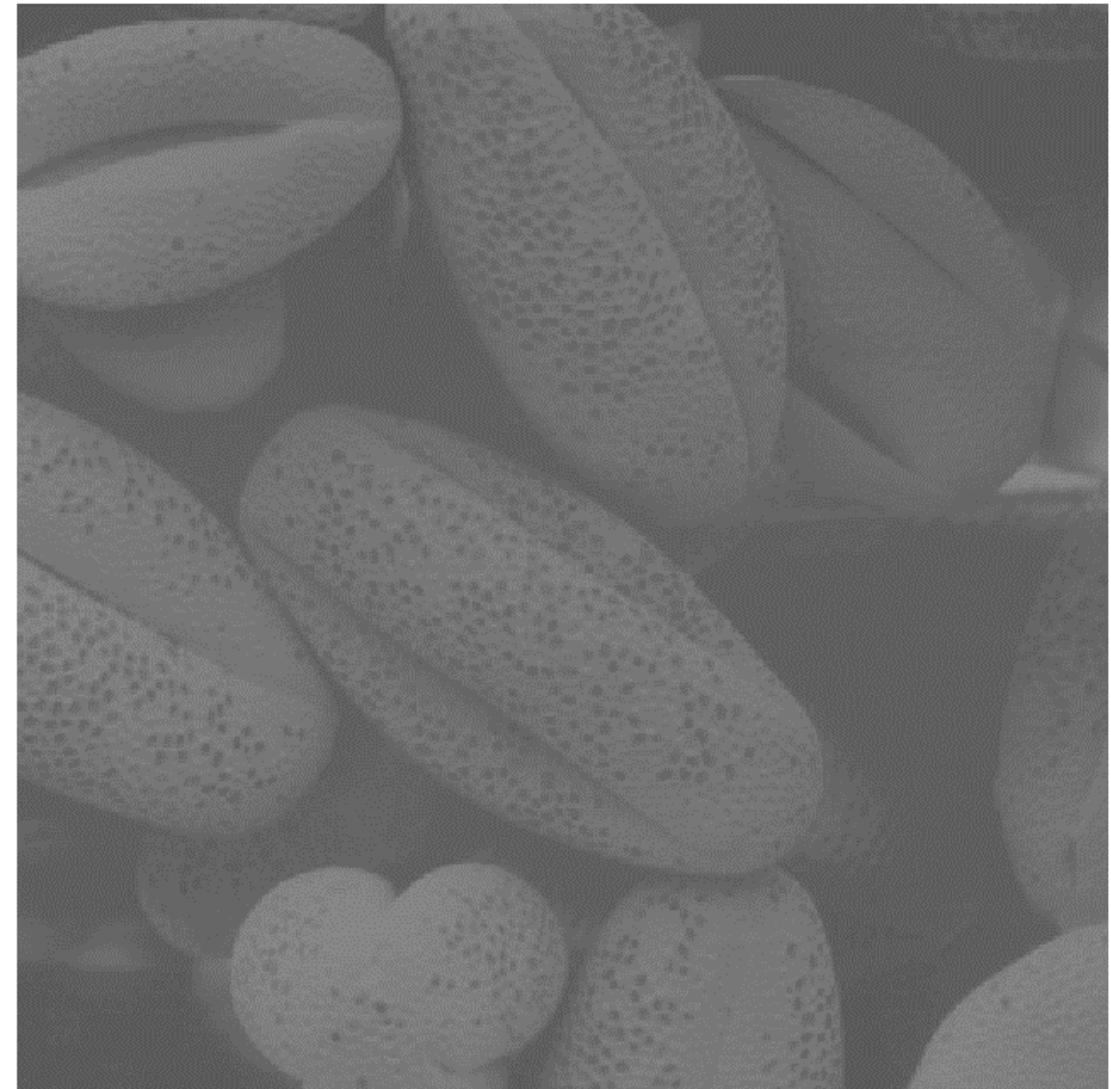
Histogram of the transformed image after equalization



As expected, the resulting histogram is not perfectly or even close to uniform distribution because it cannot break down large peaks into several pixel values. But it shifted the brightest peak to a lower intensity value and merged multiple lower peaks to achieve the best it can get.

Figure 4 (Original and Transformed)

Original image



Transformed image (through histogram equalization)

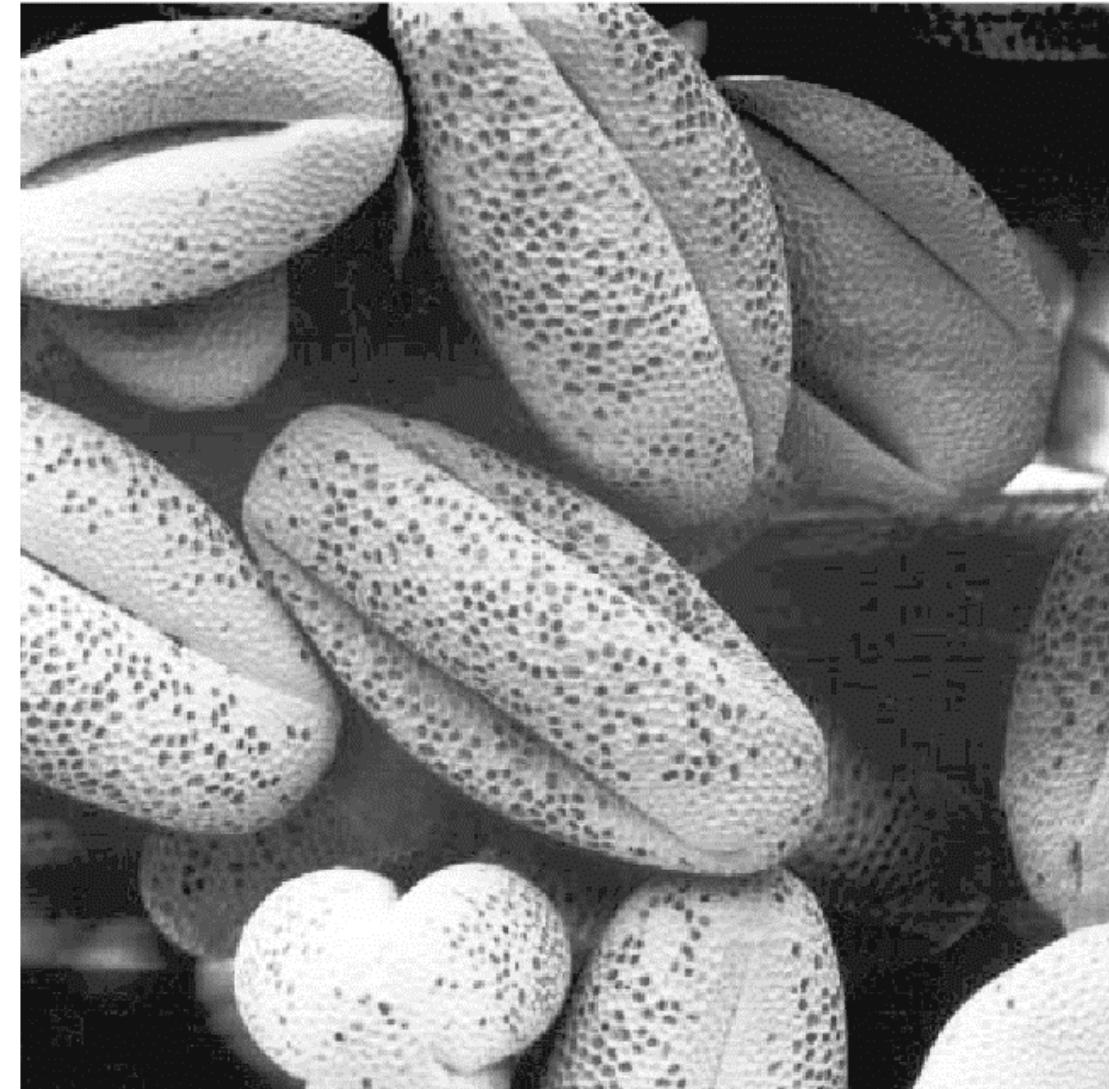
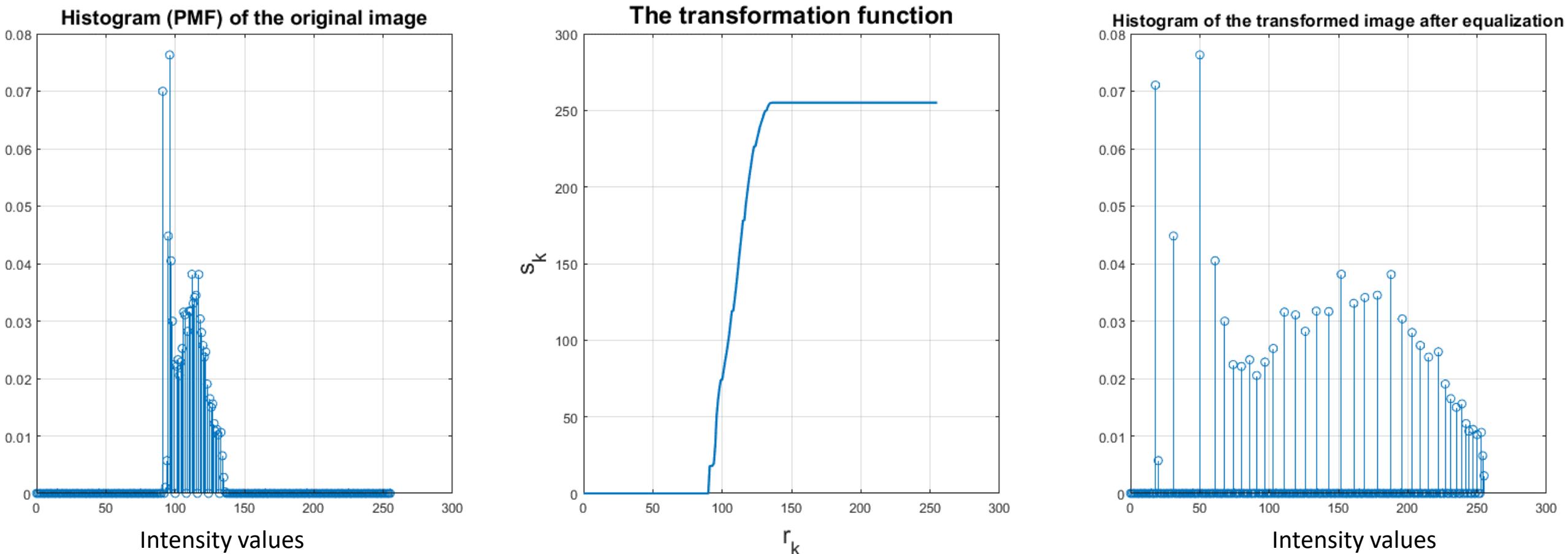


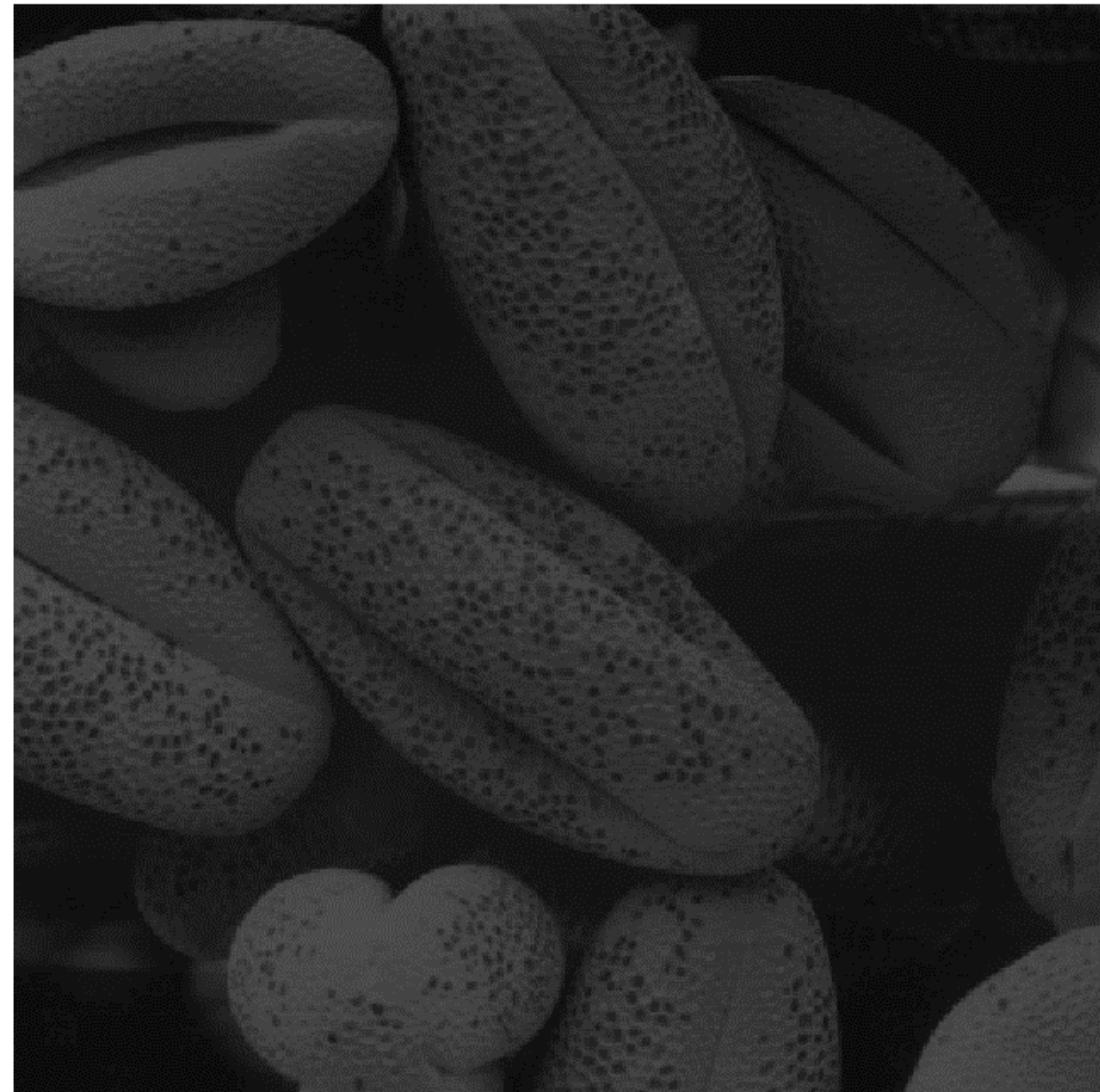
Figure4 - Original and Equalized Histograms



The final histogram is not uniform but now a lot of pixel values are enhanced in the histogram.

Figure 5 (Original and Transformed)

Original image



Transformed image (through histogram equalization)

