App Physics 157

ACTIVITY 1 REPORT

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Objectives 1.1

Activity 1.1 Image DIY

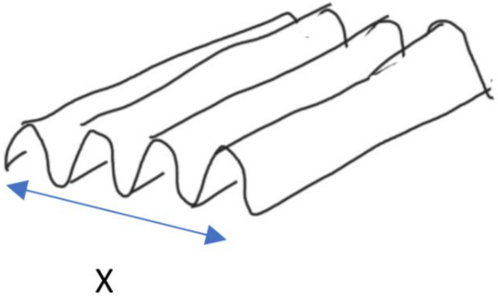
It's your turn!

Mathematically create the following images.

For items 1 and 2, X ϵ [-2 cm, 2 cm], Y ϵ [-2 cm,2 cm] , we are simulating a 4cm x 4cm optical element. The image size should be 400x400 pixels.

Hand-drawings are for reference and are NOT drawn to scale.

1. Sinusoid along the x-direction, frequency is 4 cycles/cm.



*Note: Physical images do not have negative values. What should you do such that the range of intensities of your sinusoid is between between 0 and 255?

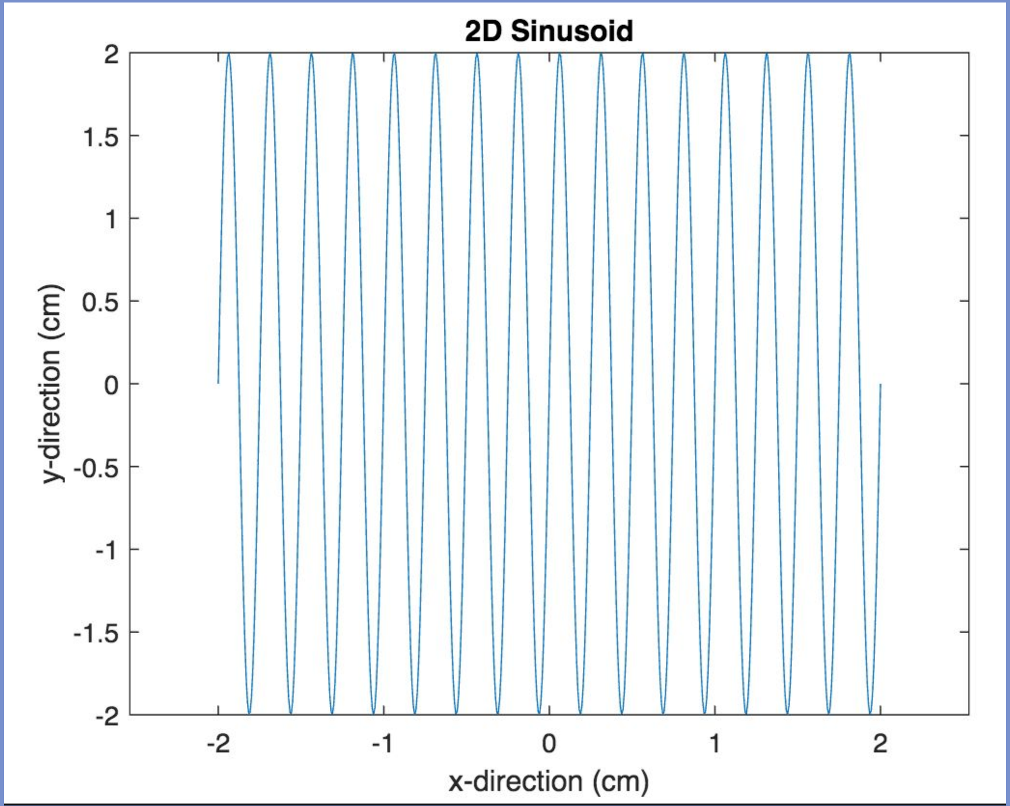
2. Grating, frequency is 5 line pairs/cm. A line pair is a strip of black (0) and white (1)

For the following items you may choose your own image size, but not to exceed 2000x2000 pixels.

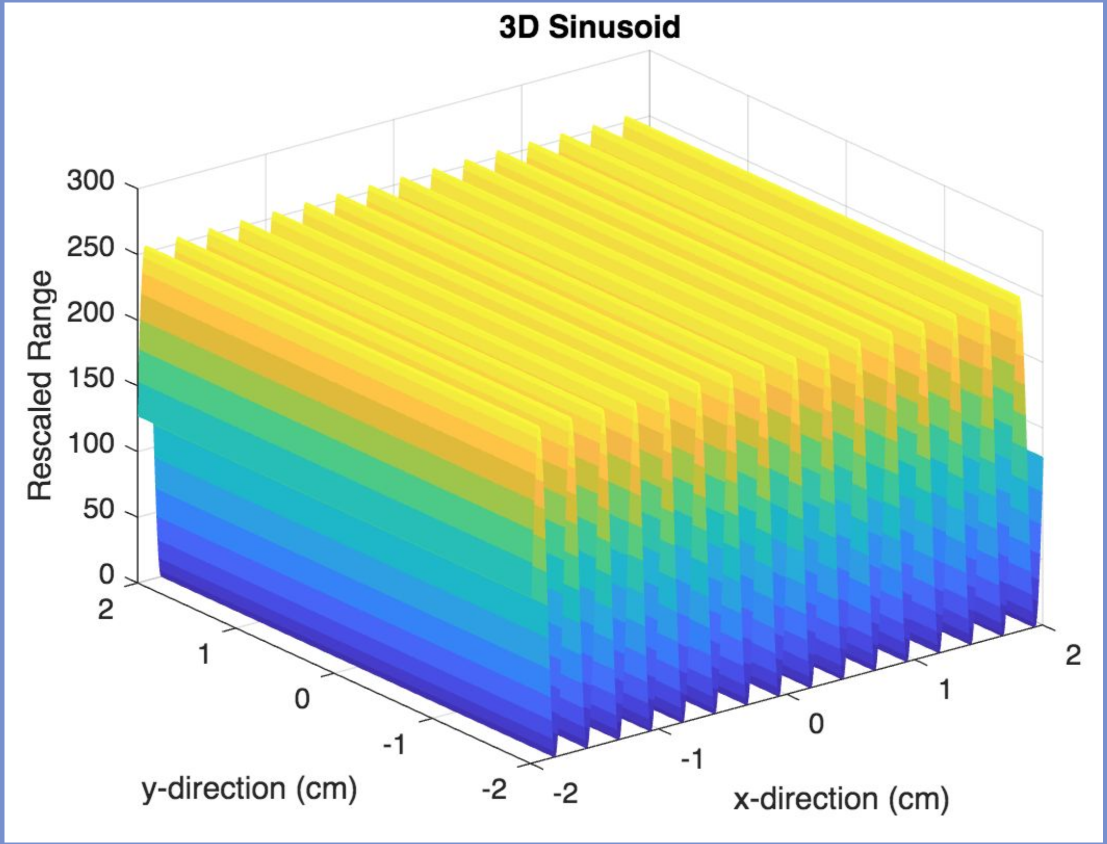
3. Hubble's Primary Mirror – Circle with a hole in the middle (annulus).

