ME579: Fourier Methods in Digital Signal Processing
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Course Syllabus

1. Introduction to Signal Processing

2. Deterministic Signals
   2.1 Classification of deterministic data
   2.2 Fourier series
   2.3 Fourier integrals
   2.4 The effect of filters and windows: multiplication and convolution
   2.5 Sampling signals, analog to digital conversion and aliasing
   2.6 The Discrete Fourier Transform (DFT)
   2.7 Computation of Discrete Fourier Transforms

3. Introduction to Digital Filtering
   3.1 Review of z transforms
   3.2 Digital filter realizations
   3.3 Frequency response of digital filters
   3.4 Design of IIR filters
   3.5 Design of FIR filters

4. Random Processes
   4.1 Probability, distributions and density functions, expectation: mean, standard deviation, moments
   4.2 Stochastic Processes: ensembles, probability density functions, moments of a stochastic process, correlation functions, stationarity, ergodicity, time averaging
   4.3 Spectra: power and cross spectral densities
   4.4 Input-output relationships for linear systems
   4.5 Ordinary, partial and multiple coherence functions

5. Estimation Methods
   5.1 Estimator errors and accuracy: bias and variance of estimators
   5.2 Estimators for stochastic processes
   5.3 Estimation of power spectra
   5.4 Estimation of cross spectral densities
   5.5 Estimation of the coherence function
   5.6 Frequency response function estimates
References for Additional Reading

K. Shin and J. K. Hammond
Covers most of what we do in the course but not digital filter design. Written from a more Mechanical Engineering perspective than most signal processing books. Many basic undergraduate EE text books that cover digital filtering. The first two books below also cover that.

J.G.Proakis and D.G.Manolakis
Covers most of what we do in the course, and a lot of other things too.

A.V.Oppenheim and R.W.Schafer
My personal favorite signal processing text, treatment is mathematical. or
Similar to (a) but certain sections are missing. It contains more illustrations and is more user friendly. Sometimes used as a text in undergraduate EE courses. Neither are good texts for an in depth treatment of spectral analysis of random signals nor for transfer function estimation.

J.S.Bendat and A.G.Piersol
If much of the analysis that you do is with random data (e.g., wind noise, random excitation of structures) this book will be useful; it covers sections 4 and 5 of the course.

General Homework Instructions

1. Start each problem on a new sheet of paper and write on one side of the paper only.
2. Make sure that your name, problem number, and homework set number as well as ME579 is written on each problem solution. Number pages in multiple-page solutions: e.g., Home5.Prob3.Page 2/4. Staple or paper clip the pages together.
3. It is preferred that you use engineering paper.
4. Be neat and tidy, using a ruler for drawing straight lines.
5. Your solutions should be easy to follow. Guide the grader through the graphs and computer code by including comments. Include Figure captions and annotations, when appropriate, on the graphs, hand written is fine.
6. Don’t spend time typing up homework solutions unless you really want to do it this way, I would rather you spent the time doing more analysis and making sure that your solution and comments are correct.
7. Computer programming should be done in MATLAB and the program should be attached to your solution and graphs (see below).
8. **HANDING IN YOUR HOMEWORK**
   All students must submit homework at the start of class on the date due.

9. **DO NOT COPY OTHER PEOPLE’S SOLUTIONS**
   This is not a good way to learn and it is very obvious to the person grading. Do the problems yourself, and get some help when you are having difficulty.

**Copying, Discussing Homework, Working in Groups, etc.**

*I expect you to do homework on your own.* While some discussions with classmates may be appropriate when you are trying to figuring things out, or you are having trouble getting YOUR OWN code to work, doing the homework together in a group is not, except for those assignments when you are specifically asked to do so.

Using other people’s programs, including the ones written in MATLAB by Mathworks programmers, unless specifically directed to do so, is not acceptable. Note when grading homeworks, it is typically VERY OBVIOUS when people copy.

**Follow-up on Completion of Assignments**

The point of doing homework is to learn, not just to get a grade. Unfortunately, particularly with the coding parts of the homework, it is important to get every little thing right for it to work. Small errors can often lead to quite large differences in the solution, so you need to be very detail oriented and persevere to get it right.

When the solution is posted, you should go through it and see where you made mistakes and where you should have commented more on the solution. If your code (M-file) didn’t work, copy the solution code and get it to work. Go through it line by line and compare with your program to see why your code didn’t work. If your analysis was incorrect, go through the solution and then sit down and redo the question without the solution in front of you, to see if you are now able to do it.

**Office Hours**

Usually, but not always, I will be available after class on Monday and Wednesday, 3:30-5:30 and Friday 3:30-4:30. I will be in my ME Office ME3061J. Phone number 765-494-9274. I will usually be around until about 7:30 Monday, Wednesday and Friday (after 5) and don’t mind you finding me for help then, too.

I am usually around through early evening (before 7:30), at my Herrick office HLAB 2012, ph: 765-494-9274, same as the ME office, on Tuesday and Thursday. Call to make sure I am there and available. Donna Cackley (765 494 2129) has my schedule so you can contact her. After 5pm you will need to call me so I can let you into the building.
I may also be available at other times, check with Donna to make an appointment. When you are struggling with the material, please make every effort to find a time to sit down with me so we can go through the concepts again.

MATLAB Computing Assignments in Homework

I expect you to do the programming in MATLAB for this class. DO NOT USE EXCEL or other software packages for your homework assignments. This is for ease of homework grading, and also so that the person grading can clearly see what you did to produce the answers that you present.

Programs should be well commented and easy to follow.

Sometimes you will be able to use in-built MATLAB functions to do specific signal processing tasks, and sometimes you will be asked to program an algorithm directly, which you can also do in MATLAB using their own programming language.

If you are unfamiliar with MATLAB, there are some on-line tutorials:

and there are also some notes that you can download from the ME579 website that we have developed for one of our undergraduate classes. These notes contain a very basic introduction to Matlab together with some examples that are relevant to the measurements class for which the notes were developed. It can be accessed at:
https://engineering.purdue.edu/ME579/information/Revised_Matlab_Notes.pdf

Note that there are many very good Introduction to MATLAB notes on the web developed for courses in many different Universities. MATLAB’s own website is also a good resource for you, even though sometimes it is difficult to find exactly what you want.

What I Expect to See in Your Solution

1. When you use MATLAB to do the calculations and plotting, put all the commands that you use together in a program (m-file) and run the program, rather than doing it line by line from the command line. In this way errors can be easily corrected and the program re-run without much effort, and the grader will be able to see what you did by looking at the print out of your m-file you include with your solution.

[ An M-file is a program, i.e., a listing of the commands used to generate, analyze and plot the data. M-files should be easy to follow, i.e., contain useful comments and have blank lines separating different sections of the code, indents for programming structures etc. The first few lines should contain comments that include the program name, your name, the assignment]
number, and a brief description of what this program does.)

In addition to the plots or other outputs when using MATLAB, you MUST also include a print out of all the M-files used to get these outputs. If you do not, you will get zero for that problem.

2. When you are asked to generate a time history or spectrum, I usually expect to see a graphical output using scales that help illuminate all the pertinent features of the results. A printout of array values is not an acceptable alternative.

To show particular features not so obvious when the entire plot is shown, you may need to supplement the plots that are requested in the assignment with additional “zoomed in” portions of the plots.

3. Remember that most spectra will be complex and we typically plot both the magnitude and phase unless directed to only plot one of these. Take care labelling plots \( |H(j2\pi f)| \) is the magnitude of the function \( H(j2\pi f) \), so if you are plotting the magnitude, the label should be \( |H(j2\pi f)| \) not \( H(j2\pi f) \). Take care to be precise in your labeling and descriptions.

4. Annotate the graphical output, which can be done by hand or by using the MATLAB programs: title, xlabel, ylabel, gtext etc. Specifically:
   - Axes should be labeled and units included when known.
   - The data should be plotted against a physically meaningful parameter, e.g., time, frequency, distance, or wave-number, as appropriate. Plotting data against point number is NOT acceptable. If a sample rate is not given in any problem, you may assume as a default that the sample rate is 1000 samples per second.
   - In the title to your graph, put in your name, and the problem number, e.g., "Jie Abfal HW1 Q3(a) ME579 Sp2017". As noted above, also put this information as a comment at the beginning of your M-file.
   - Label interesting features that illustrate the signal processing effects that you are examining in the homework problem. See note above on zooming in on interesting features.

5. When making comparisons between different ways of analyzing data, try to put results on one graph, or on several graphs on the same page using the same scale limits on each if possible (use the subplot command to do the latter). All graphs should be accompanied by some comments and/or discussion. For example, if you are asked to change an analysis parameter, describe how that parameter is affecting the plots that are being drawn.

6. Learn how to write your own functions in MATLAB so that you can reuse code without having to edit it. Think about what parameters would typically change when doing similar things and treat them as input variables to the function. These functions can become building blocks in more complicated code and will be ready for you to use in your research. Don’t forget to print the functions out with your main program and attach to the solution.
Quizzes, Exams and Course Grades

• There may be unannounced quizzes during classes.

• There will be a mid-term and a final exam. The exams will be closed book, with no
  calculators or other electronic/wireless/storage devices allowed – this includes smart
  watches and other such devices.

  You should only bring a pencil, pencil sharpener, eraser, and a straight edge (e.g., ruler) to
  the exam. The final exam covers material from the start to the end of the class, i.e., is
  comprehensive.

• The proportion of your final grade that comes from quizzes, exams and homework is not
  pre-determined, but typically, I do look at how weighting these parts differently affects the
  final grade. I look at how your performance has improved through the class, whether you
  have handed in all your homework, and how you have been able to learn from your earlier
  mistakes. Final exam performance is an important factor in your grade because it should be
  a reflection of how much you know about the material covered in this class.

• I don’t curve the class. Grades are meant to reflect your knowledge of the subject and your
  ability to demonstrate that knowledge through your homework, and quiz and exam
  performance.

  I will point out that exam grades are typically highly correlated with homework grades and
  homework grades are highly correlated with class attendance and attentiveness in class. It
  is very important to do the homework and to persevere so that you can do well in this part
  of the class.

• IT IS IMPORTANT TO TAKE NOTES IN CLASS and to go through those after class, reworking
  the class examples and derivations to make sure you can do them yourself (and to check
  that I didn’t make any mistakes!).

• When you need help, you must make every effort to come to office hours or make an
  appointment to meet at other times, so we can overcome problems that you are having.