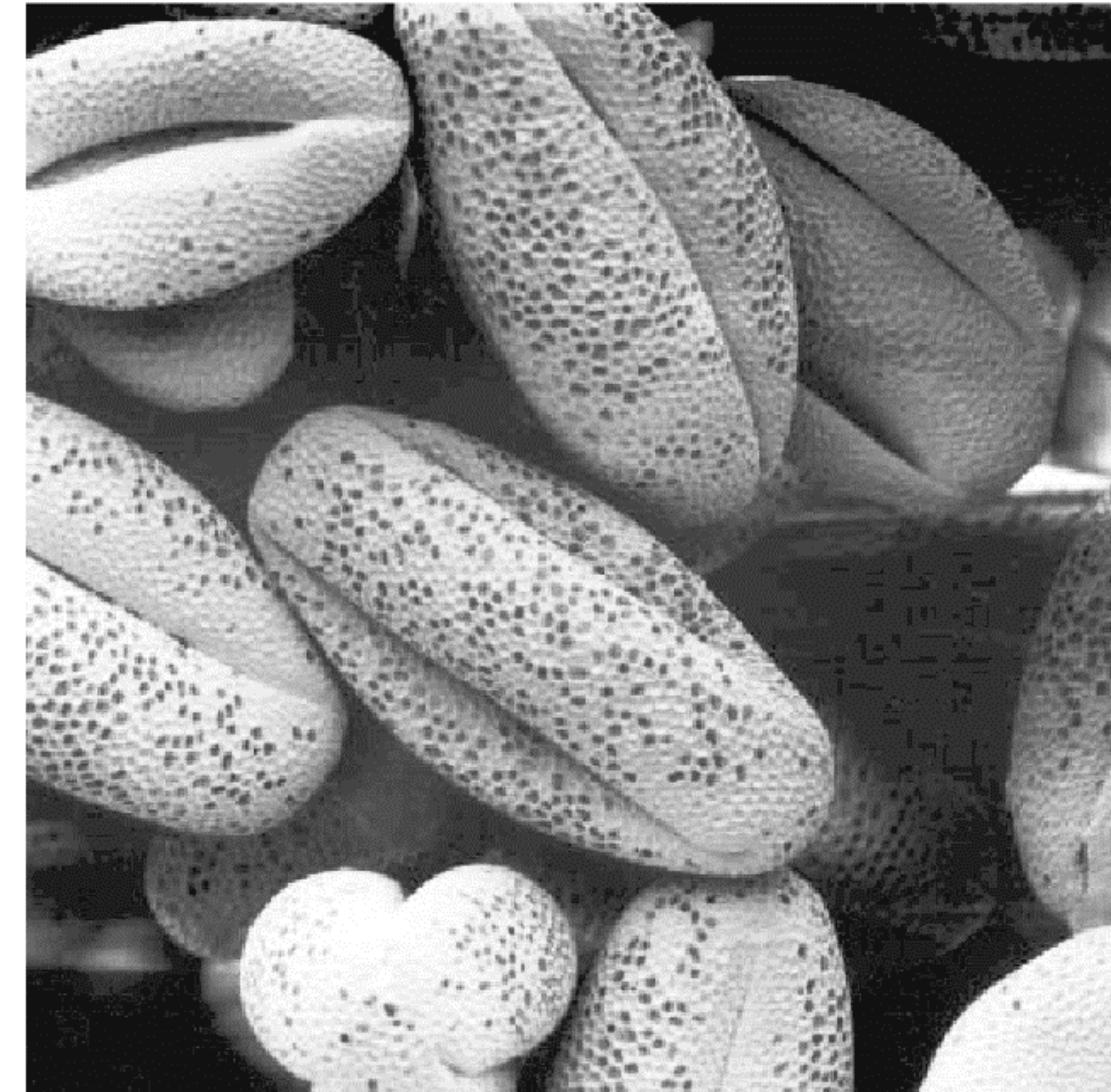
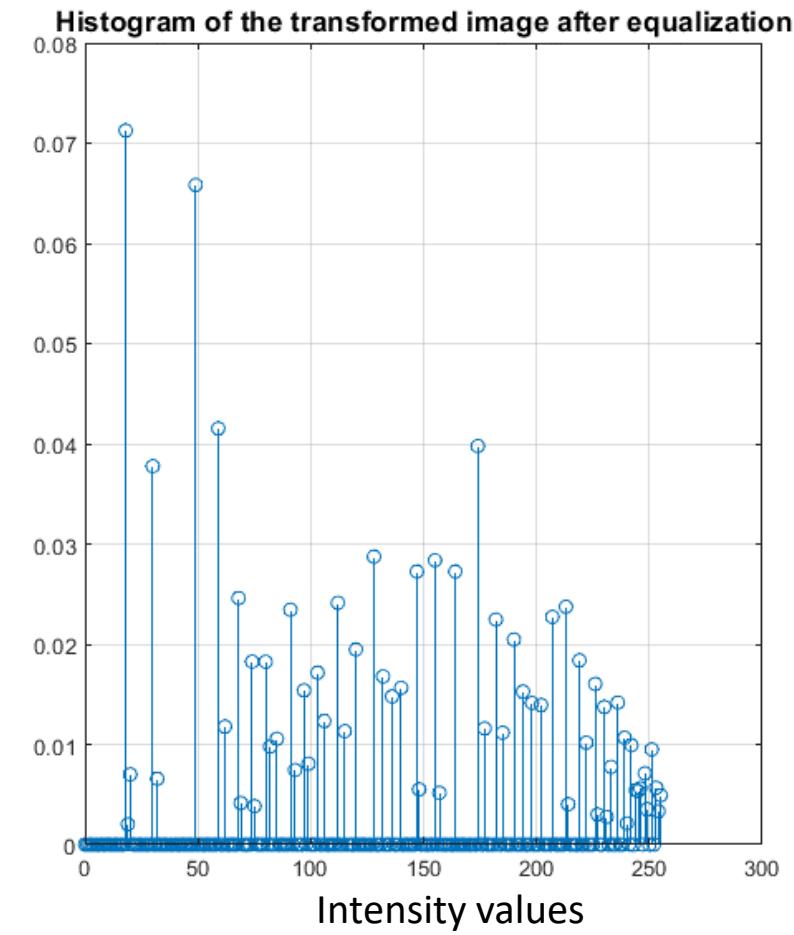
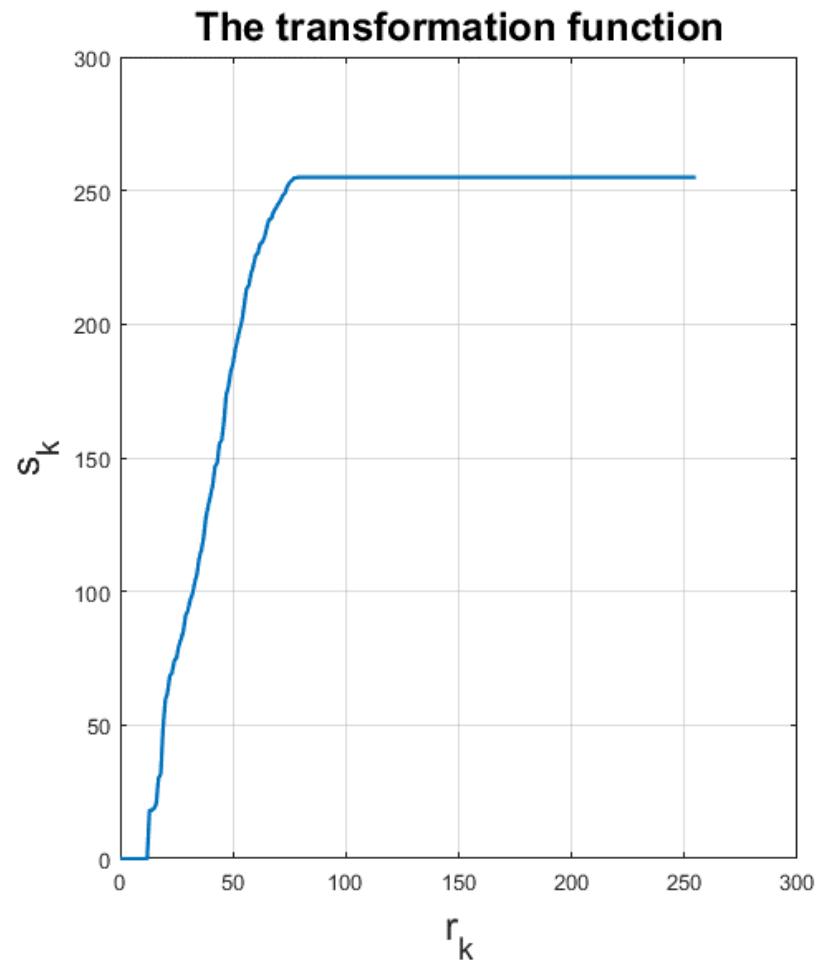
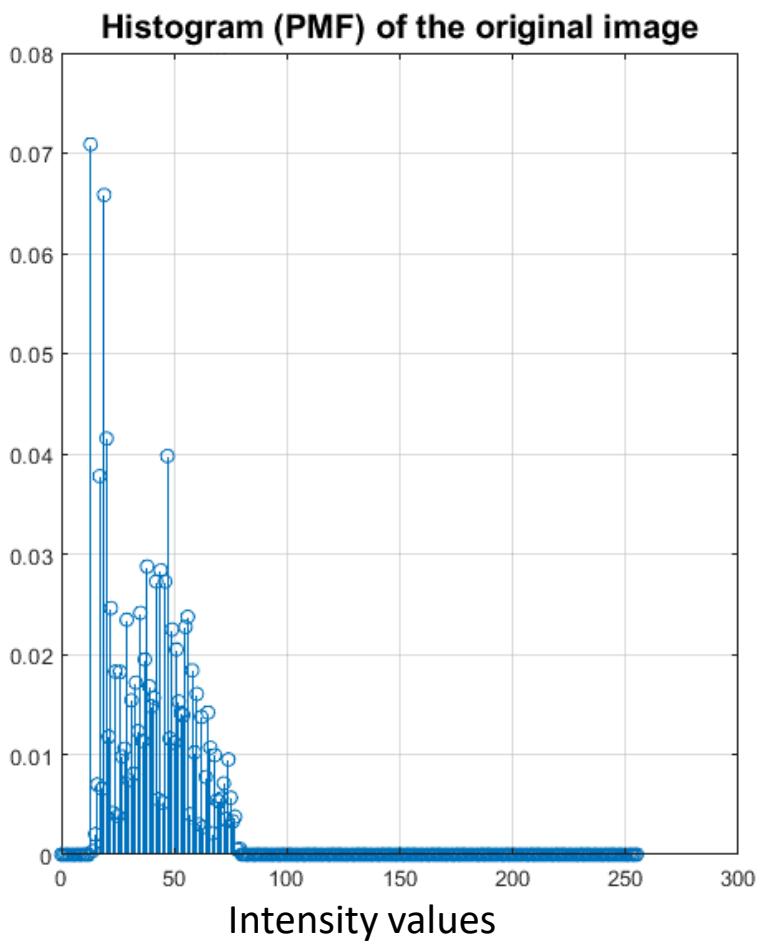
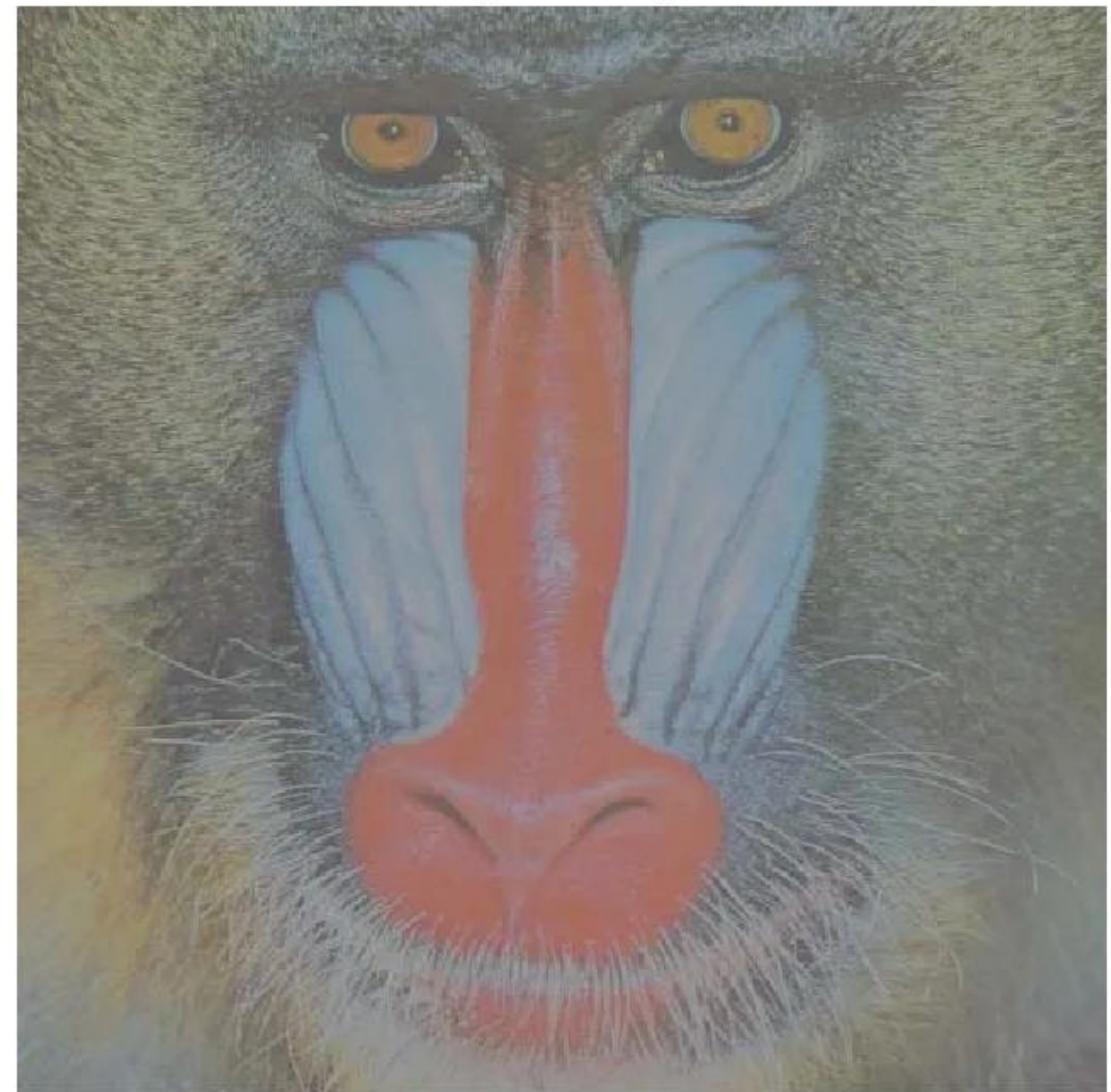


Figure5 - Original and Equalized Histograms

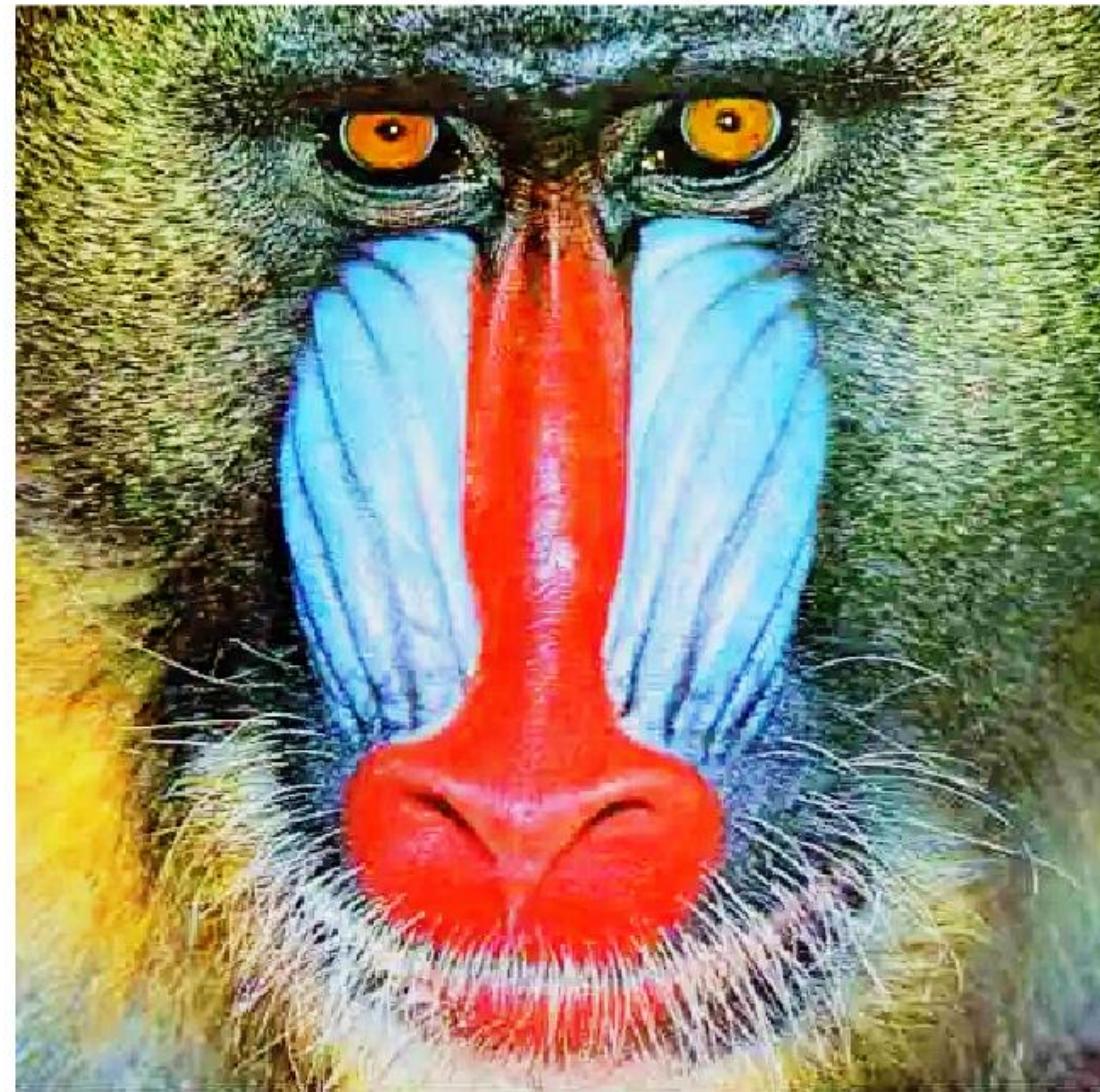


Colored image 1 (Original and Transformed)

