The same general instructions apply as in previous assignments.

Question 1 (50 points)

I strongly recommend that you study the lecture notes and do exercises 14-16 before you do this question.

Recall the Assignment 2 Question 1 where you defined a set of 2D Gabor filters. A 2D Gabor filter is sensitive to a set of 2D spatial frequency components \((k_x, k_y)\) that is concentrated around a particular frequency \((k_0, k_1)\). In this question, you will gain a better understanding of the 2D spatial frequency properties of 2D Gabors.

Your task is to define a set of 2D sine Gabor functions (don’t bother with cosine Gabors) that have four different orientations and three different sizes. Use orientations 0, 45, 90, 135 degrees. For size variations, recall in Assignment 2 how you used only Gabors of a window size \(M=32\). Here you will use Gabors defined on window sizes \(M=16, 32, 64\).

For each window size \(M\), the Gabors you define will have a spatial frequency of \(k=4\) cycles per \(M\) pixels. You must choose the 2D Gaussian for your Gabors so that all the Gabors have constant octave bandwidth. Bandwidth of a 2D function is defined in the same way as in 1D, according to the range of values of \(k\) where \(k = k_0^2 + k_1^2\).

To achieve the above size and bandwidth requirements, you will need to rewrite the mk2DGabor function from A2. Add one input parameter to this function, namely the octave bandwidth \(\beta\). Choose the sigma of the Gaussian of your Gabor based on the input parameters for your mk2DGabor function, namely parameters \(M, k_0, k_1\) and \(\beta\). See the Exercises 16 Q3 (added March 30) for formulas that you will need. The solution you submit should use \(\beta=1\). But you should also examine other \(\beta\) values so you can see how the Gabors vary with \(\beta\).

For each of the three sizes \(M\), submit four pairs of image plots showing each Gabor in the spatial domain and in the frequency domain (amplitude spectrum only), that is, one pair of plots for each orientation. I suggest you organize the four pairs using the subplot command.

To compute the amplitude spectra of a Gabor, use the matlab functions \texttt{fft2} and \texttt{fftshift}. These can be tricky to use for the first time, so I suggest you work through
a few simple examples similar to those covered in the lecture notes, before working with 2D Gabors.

Further requirements:

- To compare Gabors defined by different M values, your plots (both in spatial domain and spatial frequency domain) must be of size $N \times N$ where $N = 128$. You will need to insert the MxM image window containing each Gabor into an $N \times N$ zeros image.

- For both the spatial domain and spatial frequency domain plots, the origin (0,0) must be at the center of the plot. You must also label the axes and show values on these axes. E.g. Use `imagesc(-N/2:N/2-1, -N/2:N/2-1, imagename )`;

- Submit your plots in a PDF. Also hand in all code you used to generate the plots.

If you do this question correctly, then you will see that your Gabors functions tile (cover) most of the 2D frequency domain.

**Question 2 (50 points)**

I will post this question by Tuesday April 4 (latest).