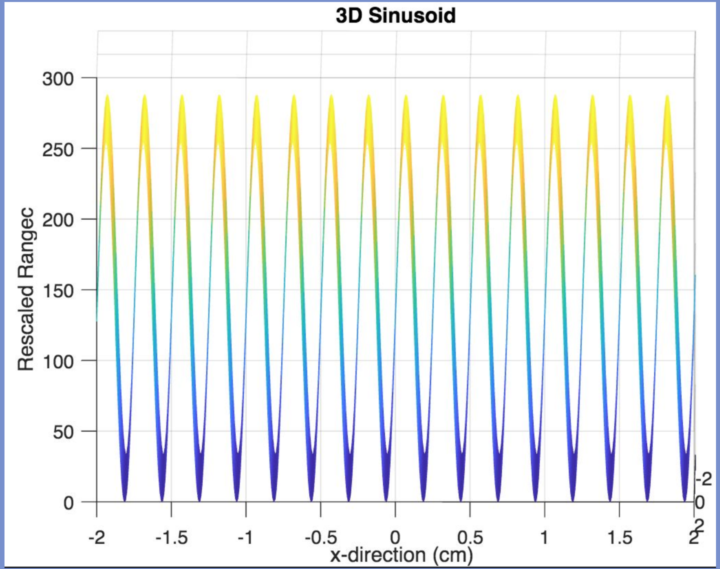
4. Hexagon Array, simulating the mirrors of the James Webb Space Telescope (image credit NASA)

Results & Analysis 1.1

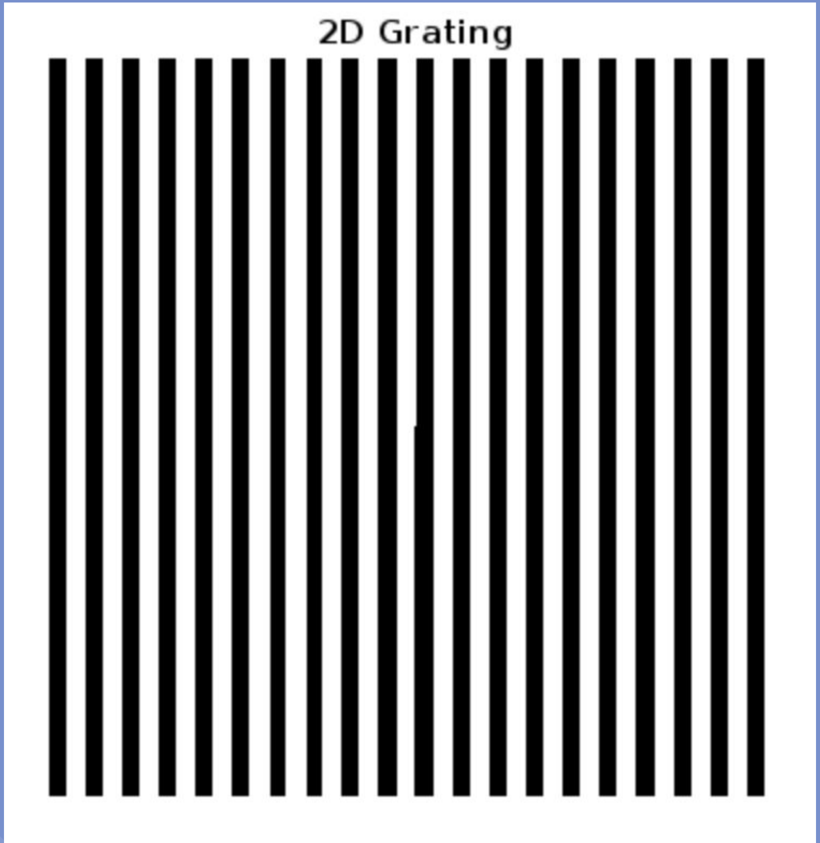

2D Sinusoid
y-direction (cm)
x-direction (cm)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1
0
1
2

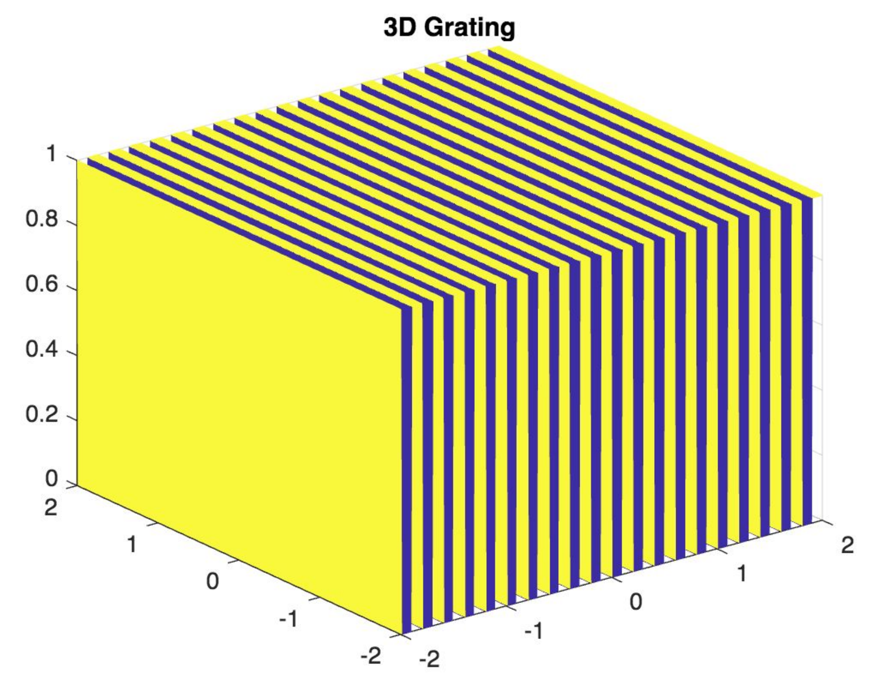
1 SINUSOID


3D Sinusoid
Rescaled Range
300
250
200
150
100
50
0
2
1
0
-1
-2
y-direction (cm)
-2
-1
0
1
2
x-direction (cm)

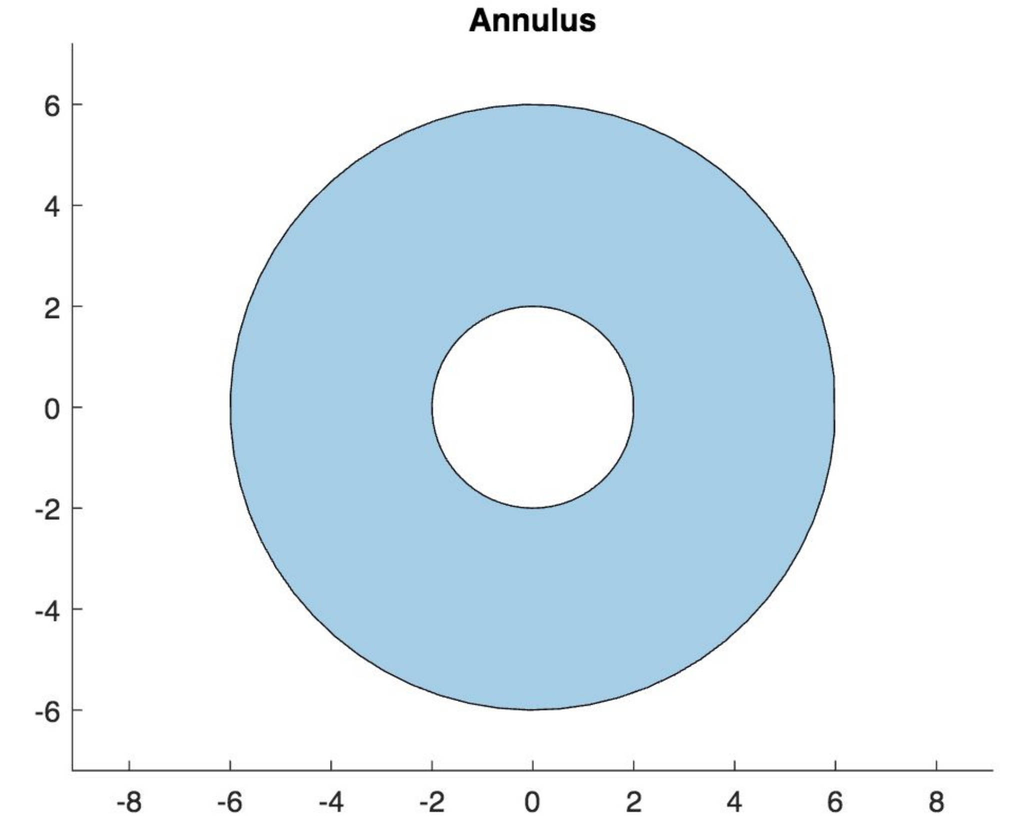

3D Sinusoid
Rescaled Rangec
300
250
200
150
100
50
0
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
x-direction (cm)

1 SINUSOID

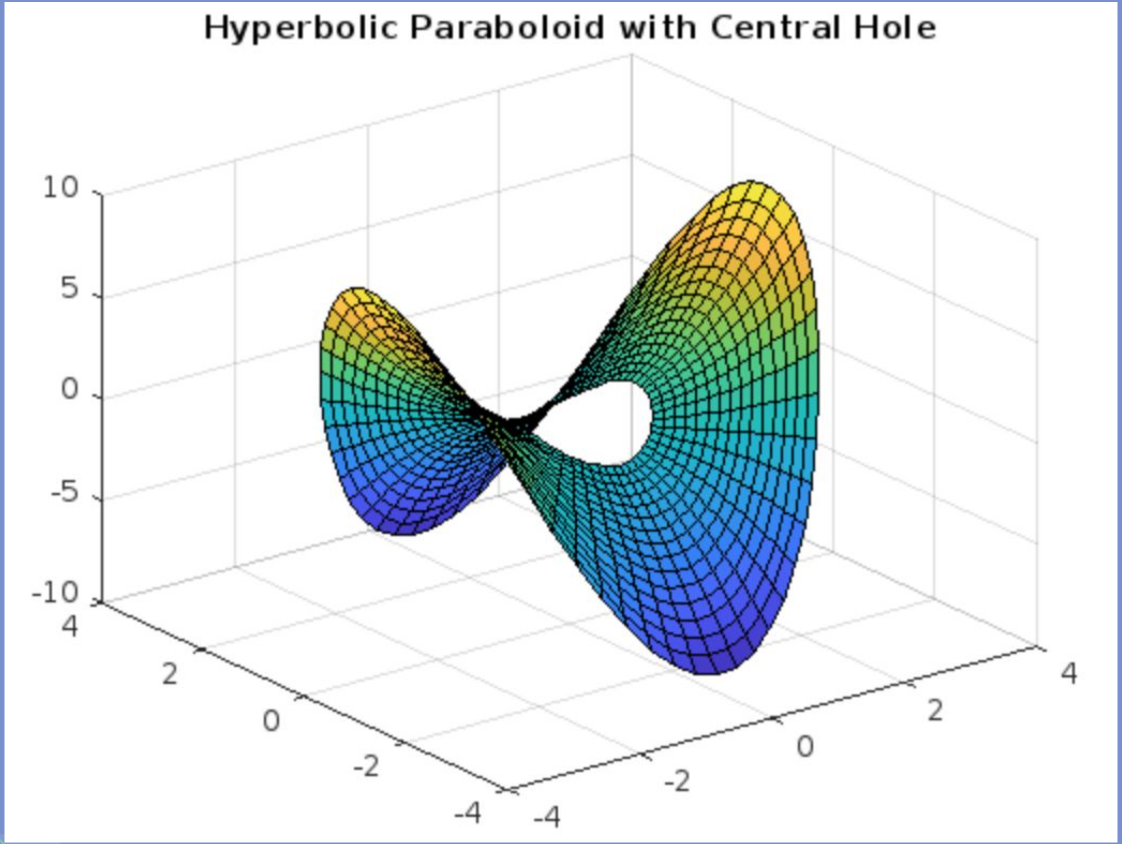


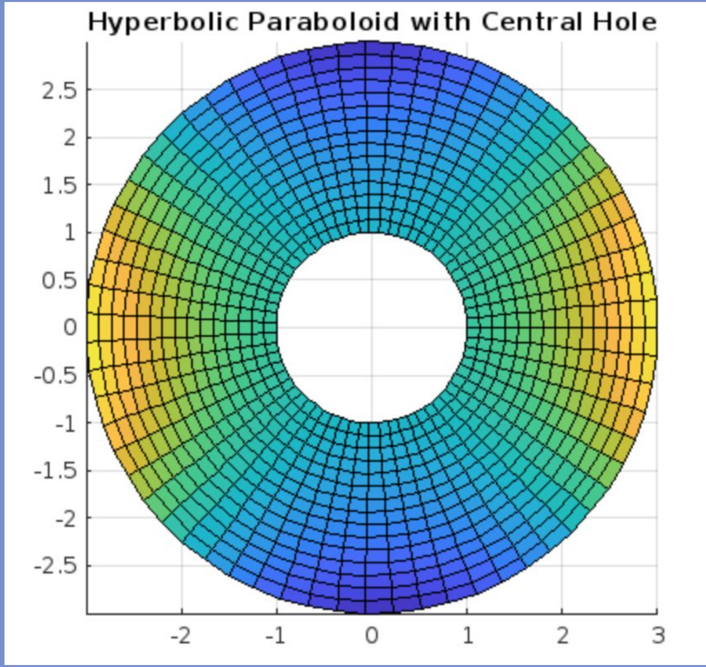


2 GRATING

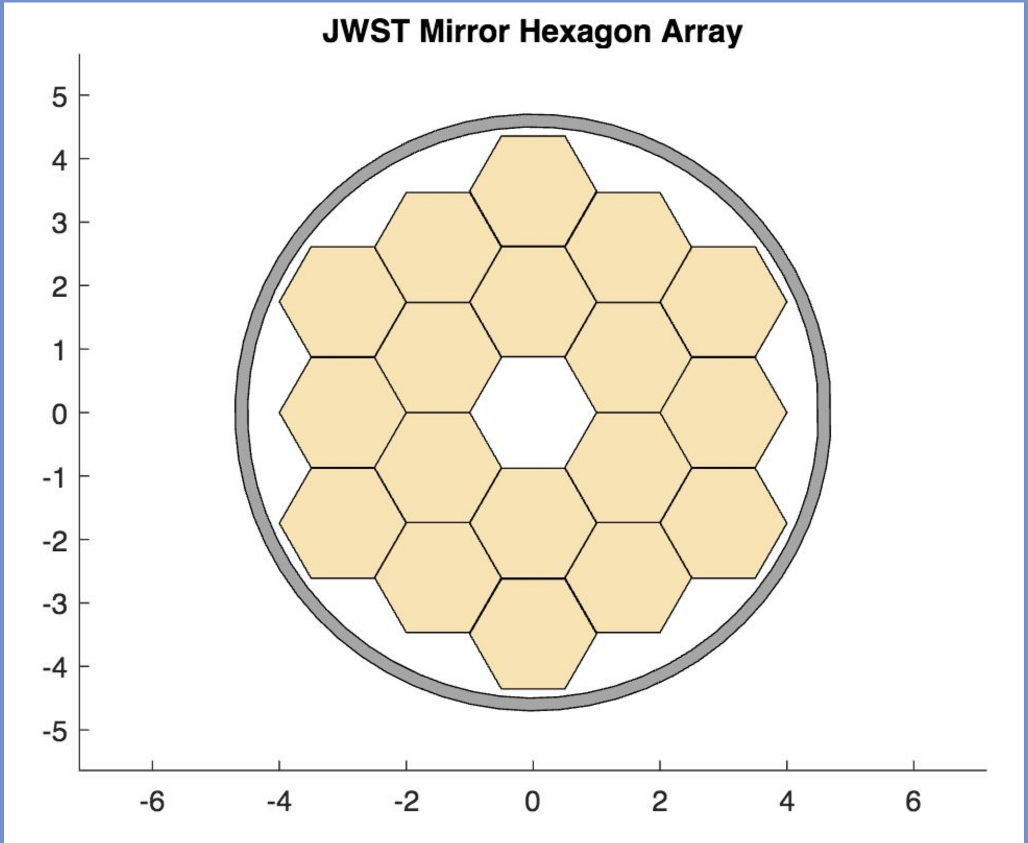


3 ANNULUS


Hyperbolic Paraboloid with Central Hole
10
5
0
-5
-10
4
2
0
-2
-4
-4
-2
0
2
4


Hyperbolic Paraboloid with Central Hole
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-2
-1
0
1
2
3

3 ANNULUS



4 JWST HEXAGON ARRAY

Creating and analyzing synthetic images with the aid of numerical methods have given us the opportunity to alleviate the limitations and challenges of the human mind, with the accuracy of computer programming.

Images such as the hexagon array and annulus above, show precise positioning in appropriate coordinates and symmetry, which can be challenging when being drawn manually by a human on a piece of paper, due to human errors.

The image of the hyperbolic paraboloid and 3D sinusoid, which are 3-dimensional images, also show varying colors depending on the height, which is a very useful aspect in visualizing the dynamics of an image.

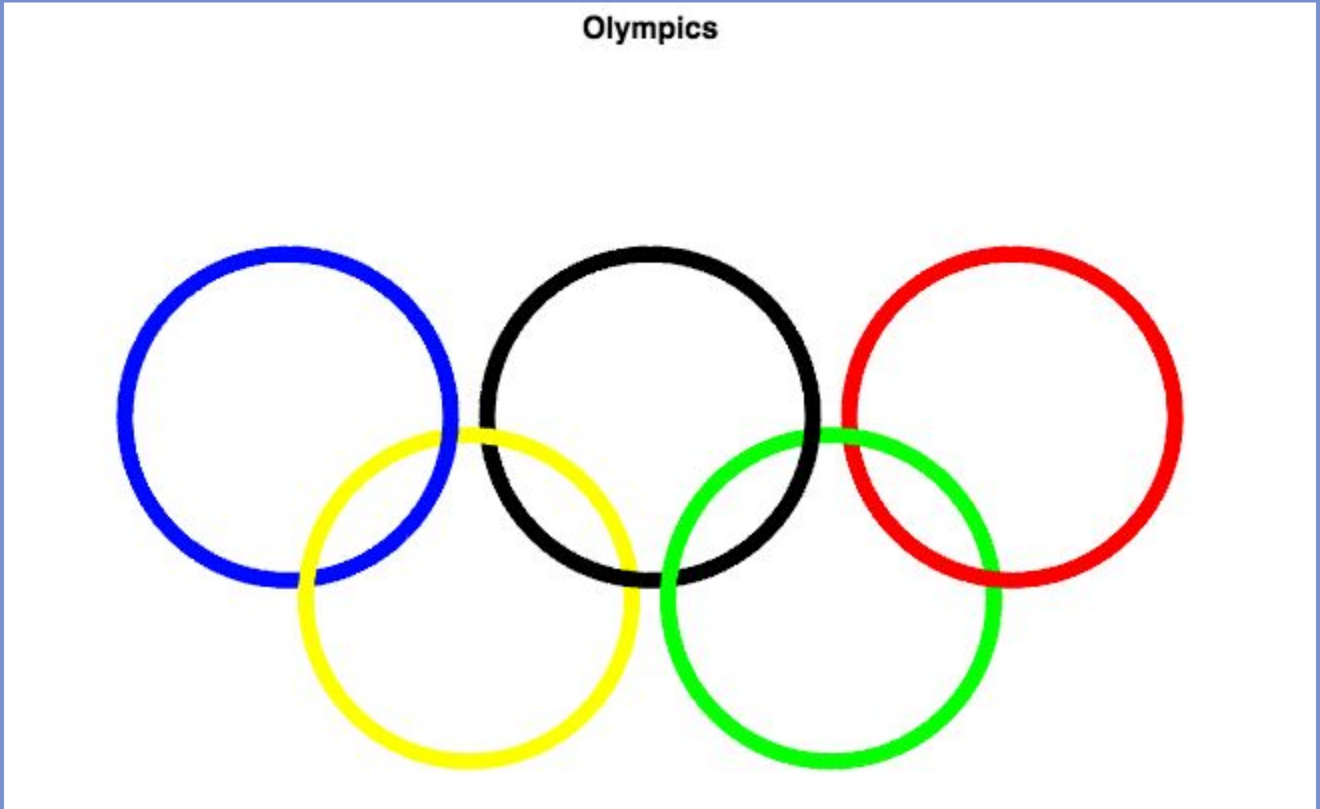
ANALYSIS

Activity 1.2 Color Image

1. Mathematically recreate the Olympics logo as an image. No need to make it as accurate as the logo below. It is fine if the colors overlap where the rings intersect.

Objectives 1.2

Results & Analysis 1.2



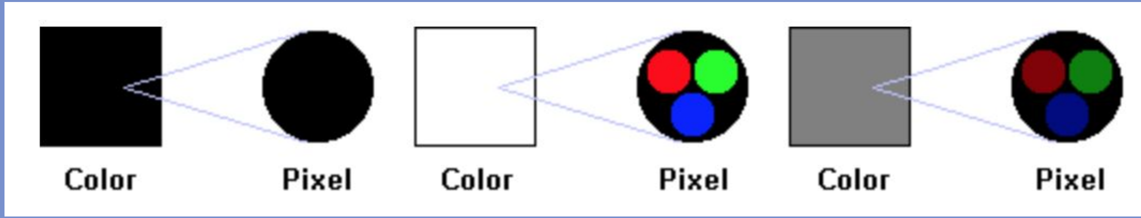
1 OLYMPICS LOGO

The human eye is trichromatic, which means it has 3 receptors in the retina responsible for perceiving color. These receptors are sensitive to red, green, and blue light. This is why the computer display only generates these 3 basic colors.

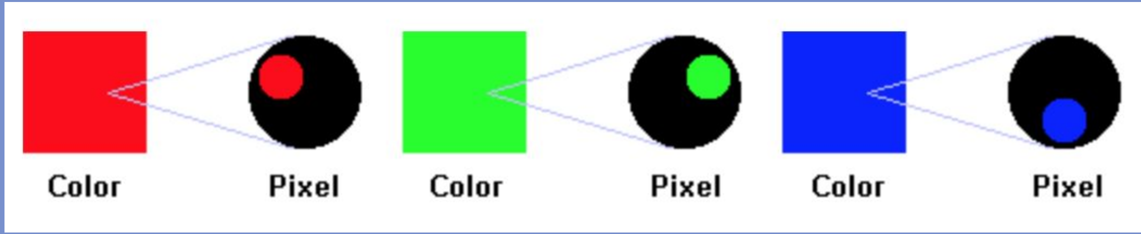
Every pixel in a computer display is made of 3 points of compounds called phosphor. Each of these phosphors emit red, green, and blue light when struck by electron beams.

ANALYSIS

The screen or a pixel appears black when no electron beam strikes the phosphors. It appears white when all phosphors are excited with relative intensities from sunlight. The color gray is displayed when all phosphors are hit but at lower intensities.

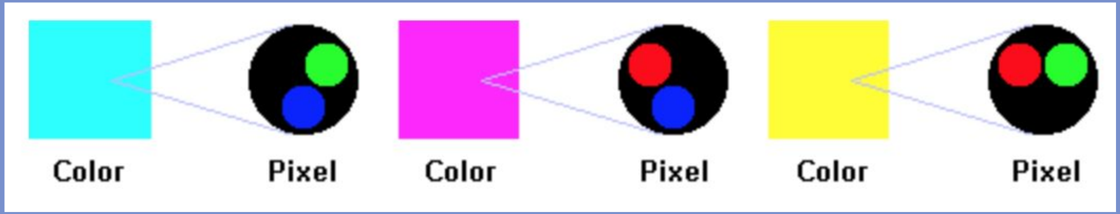


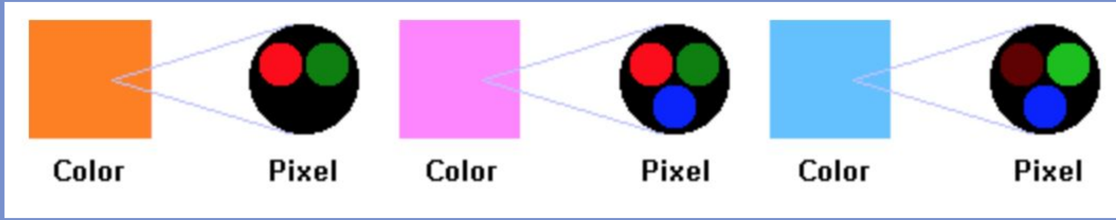
Red, green, and blue are shown by a pixel on the screen when each phosphor is excited individually.



ANALYSIS

All the other colors of the visible spectrum are basically combinations of the RGB phosphors with varying intensities.





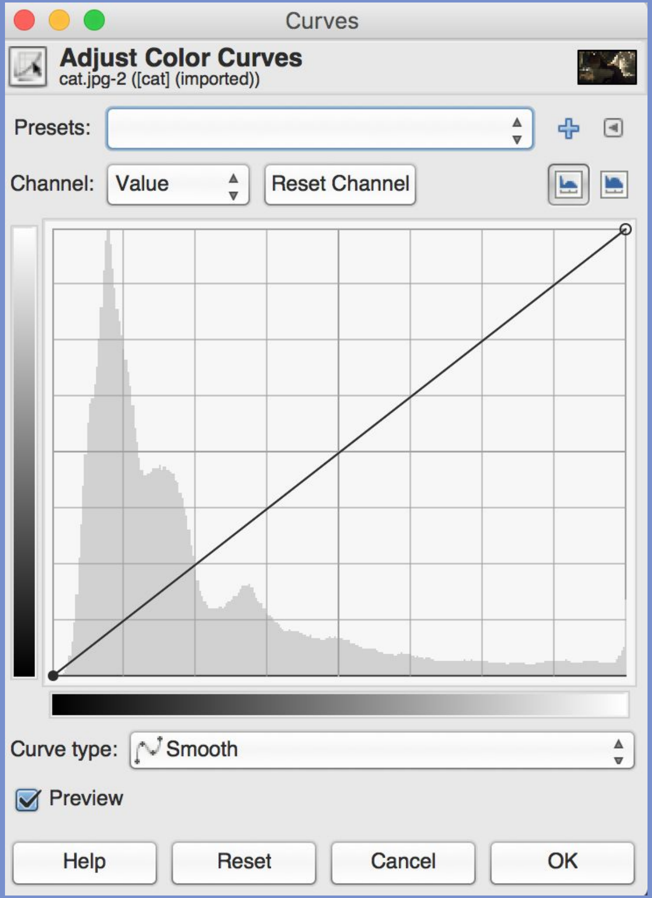
ANALYSIS

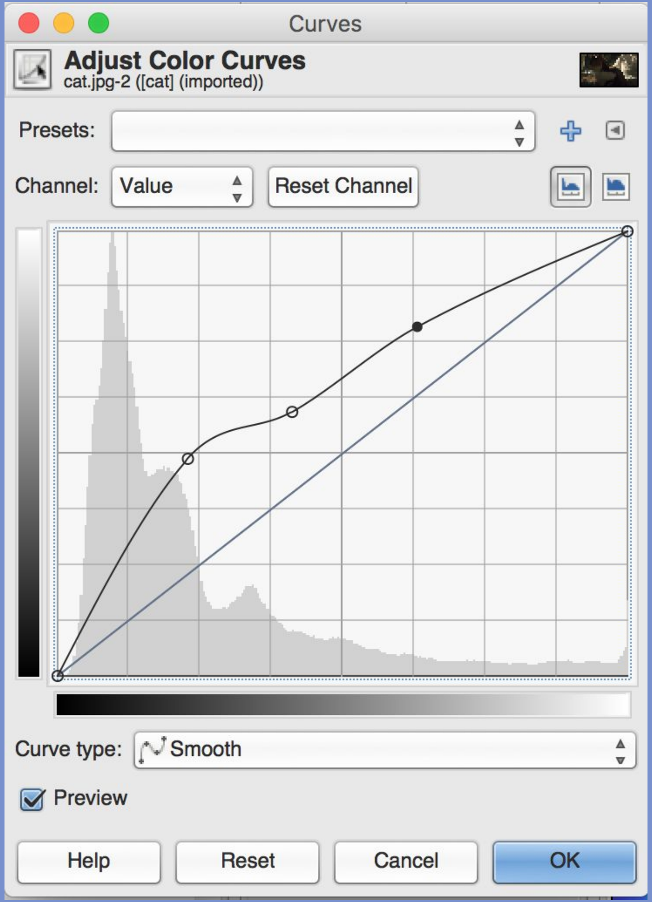
Activity 1.3 Altering the Input-Output Curve

1. Look for a dark-looking digital photo from your collection.
2. Open the image using GIMP (or any software that has histogram manipulation functions).
3. In GIMP, from the **Colors** drop-down menu select **Curves.** A separate interactive window will pop-up showing the histogram of the image. By default it shows the **VALUE** histogram. Value is the brightness of the pixel. See Figure 7.
4. The diagonal line across the histogram is the input-output curve of the value. Drag any point along this line to alter the I-O curve and play around with it until you see details in the dark portions of your image.

Objectives 1.3

Results & Analysis 1.3





1 I/O CURVE ALTERED IN GIMP

1 I/O CURVE ALTERED IN GIMP

A histogram of an image is a plot of the distribution of pixel intensity values in the image. It shows the frequency of occurrence of each intensity value in the image, with the x-axis as range of intensity typically from 0 (black) to 255 (white), and the y-axis as the number of pixels in the image that have that intensity.

Histograms are made up of sections called bins, with each bin representing a certain intensity range. The histogram is computed by examining all pixels in the image and assigning each to a bin depending on the intensity of a pixel. The final value of a bin is the number of pixels assigned to it.

Thus the histogram will have higher values on the left side of the graph if an image has a lot of dark pixels, indicating a higher frequency of low intensity values, which can be seen from the GIMP histogram of the dark image of the cat above.

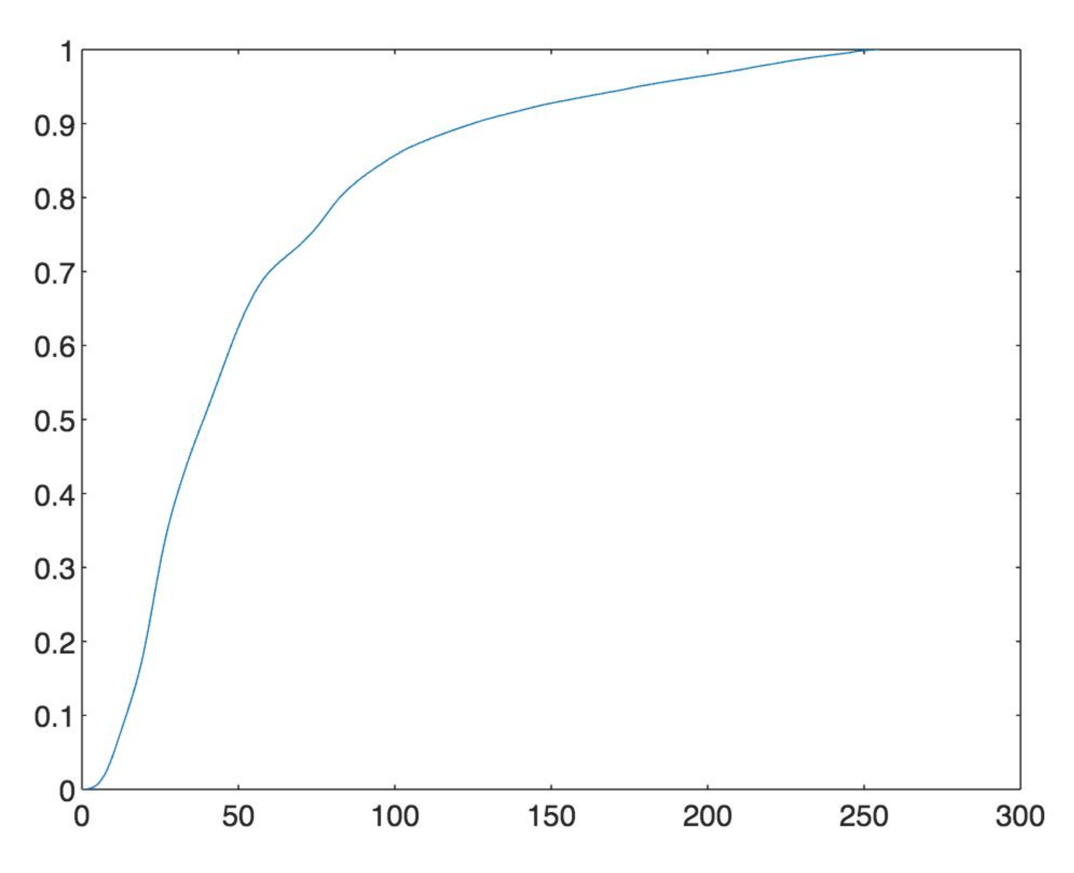
Equally, the it will have higher values on the right side of the graph if an image has a lot of bright pixels,, indicating a higher frequency of high intensity values.

ANALYSIS

Activity 1.4 Histogram Backprojection on Grayscale Images

Objectives 1.4

Results & Analysis 1.4



1 GRAYSCALE HISTOGRAM BACKPROJECTION

1 GRAYSCALE HISTOGRAM BACKPROJECTION

The backprojection is calculated from the histogram. It replaces every pixel by its probability to occur in the image.

A grayscale image of the original image is obtained, from which its histogram is derived. The histogram is then normalized by the number of pixels of the image to get its probability distribution function (PDF).

The cumulative distribution function (CDF) of the PDF is basically shows the cumulative probability of each value in the PDF less than or equal to that value, which are 0 to 255.

ANALYSIS

Activity 1.5 Contrast Enhancement

1. Contrast stretch your dark picture by applying Equation (2) to its grayscale. Try out different percentiles for the minimum and maximum intensities.

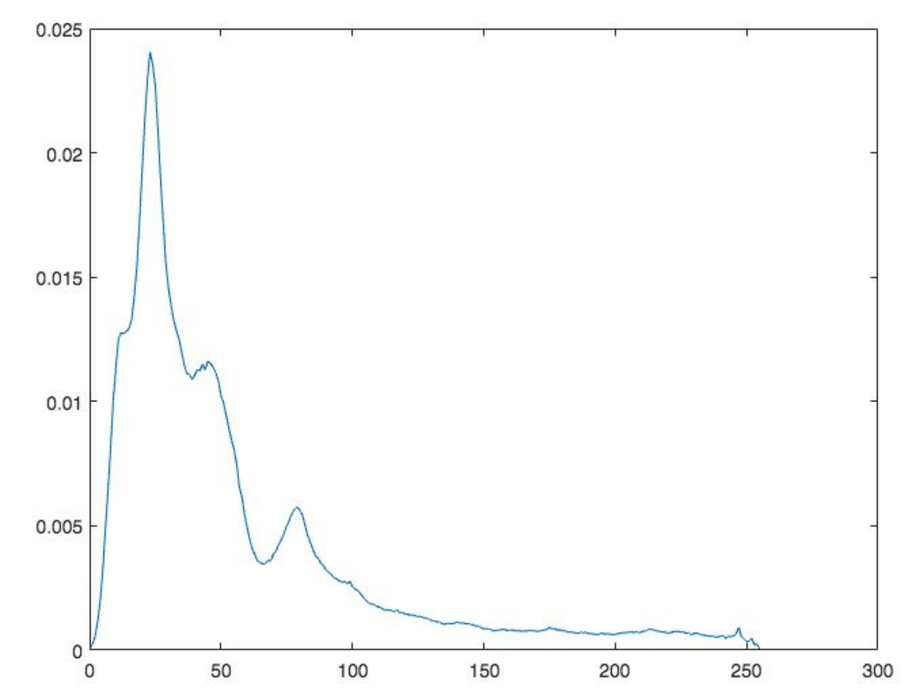
Objectives 1.5

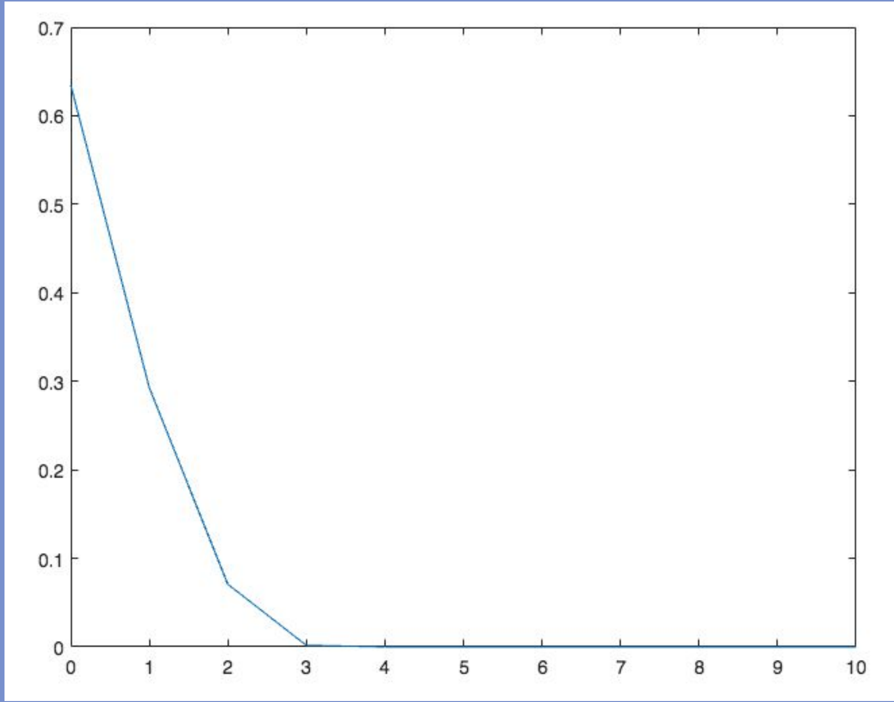
Results & Analysis 1.5

1 CONTRAST ENHANCEMENT

Contrast stretched images with percentiles 10, 30, and 50 respectively

1 CONTRAST ENHANCEMENT





Histograms of the original and contrast stretched images respectively

1 CONTRAST ENHANCEMENT

Contrast stretching, also called normalization, is a method that varies the contrast of an image by changing the pixel values to span a larger range of intensity values, thus it 'stretches' the range to span a different range of values.

The normalized/contrast stretched values of an image is given by

$$I_{new} = \frac{I_{old} - I_{min}}{I_{max} - I_{min}}.$$

Where Iold is set of values of an array of the original image, Imin and Imax are the minimum and maximum values of that array, and Inew is the contrast stretched values.

ANALYSIS

Below is a snippet of the code of the contrast stretching above. It shows the grayscale of the image being normalized according to the formula above, where Rold is Iold, Rmin is Imin, Rmax is Imax, and contrast is Inew. the percentiles are also calculated since the image is in grayscale.

```
Rold = double(Original_Image);
Rmin = double(min(Original_Image));
Pmin1 = prctile(Rmin, 10);
Rmax = double(max(Original_Image));
Pmax1 = prctile(Rmax, 10);
contrast = ((Rold - Pmin1)./(Pmax1 - Pmin1));
```