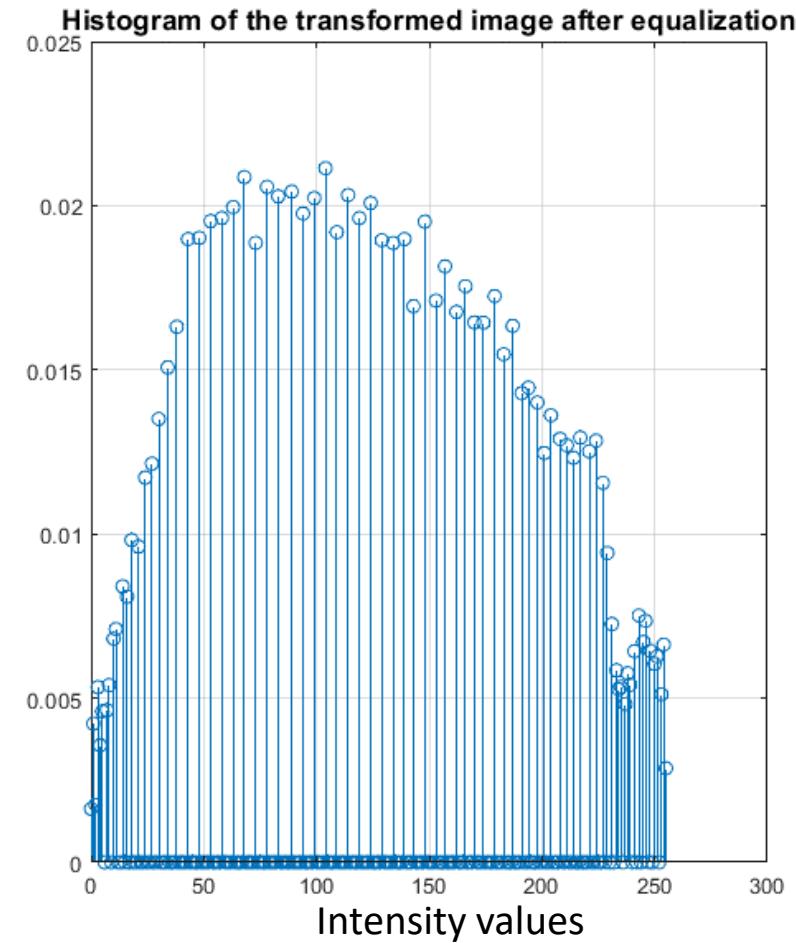
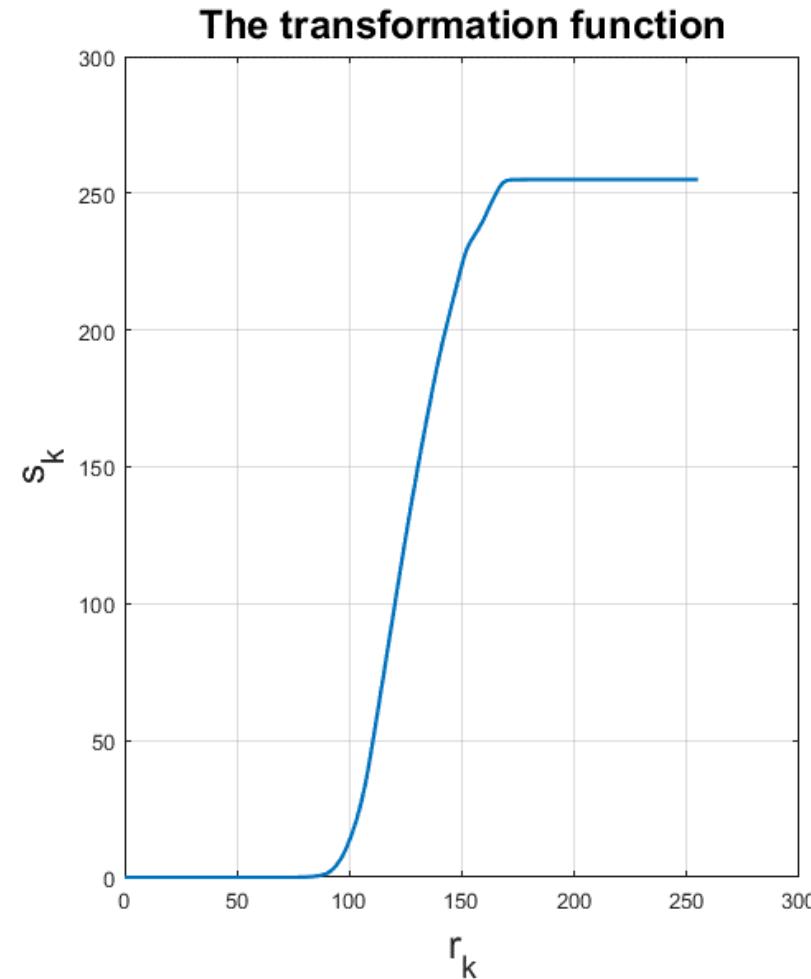
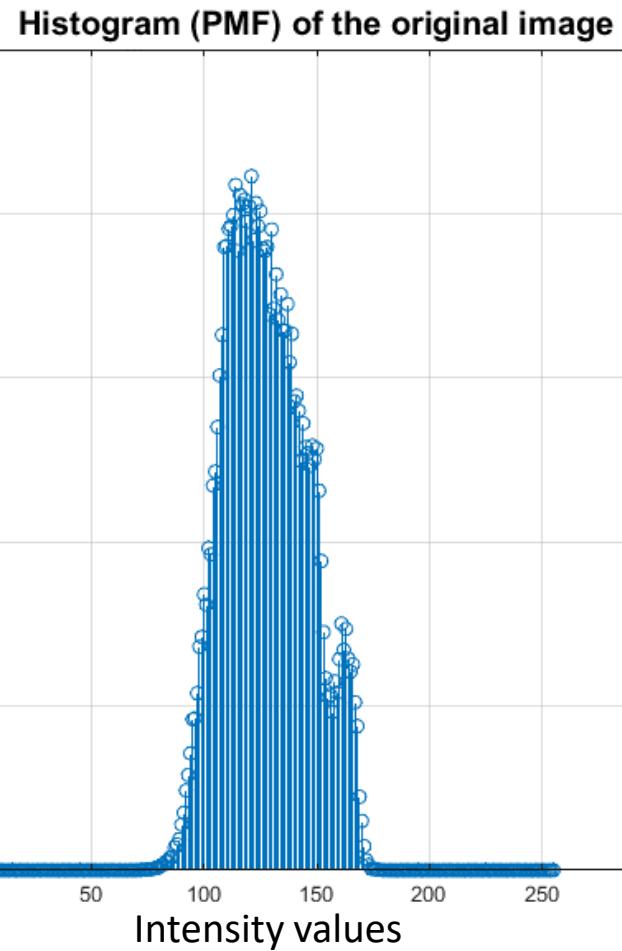
Original image



Transformed image (through histogram equalization)



Colored image 1 - Original and Equalized Histograms



Colored image 2 (Original and Transformed)

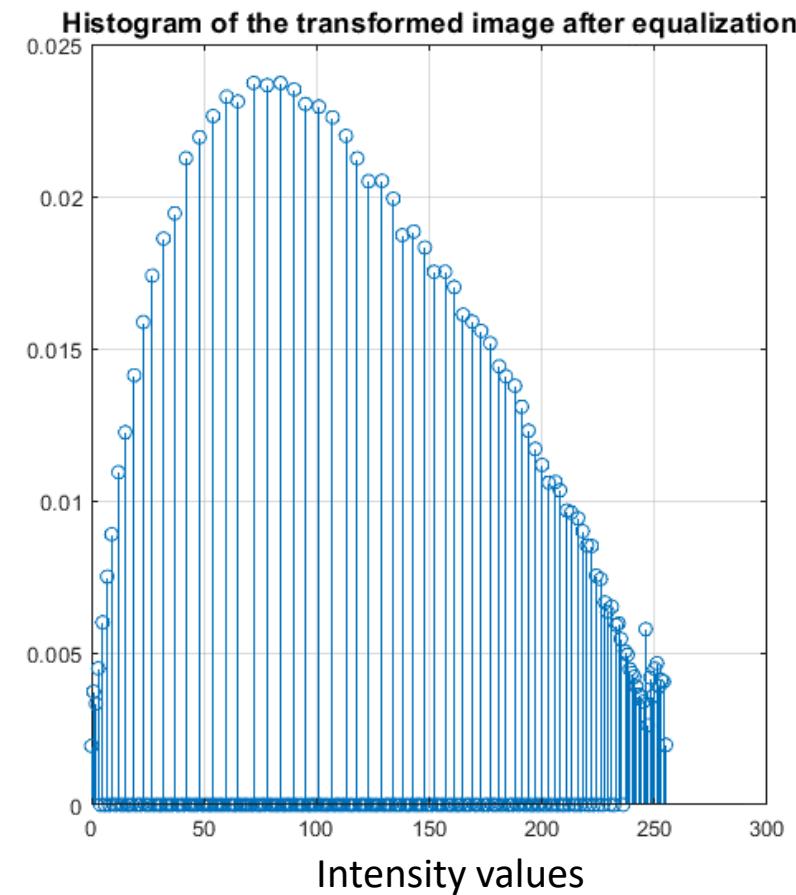
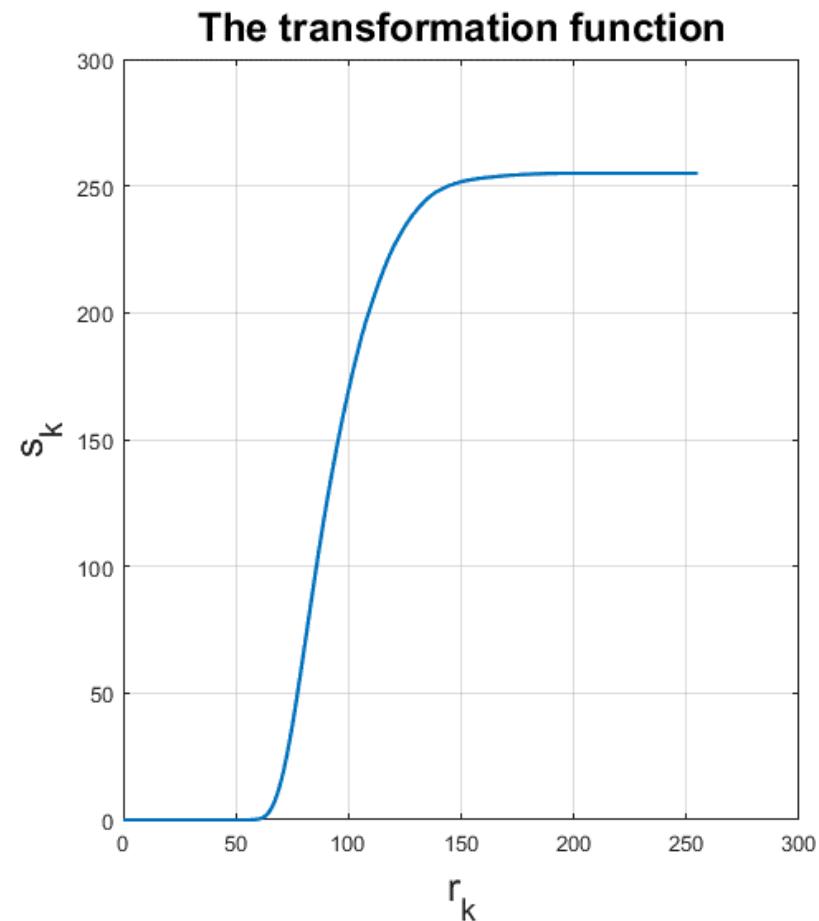
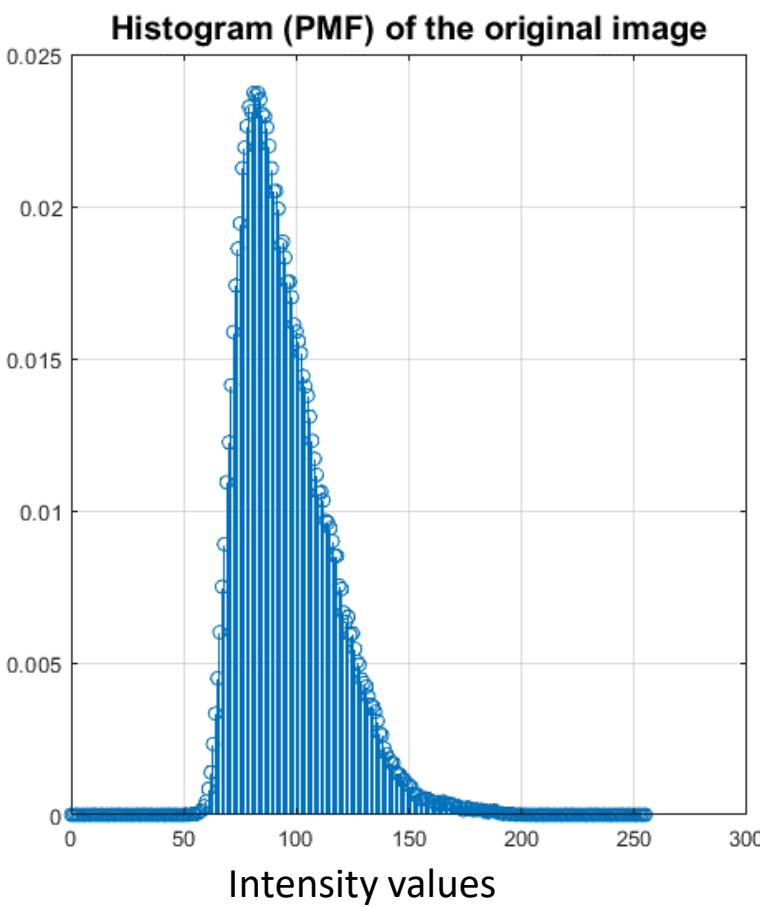
Original image



Transformed image (through histogram equalization)

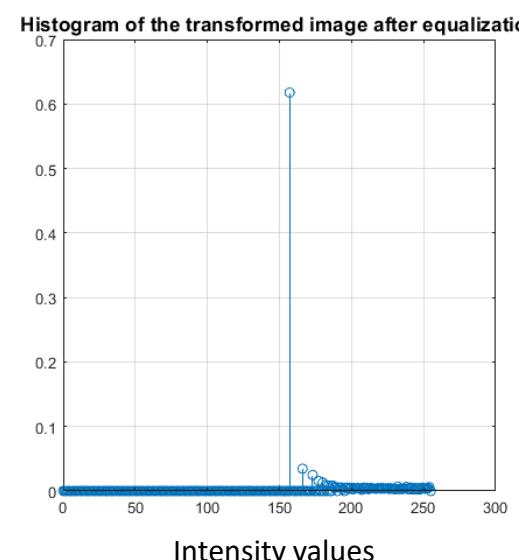
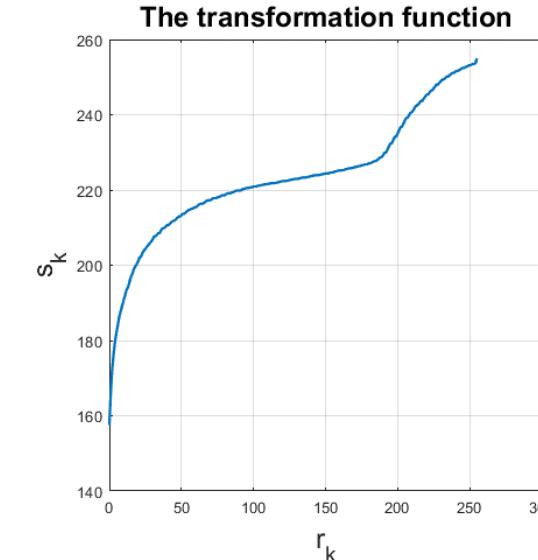
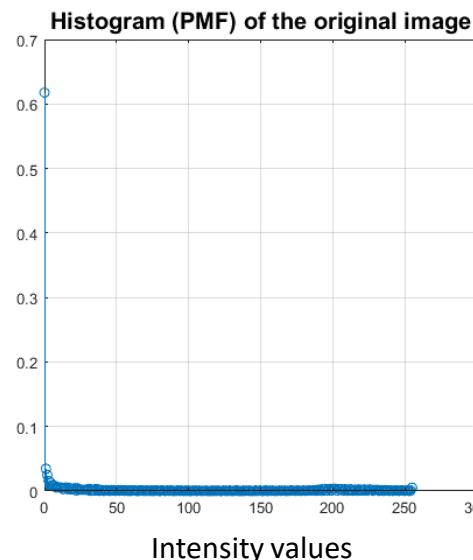
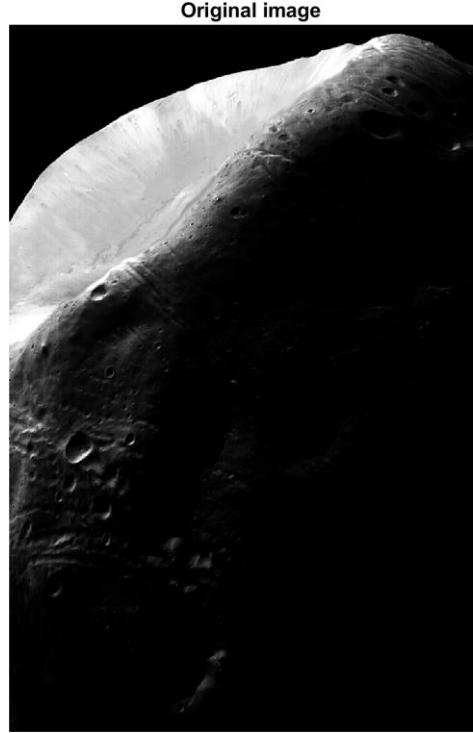


