Purpose: Gain familiarity with using MATLAB for simple image processing tasks: create artificial test images, use and manipulate a real image, and explore the sampling theorem as it applies to 2D images. Learn to use low level image plotting routines in MATLAB.

Procedure: For *each* MATLAB m-file you write, be sure to comment the code sufficiently, and include initial comments as a basic help system. That is, if a user types "help" followed by your m-file name, comments must print on the screen which tell the user what the program does, what the proper syntax is to use the program, and any other useful tidbits. No Image Processing Toolbox programs should be used;[1] you can use the low-level MATLAB routine `image` (not `imagesc`) in your code to display the images, or the supplied `ip_disp.m` program.

For all images you show, the origin should be located in the upper left corner, and the image axes should be such that the x and y dimensions of an individual pixel should appear to be square (to preserve the aspect ratio of the image). The x-axis is for the rows and the y-axis is for the columns. Assume an 8-bit gray level range, where the gray levels map 255 to white and 0 to black unless otherwise specified.

- ➪ Create a 256×256 image that consists of alternating black and white vertical bars, beginning with black at the far left. Black bars should have a gray level of 0, and white bars should have a gray level of 255. There should be 16 total bars (i.e., 8 black bars and 8 white bars, or you could say there are 8 "line pairs") in your image. The image should contain no other gray level values except 0 or 255.
- ➪ Create a 256×256 image that consists of a horizontal sinusoid, with the same period and intensity max/min as the black and white bar pattern. A horizontal sinusoid varies only along the horizontal axis; it has a constant value along the vertical axis, in a similar fashion to the vertical bars described above.
- ➪ Create a 256×256 image that consists of two concentric disks, centered in the "middle" of the image. The larger disk should have a radius of 64 pixels and a gray scale value equivalent to 127. The smaller disk should have a radius of 32 pixels and a gray scale value equivalent to 255. The background of the image should be black.
- ➪ Load the "lena.mat" data file[2] from the course web site `Files-->Images` section. This MAT file contains two data matrices that are images of Lena: a 256×256 version called A, and a 512×512 version called A512. Both matrices contain pixel values as unsigned integers in the range of 0 to 255. **For this part of the project, you will use the 512×512 version.** Display the image normally, display a version that has been "flipped" left to right, and display a version that is upside down.
- ➪ Using your vertical bar image previously created for this project, create new images with a lower *effective* spatial sampling frequency (by powers of two) until you find the sampling frequency at which you can no longer tell there are line pairs present in the image. The actual size of the image should not change (from the original 256×256) as the effective sample frequency changes.[3]

[1] I *do* encourage you to explore the Image Processing Toolbox on your own to try out various aspects of image processing. Just don't use it to complete the assignments.

[2] Simply use the `load` command in MATLAB; the image file conversion has already been done for you.

[3] You may want to look at some of the m-files on the course web page to get some ideas about one method of changing the effective sampling rate.

- ➪ Repeat the previous step, but using your sinusoidal image, lowering the *effective* spatial sampling frequency (by powers of two) until you find the sampling frequency at which the image no longer seems to represent a sinusoid. This will require a judgment call on your part.
- ➪ Repeat the previous step, but using your concentric disks image, lowering the *effective* spatial sampling frequency (by powers of two) until you find the sampling frequency at which the smaller disk is no longer very "disk-like" and the sampling frequency at which the larger disk is no longer very "disk-like." This will require a judgment call on your part regarding what is and what is not "disk-like." The actual size of the image should not change as the effective sample frequency changes.

Questions/Discussion: The write-up for this project report should be concise *but **be sure** to adhere to the report format on the course web page* (see the `Files-->Admin` section). Keep the discussion short and to the point. Be sure to include figures in your report (with numbered, descriptive captions at the bottom of each figure) of any images you create, modify, or that otherwise show results of your code. If you aren't sure if you should include it as a figure, then you probably *should* include it! Also, don't make image figures too small just to fit more on a page. The figures need to be large enough so that a hard-copy printed version of your report would show the important details of the image.

As a minimum, address these points in your project report (**optional for Fall 2020**).

- ➪ In your sampling rate experiments, do your results match your expectations with respect to the sampling theorem?
- ➪ Based on your knowledge of Fourier transforms, how would the "frequency content" of the "black and white" bar pattern compare to that of the sinusoidal pattern with the same period?
- ➪ Why does the smaller disk become unrecognizable as a disk before the larger disk does as you lower the sampling frequency?

Turn in: For this Project, turn in (as one or more e-mail attachments sent to me as part of a single e-mail message):

- ➪ An electronic project report (as a PDF file regardless of the program used to create the report). Name your PDF file "`Last1_Last2_proj01.pdf`" please, where "Last1" is the last name of team member 1, and "Last2" is the last name of team member 2. Be sure to **follow the project report format** given on the course web site (see the `Admin` section of the course web site). There is an example report on the web site that can easily clear up most questions about formatting.
- ➪ Any MATLAB m-files you created for this project. There is no need to send me any data or image files that you generated. I'll run your m-files and generate your images myself. If for some reason I need additional files from a particular student, I'll request them separately.

Don't try to get too fancy on this assignment. More pages do *not* necessarily translate into a higher grade! The written part should be brief, clear, and concise.[4] If you keep it simple and have been keeping up with class, it *really* shouldn't take very long to write the m-files and prepare the report. Of course it will take longer if you have to learn it as you go!

❄❄❄ Enjoy… ❄❄❄

[4]Be sure to use proper grammar and logical, organized sentences. **Any equations in your report should be typeset with an equation editor** (or use the math mode of LaTeX). All figures or tables should have numbered, descriptive captions.