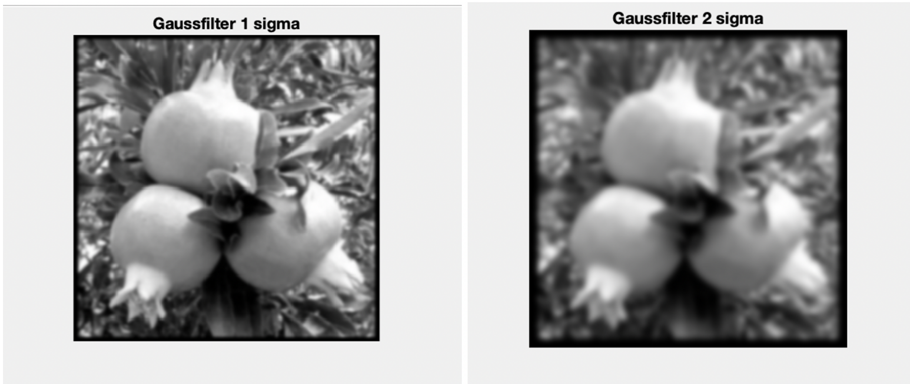
Lab work Lecture 1:
Simulating receptive fields (I)

1. Gaussian kernel:

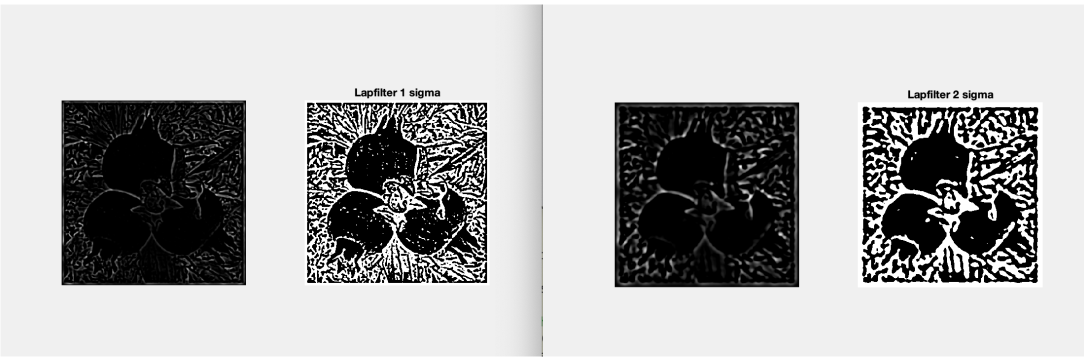
Gaussian kernels with σ=1 and σ=2. The *conv2* is applied to convolve one image (in this case one of the color components of an RGB color image is used) with each kernel and display the image and convolution results.
The results show below:



We can see gaussian kernel with σ=2 give us more blur image after convolution. It means that higher sigma value has higher ability of smoothing.

2. Laplacian of Gaussian kernel: Ganglion cells

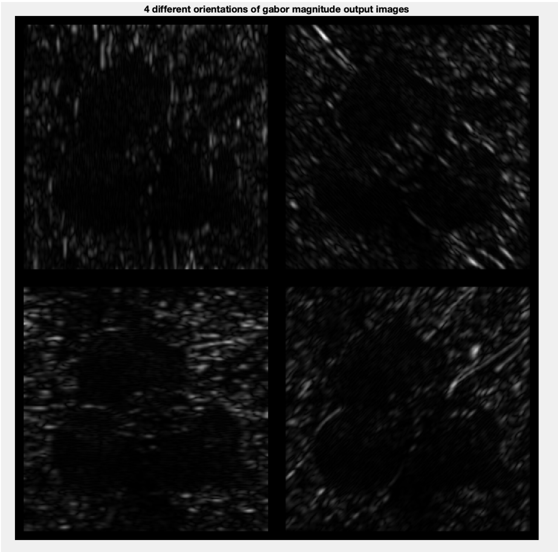
The second derivative changes sign (crosses zero) at the locations of intensity changes in the original image. The process of finding the locations of these intensity changes is often referred to as "edge detection"
The results show below:

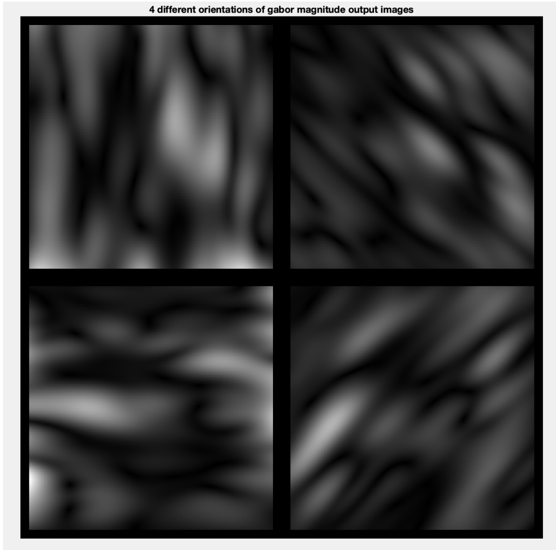


We can see the Laplacian with high sigma value give us less detail information about images. It means that less detail about edge of images being detected. It allows us easy to distinguish the interested area from the background. Larger sigma values means that the larger scale edges are detected.