ANALYSIS

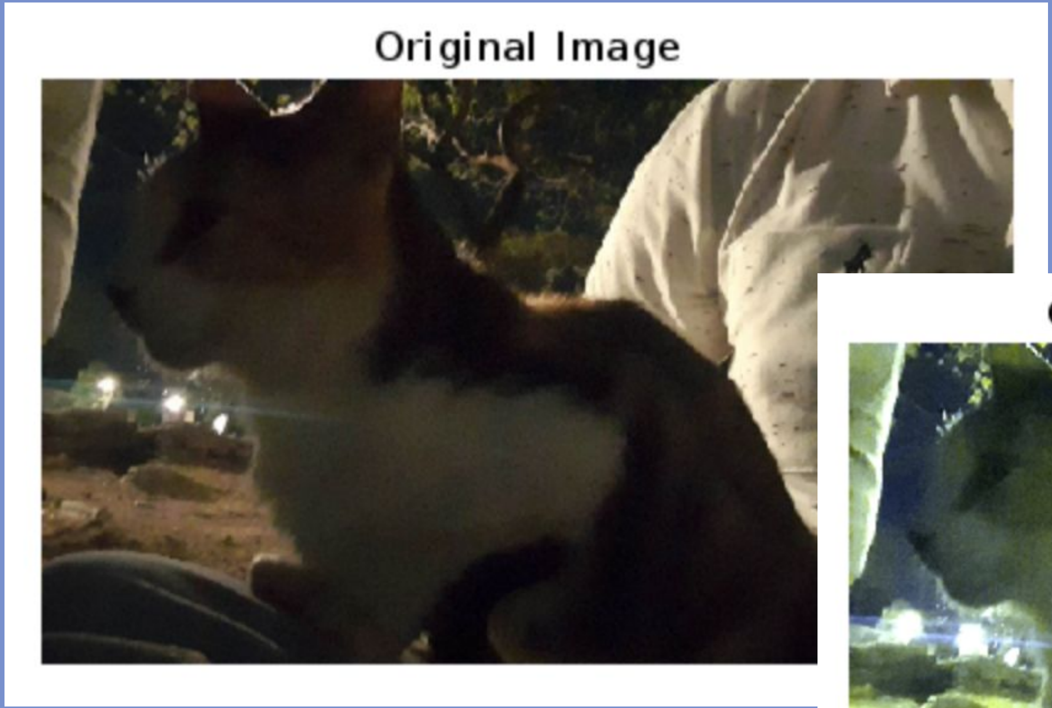
Activity 1.6 Restoring Faded Colored Photographs

Objectives 1.6

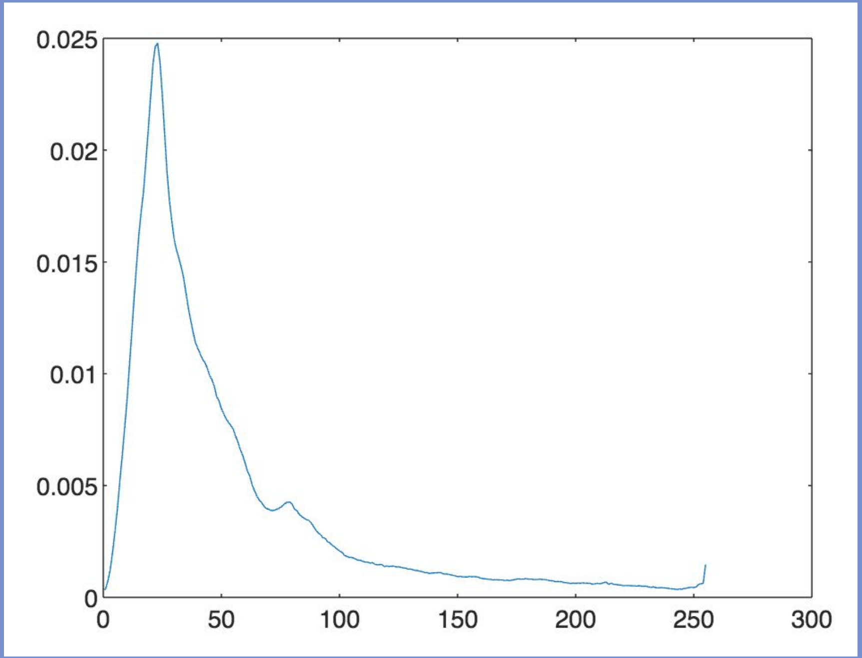
Results & Analysis 1.6

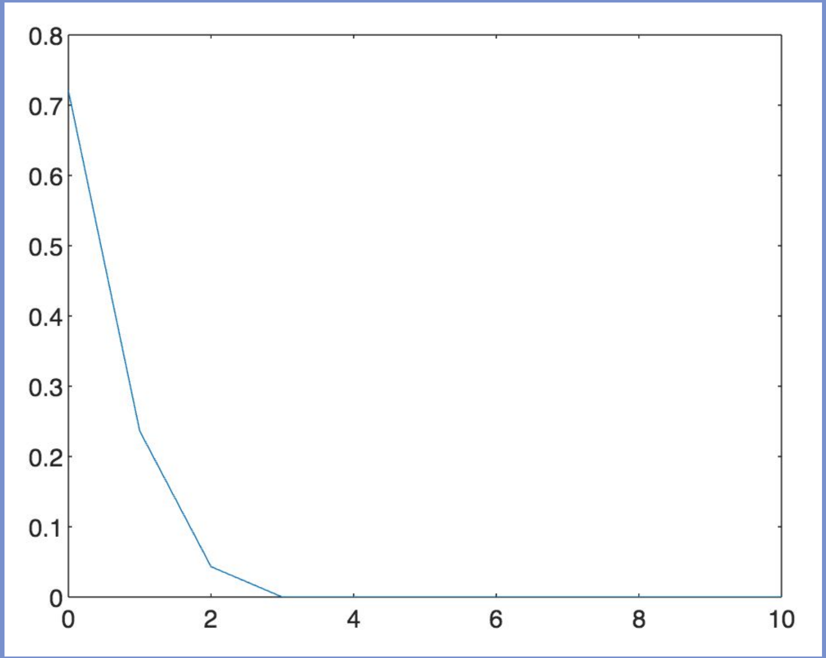
Isolated RGB channels of the original image