Colored image 2- Original and Equalized Histograms



Try Histogram Equalization on Figure 7

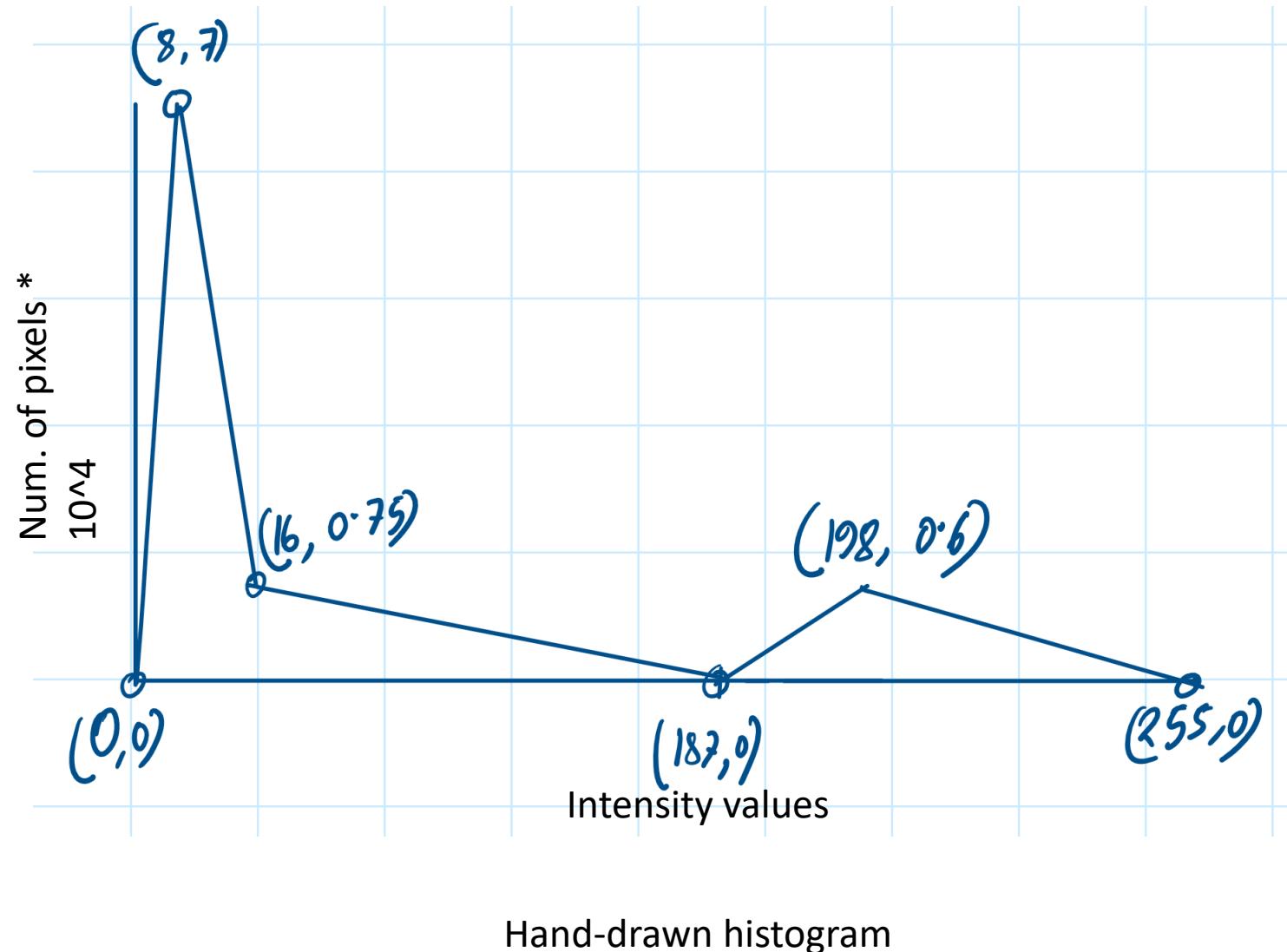
- Not good result
- Most of the part of the original image is dark, hence the peak in the histogram corresponding to this darkness shifted to a brighter value and whole image became unnecessarily bright. Histogram equalization is not expected here.
- Histogram specification should be performed.



Part 3: Histogram Specification

The Target Histogram

- Discontinuity points are approximately determined.
- 1D linear interpolation using `interp1()` function of MATLAB was performed to generate the stem plot of the specified histogram



Hand-drawn histogram

MATLAB Code for histogram specification

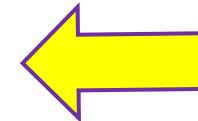
```
clc; clear; close all; font = 18;
I = imread("Figure6.tif");
figure(1); subplot(121); imshow(I);
title("Original image", "fontsize", font);

[pr, r] = imhist(I); pr = pr / sum(pr);
figure(2); subplot(221); stem(r, pr); grid on;
title("Histogram (PMF) of the original image", "fontsize", font);
xlabel("Intensity values", "fontsize", font - 5);
ylabel("Number of pixels", "fontsize", font - 5);

cdf = cumsum(pr); L = 256; s = (L - 1) .* cdf;
figure(2); subplot(222); plot(r, s, "linewidth", 1.7); grid on;
xlabel("r_k", "fontsize", font); ylabel("s_k", "fontsize", font);
title("The transformation function", "fontsize", font);
I_tr = uint8(round(s(I + 1)));
figure(1); subplot(122); imshow(I_tr);
title("Transformed image (through histogram equalization)", "fontsize", font - 3);
[pr_tr, r_tr] = imhist(I_tr);
```

MATLAB Code for histogram specification

```
z = [0 8 16 187 198 255];  
s2 = (10^4)*[0 7 .75 0 .6 0];  
zi = 0:255;  
s2i = interp1(z,s2,zi,'linear');  
s2i=s2i/sum(s2i);
```

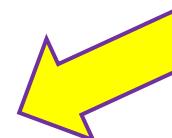


The specified histogram

```
figure(2); subplot(223); stem(zi,s2i); grid on;  
xlabel("Intensity values","fontsize",font-5);  
ylabel("Number of pixels","fontsize",font-5);  
title("Specified histogram","fontsize",font);
```

histogram equalization of
the specified histogram

```
cdf2 = cumsum(s2i); s22 = (L-1).*cdf2;  
figure(2); subplot(224); plot(zi,s22,"linewidth",1.7); grid on;  
xlabel("z_q","fontsize",font); ylabel("s_k","fontsize",font);  
title("The 2nd transformation function","fontsize",font);
```



```
figure(3); subplot(121); imshow(I);  
title("Original image","fontsize",font);
```

Continued at the next slide

MATLAB Code for histogram specification

```
Itemp = s(I+1);  
siz = size(I);
```

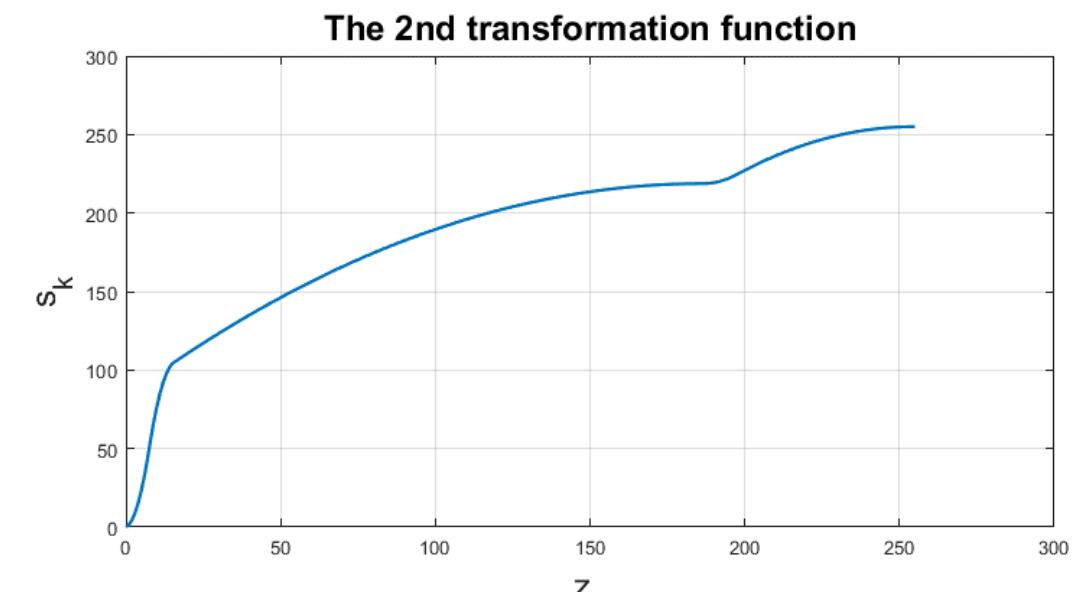
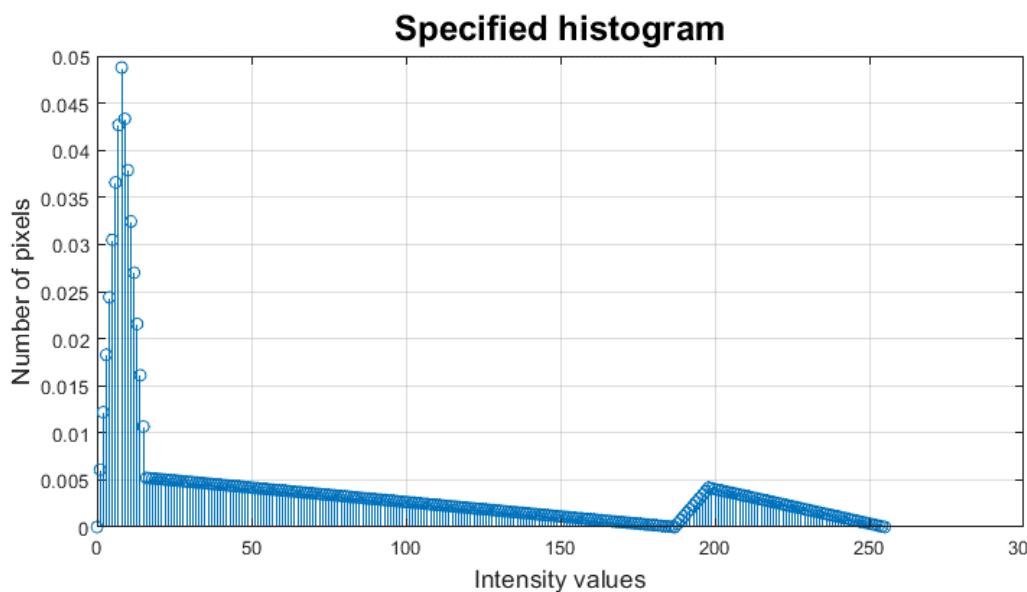
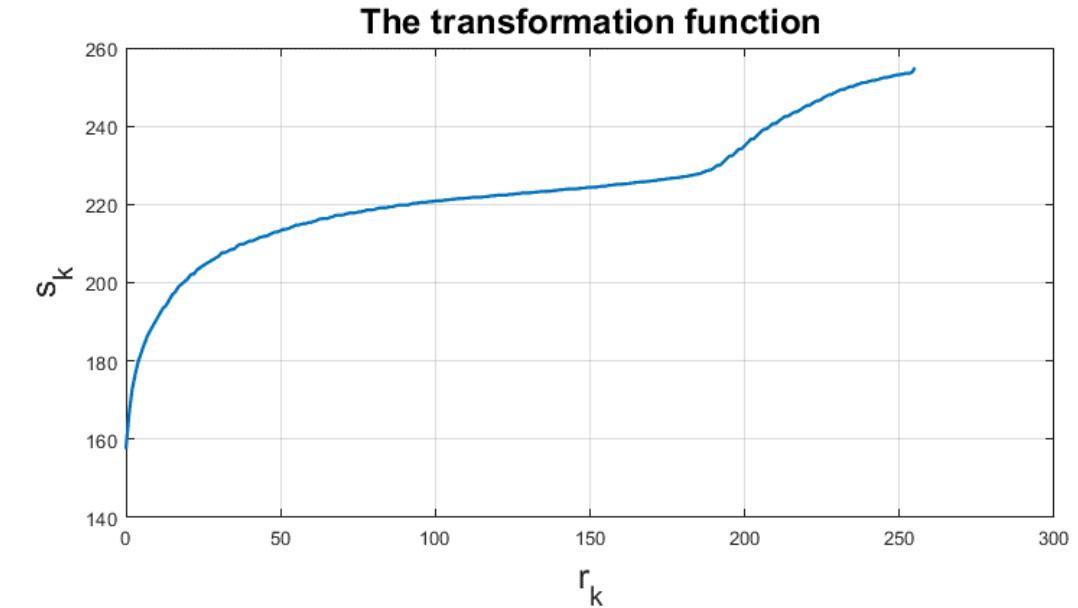
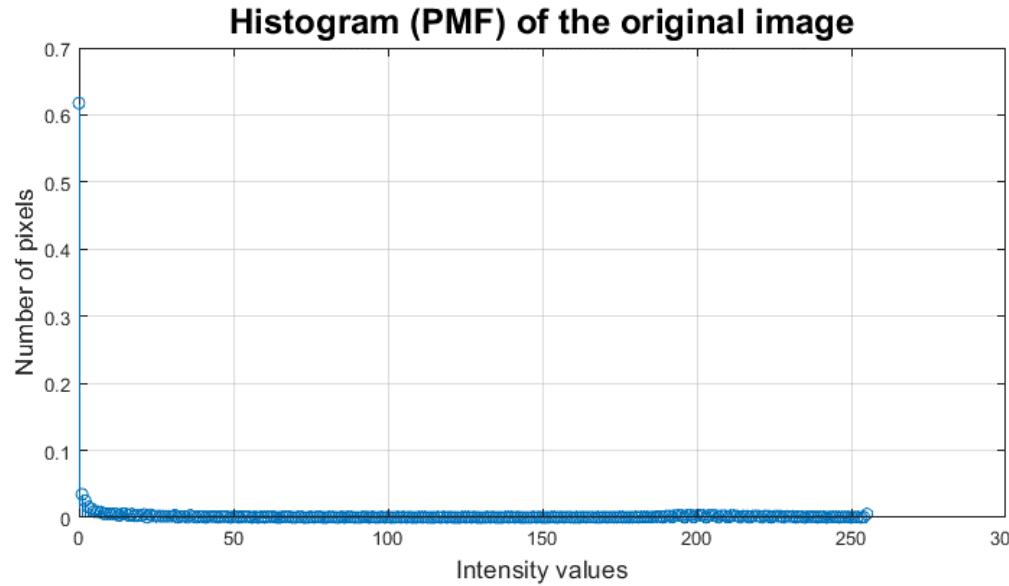
The inverse transformation

```
for i = 1:siz(1)  
    for j = 1:siz(2)  
        [minval, argmin] = min(abs(Itemp(i,j)-s22));  
        Itr2(i,j) = uint8(zs(argmin));  
    end  
end
```

```
figure(3); subplot(122); imshow(Itr2);  
title("Transformed image (through histogram  
specification)", "fontsize", font-3);
```

```
[pr2, r2]=imhist(Itr2); pr2 = pr2/sum(pr2);  
figure(4); stem(r,pr2); grid on;  
title("Histogram (PMF) of the transformed image (after histogram...  
specification)", "fontsize", font-3);  
xlabel("Intensity values", "fontsize", font-5);  
ylabel("Number of pixels", "fontsize", font-5);
```