3. Gabor kernel: Simple cells

The Gabor function can be simulated to represent the spatial receptive field of simple cells in V1 area of human visual system since gabor filter is able to extract features from different orientation and different scales.
The results show below:



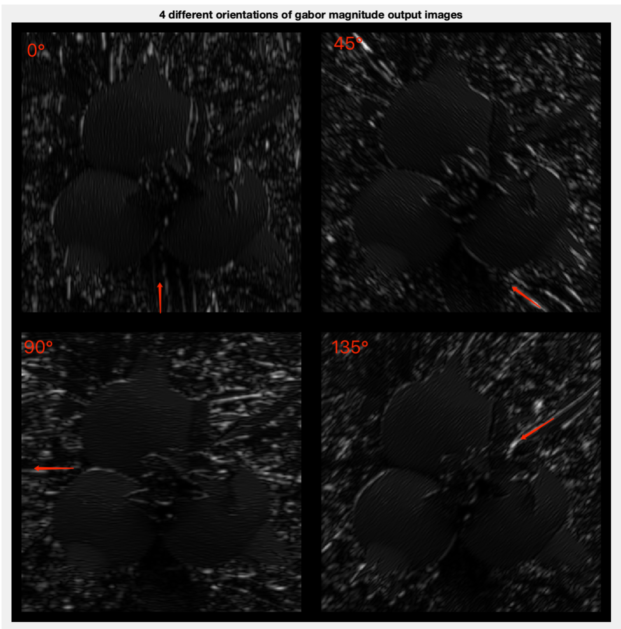


The build-in gabor filter function *g* = *gabor((wavelength,orientation)* and *outMag* = *imgaborfilt(A,g)*. The *g* is gabor filter and imgaborfilt is gabor filter operation. We set *wavelength* = 4 (in pixel) and *orientation* are [0, 45, 90, 135] in degree.

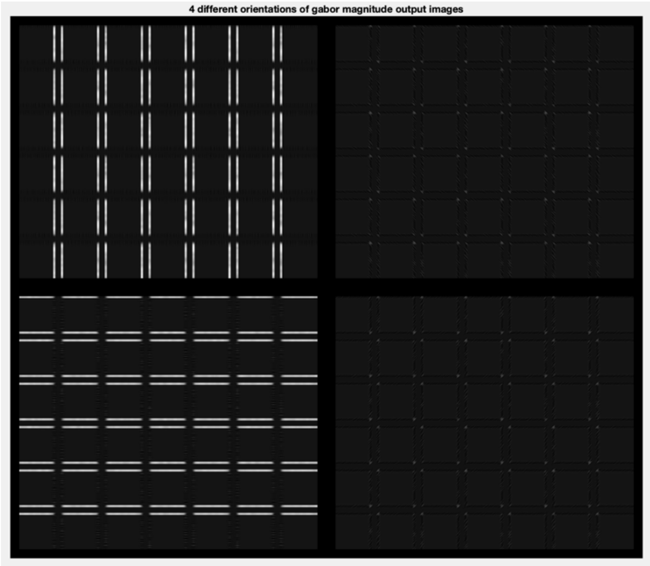
The wavelength here are more like scale effect, the higher wavelength means bigger size of filter. It means we get from local feature to global feature if we keep increase the value of wavelength. For example, the left image above use wavelength = 4 and right image use wavelength = 40, which is 10 times difference. We can notice that right image focus more on outline information of image.

