LAB #4 Report Shuchen Zhang (szhan114)

Introduction:

In this lab, we generate several artificial images to learn how the human visual system works to process images. Artificial images with vertical and horizontal mach bands, sinusoid grating, center/surround fields for simultaneous contrast were implemented. In order to examine Weber's Law, several experiments were performed by tuning the pixel intensity of center and surround boxes and see the difference in response of eyes.

In Part A1 and A2, both horizontal and vertical mach bands were implemented in the artificial images. The intensity discontinuities that exist at the boundaries between bands cause overshoots and undershoots in perceived brightness. To explain this phenomenon, we could first look at what is going on in visual system when eyes perceiving luminance information. There are receptors located on the surface of retina which is capable of absorbing light and initiating neural response. The ganglion cells generate electric pulses that are transmitted to the visual cortex via optic nerves. When excited by a light stimulus, amacrine and horizontal cells use their lateral connections to reduce the signal from adjacent cells. This is the phenomenon of lateral inhibition. In mach band effect, there's spatial high-boost filtering performed by visual system and the luminance of the image is captured by the retina with lateral inhibition happens among neurons. Lateral inhibition makes the dark area falsely seems even darker and lighter area falsely appear even lighter.

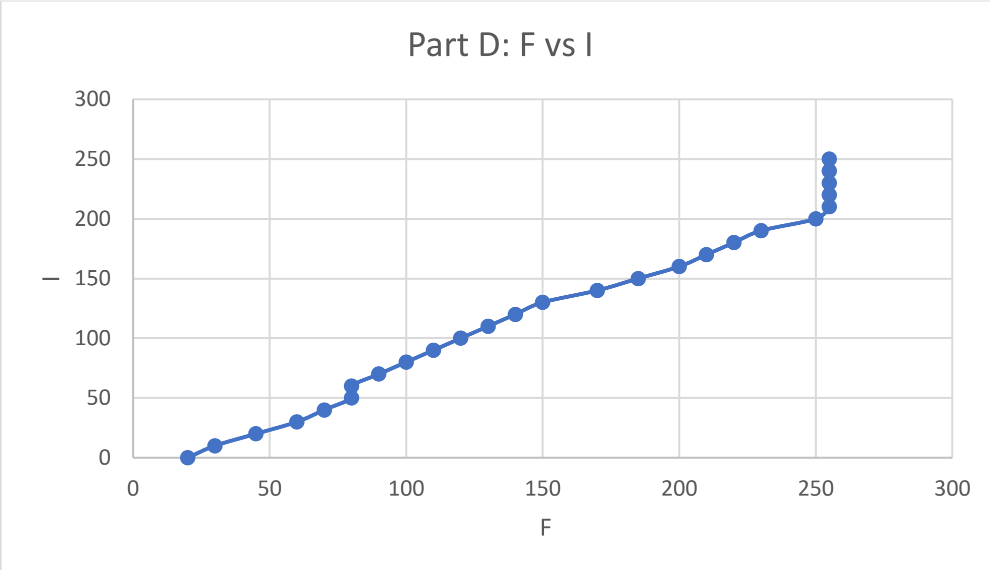
In Part B, we generate artificial image using sinusoidal grating. This method can be used to analyze the frequency response of the eye. The contrast is the strongest in the frequency range between 0 to pi/24. As the amplitude increase, the contrast of bright and dark color band are more obvious, and the frequency range for strong contrast will increase. The strong contrast region will expand toward right. Modulation Transfer Function which is defined as magnitude response of the optical system to sinusoids of different spatial frequencies. Modulation Transfer Function is a decreasing function of spatial frequencies. As spatial frequency increase, the magnitude response of optical system will decrease. As I am at greater distance from computer monitor observing the grating image, the contrast of bright and dark will be less obvious especially for the high spatial frequency region.

