Digital Image Formation and Enhancement

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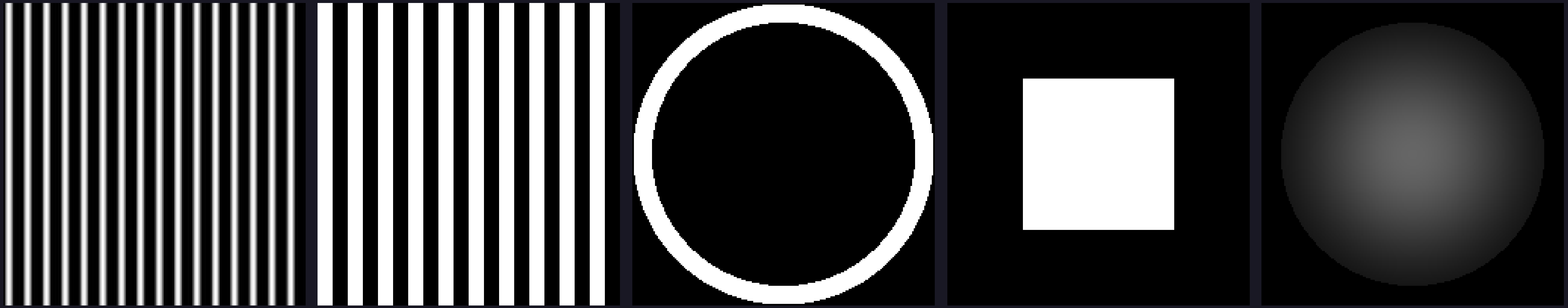
OBJECTIVES

- Mathematically create images.
- Save an image in an appropriate file format.
- Open and capture images using Python or Matlab
- Improve the appearance of graylevel and color images
- Use the backprojection technique to transform the histogram of an image to a desired distribution
- Restore faded photographs using white balancing algorithms

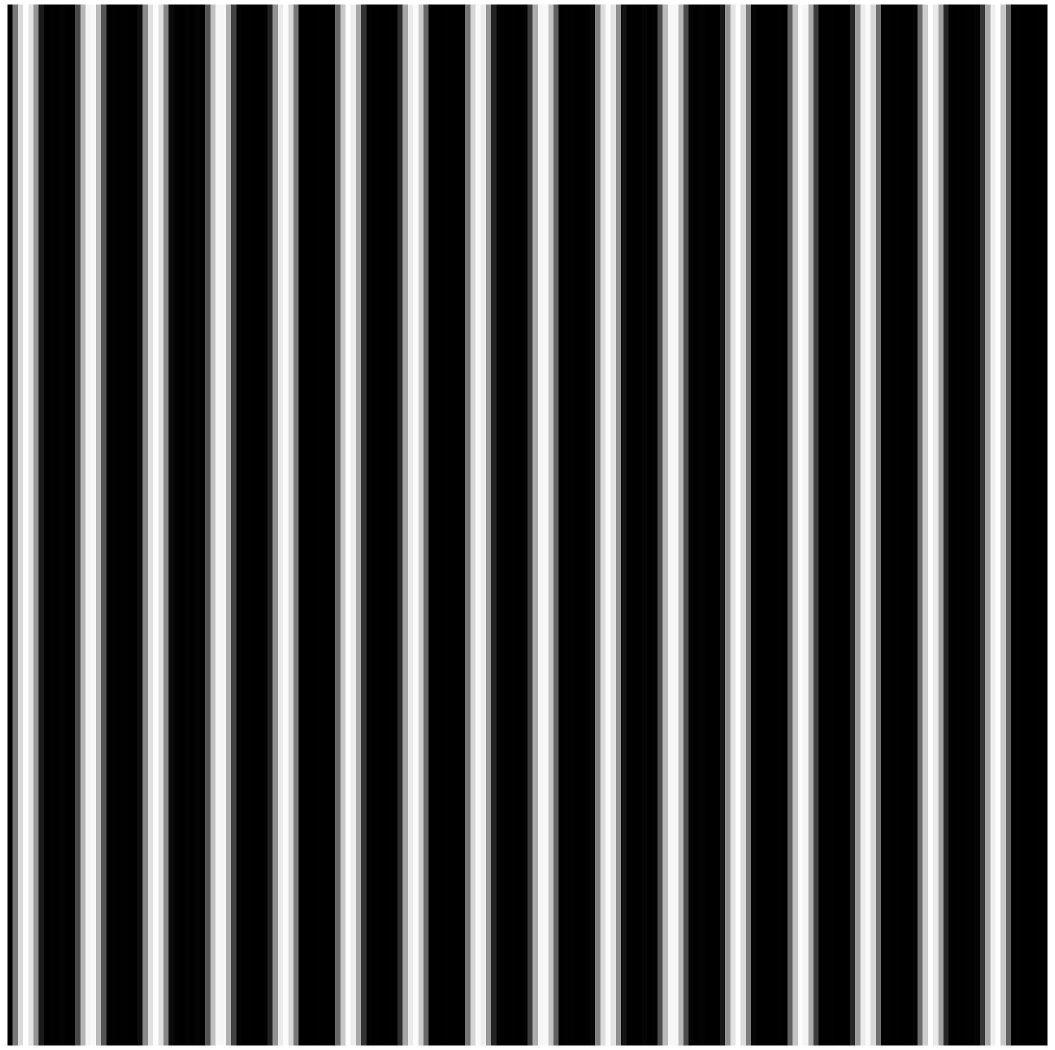
CREATING SYNTHETIC IMAGES



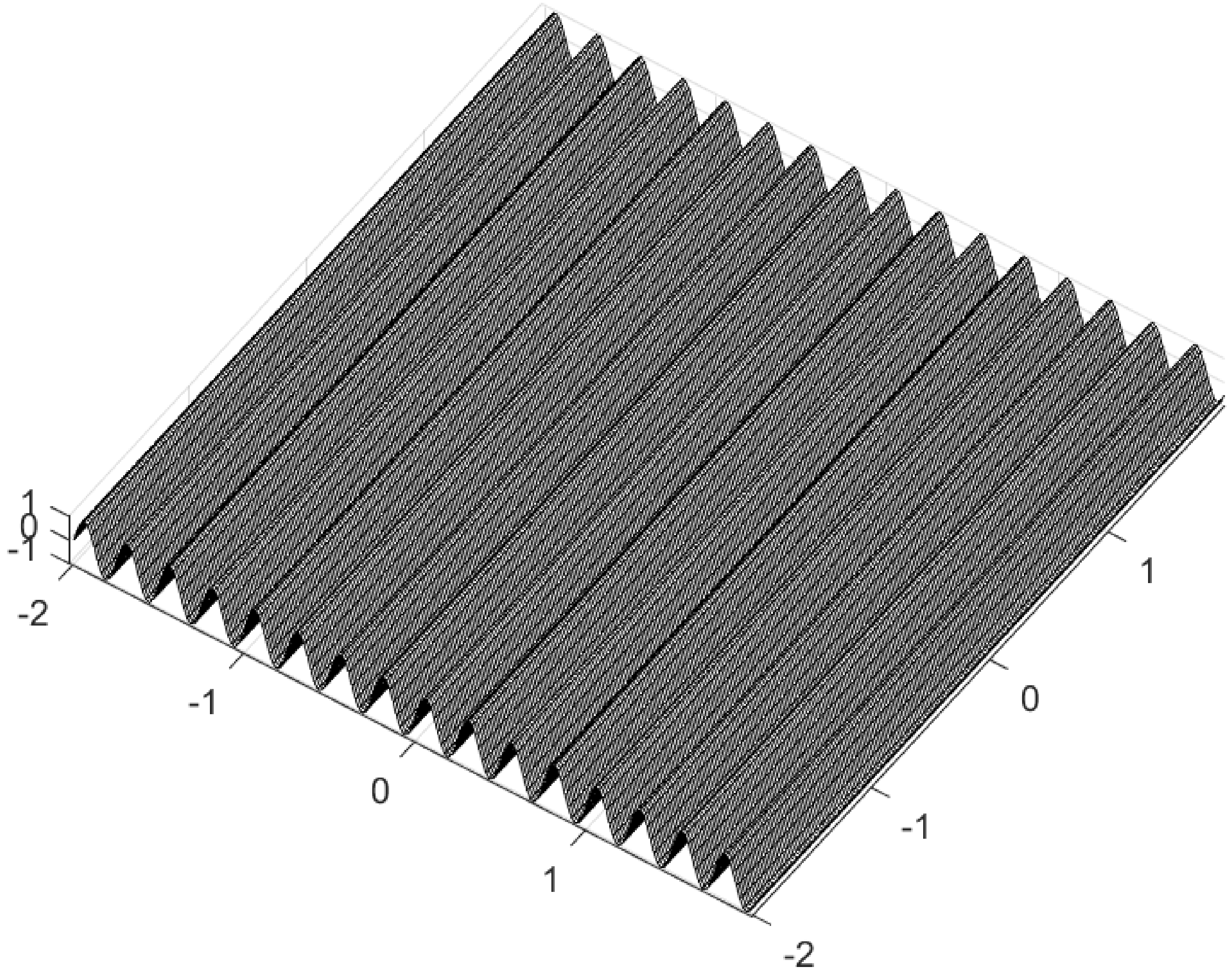
(a) (b) (c) (d) (e)

Figure 1. Different 2x2 cm synthetic images are generated using different functions in Matlab : (a) sinusoid and (b) grating along x direction, (c) annulus, (d) square, and (e) circular aperture with gaussian transparency

SINUSOID ALONG THE X-AXIS



(a)



(b)

Figure 2. Generated sinusoid image (a) having a frequency of 4 cycles/cm and amplitude of 1. Its forms a corrugated roof profile (b).

The sinusoid image is generated by using the sine function across the x-direction:

$$k = A\sin(2\pi fX)$$

where A is the amplitude and f is the frequency

GRATING

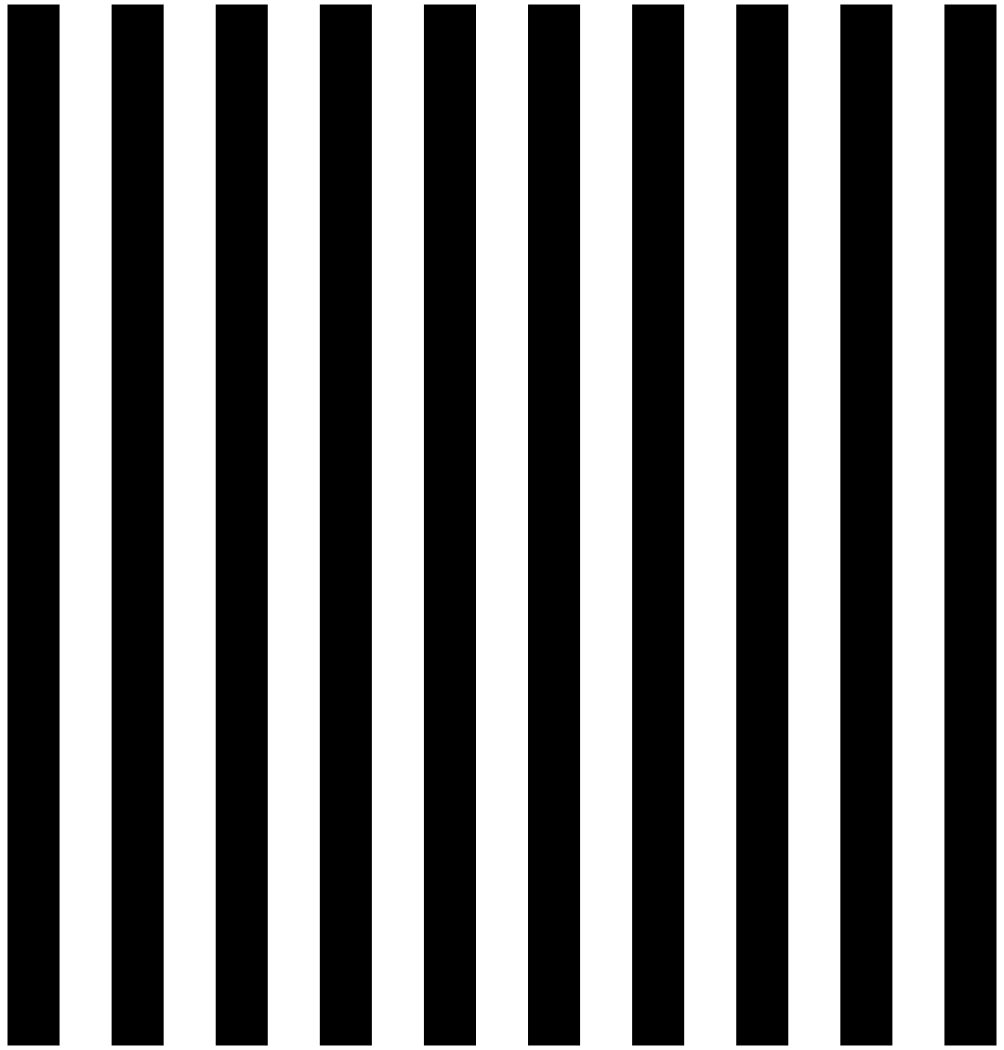


Figure 3. A grating image with a 5 black and white pairs/cm can be generated by the binarization of the sinusoid image .