Histograms and Both Transformation Functions

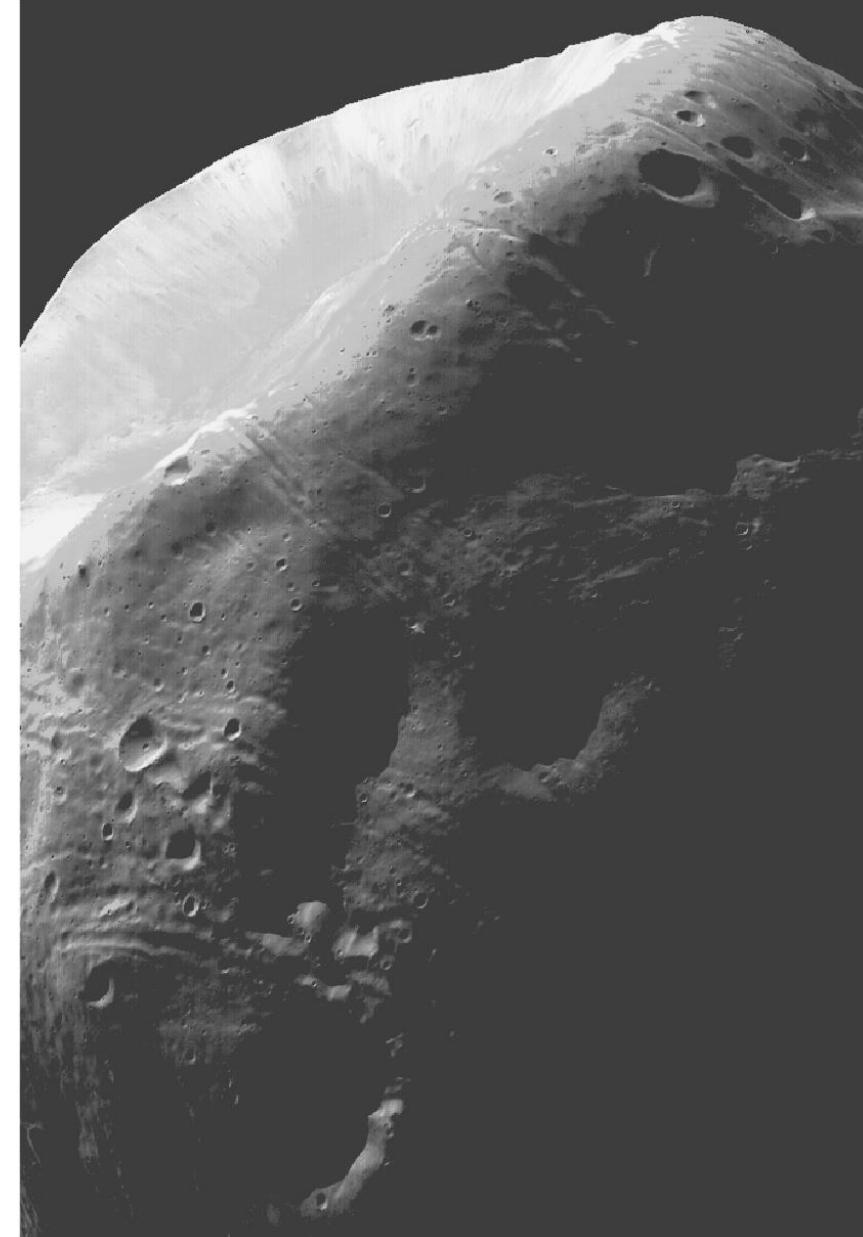


Result of Histogram Specification

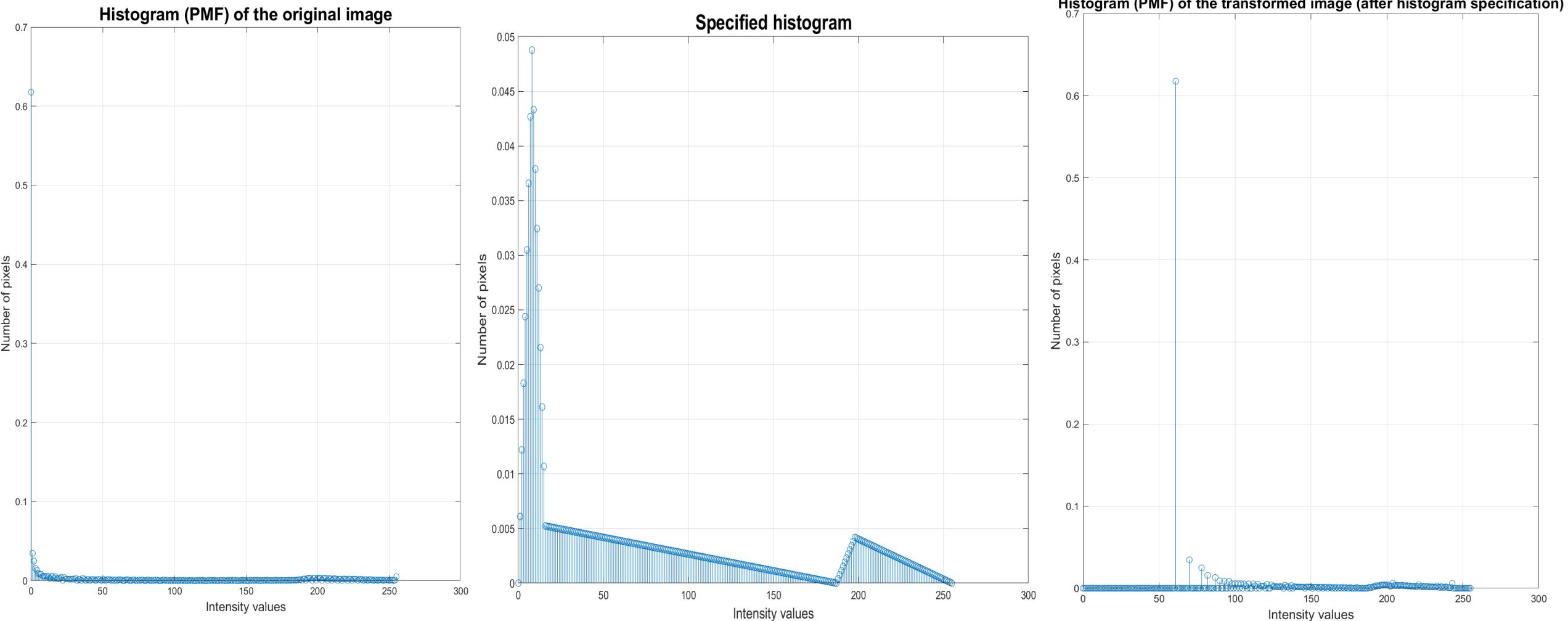
Original image



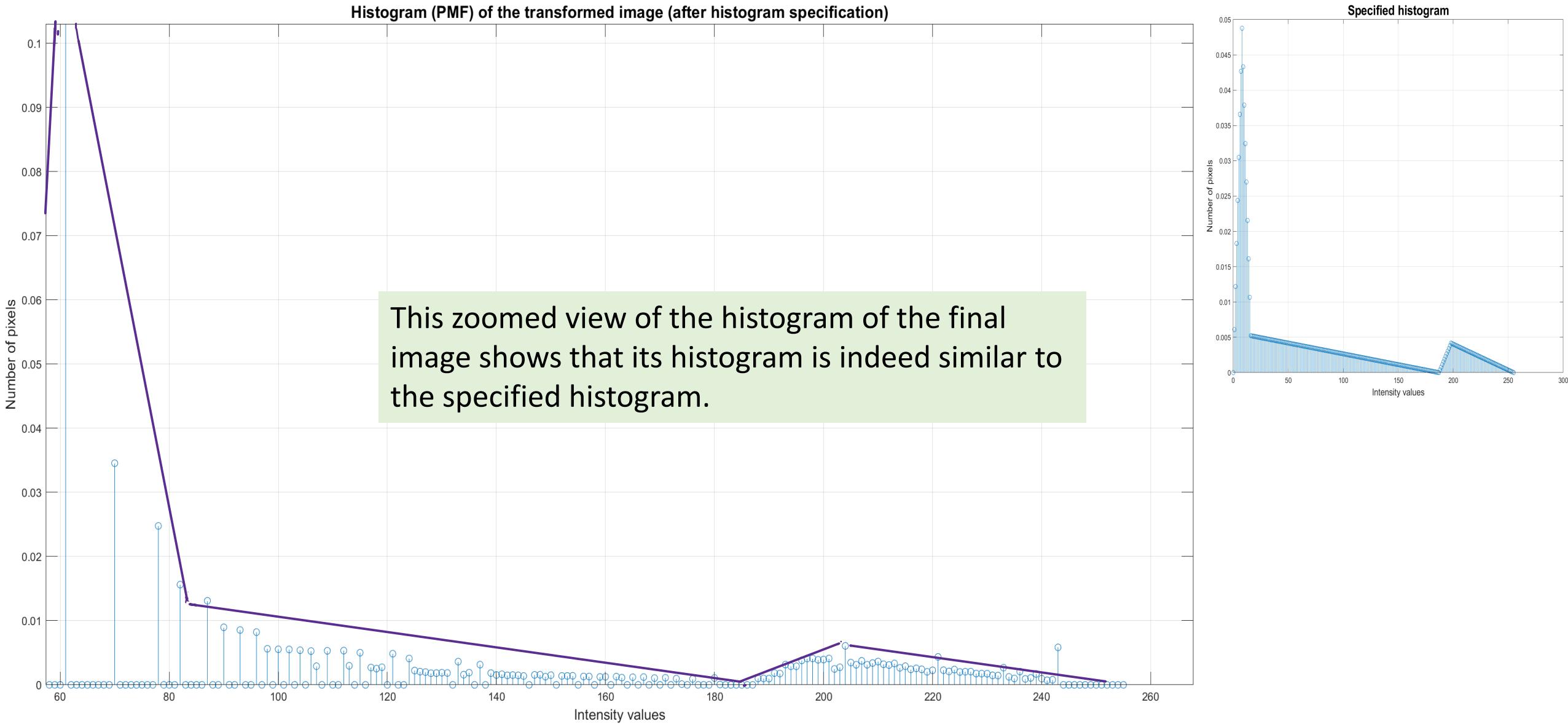
Transformed image (through histogram specification)



Histogram of the Transformed Image



Histogram of the Transformed Image



Color tone swap

The following two images with different color tone have been chosen.



Image 1 with color tone 1
(Blue tone)

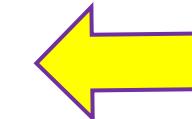


Image 2 with color tone 2
(Sepia tone)

MATLAB code for color tone swapping

```
clc; clear; close all; font = 18; I1 = imread("colortone1.jpg");I2= imread("colortone2.jpg");
figure(1);subplot(121);imshow(I1);title("Image with color tone 1","fontsize",font);
subplot(122);imshow(I2);title("Image with color tone 2","fontsize",font);
```

```
[pr11, r11]=imhist(I1(:,:,1));pr11 = pr11/sum(pr11);
[pr12, r12]=imhist(I1(:,:,2));pr12 = pr12/sum(pr12);
[pr13, r13]=imhist(I1(:,:,3));pr13 = pr13/sum(pr13);
[pr21, r21]=imhist(I2(:,:,1));pr21 = pr21/sum(pr21);
[pr22, r22]=imhist(I2(:,:,2));pr22 = pr22/sum(pr22);
[pr23, r23]=imhist(I2(:,:,3));pr23 = pr23/sum(pr23);
```



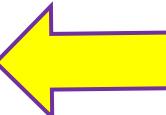
Initial histograms of both images for all 3 channels

```
figure(2); subplot(231); stem(r11,pr11);grid on;
title("Image with color tone 1 (ch 1)","fontsize",font-3);
xlabel("Intensity values","fontsize",font-5);ylabel("Number of pixels","fontsize",font-5);
subplot(232);stem(r12,pr12);grid on;title("Image with color tone 1 (ch 2)","fontsize",font-3);
xlabel("Intensity values","fontsize",font-5);ylabel("Number of pixels","fontsize",font-5);
subplot(233); stem(r13,pr13);grid on;title("Image with color tone 1 (ch 3)","fontsize",font-3);
xlabel("Intensity values","fontsize",font-5); ylabel("Number of pixels","fontsize",font-5);
subplot(234); stem(r21,pr21);grid on;title("Image with color tone 2 (ch 1)","fontsize",font-3);
xlabel("Intensity values","fontsize",font-5);ylabel("Number of pixels","fontsize",font-5);
subplot(235); stem(r22,pr22);grid on;title("Image with color tone 2 (ch 2)","fontsize",font-3);
xlabel("Intensity values","fontsize",font-5);ylabel("Number of pixels","fontsize",font-5);
subplot(236); stem(r23,pr23);grid on;title("Image with color tone 2 (ch 3)","fontsize",font-3);
xlabel("Intensity values","fontsize",font-5);ylabel("Number of pixels","fontsize",font-5);
```

Continued at the next slide

MATLAB code for color tone swapping

```
L = 256;cdf11 = cumsum(pr11); s11 = (L-1).*cdf11;cdf12 = cumsum(pr12); s12 = (L-1).*cdf12;
cdf13 = cumsum(pr13); s13 = (L-1).*cdf13;cdf21 = cumsum(pr21); s21 = (L-1).*cdf21;
cdf22 = cumsum(pr22); s22 = (L-1).*cdf22;cdf23 = cumsum(pr23); s23 = (L-1).*cdf23;
siz1 = size(I1);Itemp11 = s11(I1(:,:,1)+1);
for i = 1:siz1(1)
    for j = 1:siz1(2)
        [minval, argmin] = min(abs(Itemp11(i,j)-s21));
        Itr2to1_1(i,j) = uint8(r21(argmin));
    end
end
Itemp12 = s12(I1(:,:,2)+1);
for i = 1:siz1(1)
    for j = 1:siz1(2)
        [minval, argmin] = min(abs(Itemp12(i,j)-s22));
        Itr2to1_2(i,j) = uint8(r22(argmin));
    end
end
Itemp13 = s13(I1(:,:,3)+1);
for i = 1:siz1(1)
    for j = 1:siz1(2)
        [minval, argmin] = min(abs(Itemp13(i,j)-s23));
        Itr2to1_3(i,j) = uint8(r23(argmin));
    end
end
Itr2to1(:,:,:)=Itr2to1_1(:,:); Itr2to1(:,:,:2)=Itr2to1_2(:,:); Itr2to1(:,:,:3)=Itr2to1_3(:,:);
```

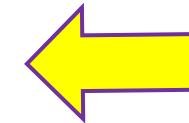


Transferring color tone 2 to 1
for all three channels

Continued at the next slide

MATLAB code for color tone swapping

```
siz2 = size(I2);Itemp21 = s21(I2(:,:,1)+1);
for i = 1:siz2(1)
    for j = 1:siz2(2)
        [minval, argmin] = min(abs(Itemp21(i,j)-s11));
        Itr1to2_1(i,j) = uint8(r11(argmin));
    end
end
Itemp22 = s22(I2(:,:,2)+1);
for i = 1:siz2(1)
    for j = 1:siz2(2)
        [minval, argmin] = min(abs(Itemp22(i,j)-s12));
        Itr1to2_2(i,j) = uint8(r12(argmin));
    end
end
Itemp23 = s23(I2(:,:,3)+1);
for i = 1:siz2(1)
    for j = 1:siz2(2)
        [minval, argmin] = min(abs(Itemp23(i,j)-s13));
        Itr1to2_3(i,j) = uint8(r13(argmin));
    end
end
Itr1to2(:,:,1)=Itr1to2_1(:,:,1);Itr1to2(:,:,2)=Itr1to2_2(:,:,2);Itr1to2(:,:,3)=Itr1to2_3(:,:,3);
figure(3);subplot(121);imshow(Itr2to1);
title("Transformed image (color tone swapped from 2 to 1)","fontsize",font-3);
subplot(122);imshow(Itr1to2);
title("Transformed image (color tone swapped from 1 to 2)","fontsize",font-3);
```



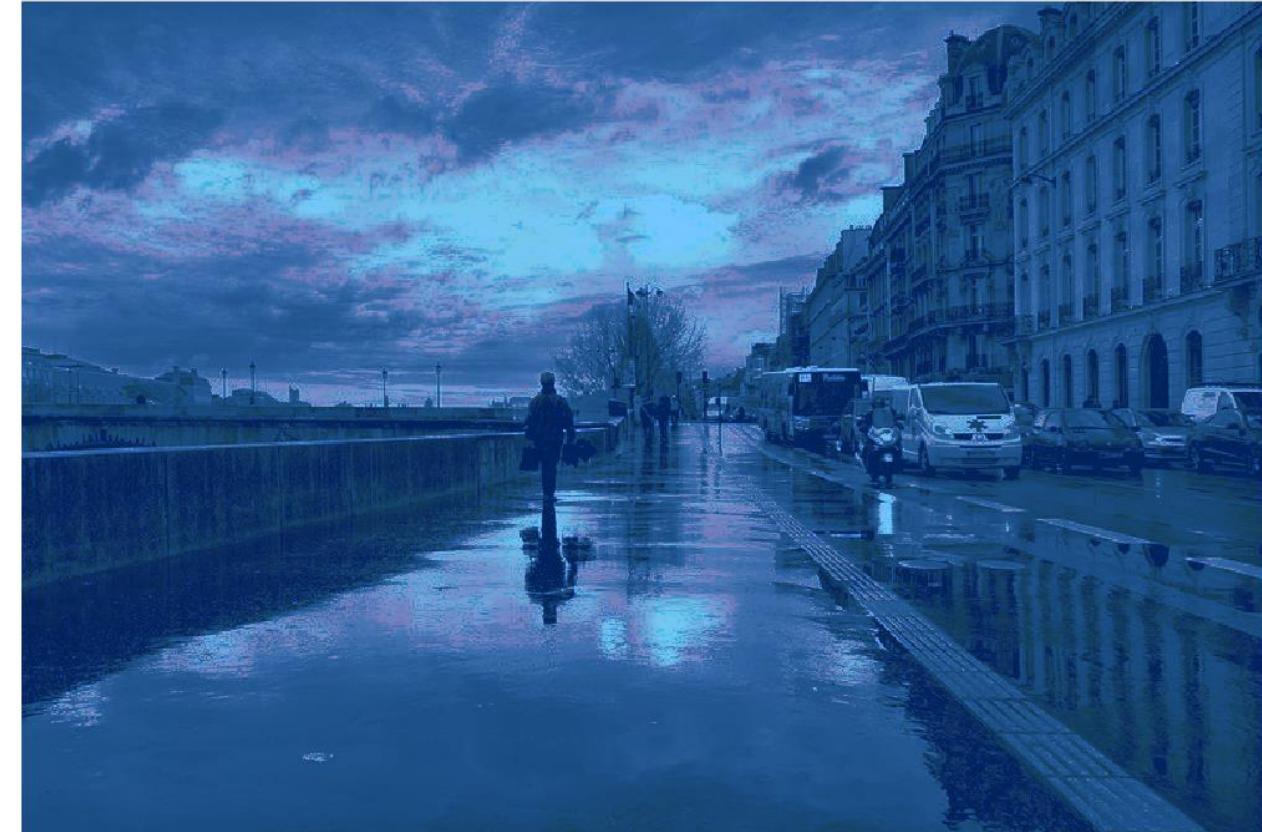
Transferring color tone 1 to 2
for all three channels

After swapping

Transformed image (color tone swapped from 2 to 1)



Transformed image (color tone swapped from 1 to 2)



Color tone swapping – before and after

Image with color tone 1



Transformed image (color tone swapped from 2 to 1)



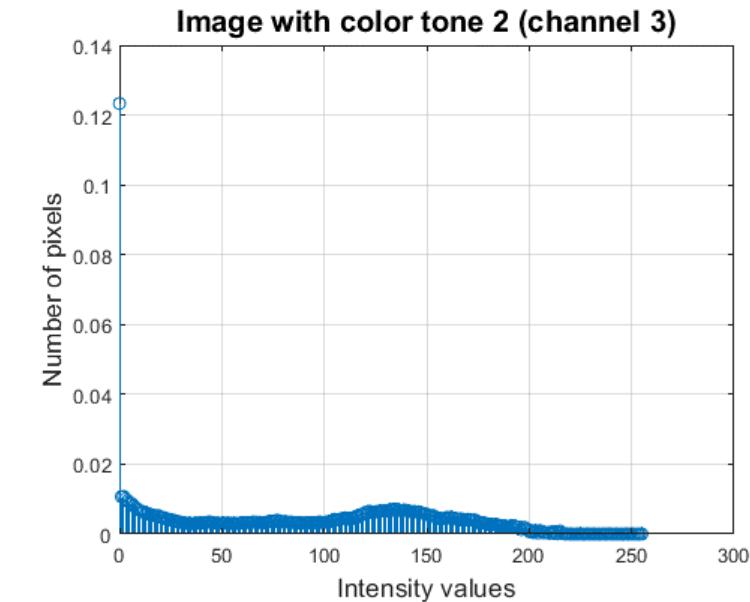
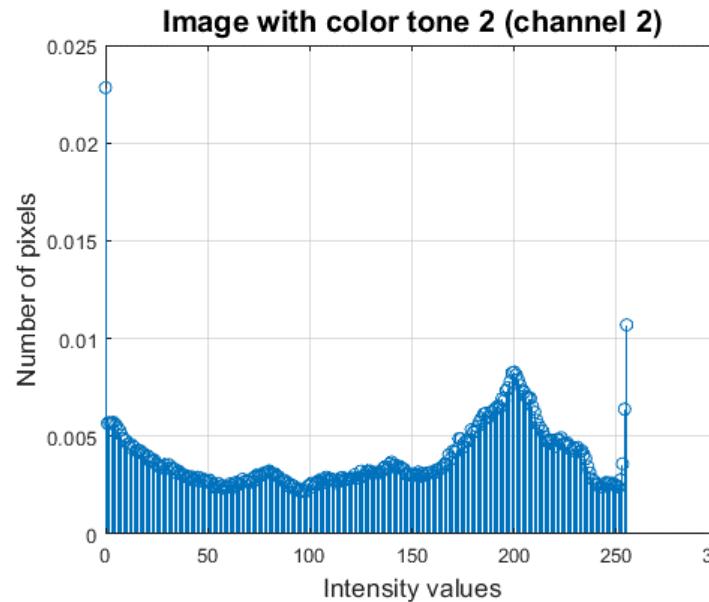
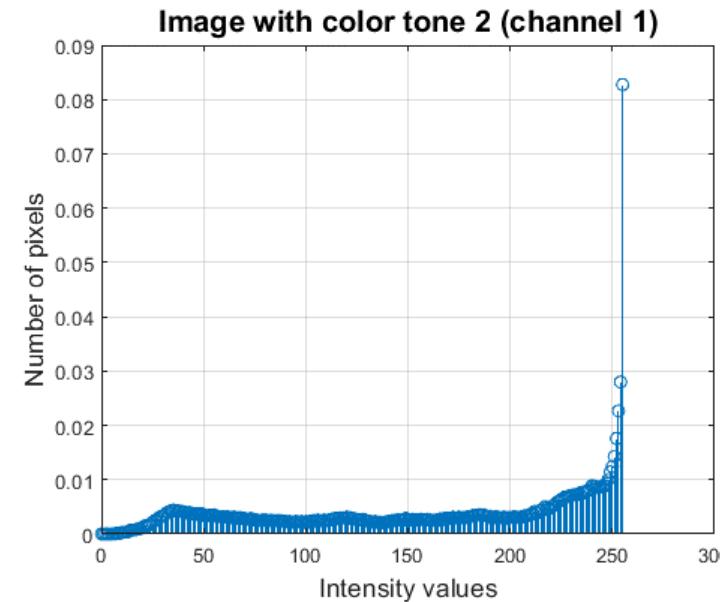
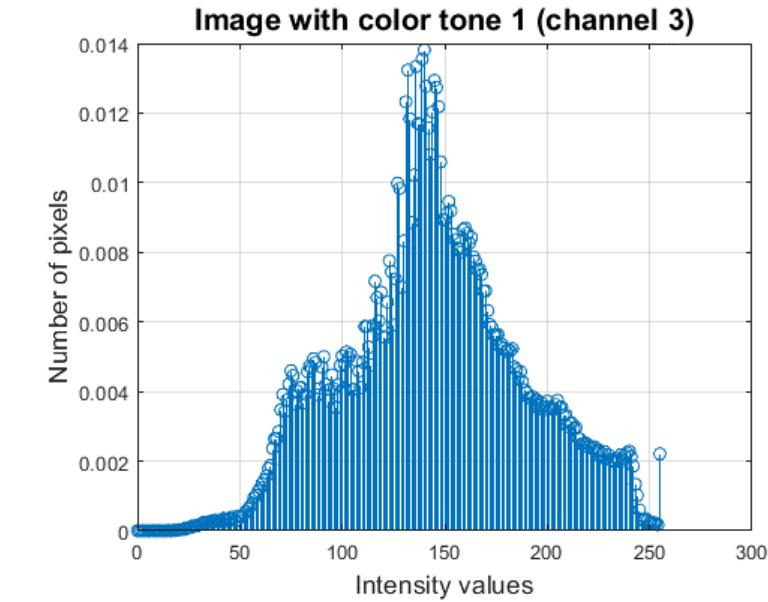
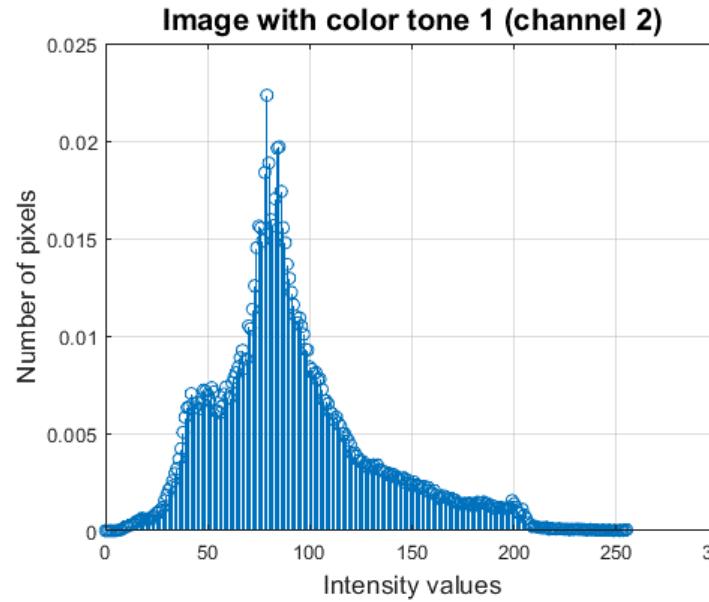
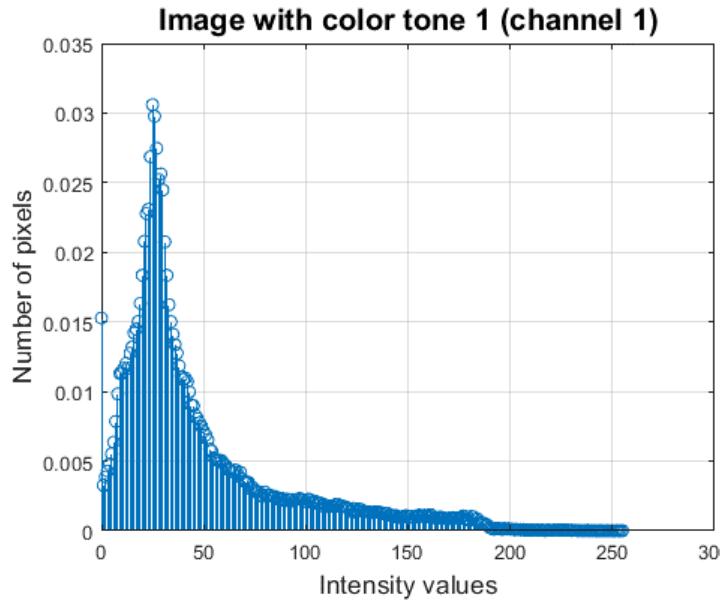
Image with color tone 2



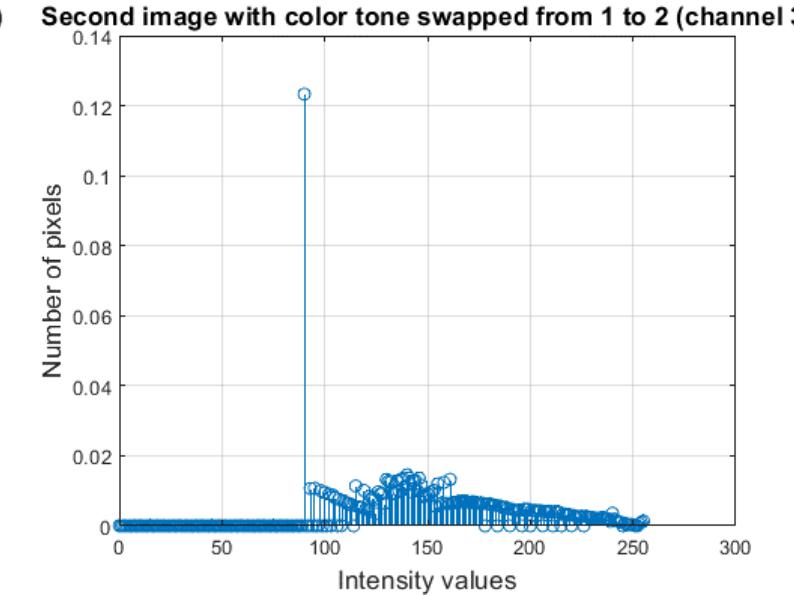
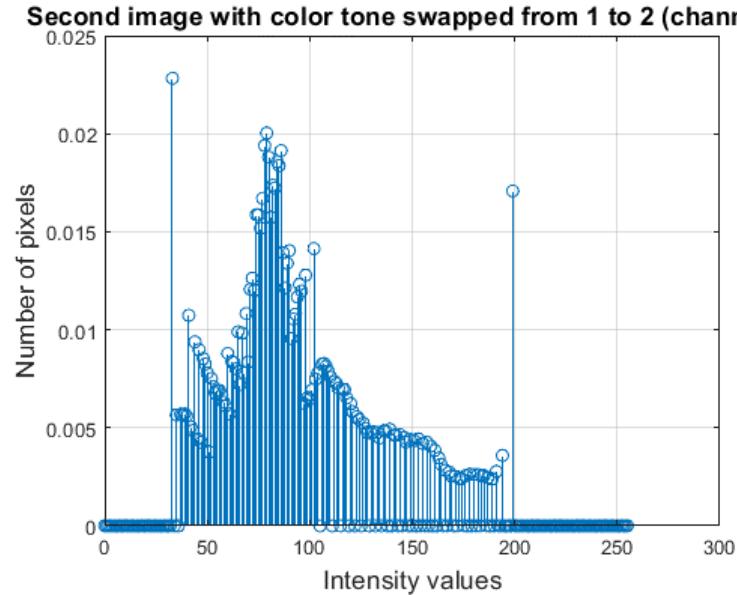
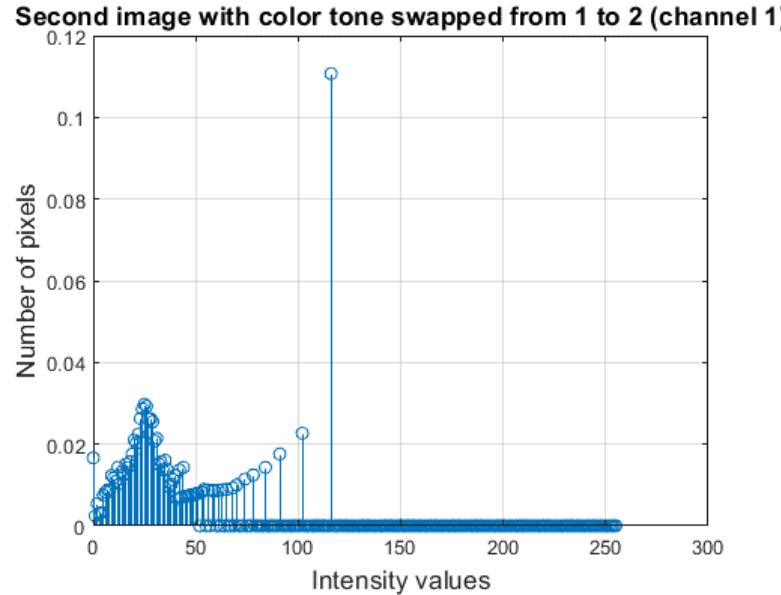
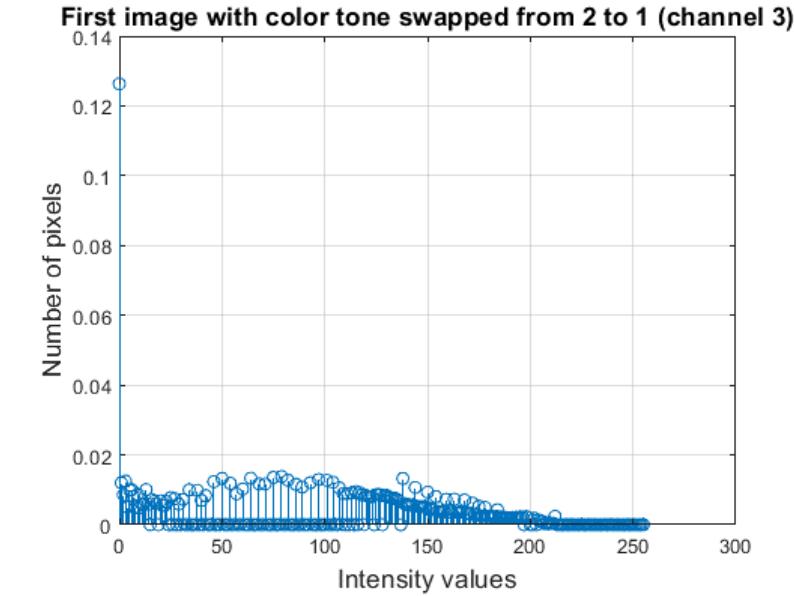
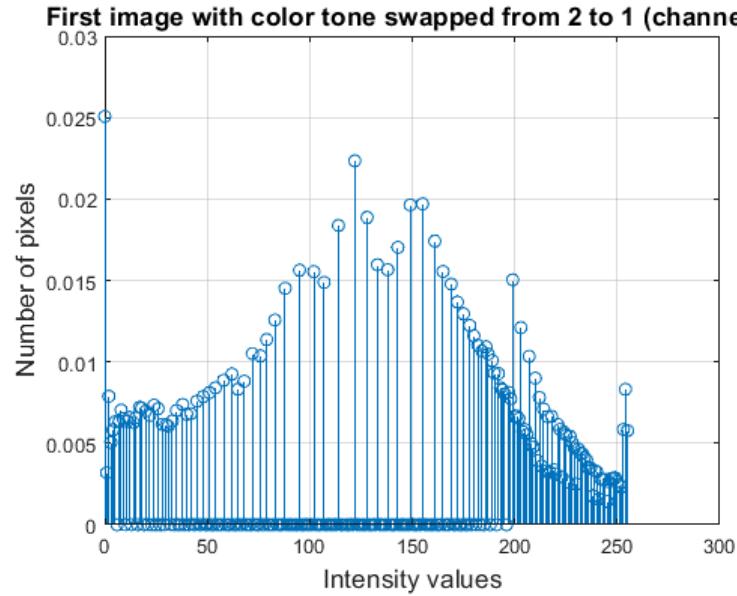
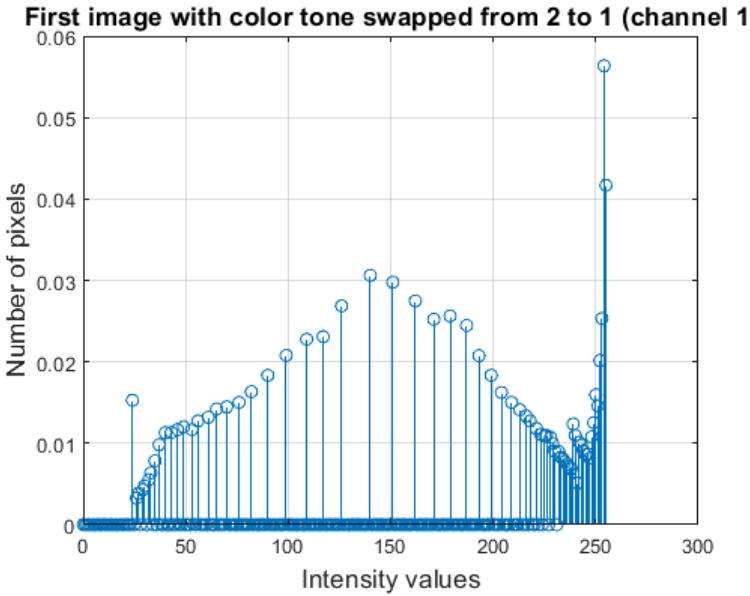
Transformed image (color tone swapped from 1 to 2)



Initial histograms

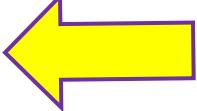


Histograms After Color Swapping



Part 4: Combined Image Enhancement

MATLAB Code For Combined Image Enhancement

```
clc; clear; close all; font = 11;  
a = imread("Figure7.tif"); a = im2double(a);  
figure(1); subplot(241); imshow(a);  
title("(a) Original Image", "fontsize", font);  
  
laplace = [1 1 1; 1 -8 1; 1 1 1]; %Lapacian filter  
b = convn(a, laplace, 'same');  
subplot(242); imshow(b);  
title("(b) After Applying Laplacian Filter", "fontsize", font);  
  
c = a-b; c(find(c<0))=0;   
Set the negative values to zero  
in the sharpened image  
subplot(243); imshow(c);  
title("(c) Sharpened Image ((a)-(b))", "fontsize", font);  
  
sobelx = [-1 -2 -1; 0 0 0; 1 2 1];  
sobely = [-1 0 1; -2 0 2; -1 0 1];  
dx = convn(a, sobelx, 'same');  
dy = convn(a, sobely, 'same');  
d = abs(dx) + abs(dy);  
subplot(244); imshow(d);  
title("(d) After Applying Sobel Operator", "fontsize", font);
```