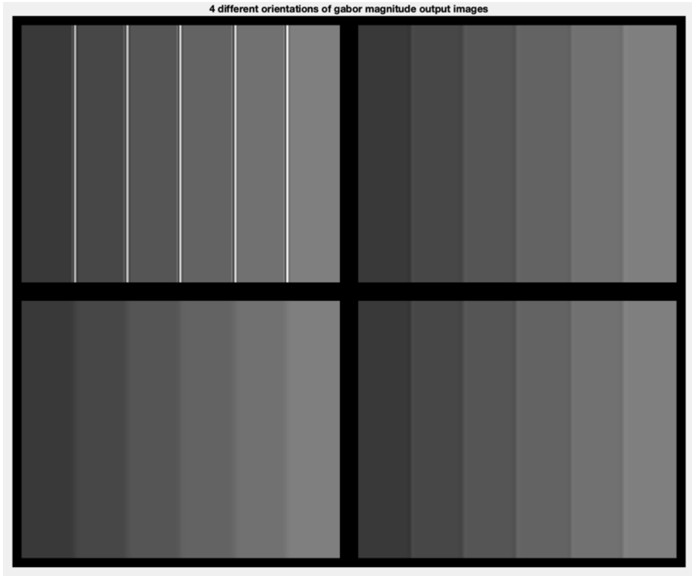
There are also two other parameters for gabor function. The spatial-frequency bandwidth determines the cutoff of the filter response as frequency content in the input image varies from the preferred frequency. Values typical of the receptive fields of simple cells lie between 0.4 and 2.5. Aspect ratio of Gaussian specifies the ellipticity of the Gaussian factor. Values typical of the receptive fields of simple cells lie between 0.2 and 1.

After adjust the parameter properly, the results below show better. we can clearly distinguish 4 the orientation of filter. The arguments used in this image for those two parameters are 1.25, 0.6 respectively.



4. Visual illusions related to Center-Surround processing





Mach bands is an optical illusion. It exaggerates the contrast between edges of the slightly differing shades of gray, as soon as they contact one another, by triggering edge-detection in the human visual system. The Hermann grid illusion is also an optical illusion. The illusion is characterized by "ghostlike" grey blobs perceived at the intersections of a white (or light-colored) grid on a black background. The grey blobs disappear when looking directly at an intersection.

The Mach band and Herman band processed image shows above in left and right respectively. Those two images both are computed from our simulated simple cell. Looking at results image, the corresponded illusion effects are still show to us.

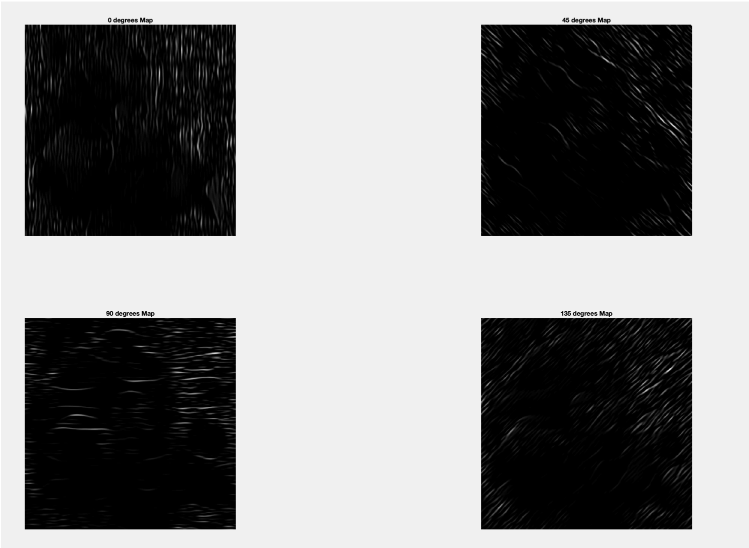
Simulating Receptive fields: applications (II)

5. Computing Conspicuity Maps

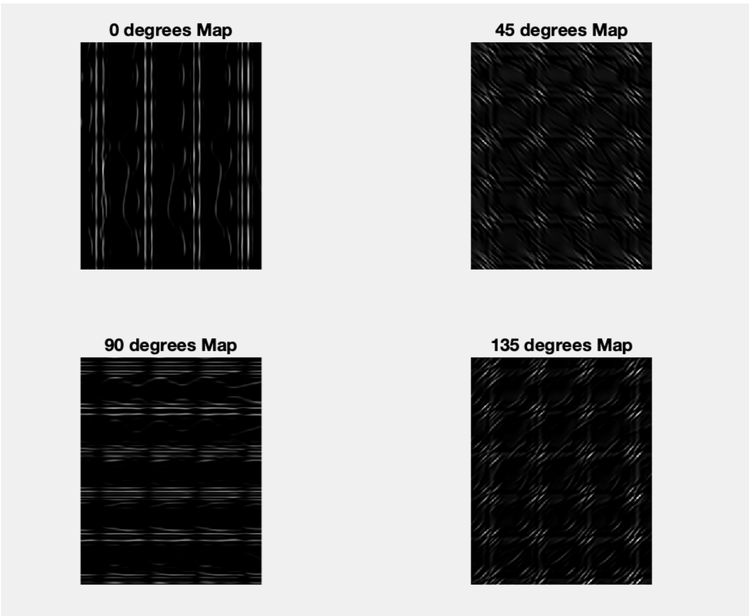
Here, we only compute the results of simulation of the center-surround organization and lateral inhibition of simple cells.