To generate the grating in Figure 3, we simply take generating the function for the sinusoid, with A=1 and f=5.

Values less than 0 are then set to 0 and values greater than 0 are set to 1

SQUARE APERTURE

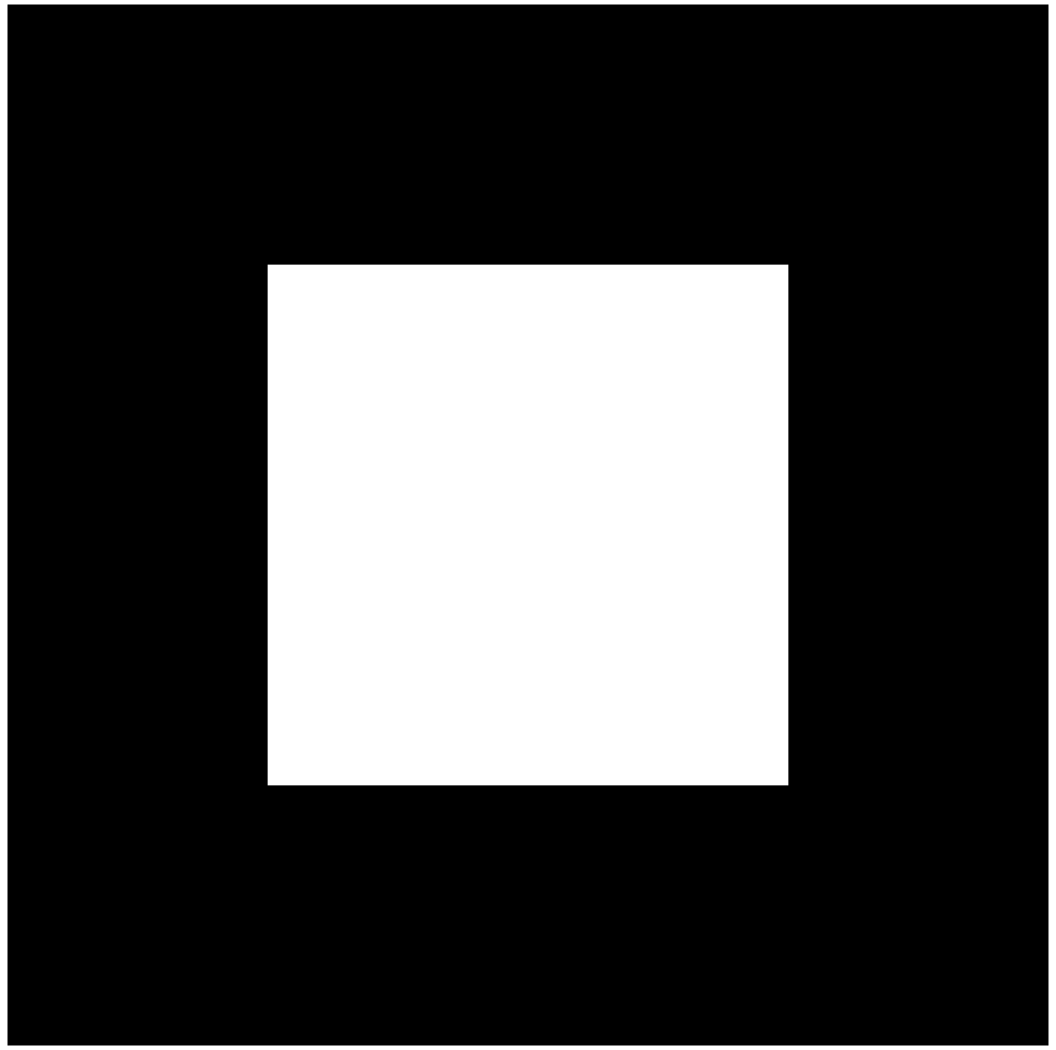


Figure 4. Generated image having a centered 1x1 cm square aperture.

The square aperture in Figure 4 can be simply generated by setting values to 1 in the linear boundary conditions:

$$\mathrm{abs}(X)<s$$
$$\mathrm{abs}(Y)<s$$

where s corresponds to half its side length.

ANNULUS

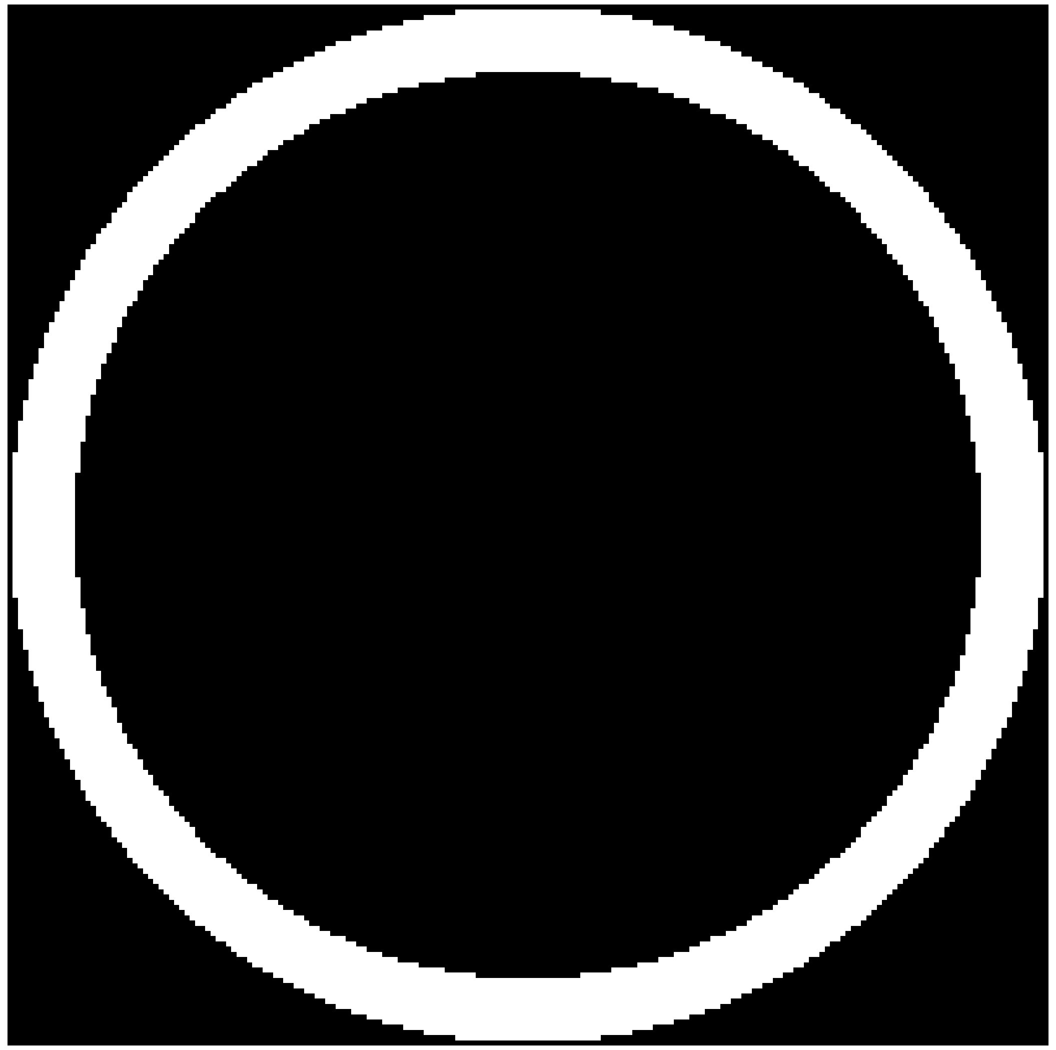


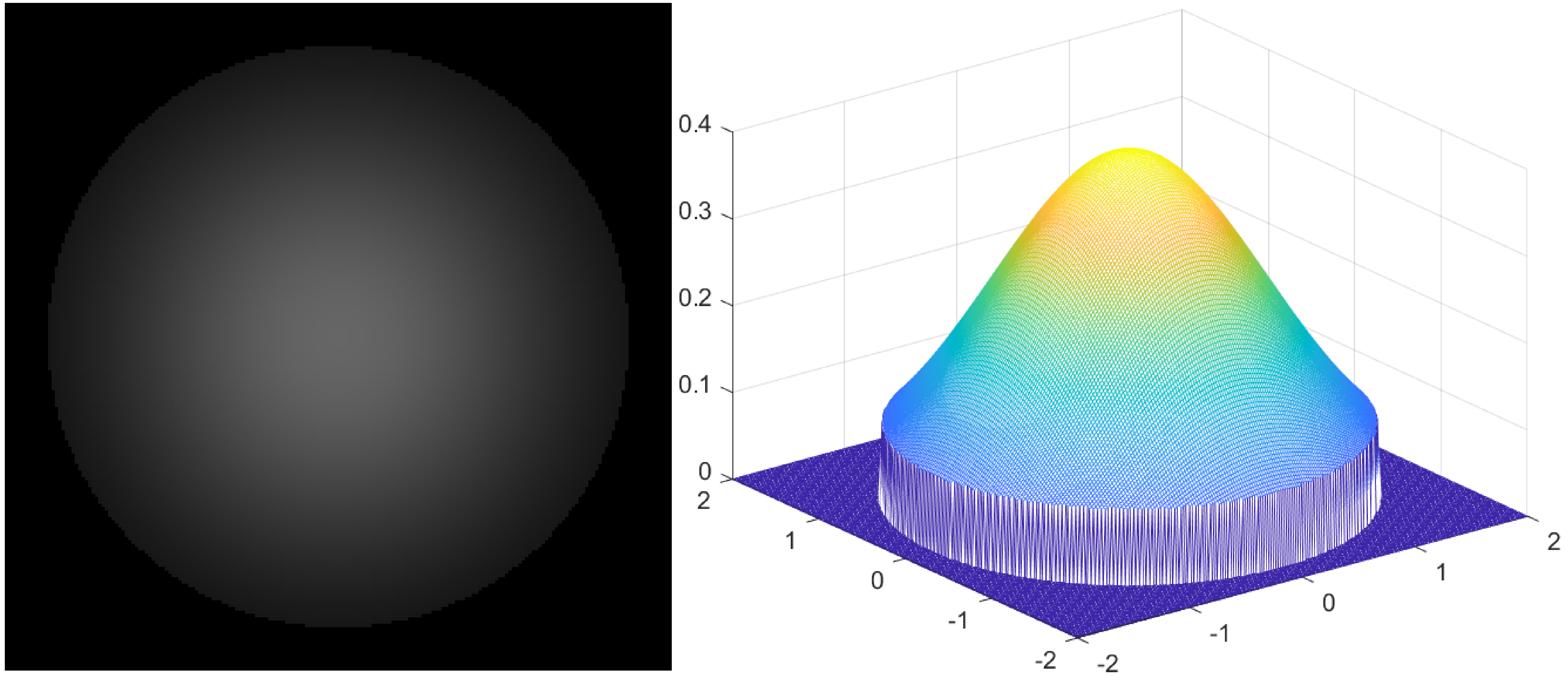
Figure 5. An annular aperture with an outer radius of 2cm and thickness 0.25cm generated using the distance function.

