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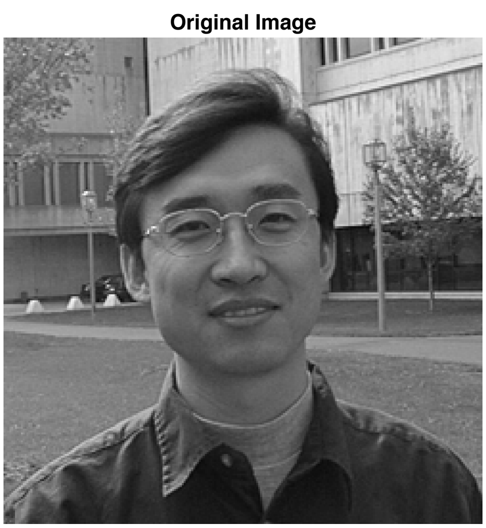
CSC I6716
Assignment 2

Question 1

An image histogram is a graphical representation of the number of pixels in an image as a function of their intensity. An image histogram discards the spatial information and shows the relative frequency of occurrence of the gray values. Histograms are made up of bins with each bin representing a certain intensity value range. A histogram is computed by examining all pixels in the image and assigning each to a bin, depending on the pixel intensity. The final value of a bin is the number of pixels assigned to it.

I created the intensity image of IDPicture.bmp by using the formula I = 0.299 * Red + 0.587 * Green + 0.114 * Blue and generated its histogram.



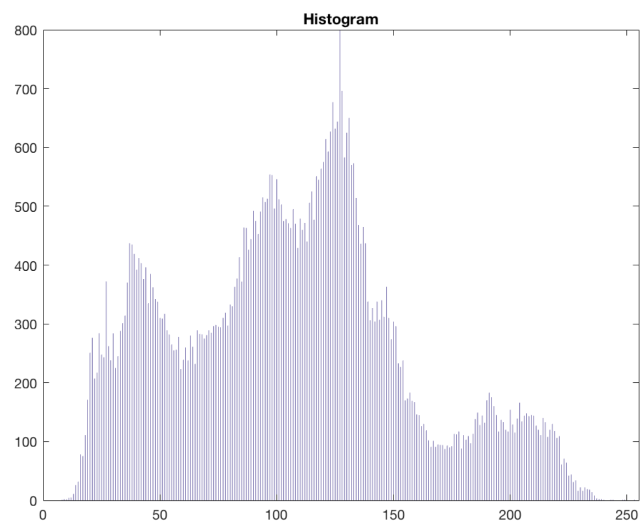


Figure 1. Intensity image and corresponding histogram

A histogram has peaks, which represent many pixels concentrated in a few gray levels and plains, which represent a small number of pixels distributed over a wider range of gray levels. In the histogram of the original intensity image we see that the most pixels are concentrated in the gray levels between approximately 80 and 130.

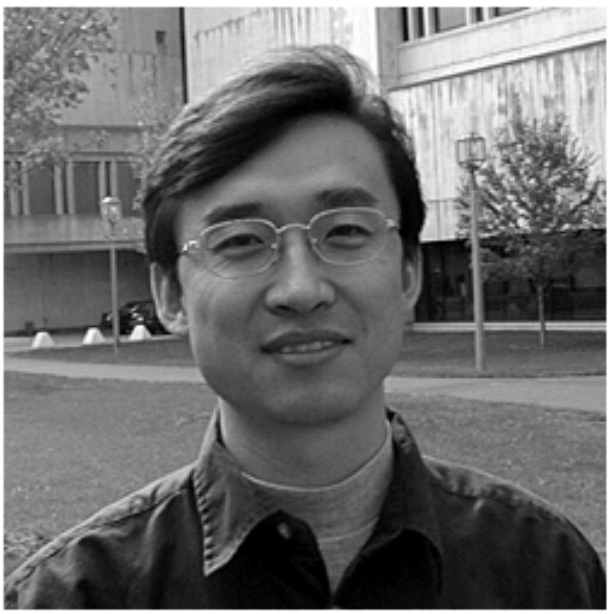
The histogram operations: contrast enhancement, thresholding, and histogram equalization are performed.