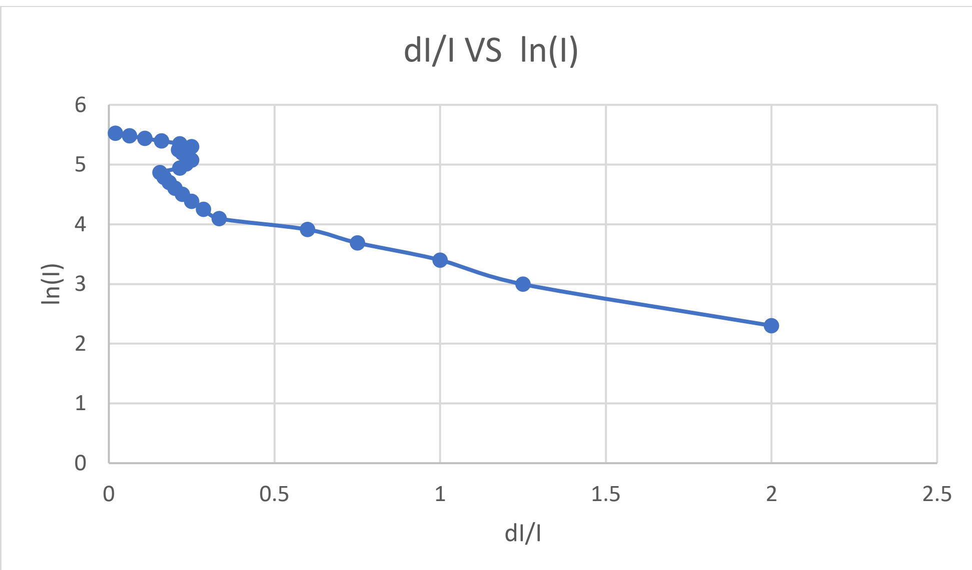
In Part C, a 512x1024 image is generated with two "outer squares" side by side and two 64x64 squares centered inside of the corresponding outer square. I tried all the combination of intensities 0,128,255 for X(background intensities) and S1(surround intensities). I found that even if small squares in the center have equal pixel intensity but they appear to have different brightness if they are within different surround color. For instance, for X =128, S1 = 255, S2 = 0. The square on the right which is within the black surrounding square appear to be have lighter grey color(brighter) than the one within the white surrounding square.

In Part D, compared to part C, we generate an outer square with surround intensity I with a much smaller square in the center with foreground intensity F. The difference between F and I is denoted as dI = F-I. I examine the dI for I =0,10,20…250, for dI value selected based on whether I notice the difference of F and I. The F vs I table and dI/I vs ln(I) table is shown below as well as the plots:

di/I	ln(I)
0	0
2	2.302585
1.25	2.995732
1	3.401197
0.75	3.688879
0.6	3.912023
0.333333	4.094345
0.285714	4.248495
0.25	4.382027
0.222222	4.49981
0.2	4.60517
0.181818	4.70048
0.166667	4.787492
0.153846	4.867534
0.214286	4.941642
0.233333	5.010635
0.25	5.075174
0.235294	5.135798
0.222222	5.192957
0.210526	5.247024
0.25	5.298317
0.214286	5.347108
0.159091	5.393628
0.108696	5.438079
0.0625	5.480639
0.02	5.521461

F	I
20	0
30	10
45	20
60	30
70	40
80	50
80	60
90	70
100	80
110	90
120	100
130	110
140	120
150	130
170	140
185	150
200	160
210	170
220	180
230	190
250	200
255	210
255	220
255	230
255	240
255	250





The plot I get is not exactly consistent with Weber's law, but it does show some similar patterns. For I that is very small, the Weber ratio which is dI/I increases. For I that is very large, due to the limitation of pixel intensity (maximum at 255), Weber ratio which is supposed to be large is not showing increase. But it is harder for me to tell the difference between F and I if the dI is small for very large I. This is consistent with Weber's Law.

Three important applications that require a model of spatial frequency response of the eye:

1. Fingerprints recognition by computer. Computer need to be capable of differentiate one fingerprints from another by noticing the difference in the fingerprints shape and its dark and light curving patterns.
2. Barcode imaging using a light field camera. Barcode contains black lines of varying width and distance from one another containing important information about items.

When we need to estimate the barcode depth directly from the raw sensor image, we need to characterize the relationship between depth and the code's spatial frequency.

3. Facial recognition. Spatial frequencies are important in recognition faces which requires similar functions as human eye to fast process the facial information. Spatial frequencies should be carefully selected to increase accuracy.

Conclusion:

In this lab, we learn how the human visual system process images by examining the eye response of several artificial images generated with methods of mach bands, sinusoid grating, center/surround fields for simultaneous contrast. Through this lab, we examine the Weber's Law and learn the importance of spatial frequency response model of human eye in computer vision applications.