For the annular aperture, we use the distance function:

R=sqrt(X.^2+Y.^2)

as the generating function, similar to the circular aperture example. However, we set another condition for the inner radius of the annulus, so that the regions between the inner and outer radius is white or '1'.

CIRCULAR APERTURE WITH GRADED TRANSPARENCY



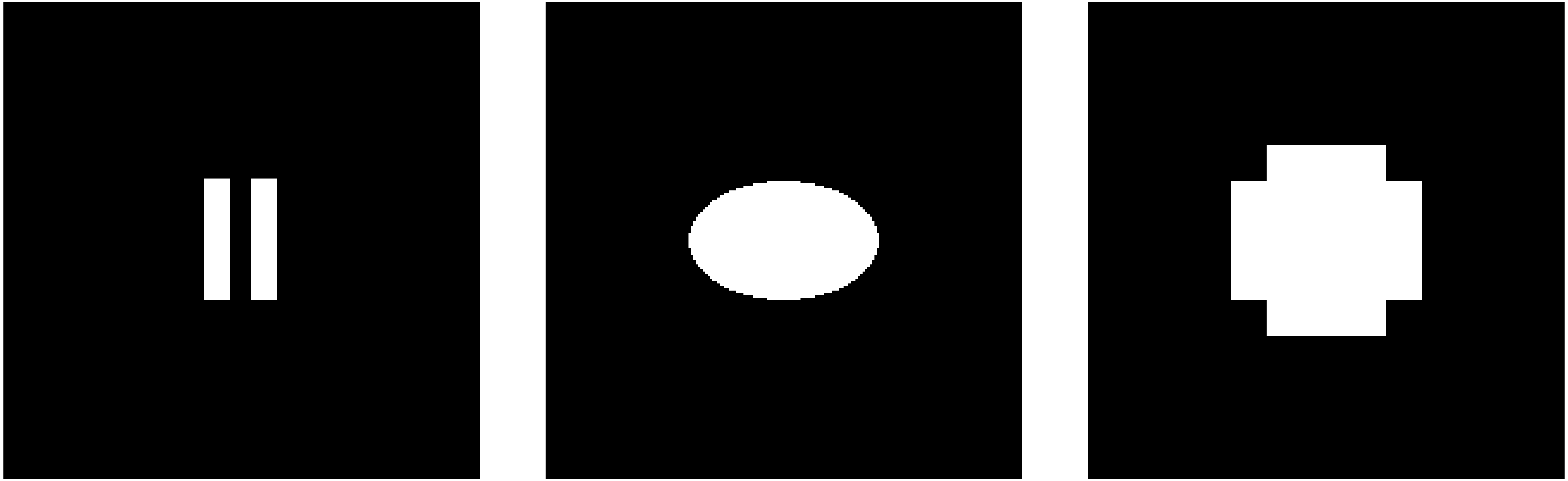
(a) (b)

Figure 6. A 1.75cm circular aperture with gaussian transmittance of σ=1.0. From its profile in (b), we could see a sudden truncation of the gaussian function, since the given sigma value coincides with the given radius of the aperture.

Two generating functions are applied for this aperture:

- gaussian function for the graded transmittance
- distance function for the circular aperture

CREATING SYNTHETIC IMAGES



(a) (b) (c)

Figure 7. Other figures can be generated using Matlab such as: (a) double slit aperture, (b) elliptical, and (c) cross aperture. These images are constructed by modifying the functions used in the previous synthetic images.

COLOR IMAGES

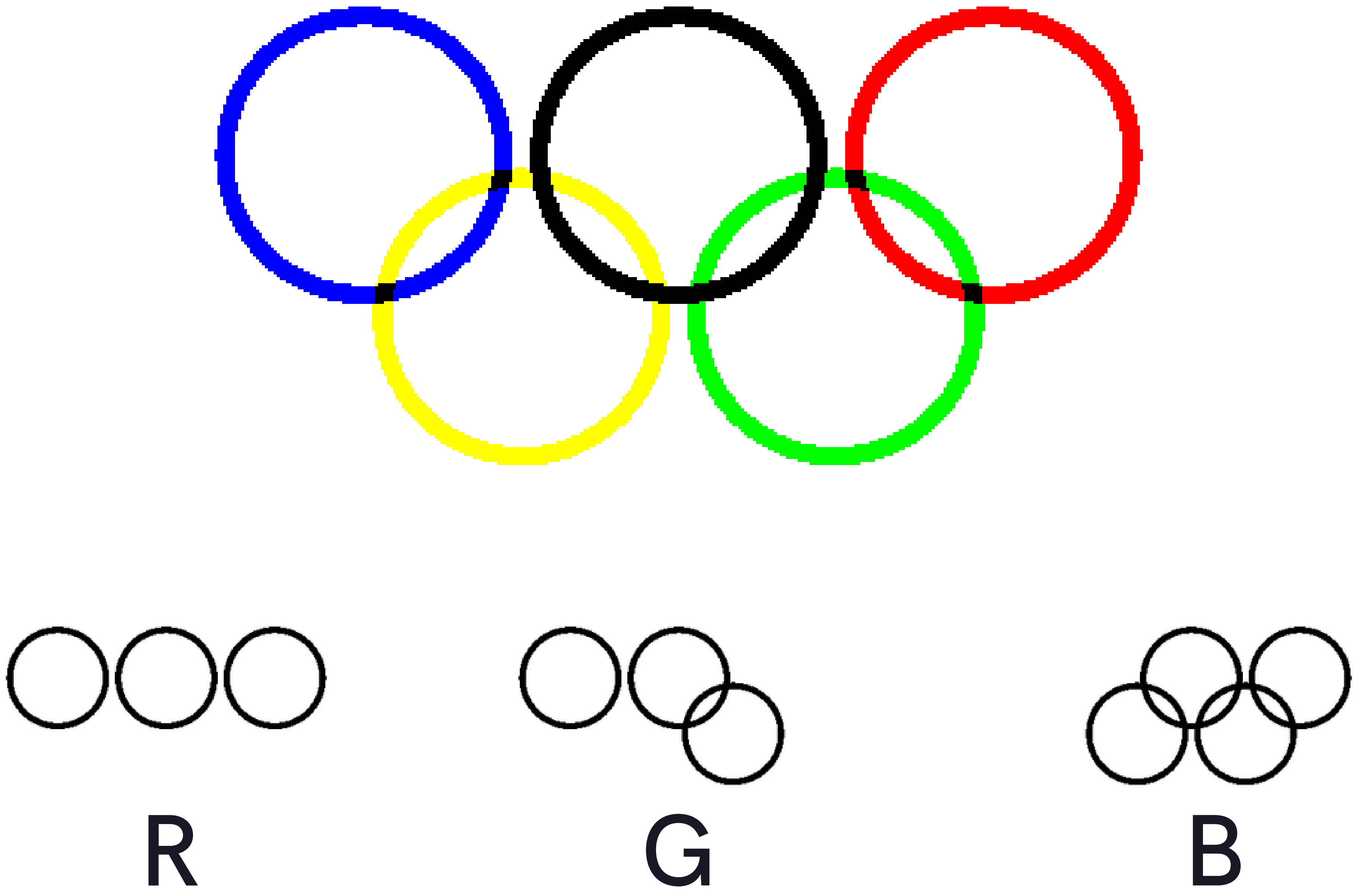


Figure 8. The Olympic logo(top) is recreated by manipulating the RGB layers (bottom) of the image .

Code snippet for the assignment of values to the individual RGB channels

```
%black ring
R = sqrt((X.^2) + (Y+Rt).^2);
Rd(R<r1 & R>r2) =0;
Gn(R<r1 & R>r2) =0;
Bl(R<r1 & R>r2) =0;
%green ring
R =sqrt((X-xt).^2 + (Y-yt).^2);
Rd(R<r1 & R>r2) = 0;
Bl(R<r1 & R>r2) = 0;
%yellow ring
R = sqrt((X+xt).^2 + (Y-yt).^2);
Bl(R<r1 & R>r2) = 0;
%red ring
R = sqrt((X-2*xt).^2 + (Y+Rt).^2);
Gn(R<r1 & R>r2) = 0;
Bl(R<r1 & R>r2) = 0;
%blue ring
R = sqrt((X+2*xt).^2 + (Y+Rt).^2);
Rd(R<r1 & R>r2) = 0;
Gn(R<r1 & R>r2) = 0;
```

To recreate the Olympic logo, we utilize the techniques used in the generation of synthetic images to formulate the rings' region and positions with distance functions with translations specific to a ring.

Since we have a blank ring, we initialize the color arrays to be composed of ones. The channels not needed to create the specific color ring are set to zero. Take for example the yellow ring, yellow can be created with red+green, so the blue array is set to zero in the region of the yellow ring.

IMAGE FILE FORMATS

JPG (Joint Photographics Expert Group)

- lossy image compression
- easier transfer and sharing of images

PNG (Portable Network Graphics)

- lossless image compression
- supports transparency

BMP (Bitmap)

- lossless image compression
- generally compressed or uncompressed

TIFF (Tag Image File Format

- lossless image compression
- for document formatting and archiving

IMAGE FILE FORMATS

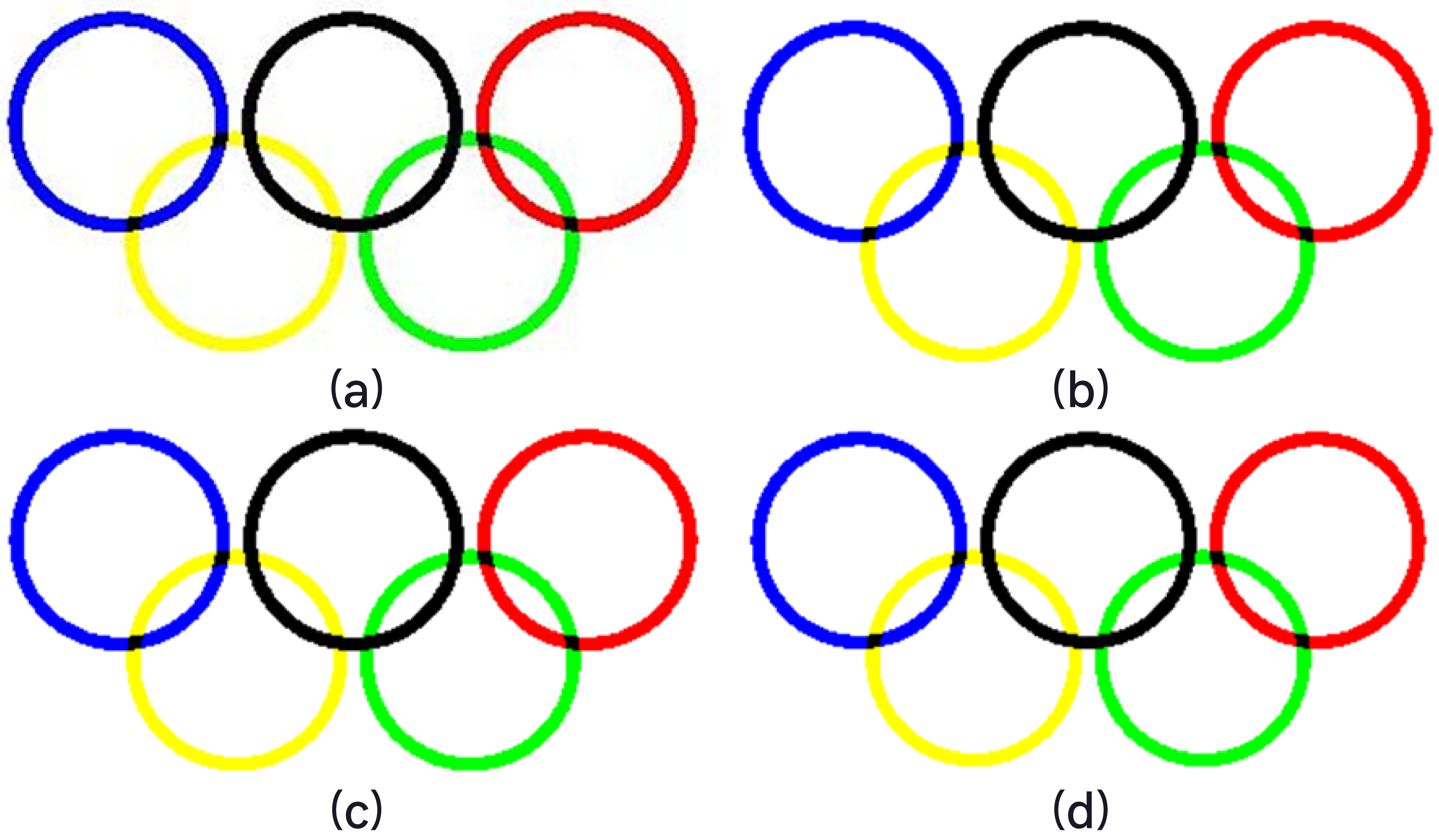


Figure 9. Olympic logo imaged is saved in (a) JPG, (b) PNG, (c) BMP, and (d) TIFF file formats using the imwrite() function. The image sizes for (a),(b),(c), and (d) are 15KB, 5KB, 733KB , and 34KB, respectively.

From the saved images for the olympic logo image, The difference in quality between the TIFF, PNG, and BMP is not easily visible, but there is a noticeable decrease in resolution in JPG.

The file size is smallest with the PNG file format while the largest is with the BMP file format.

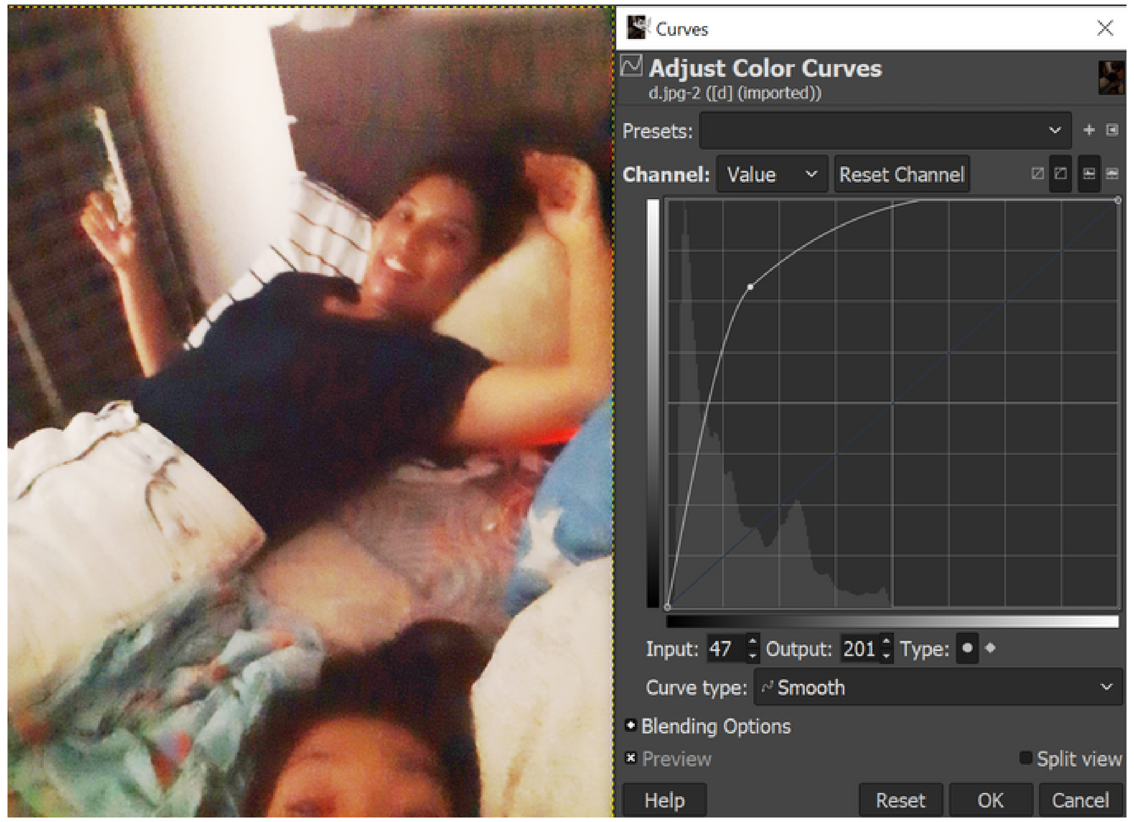
This demonstrates the image compression characteristics for each file format

Figure 10. Dark image to be enhanced

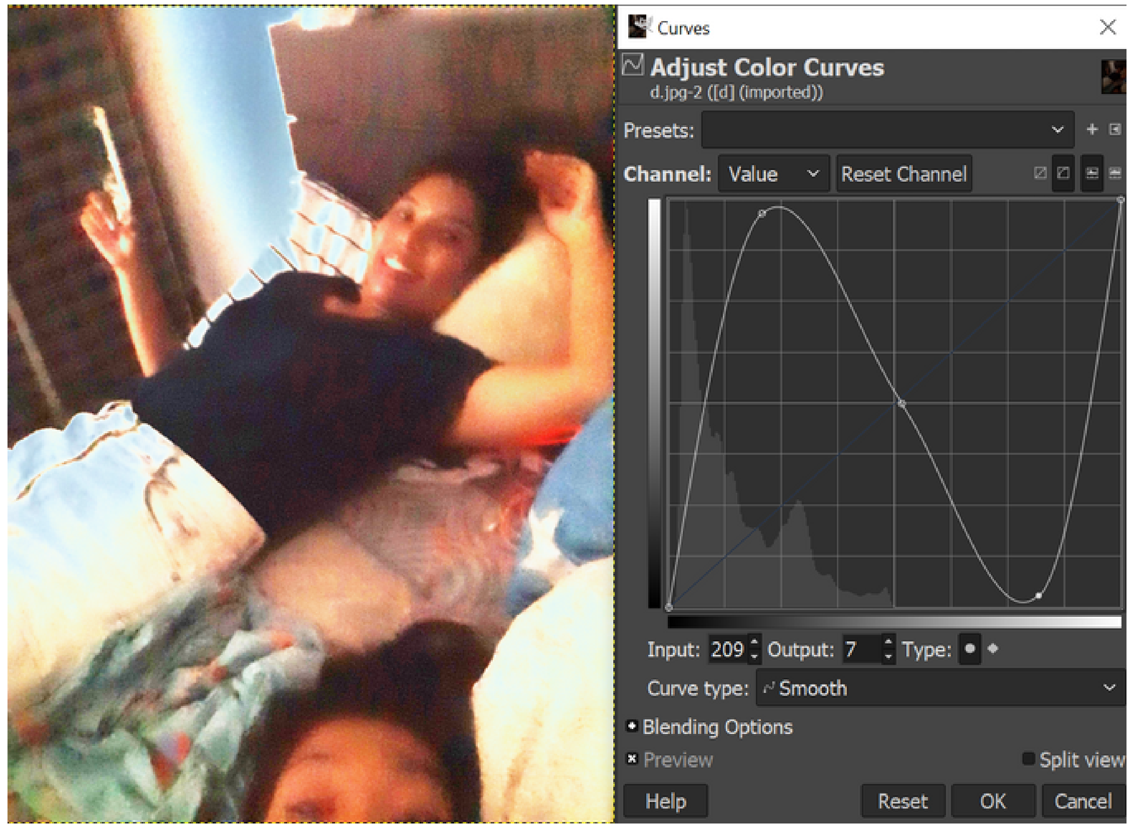
IMAGE ENHANCEMENT

- Altering input-output curve
- Histogram Manipulation
- Contrast Stretching

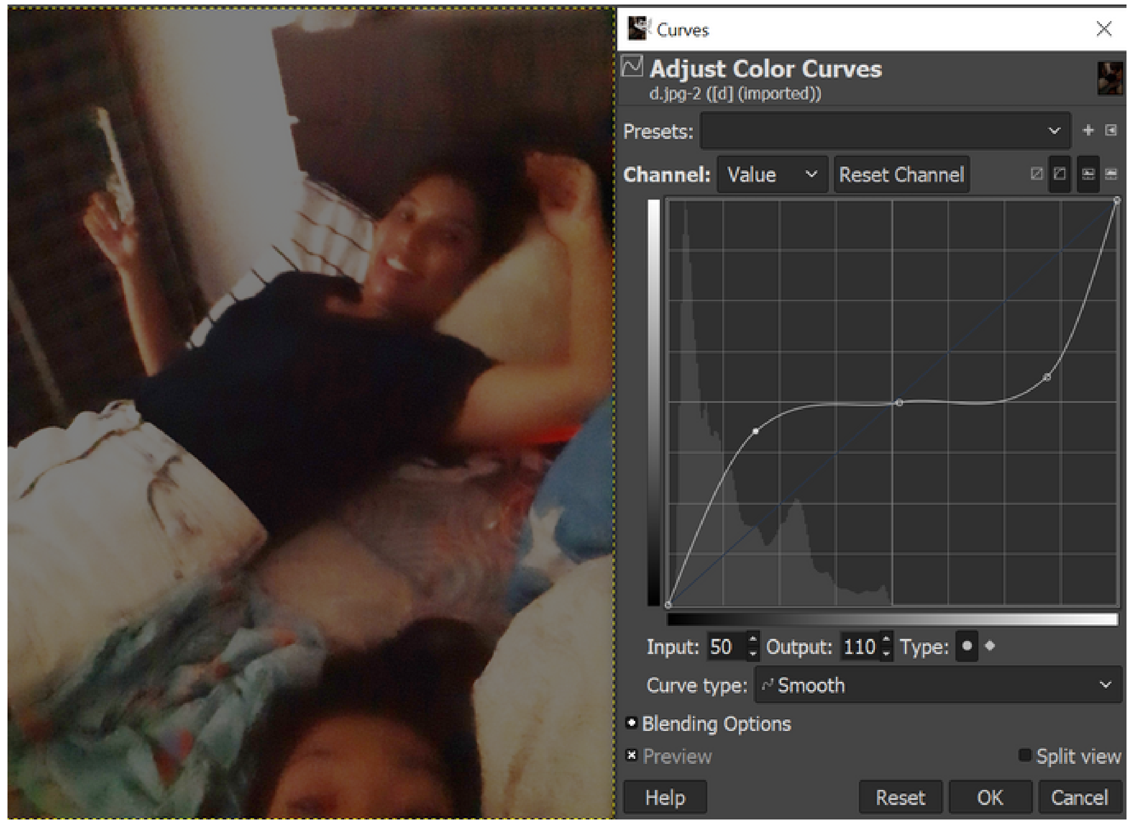
ALTERING THE INPUT-OUTPUT CURVE



Curve 1



Curve 2



Curve 3

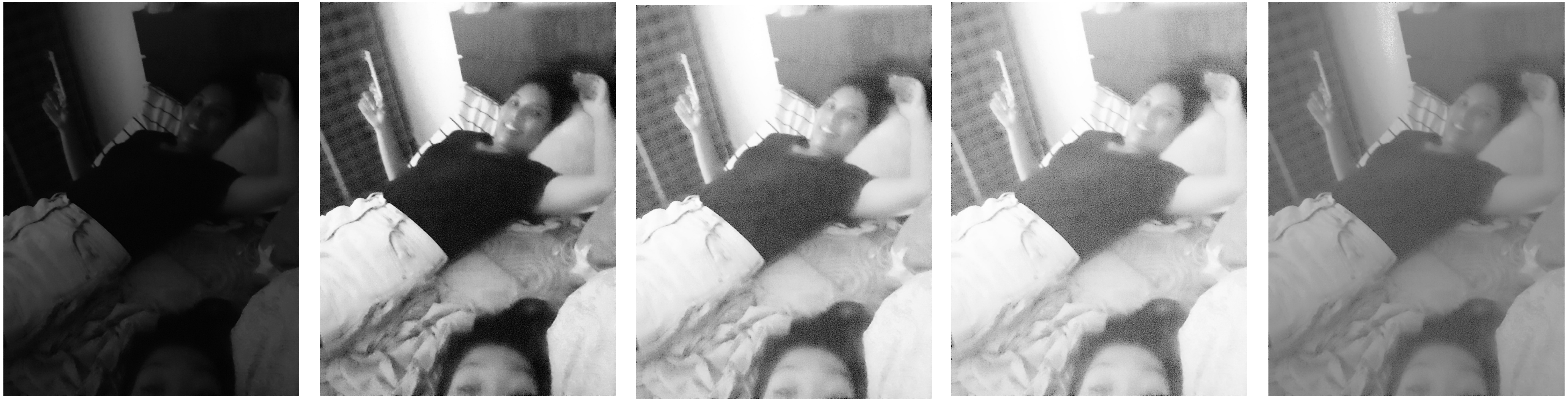
Figure 11. Brightness of image is change by altering the input-output curve of the brightness value using GIMP

ALTERING THE INPUT-OUTPUT CURVE

Original Curve 1 Curve 2 Curve 3

Figure 12. Altering the input-output curve reveals more details in the image. The checkered pattern in the dressing cabinet is now more visible under the different curve adjustments.

HISTOGRAM BACKPROJECTION ON GRAYSCALE IMAGES



(a) (b) (c) (d) (e)

Figure 13. Image transformation of the (a) original grayscale image using several desired CDFs : (b) linear, (c) quadratic, (d) cubic, (e) sigmoid CFDs

LINEAR CDF

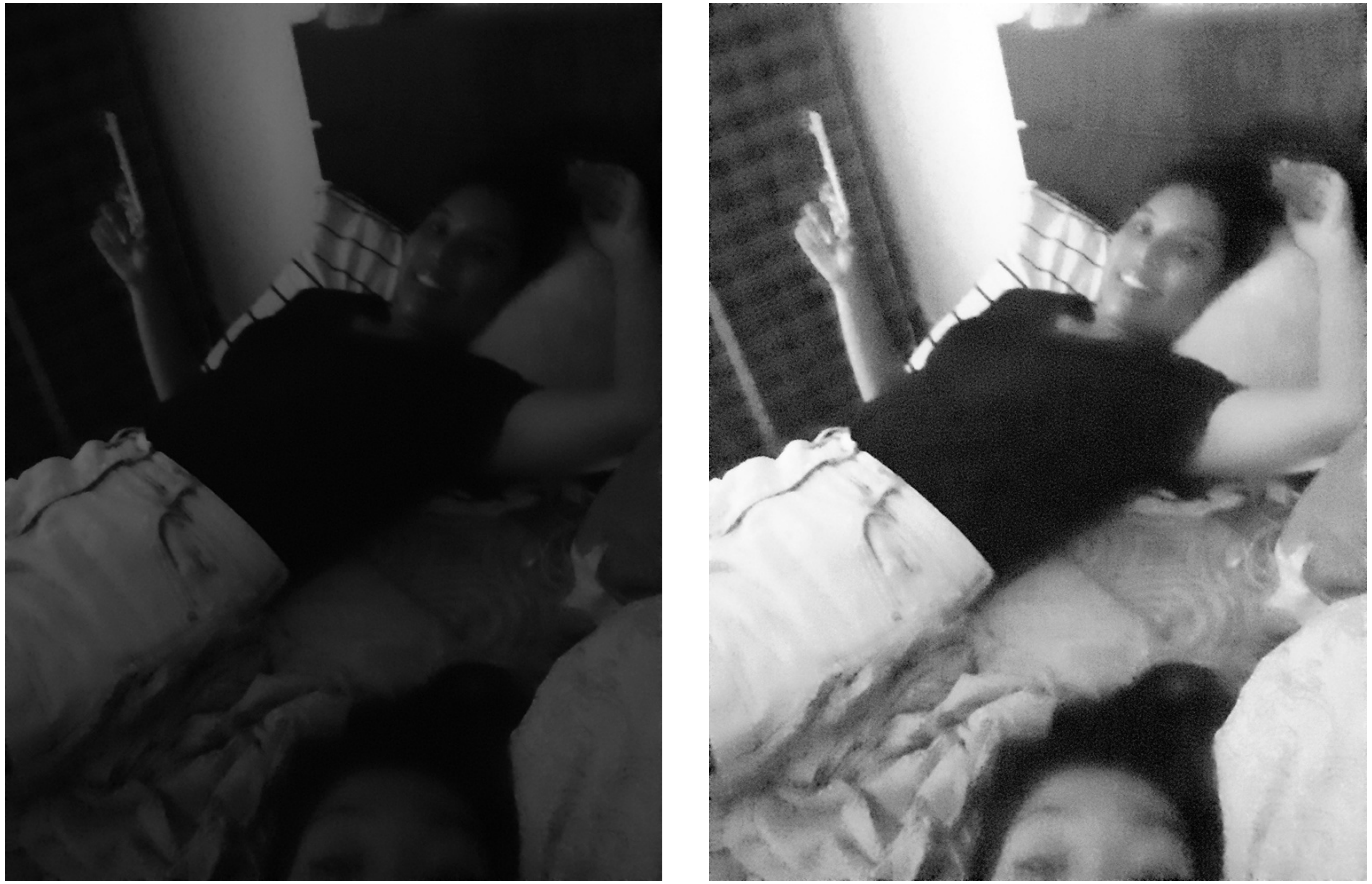


Figure 14. The original grayscale image (left) is enhanced through a linear CDF (right)

The backprojection using a linear CDF returned an enhanced and a sharper image. More details are much more visible in the backprojected image, like the patterns in the cabinet and the bed sheet.

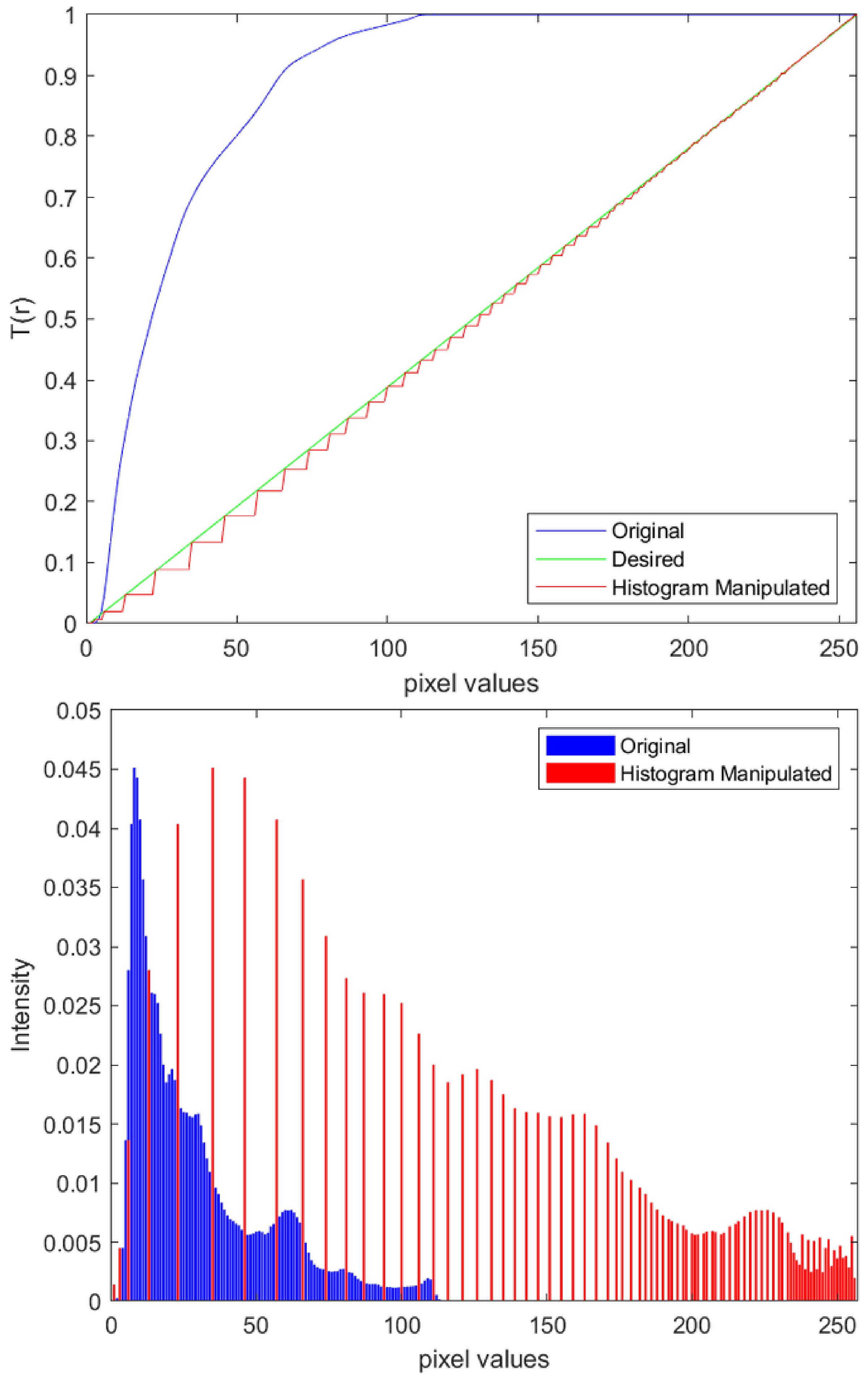


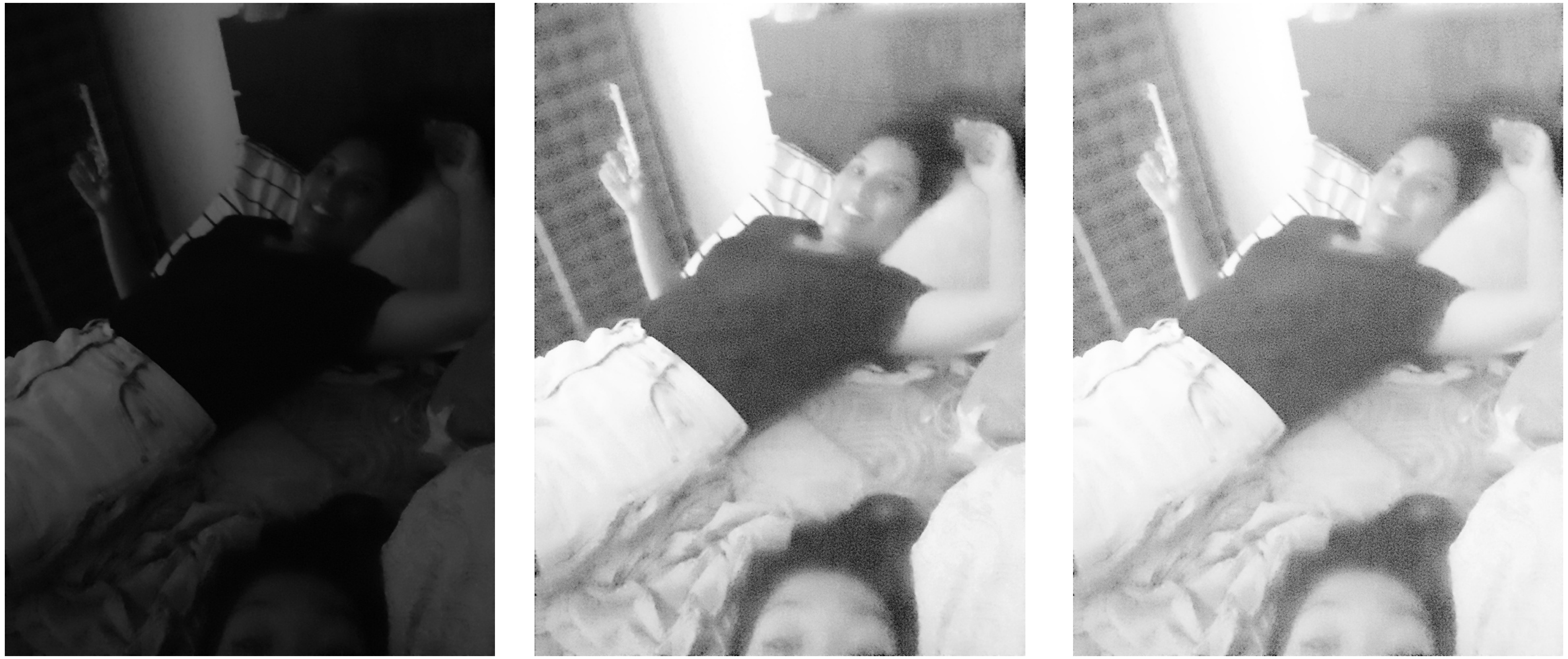
Figure 15. CDF (top) and Histogram (bottom) and of the original grayscale image and the back-projected image with desired linear CDF.

LINEAR CDF

The Cumulative Distribution Function (CDF) of the enhanced image mimics the desired linear CDF employed to enhance the image.

The Probability Distribution Function(PDF) of the enhanced image shows a more spread distribution.

QUADRATIC & CUBIC CDF

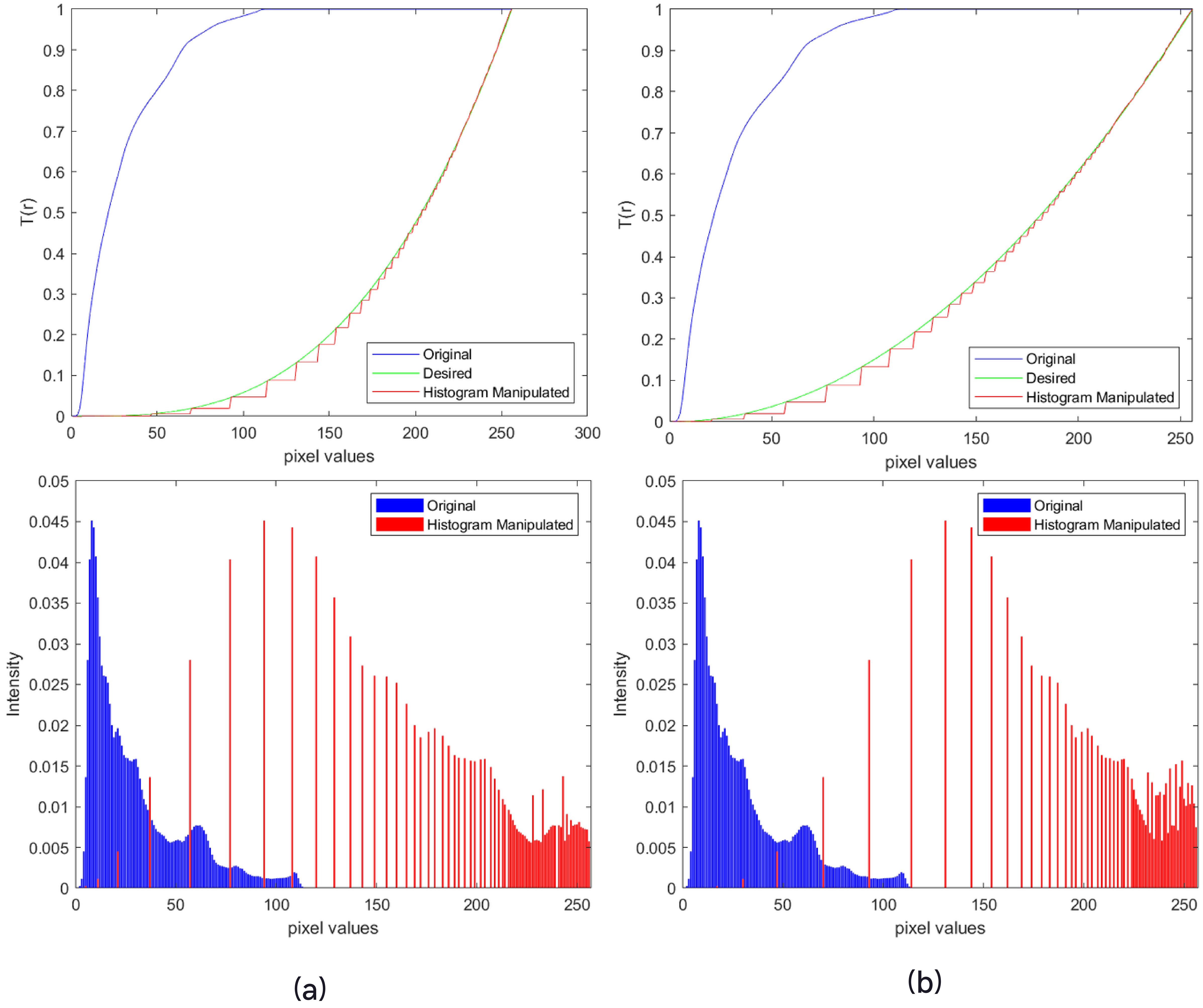


(a) (b) (c)

Figure 16. The (a) original grayscale image is enhanced through a (b) quadratic and (c) cubic CDFs.

Quadratic and cubic CDFs were also able to enhance and reveal the details in the dark image, though the contrast is not as high as in the linear CDF.

The images were brighter and with fading shadows.



The resulting CDFs resemble the ideal CDFs for the quadratic and cubic backprojections.

From the histogram data, we see the slow accumulation of dark pixels, thereby brightening the image. It is also observed that as the power increases, larger frequencies approach larger pixel values

Figure 17. CDF (top) and Histogram (bottom) of the original grayscale image and the back-projected image with desired (a) quadratic and (b) cubic CDF.

SIGMOID CDF

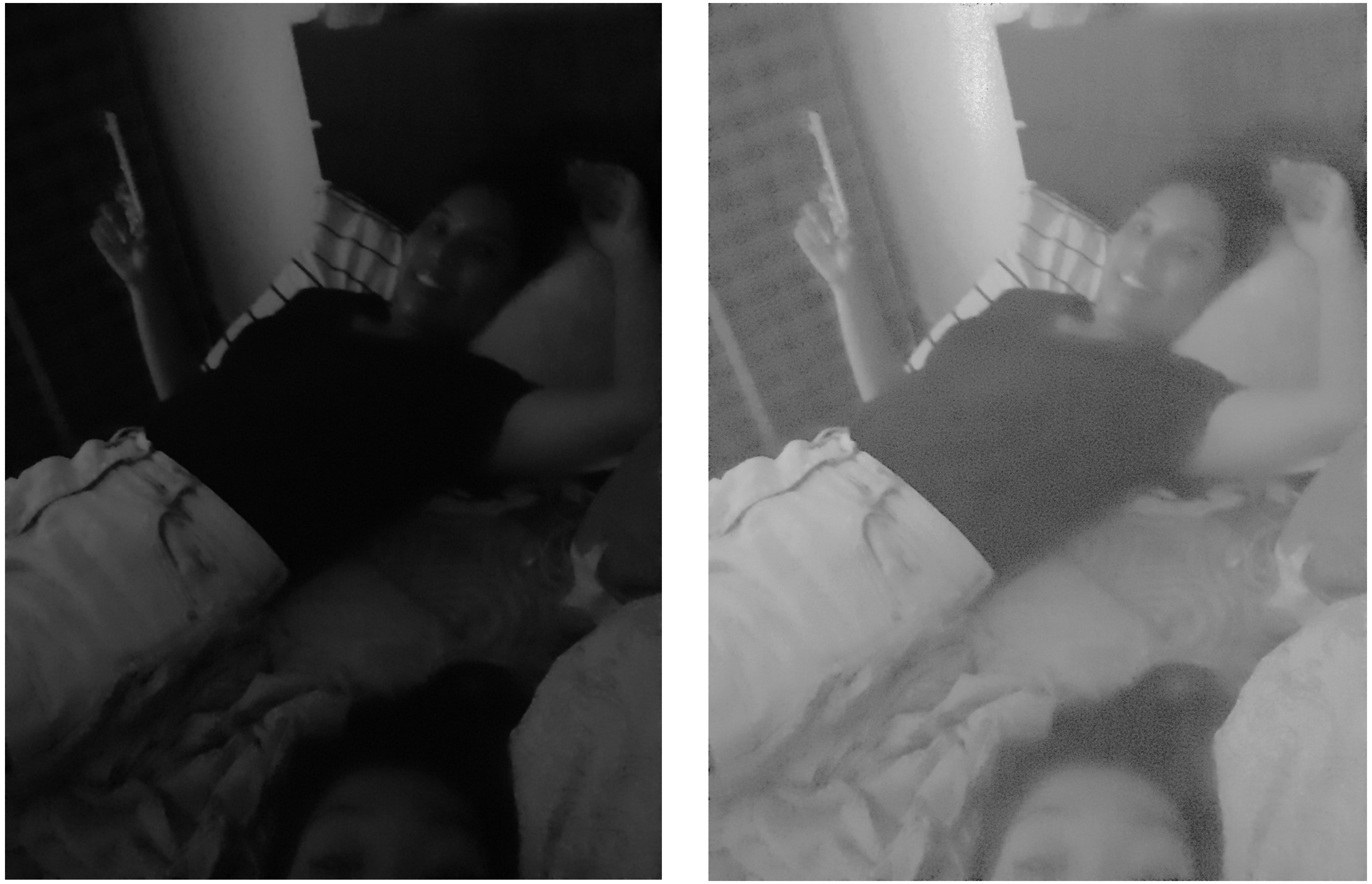


Figure 18. The original grayscale image (left) is enhanced through a linear CDF (right)

The image is also significantly enhanced using the sigmoid or erf CDF. The enhanced image, however, tends to be foggy in comparison with the other CDFs.

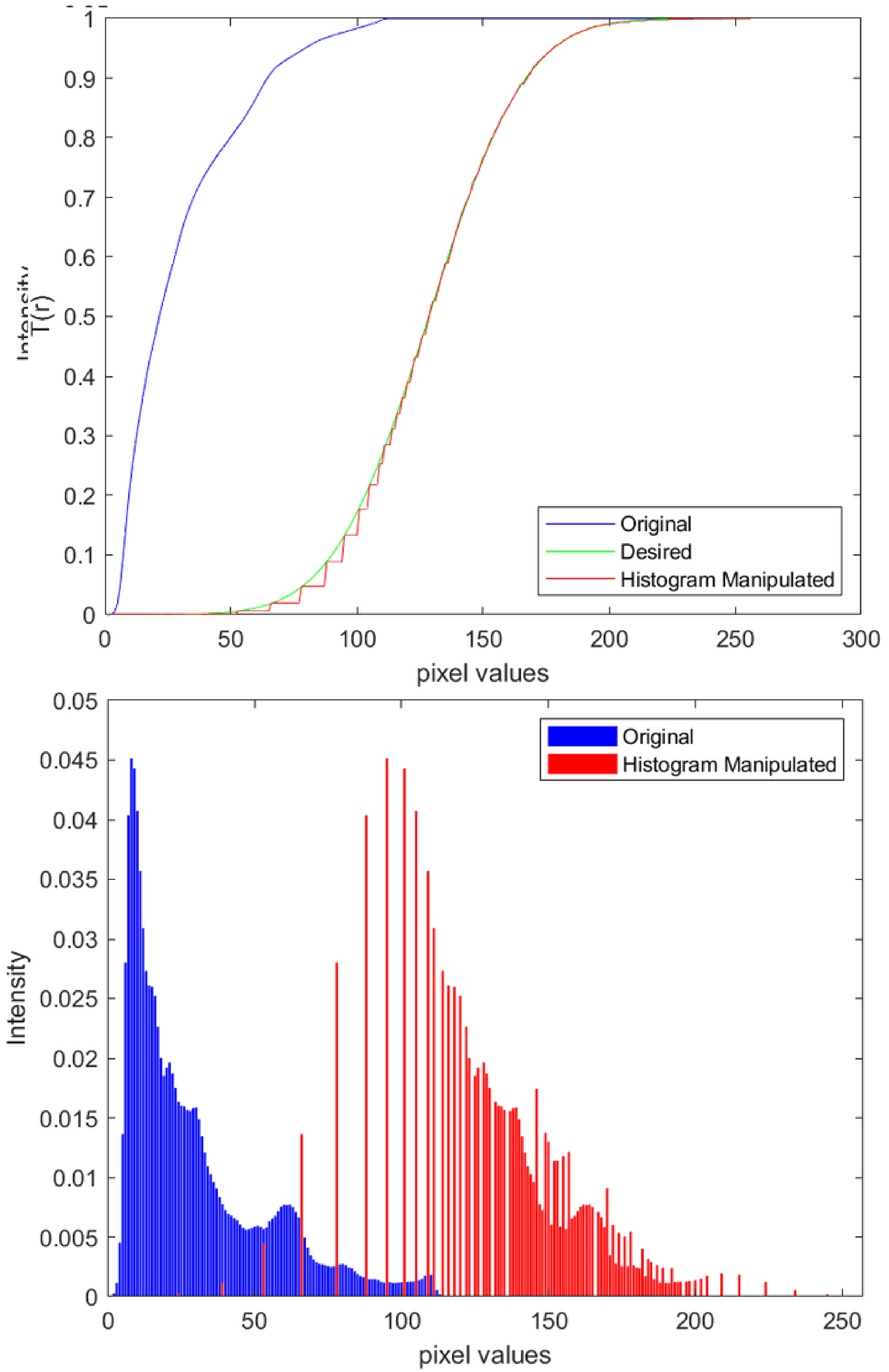


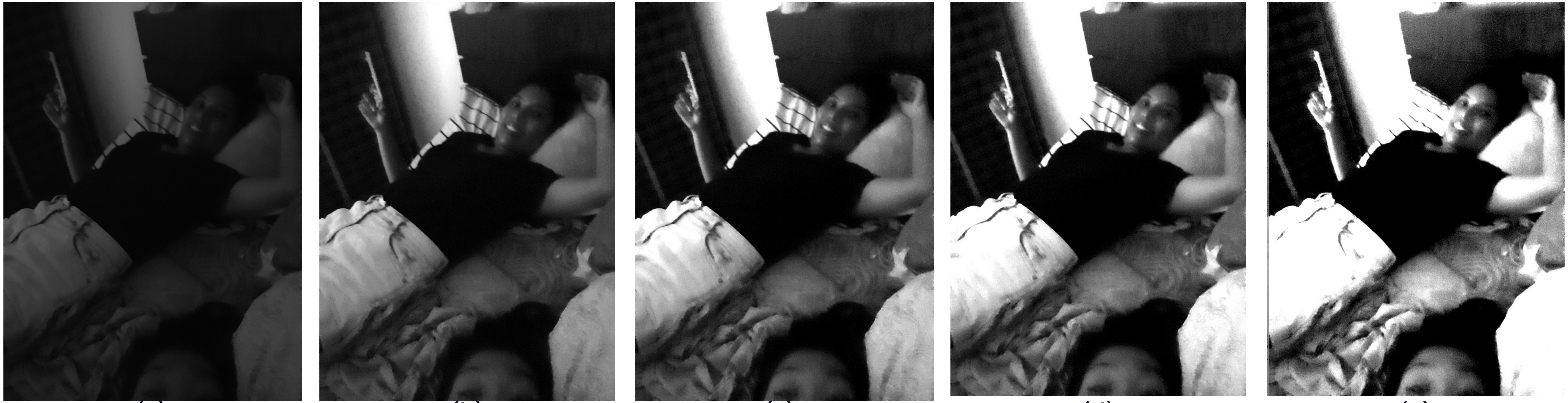
Figure 19. CDF (top) and Histogram (bottom) and of the original grayscale image and the back-projected image with desired linear CDF.

SIGMOID CDF

The resulting CDF of the enhanced image resembles the desired sigmoid CDF.

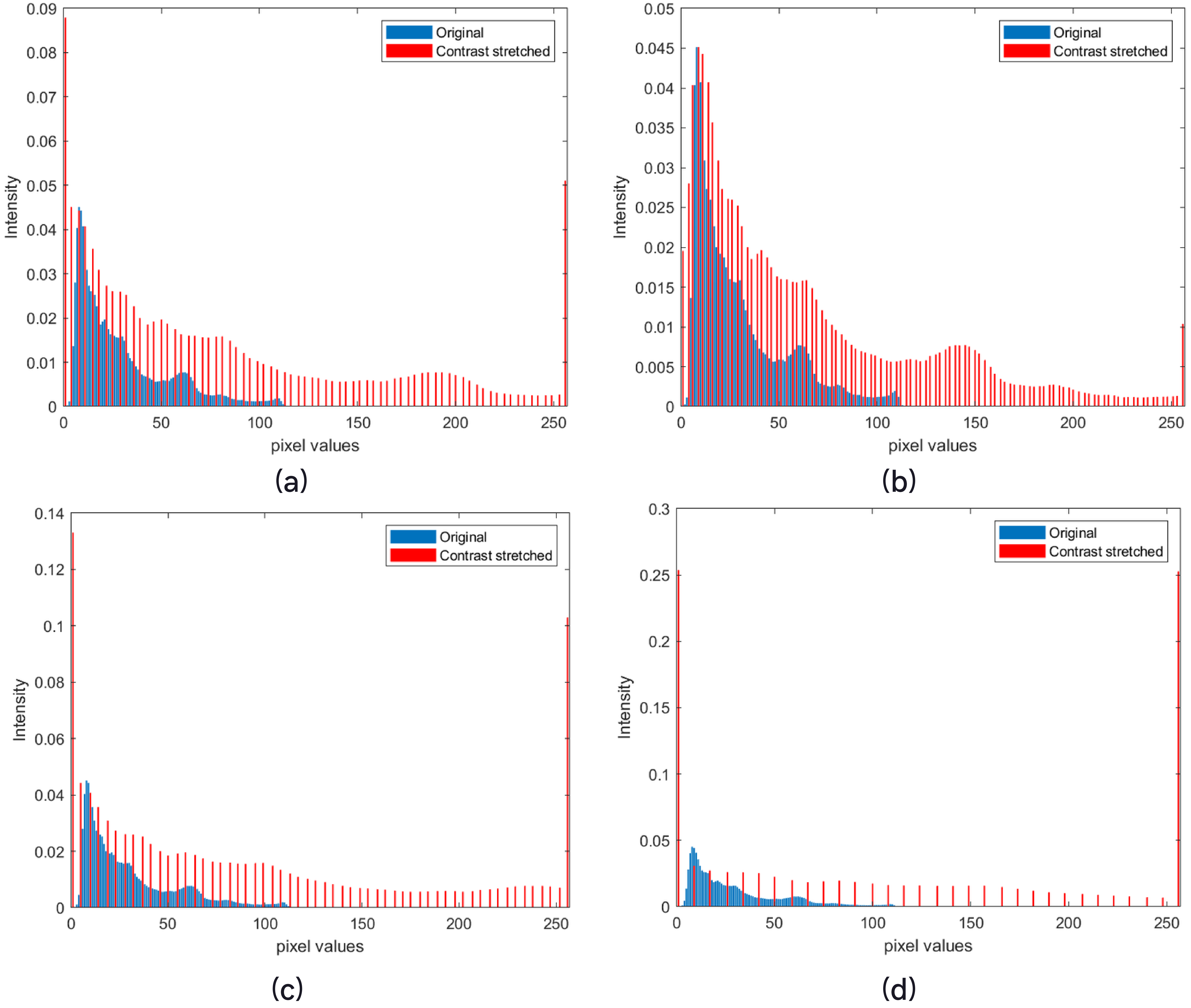
The PDF via the sigmoid function is concentrated to the gray pixels in the center, hence resulting in the low-contrast or 'foggy' enhanced image in Figure 18.

CONTRAST STRETCHING



(a) (b) (c) (d) (e)

Figure 20. Image transformation of the (a) original grayscale image via contrast stretching of different percentiles [lower, higher]: (b) [1,99] (c) [5,95] (d) [10,90], (e) [25,75]



As shown in Figure 21, contrast stretching normalizes the PDF of the original grayscale image to the certain range of values specified. This improves the contrast in the image

Figure 21. Histogram of the original grayscale image and the contrast stretched image for different percentiles: (a) [1,99] (b) [5,95] (c) [10,90], (d) [25,75]

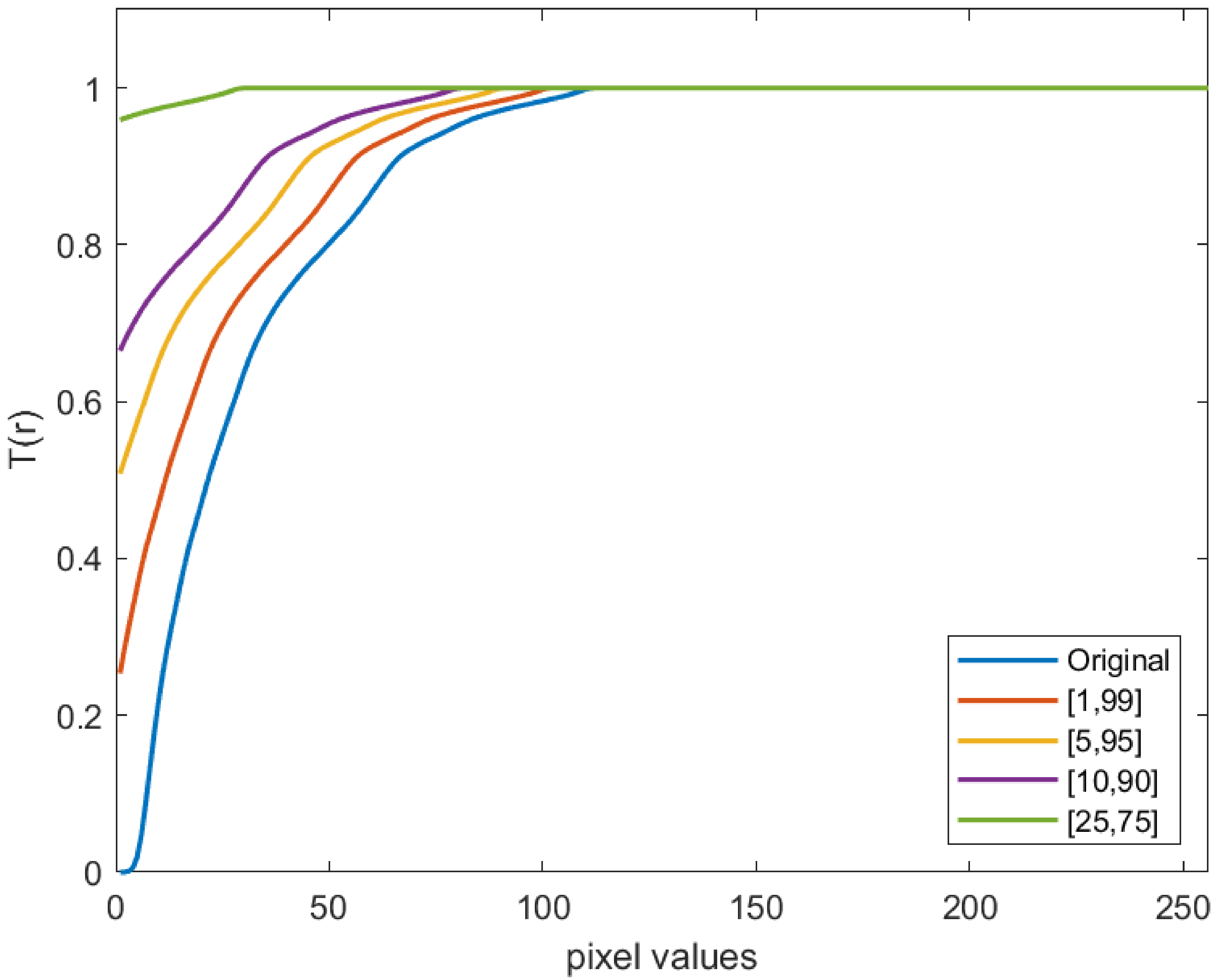


Figure 22. CDFs of the original grayscale image and the contrast stretched images shows the linear scaling of the contrast-stretching techniqueu

Contrast stretching only linearly maps the input and output values in the image, thus the enhancement of the images in Figure 20 is seemingly one-dimensional and less dramatic in comparison with the nonlinear histogram manipulation technique.

Figure 23. Photo that will be restored is my father's college class photo taken in 1991.

COLOR ENHANCEMENT

Restoration of faded photographs using various automatic white balancing algorithms.

(a) (b) (c)

Figure 24. Colored images can be separated into (a) red, (b) green, and (c) blue image channels.

CONTRAST STRETCHING


Figure 25. The individual color channels of the original image(left) are contrast-stretched and merged, resulting to the restored image(right). The restored image removed the bluish overcast that the original image had. Colors are also more vibrant in the restored image (e.g. colored shirts).

GRAY WORLD ALGORITHM

Figure 26. The individual color channels of the original image(left) are scaled and normalized, resulting to the restored image(right). The restored image has a completely different overall hue from the original image.

WHITE PATCH ALGORITHM

Figure 27. For the white patch algorithm, a white region (boxed red) is taken from the original image (left) as a scaling factor to enhance the image. This results to a brighter image (right), most noticeable on the white-colored regions in the image (e.g. sky, white shirts)

(a)

(b)

(c)

(d)

Figure 28. The (a) original faded image restored using (b) contrast-stretching, (c) gray world algorithm, and (d) white patch algorithm

Each algorithm noticeably enhanced the faded image with different end results.

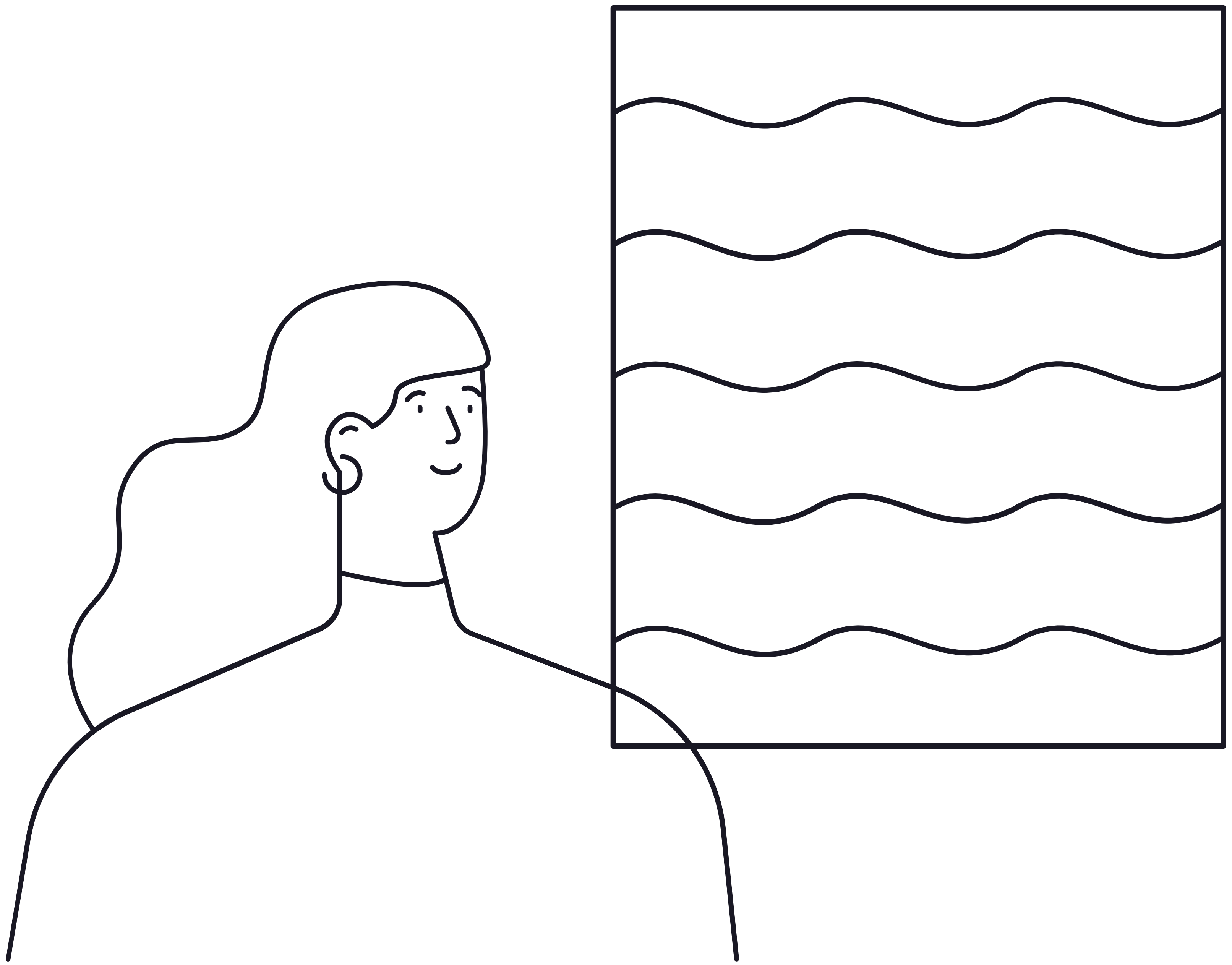
For this particular image, the white patch algorithm performed best, as the resulting image is brighter in comparison to the two other image, given that the image is also predominantly white.

Reflection

I was able to compare my results as well as gain insights from blogs of previous batches on AP186. They were very helpful guide. This activity was honestly frustrating code-wise, since I tried to use Matlab, which is pretty unfamiliar to me. Additionally, most of the error that comes from the syntax errors, I think I'll stick with Python notebooks, since I'm partial to its format.

Additional problem that I encountered was the creation of Olympic logo. This was the very last activity that I was able to do. When I already got the desired results, it was very satisfying.

Overall, I think this was a very rewarding and fascinating set of activities.



Self-Grade

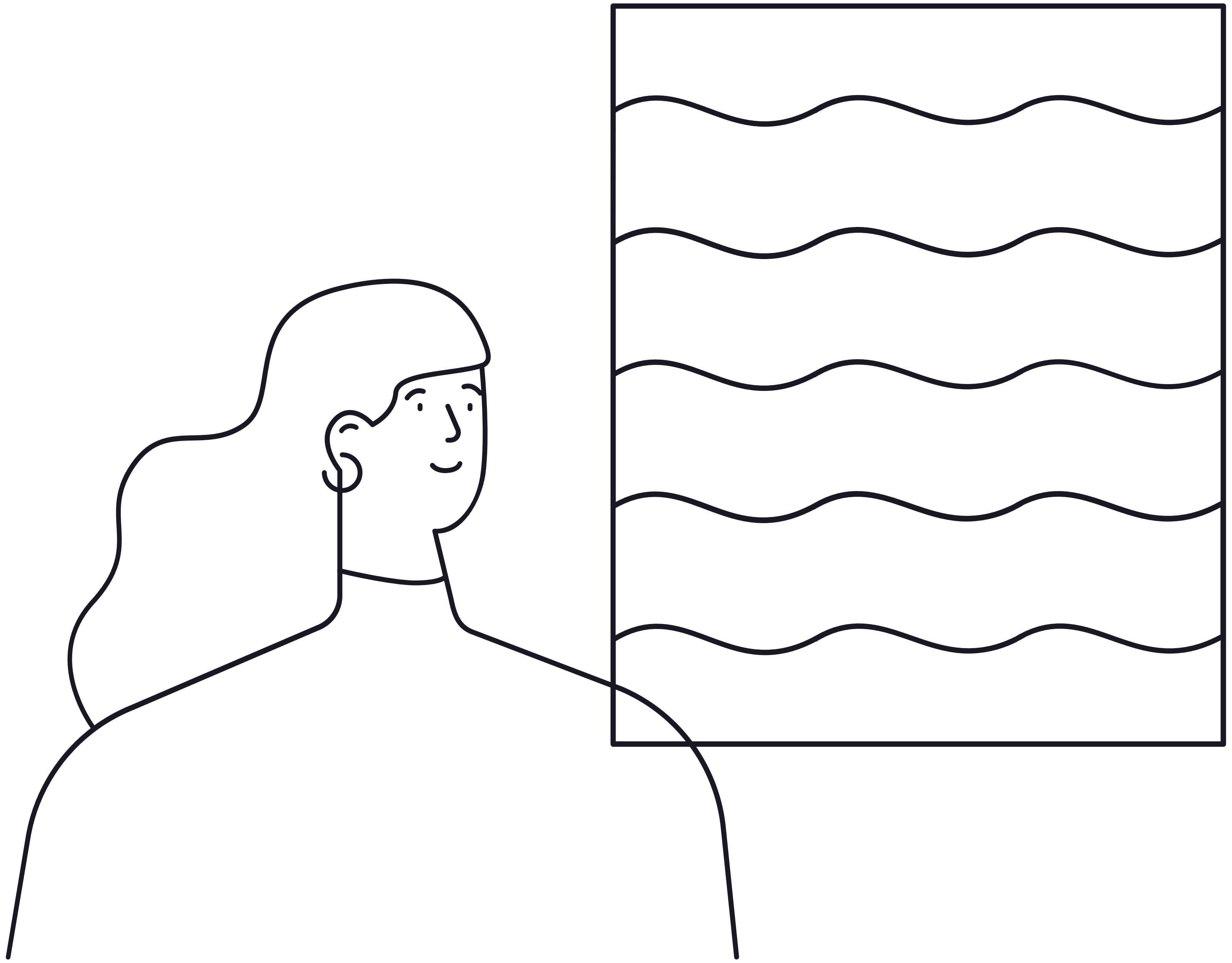
I give a score of 33.3 for technical correctness. I was able to complete all objectives and activities. I was also able to learn a lot with this activity

I give myself a score of 28.3 for the quality of the presentation. The figures were captioned and labeled properly and I have included the links for the code in the appendix. I did not give myself the full score since I think I used too many slides for this to be considered a short presentation, and it is not as uniform across each subtopic.

I give 33.3 percent for self-reflection since I acknowledged some mistakes and resources. I also followed the criteria for self-evaluation.

Lastly, I give a bonus of 1 point for the additional synthetic images I made.

Total score I give myself is 96.



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APPENDIX

Codes and images : link