I. Contrast Enhancement

Images with low contrast have pixel values concentrated near a narrow range of gray values. Using contrast enhancement we can change image value to cover a wide range.

- Linear Stretch

  Using the intensity image histogram in order to determine the original range of gray values I transformed the image using the function $g(f) = af + b$. The original gray values ranging from [s_1 s_2] are mapped into the desired range [t_1 t_2], where $g(f) = \frac{(f-s_1)*(t_2-t_1)}{(s_2-s_1)+t_1}$. From the original image histogram the gray values range is [20, 230] and the desired range is [0, 250]. Therefore, $g(f) = \frac{(f-20)*255}{210}$. The linearly transformed image has a higher contrast than the original.



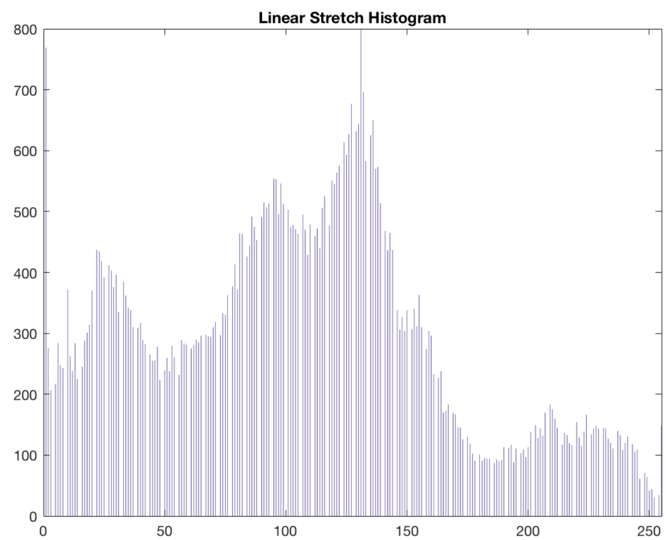


Figure 2. Linear stretch image and corresponding histogram

II. Thresholding

Image thresholding is a segmentation technique, which converts grayscale images into binary images. An image is transformed using the function $f(x) = \begin{cases} I_{max}, & I(x,y) > T \\ I_{min}, & I(x,y) \leq T \end{cases}$

As can be observed from the image and the histogram, the only pixel values available for this image are 0 and 255, black and white.

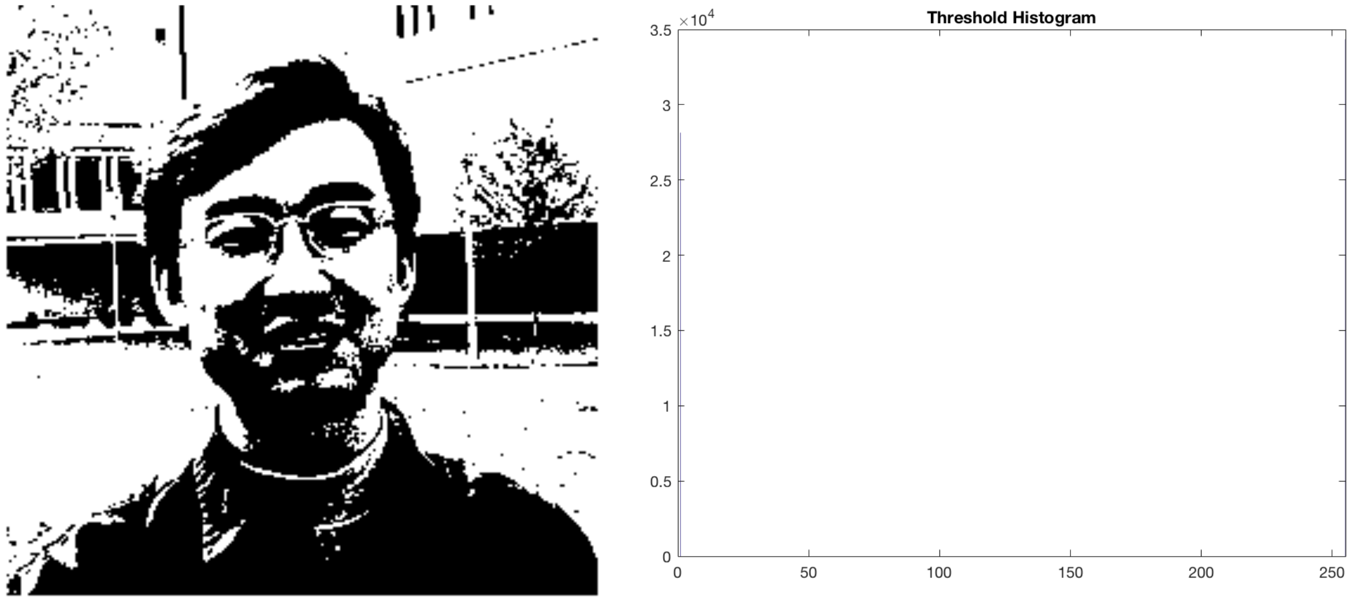


Figure 3. Threshold image and corresponding histogram

III. Histogram Equalization

Using histogram equalization we can modify the gray levels of an image so that histogram of the modified image is flat. Histogram equalization is also a method that improves the quality of the image by enhancing the contrast – by mapping the distribution of the original histogram to a more uniform distribution of intensity values.

The number pixels occupying each level will be ideally be $N_p = \frac{MN}{Gray\ Levels}$.

The output is equal to the cumulative histogram divided by N_p.

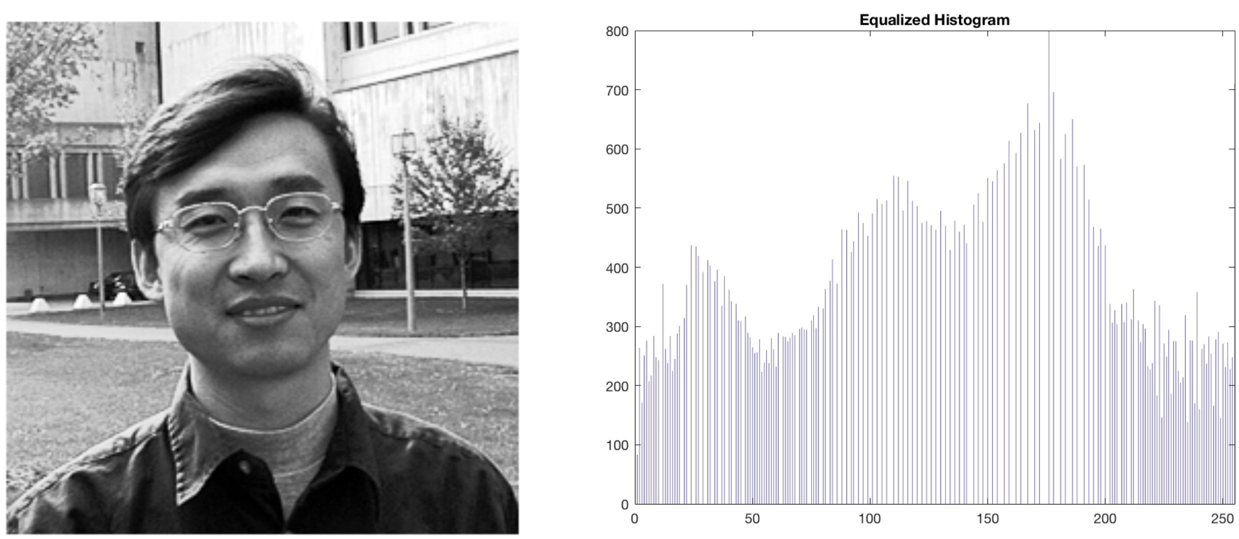


Figure 4. Equalized image and corresponding histogram

Because a histogram is an approximation to the probability density function, perfectly flat histograms are rare in histogram equalization.