The oriented edge map also takes as input the intensity signal. To create the oriented edge map, the first stage of processing is the computation of a multi-resolution Gaussian pyramid. The second stage of processing simulates the center- surround organization and lateral inhibition of simple cells in the early stages of the primate visual system by subtracting a lower resolution image from the next highest resolution image in the pyramid, and taking the absolute value of the result. Since the human visual system has non-uniform sensitivity to spatial frequencies in an image, the levels of the Laplacian cube must be weighted by the contrast sensitivity function. The final step in the creation of the oriented edge map is to represent the amount of edge information in the image at varying spatial orientations. This is done by convolving the edge image with Gabor filters at four orientations 0°, 45°, 90°, and 135°. This simulates the structure of receptive fields in area V1 neurons that are tuned to particular orientations, as well as to specific spatial frequencies.

The orientation map for edge detection by using gaussian pyramid shows below:



We can compare with the previous corresponded simulation. In this situation, the images show more larger scale edges detected and less fine future captured than previous results.
In this case, the gabor filter are operated based on gaussian pyramid. The image depth and contrast sensitivity are introduced during computing the orientation map.
Same operation on colored Herman grid, the results show below:



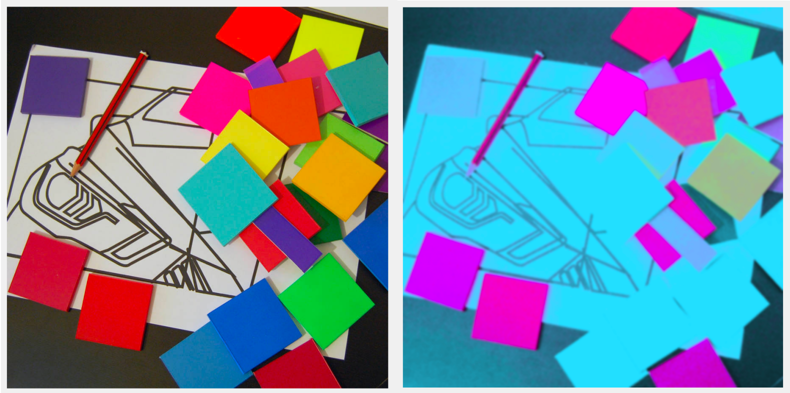
From the image, we can hardly notice the optical illusion. The edges are not perfectly detected compared with previous results.

6. Simulating color processing cells

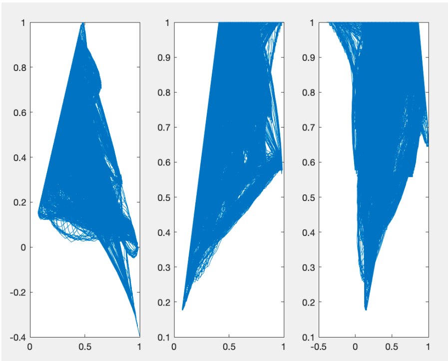
The main idea here is based on double-opponency(DO) of color constancy. The simulation includes cone layer, retinal layer, V1 layer and higher visual cortex.

1. In cone layer, the input color image is transformed into LMS space.
2. In retinal layer, the RF (receptive field) of SD (single opponency) cell is constructed with gaussian function.
3. In V1 layer, the RF of a V1 DO cell of L+M-/M+L- are constructed.
4. In higher visual cortex, cells usually have very large RF, which may enable the cells have the ability to extract light source color.

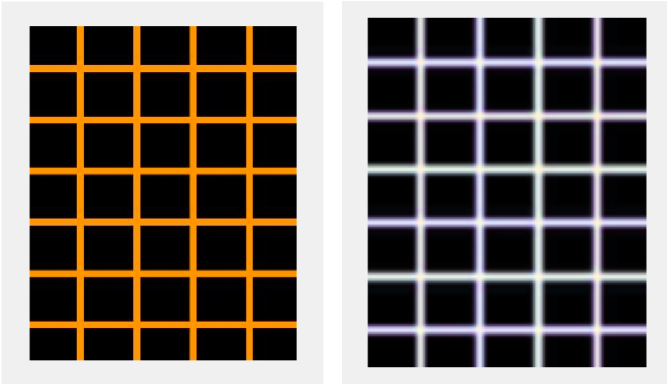
The results show below:



The original image is on left and processed image on the right. We can notice that we still can more or less distinguish the color of objects under effect of the light source color. The distribution of the normalized RGB values from double opponent cell shows below:



Some operation to the colored Herman grid image, the original is on the left and the processed is on the right. The results show below:



We can notice that the optical illusion of Herman grid still can be obtained. The distribution of the normalized RGB values from double opponent cell shows below: