1. Software Requirement:

MATLAB

2. Prerequisites:

You may refer to your lecture notes and the textbook.

3. Assignment Requirements:

Give extra attention to report document of this assignment, that is, providing only some piece of MATLAB code does not satisfy requirements. For all questions, you need to provide clear and scientific justifications; otherwise you cannot receive full points from that question.

4. Code Style and Naming Conventions

It is also required that you need to follow a standard coding style.

- All of the questions must be implemented as separate functions and function names must obey following format; “question_id_letter”. For example, if you are writing a code for question-4.a, your function name must be “question_4_a”.
- At the beginning of the each function, there must be a comment header describing the general inputs/outputs for your function. (Comment header’s format is specified in the file “comment_style.m”)
- All functions must be called by a single MATLAB script, whose name is “main.m”
- All of the output images must be written into a folder named as “outputs”.
  (see: MATLAB’s imwrite function)

5. Assignment Questions

1) Frequency Domain Basics (20 pts):

Consider the continuous function $f(t) = 5 + 2\sin(\frac{6}{5}\pi n t + \frac{\pi}{6})$.

a) What are the phase, amplitude, period and the frequency of f(t) in terms of n?

b) Plot f(t) and its Fourier transform F(μ).

c) What is the Nyquist rate for this signal? Plot the function when it is sampled
   a. twice of the Nyquist rate.
   b. half of the Nyquist rate.

Explain your results.

2) Fourier Transformation in Image Processing (25 pts) :

Assume that you are given the image f (x,y) ("Assignment_4.jpg") . For each of the following operations, ***explain their physical interpretation, mathematically,*** (i.e., explain whether the image is shifted, rotated, etc. by the corresponding operation) and implement and plot the magnitude and phase spectra after each operation on Assignment_4.jpg.

a) Multiply f(x,y) by $(-1)^{x+y}$ to obtain g(x,y).

b) Compute DFT of g(x,y) to obtain G(u,v).

c) Take the complex conjugate of transform to obtain G*(u,v).

d) Compute the inverse DFT of G*(u,v) to obtain g2(x,y).

e) Multiply the real part of g2(x,y) by $(-1)^{x+y}$.

f) Explain the relationship between g2(x,y) and f(x,y).

*****In these series of questions (3 and 4), you are going to explore the real world applications of Fourier transformation for image processing. You are advised to study chapter-4 from the computer manual of the text-book. Otherwise, you may not manage to get proper results. You can find a softcopy of this book on ODTU-Class under lecture notes section.**

3) Image Filtering in Fourier Domain (25 pts) :

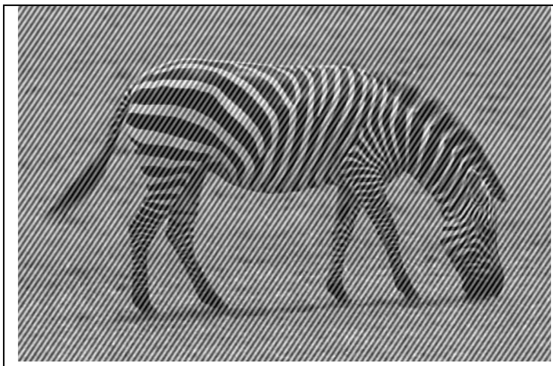
a. Design a Gaussian low-pass filter with the standard deviation of 4 pixels at x direction (row) and the standard deviation of 8 pixels at y direction (column) in the frequency domain. Obtain the filtered image by filtering the original image ***Assignment4.jpg*** with the designed Gaussian filter (i.e., this is the Gaussian low-pass filtering operation in <u>Fourier frequency domain</u>). Display the original image, the Gaussian low-pass filter (treat it as an image), and the filtered image.

b. Design a Gaussian low-pass filter with the standard deviation of 4 pixels at x direction (row) and the standard deviation of 8 pixels at y direction (column) in the <u>spatial domain</u>. Obtain the filtered image by filtering the original image ***Assignment4.jpg*** with the designed Gaussian filter (i.e., this is the Gaussian low-pass filtering operation in <u>spatial domain</u>). Display the original image, the Gaussian low-pass filter (treat it as an image), and the filtered image.

c. Provide a comparative conclusion for Gaussian low-pass filter in frequency and spatial domain.

4) A Real World Application – Periodic Noise Removal (30 pts):

a. You are given an image ("zebra.jpg") consisting of periodic sine noise with some frequency. Develop an algorithm making use of Fourier theory to remove periodic noise from the given image. See below figures for the corresponding input and output of the algorithm.

	
input	output

b. Explain and discuss your algorithm by providing spectra of both input and output images. Note that you may want to visually enhance the spectrum by log transformation.

5) Submission and Grading Policy

Assignments will be submitted via METU-Online. Create a rar or zip archive containing plain source codes (*.m files) and the document explaining your algorithms, implementations, results and discussions. Please pay attention on the documentation of your assignment.

The assignments are due at 23:59 PM on the deadline.

Any late submission will have 10% deduction for each late day.

No submissions will be accepted 2 days after the deadline.

You are expected to work individually NOT in groups. You will also be expected to follow the academic integrity rules.

Policy for Copying: ***Passing the work of others (either from another student or a code on internet etc.) off as your own is a breach of academic ethics and also of the University's disciplinary rules. Students are expected to work on the homeworks individually, <u>not as a group</u>. When you submit a work, it automatically implies that you claim the ownership of the work.***

Note that METU is subscribed to some tools which allow cross checking of submitted works as well as checking with any work on internet or any university subscribed to the system. No exceptions will be allowed and any work found to be copied will result in failing the course.

Please send your questions about the assignment to **ucinar@metu.edu.tr**.