Question 2

An edge in computer vision is defined as a rapid change within a local set of pixels. An edge, as a rapid change in an image function, results in a high local gradient, and therefore we can develop an edge detector using differentiation. Below I apply the sobel edge detector and the 1x2 edge detector, two first derivative operators.

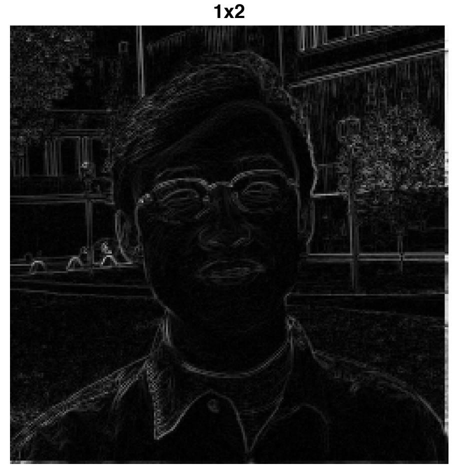
The Sobel edge detector kernel is defined as:

$$\text{x-direction} = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad \text{y-direction} = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & -2 \\ -1 & 0 & 1 \end{bmatrix}$$

The 1x2 edge detector kernel is defined as x-direction= $\begin{bmatrix} 1 & -1 \end{bmatrix}$ y-direction= $\begin{bmatrix} 1 \\ -1 \end{bmatrix}$