1 CONTRAST STRETCHING



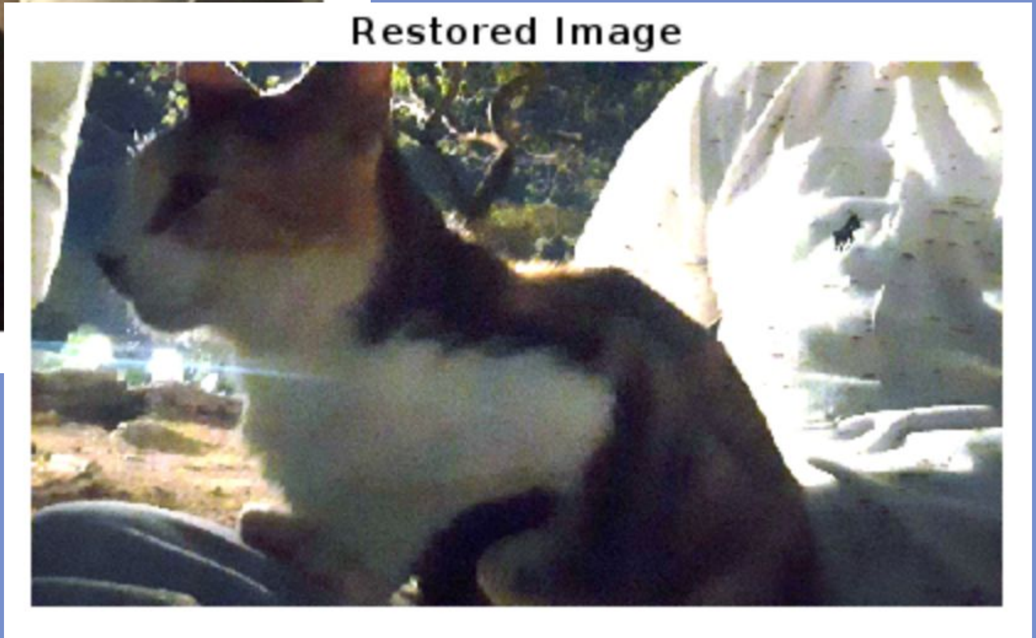
1 CONTRAST STRETCHING



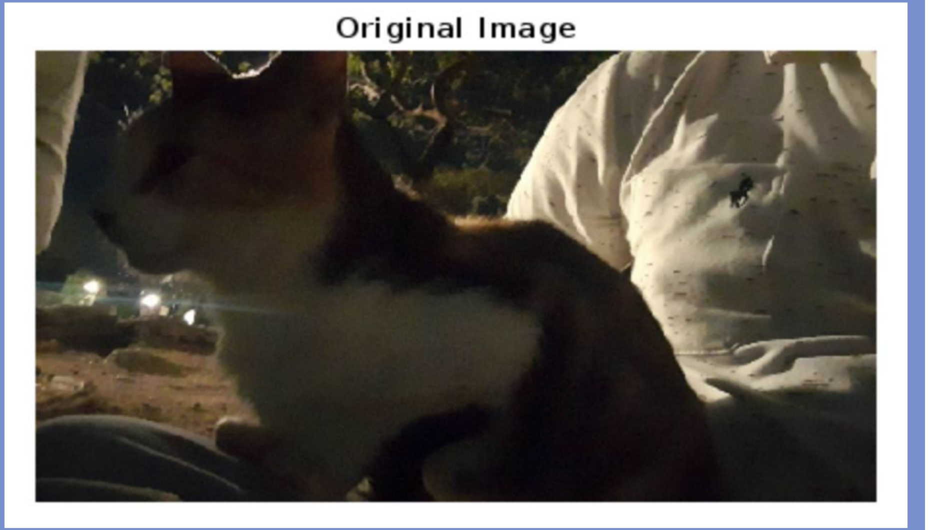


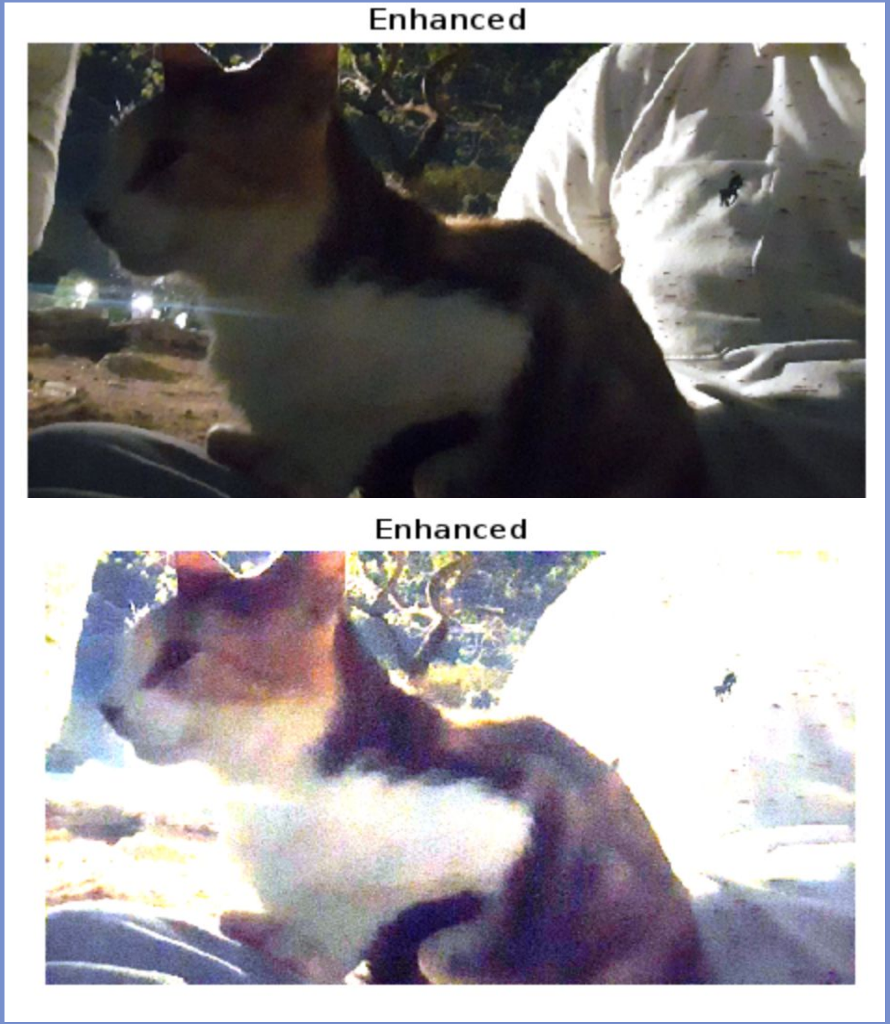
Histograms of the original and contrast stretched image respectively

1 CONTRAST STRETCHING



2 GRAY WORLD ALGORITHM





3 WHITE PATCH ALGORITHM

Activity 1.6 shows how each RGB channel plays a vital role in the overall characteristics of the image. In contrast stretching, each channel of the original image needs to undergo contrast stretching before being layered again together to form a total contrast stretched image. In gray world algorithm, each channel has to be averaged to get the constant balancing factor of the gray object. In white patch algorithm, each channel was also averaged to determine the output for a white object.

Also, it can be observed that upon calling the final image output through the function *imshow*, the brightness of the image can be varied by multiplying a decimal factor to the argument of the function, with lower values being darker, and 0.0 being pitch black.

ANALYSIS

Algorithm restoration rating:

- Contrast stretching - 6/10

As can be seen from the images, the output image seems to be very tinted and yellowish and not true to the natural colors of the object

- Gray world algorithm - 8/10

The output image seems to be very natural, where the colors of the objects in the image appear to be properly contrasted with good intensities relative to each other, but the output factor has to be considered to get the proper output brightness

- White patch algorithm - 7/10

The contrast output image is can vary depending on the selected cropped white portion. Whichever white portion is chosen will be enhanced quite accurately relative to its neighboring pixels, but will wash out other white parts of the image.

Reflection

Activity 1 was a very exciting exercise, as it was able to harness not only my technical understanding and skills, but also my creativity. Since the tasks were image processing and analytics, the visual aspect gives a very reassuring comfort on whether or not what I am doing is right or wrong.

I believe the results are completely valid as I have been able to follow instructions, and tinker a bit on my own, and are able to output visually dynamic results that are within expectations.

I must admit that I am limited by my coding skills, which have hindered my ability to finish the activity earlier. I was aided by some friends on the code, which I understood well in the end. The underlying theories were also not self-explanatory to me, of which I had to ask the guidance of some friends to explain them to me.

I also take pride of the fact that the subject of the images that I used is a very sweet cat I met in Sunken Garden. Overall, I enjoyed Activity 1. Onto the next!

Self Grade

CRITERIA	QUALIFICATIONS	SCORE
Technical Correctness	❑ Met all objectives ❑ Results are complete ❑ Results are verifiably correct ❑ Understood the lesson	35
Presentation Quality	❑ All text and images are good quality ❑ Code has sufficient comments/guides ❑ Plots are properly labeled and visually understandable ❑ Report is clear	35
Self Reflection	❑ Explained validity of results ❑ Discussed what went wrong/right in activity ❑ Justified self score ❑ Acknowledged sources	30
Initiative	❑ Experimented beyond what was required ❑ Made significant improvements to existing code	5

References

[1] Colors on a computer screen. (n.d.). *Purdue University*. Retrieved from https://www.chem.purdue.edu/gchelp/cchem/RGBColors/body_rgbcolors.html

[2] Cherry, K. (2021, March 14). The trichromatic theory of color vision. *Very Well Mind*. Retrieved from
on-2795831

[3] Image histograms. (n.d.). *Scientific Volume Imaging*. Retrieved from https://svi.nl/ImageHistogram#:~:text=An%20image%20histogram%20is%20a,a%20certain%20intensity%20value%20range.

[4] David, R. (n.d.). Histogram and backprojection. *Robin David*. Retrieved from http://www.robindavid.fr/opencv-tutorial/chapter4-histogram-and-backprojection.html

[5] Cumulative distribution function. (n.d.). *Introduction to Probability, Statistics, and Random Processes*. Retrieved from https://www.probabilitycourse.com/chapter3/3_2_1_cdf.php

[6] Fisher, R., Perkins, S., Walker, A., and Wolfart, E. (2003). Contrast stretching. *Home Pages*. Retrieved from https://homepages.inf.ed.ac.uk/rbf/HIPR2/stretch.htm#:~:text=Contrast%20stretching%20(often%20called%20normalization,the%20image%20type%20concerned%20allows.

Warm thanks also to Johnenn Manalang & Richmond Jumawan for helping me with the codes for Activity 1.5 and 1.6.