Continued at the next slide

MATLAB Code

```
mf = (1/25)*ones(5,5); %moving average filter
e = convn(d,mf,'same');
subplot(245);imshow(e);
title("(e) Sobel Image After 5\times5 Moving Avg. Filtering","fontsize",font);

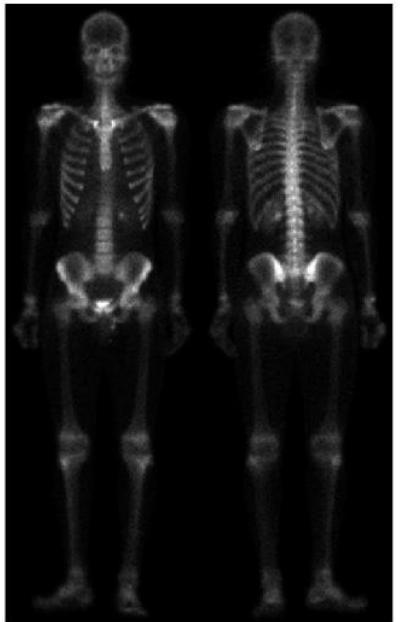
f = c.*e;
subplot(246);imshow(f);
title("(f) Mask Image ((c)\times(e))","fontsize",font);

g = a+f;
subplot(247);imshow(g);
title("(g) Sharpened Image ((a)+(f))","fontsize",font);

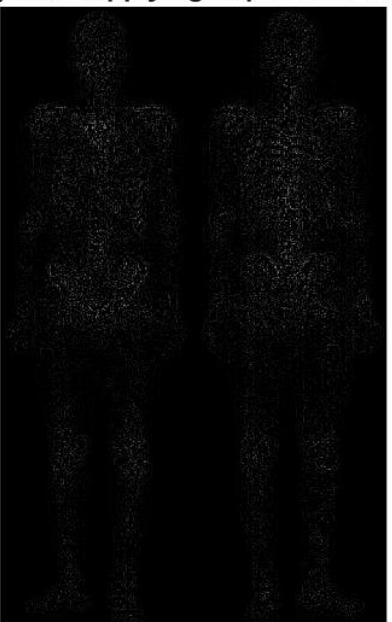
cc = 1;
gamma = 0.44;
h = cc*(g.^gamma);
subplot(248);imshow(h);
title("(h) Final Image After Power-law Trans. (c =" +cc+ ...
" and \gamma =" +gamma+" )","fontsize",font);
```

Results of combined image enhancement – figure7

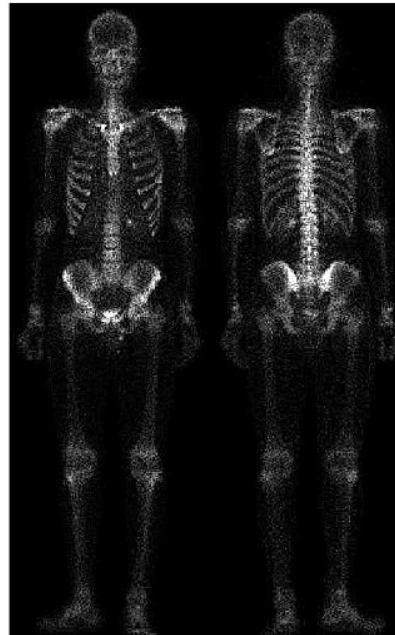
(a) Original Image



(b) After Applying Laplacian Filter



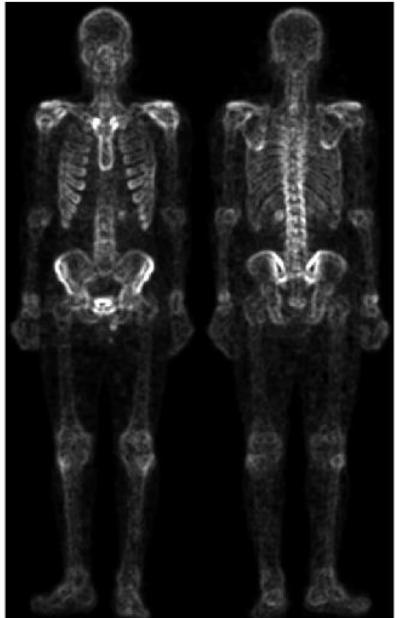
(c) Sharpened Image ((a)-(b))



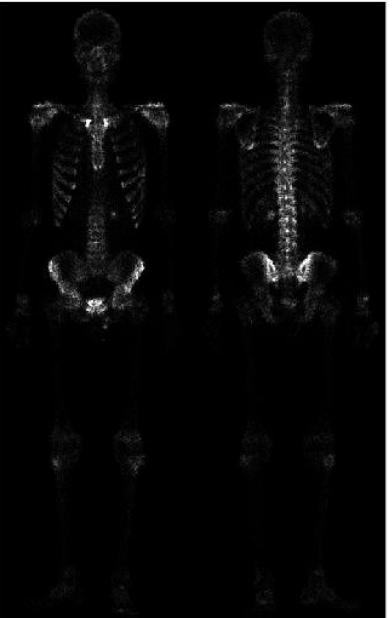
(d) After Applying Sobel Operator



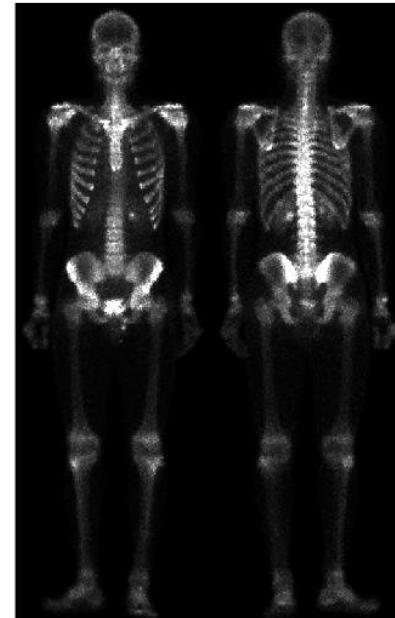
(e) Sobel Image After 5×5 Moving Avg. Filtering



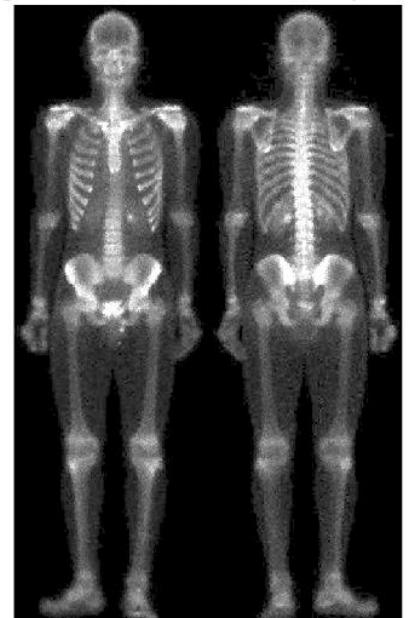
(f) Mask Image ((c) \times (e))



(g) Sharpened Image ((a)+(f))



(h) Final Image After Power-law Trans. ($c = 1$ and $\gamma = 0.44$)

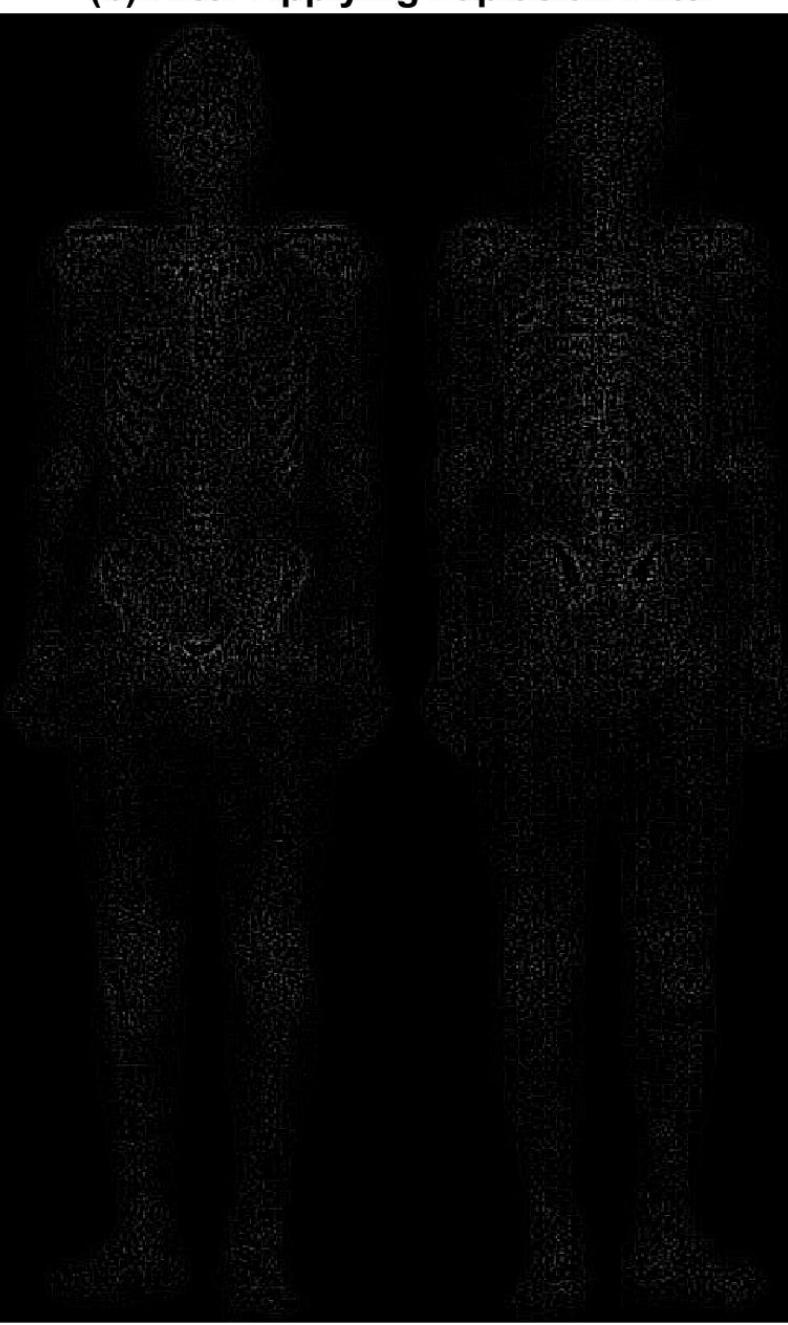


Closer look at the results

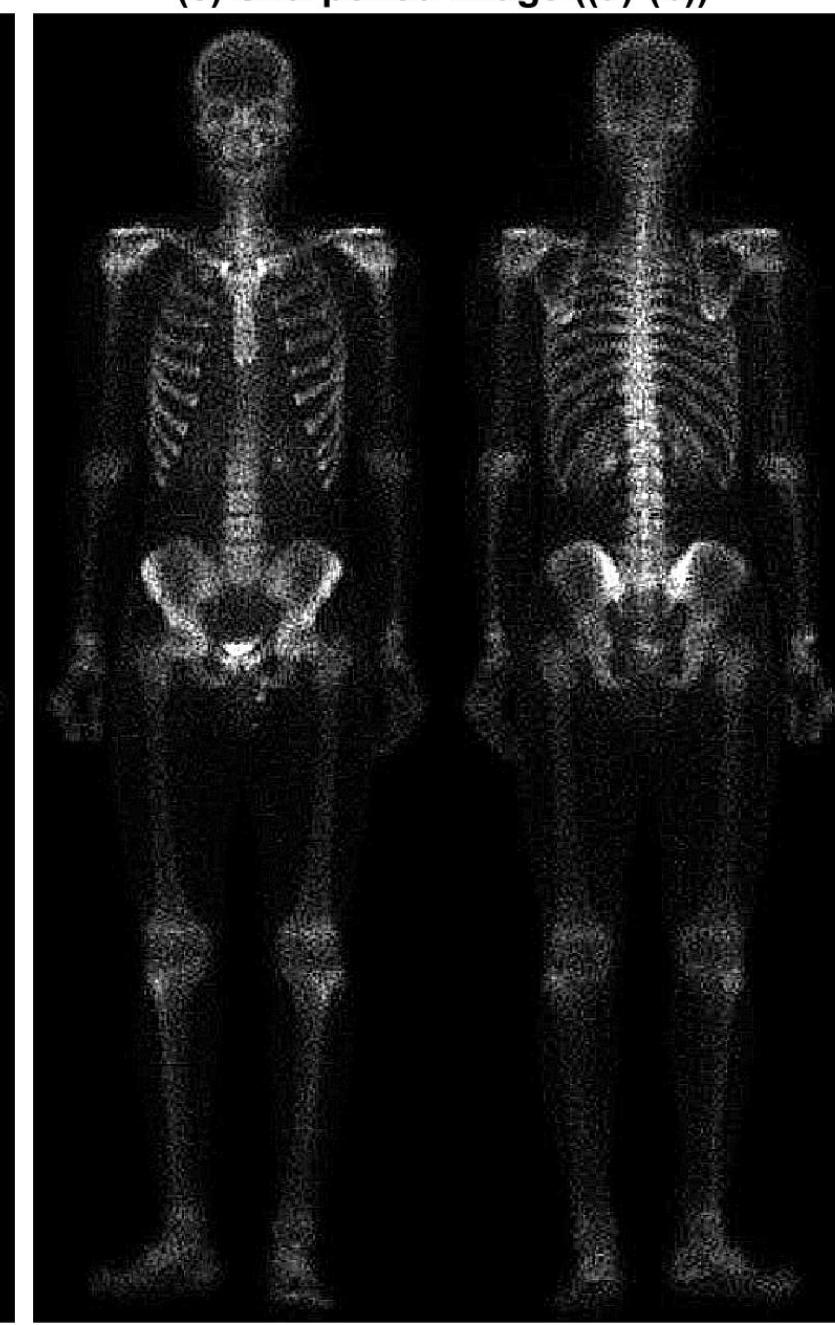
(a) Original Image



(b) After Applying Laplacian Filter



(c) Sharpened Image ((a)-(b))