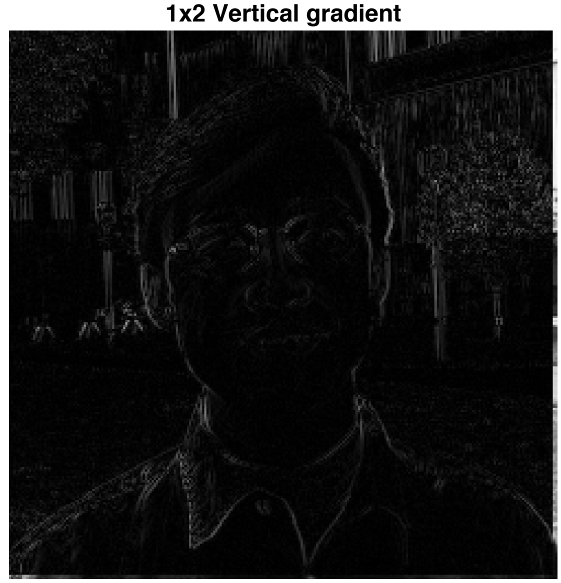
Sobel gradient

1x2



Vertical Sobel gradient

1x2 Vertical gradient



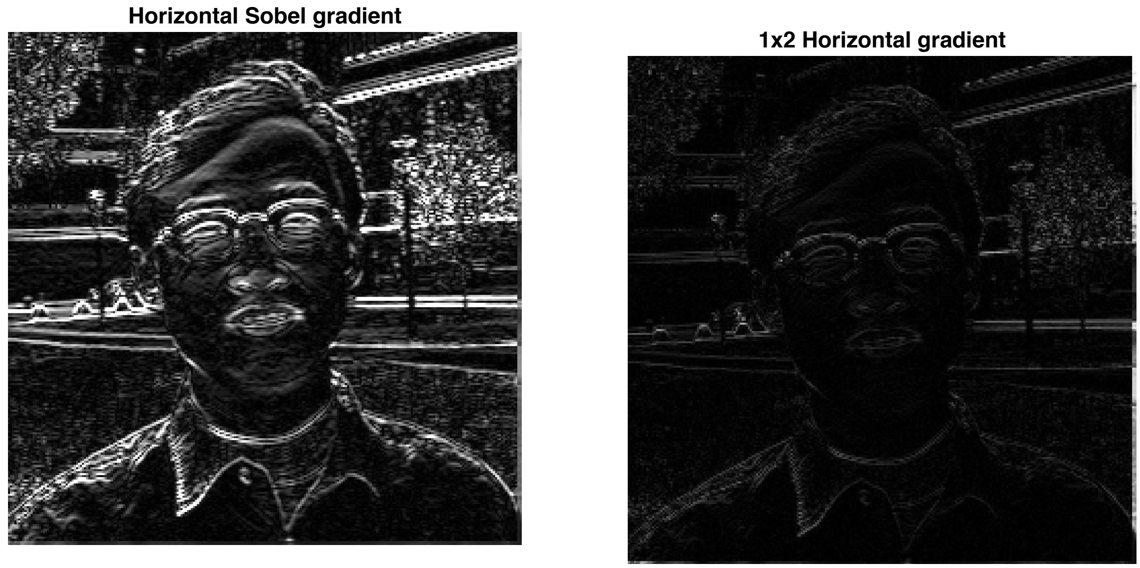


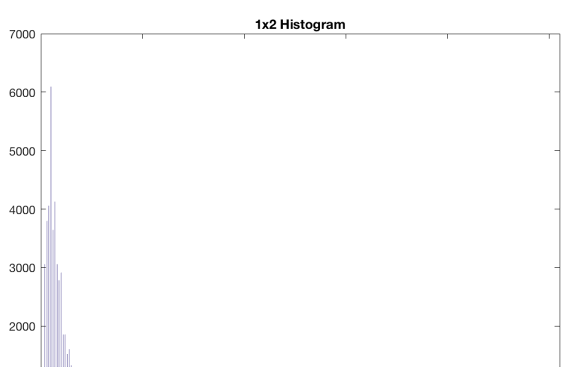
Figure 5. Gradient magnitude images from each kernel

When applying a horizontal or vertical kernel only the respective gradient is calculated, which leads to detecting only the horizontal or vertical edges. By comparing the combined sobel with the combined 1x2, the horizontal sobel with the horizontal 1x2 and the vertical sobel with the vertical 1x2 it can be observed in all cases that the sobel operator is more accurate than the 1x2 operator. This is because the 1x2 operator is very sensitive to noise. By combining the 1x2 operator with an average mask better edge detection can be achieved (as in the case of the sobel operator).

Question 3

Edge maps are generated by turning a gradient image into a binary image, through thresholding. By using the histograms of the sobel and 1x2 gradient images we can choose a threshold level.

In the histogram of the 1x2 gradient image all the peak values are approximately in the 0-50 range, so I chose a threshold value of 35 so that the pixels with the highest gradient values are edges. In the histogram of the sobel gradient image the peak values are approximately in the 5-150 range, so I chose a threshold value of 120. Because many edges can be buried into noise, thresholding helps to determine which edges pixels should be discarded as noise and which should be retained.



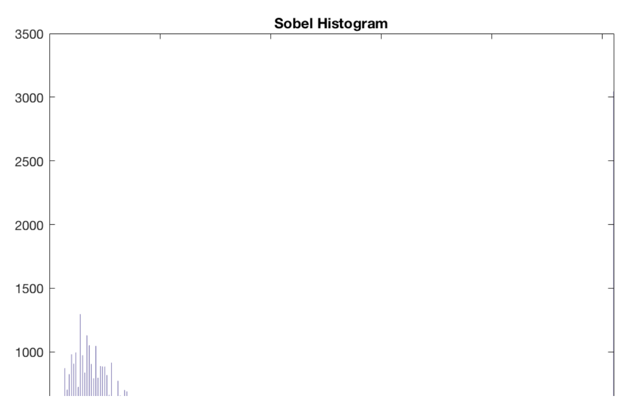


Figure 6. Histograms for the 1x2 and Sobel Edge images, respectively

Figure 7. 1x2 and Sobel edge maps

By comparing the 1x2 edge map with the sobel edge map it can be seen that the sobel operator is more accurate than the 1x2 operator. The reason for that is because since the 1x2 kernel takes the difference of consecutive pixels it is more sensitive to noise. A 3x3 kernel such as the sobel operator will always be more accurate than smaller kernels.

Question 4

As observed above, a 3x3 kernel will always be more accurate than smaller kernels but will be more computationally expensive. Increasing the kernel to 5x5 or 7x7 will result in thicker edges but will be less sensitive to noise. This is because the 1x2 kernel relies on the difference between two consecutive pixels in the horizontal and vertical directions. A larger kernel such as the Sobel operator is the result of combining the 1x2 kernel with an averaging mask. The larger convolution kernel will smooth the input image and so make the kernel less sensitive to noise.

1x2 Kernels:

x: $\begin{bmatrix} -1 & 1 \end{bmatrix}$ y: $\begin{bmatrix} -1 \\ 1 \end{bmatrix}$

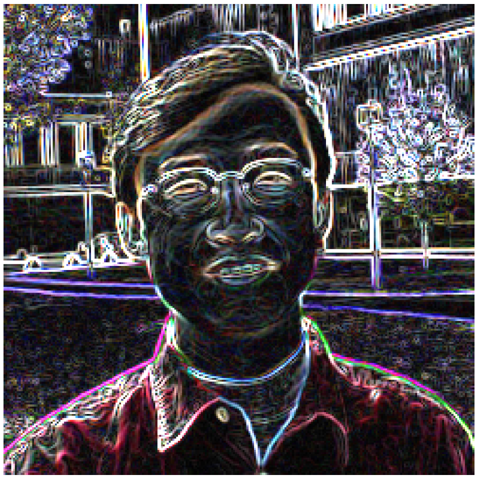
Sobel Kernels:

$$x: \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \quad y: \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & -2 \\ -1 & 0 & 1 \end{bmatrix}$$

Question 5

In order to develop an edge detector to an RGB image I applied the sobel kernel to each color band of the image and concatanated the three color gradient bands which produced the color sobel gradient image below. In order to generate the grayscale edge map I found the intensity image of the rgb sobel gradient image and using its histogram to chose a threshold value of 120 I transformed it into a binary edge map.

Color Sobel



RGB Sobel Threshold

RGB Sobel Intensity

RGB Sobel Intensity Threshold

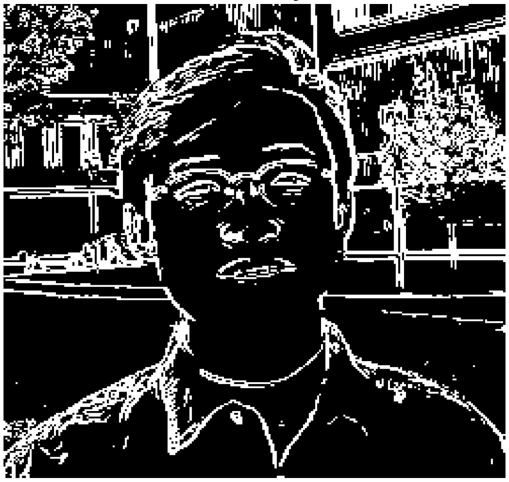


Figure 8. RGB sobel images & corresponding edge maps

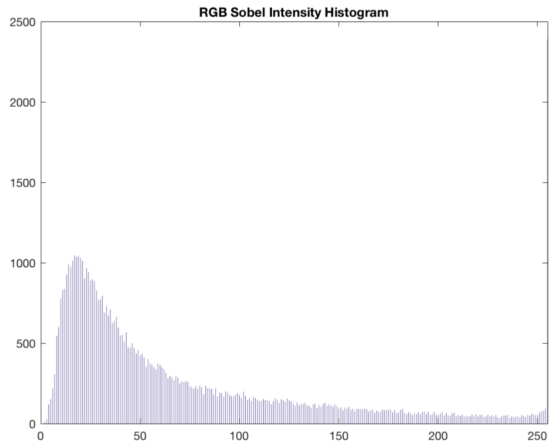


Figure 9. Histogram for RGB sobel image

By comparing the sobel edge maps created using the RGB image and the intensity image we see that there is no visible difference between the two edge maps.