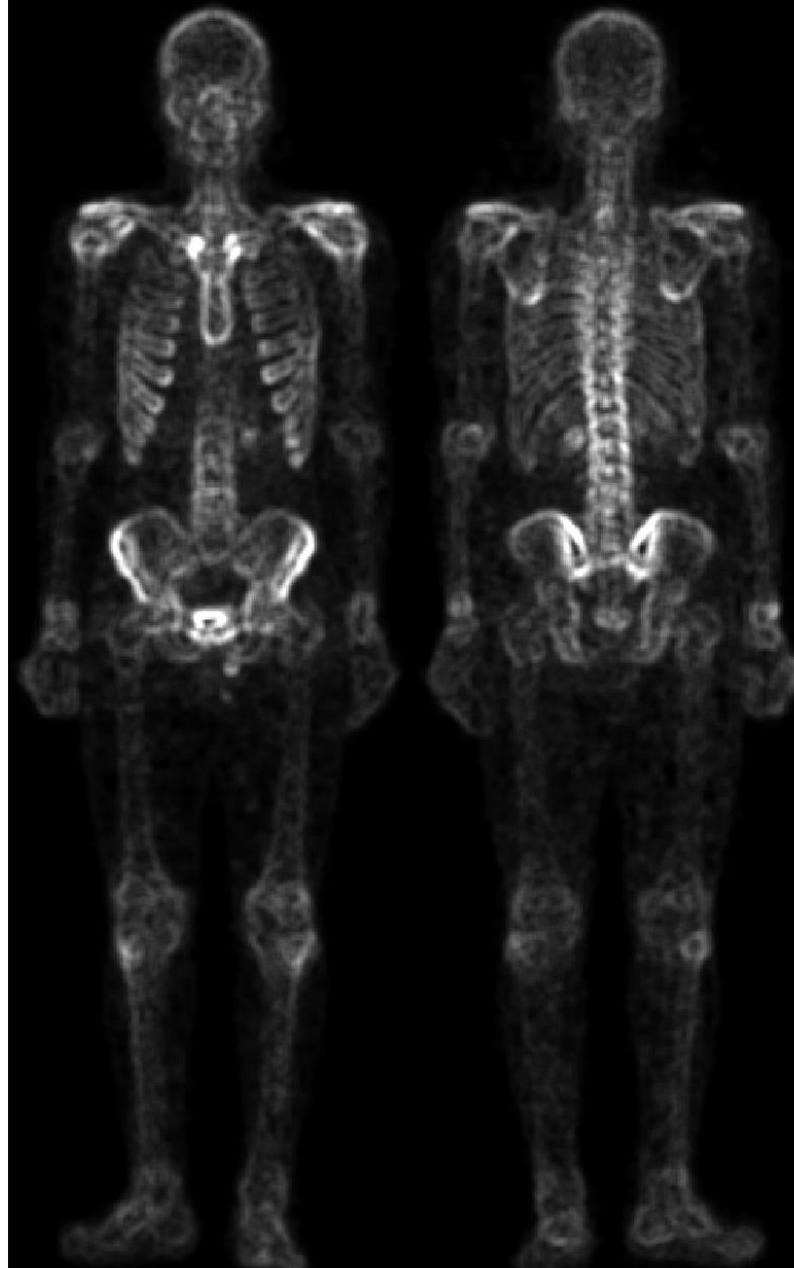


Closer look at the results

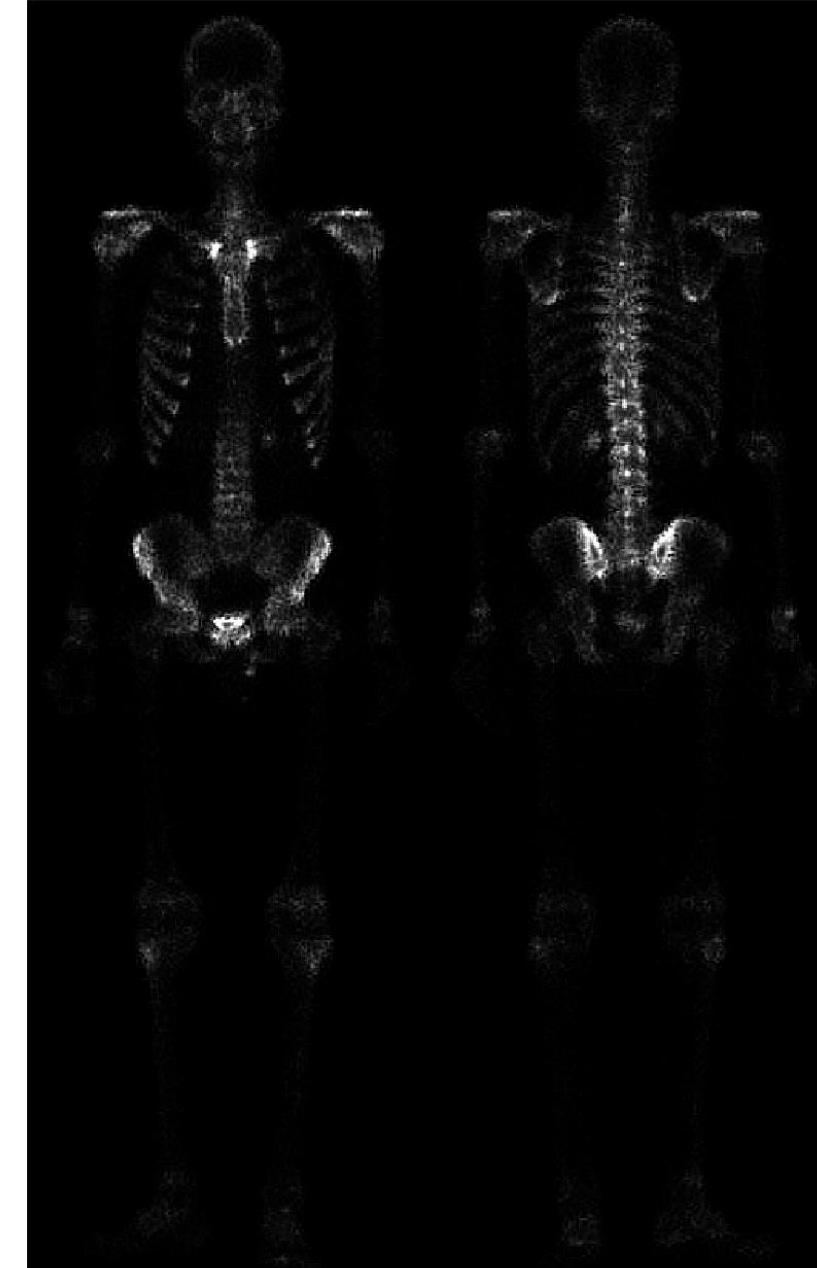
(d) After Applying Sobel Operator



(e) Sobel Image After 5×5 Moving Avg. Filtering

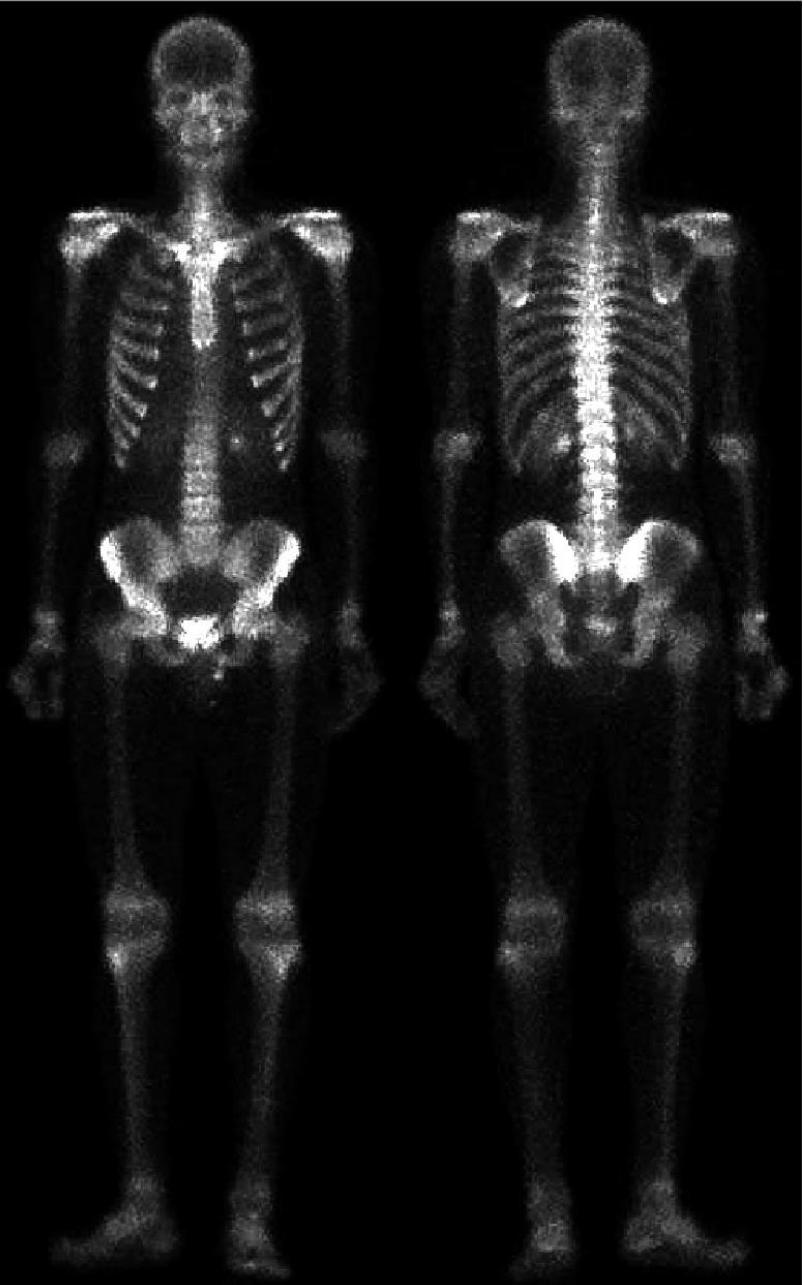


(f) Mask Image ((c) \times (e))

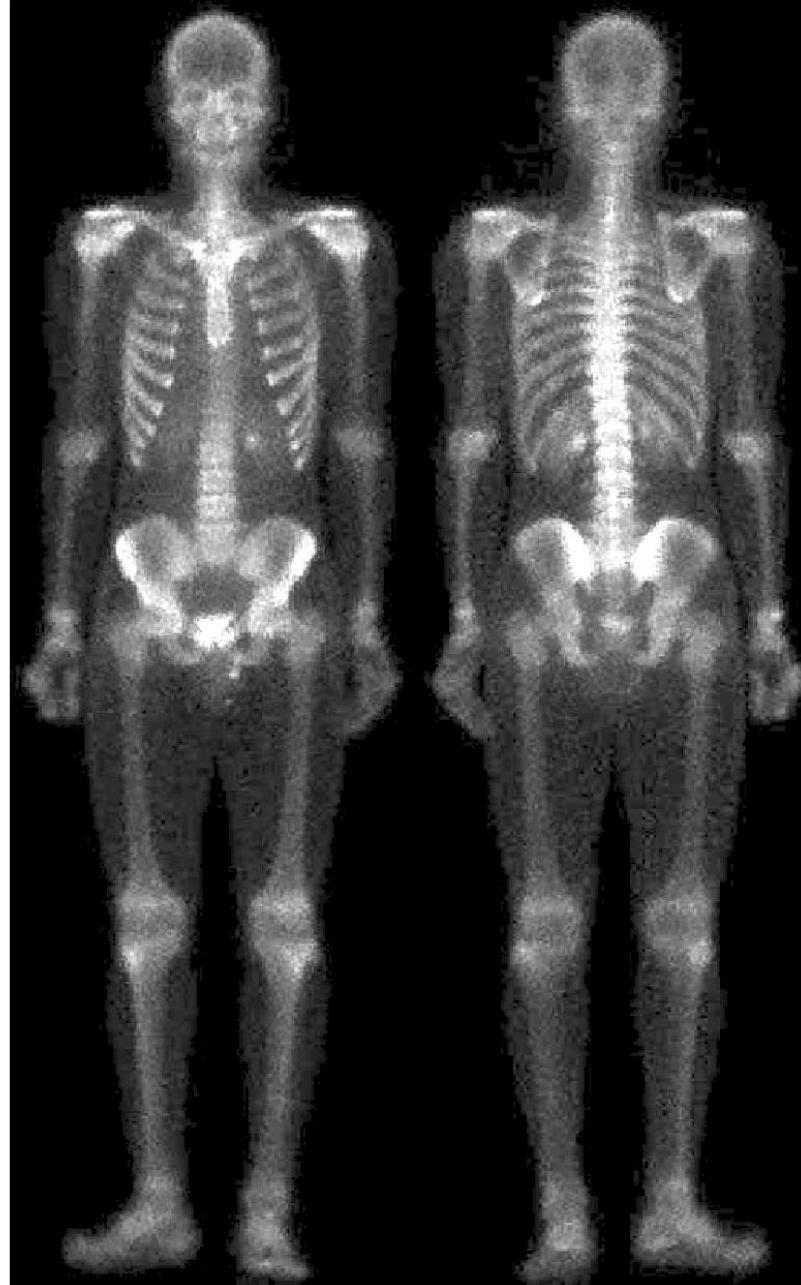


Closer look at the results

(g) Sharpened Image ((a)+(f))

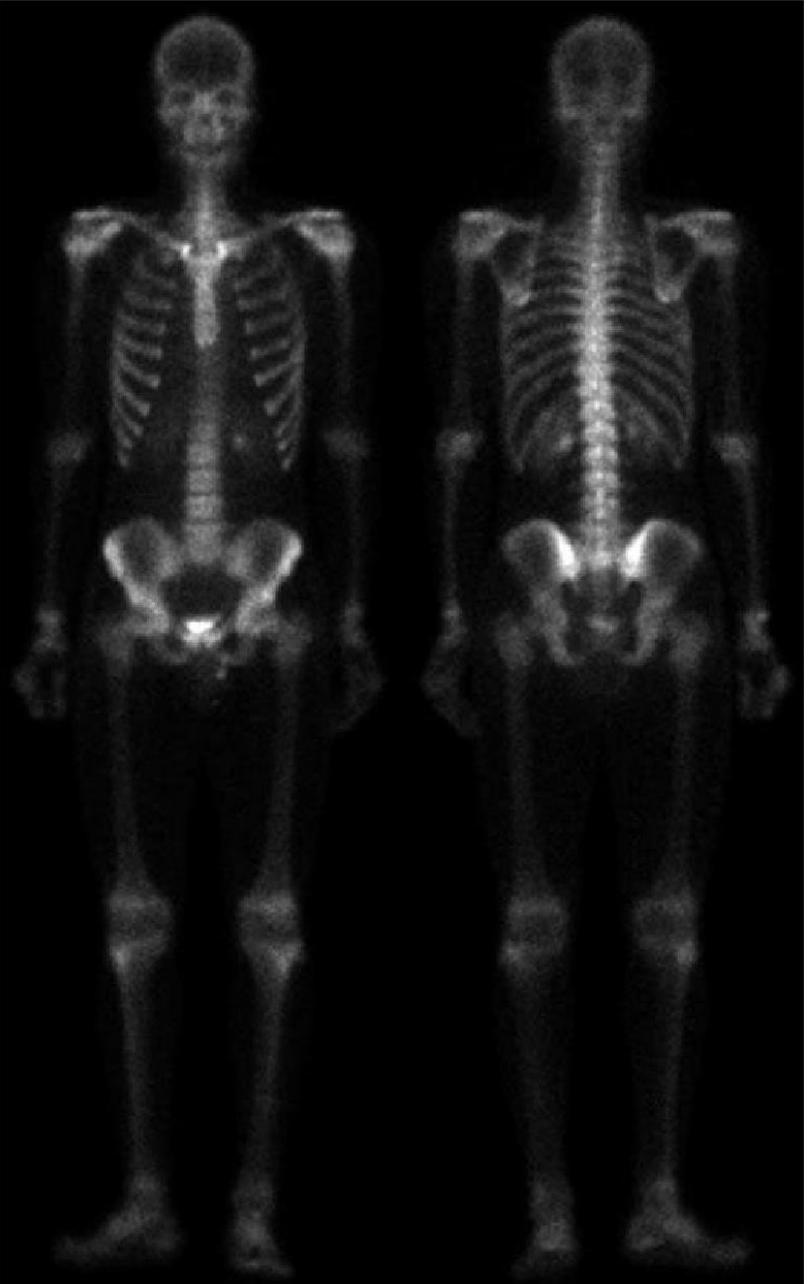


(h) Final Image After Power-law Trans. ($c = 1$ and $\gamma = 0.44$)

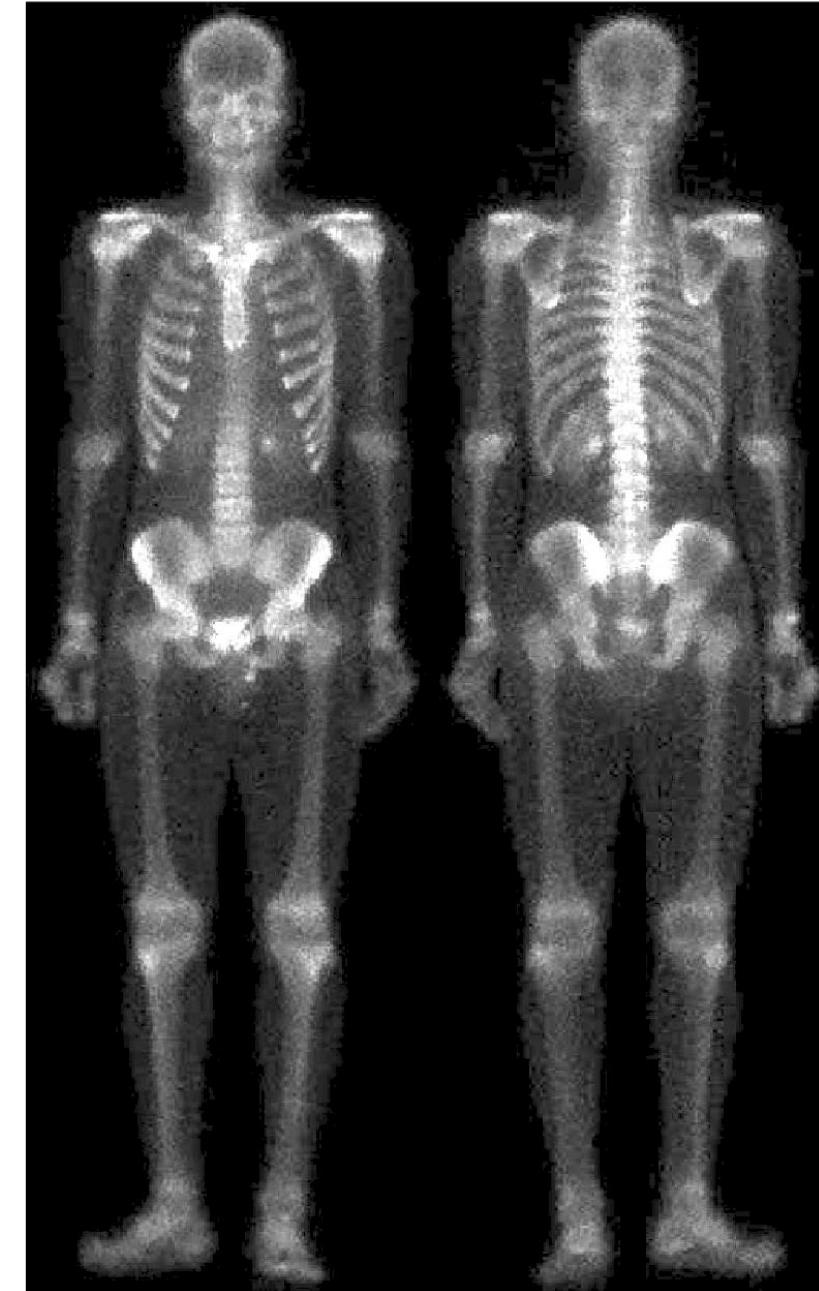


Original vs. Final Image

(a) Original Image



(h) Final Image After Power-law Trans. ($c = 1$ and $\gamma = 0.44$)



VS.

Thanks