Introduction to Digital Signal Processing

Duration: 16 weeks, Video lectures and in-class discussion/tutorials

Have you heard of the term signal processing and wondered what it was? Are you curious how a noisy signal is “filtered” to remove baseline drifts and smoothed to remove fast varying noise riding on the underlying signal? Have you heard of the term frequency spectrum of a signal? Do you want to know what a frequency spectrum is? How does one obtain or compute a frequency spectrum? How is all this stuff implemented on a computer?

If these questions have popped up in your thoughts at some point, and you are keen to find answers, then this course is for you.

This is an introductory hands-on course on the basics of traditional signal processing, focusing on time-frequency analysis. The appropriate analysis and interpretation of any signal require a good understanding of the nature of signals and the systems used to manipulate and extract relevant information from a signal. This course will expose students from different engineering disciplines and students with a clinical background to the following essential topics in digital signal processing, i.e., signal processing that can be done using a computer:

(a) Basic maths for understanding core concepts in signal processing.
(b) Introduction to Python programming.
(c) Introduction to signals and systems.
(d) Sampling.
(e) Fourier (frequency) analysis of signals.
(f) Basics of frequency-selective filtering.
(g) Introduction to time-frequency analysis.
(h) Analyzing real-world signals using Python.

This course will include 2-3 hours of lectures per week and will require an additional 6-7 hours of effect from students. There will be pen-and-paper and programming assignments for all course modules, regular quizzes, a mid-term, and a final exam.

Course Content

There will be topics in the course that might require familiarity with abstract mathematical ideas not covered in the course. Students can safely ignore these topics without the necessary background, which will be highlighted during the lectures. The topics with an asterisk (*) are not compulsory for students with a clinical background.

Module Name
Mathematical preliminaries Sets; Functions; Real numbers; Some useful functions; Complex numbers.
Python primer Introduction to python programming; Low-level vs. high-level programming; Complies vs. interpreted language; Python data types; Python operators; Function; Getting user inputs; List manipulation; String manipulation’ Conditional statements; Loops statements; Modules; numpy module; Plotting with python;
What are signals? Classification of signals; Useful signals: real and complex exponentials; sinusoidal signals; Impulse function; Step function.
What are systems? Classification of systems; Linear time-invariant (LTI) systems; Impulse response
Input-Output relationship of LTI systems: Convolution sum Derivation of the convolution sum operation; Properties of the convolution sum operation.

Introduction to Fourier representation of signals Continuous-time Fourier Series; Continuous-time Fourier Transform; Properties of continuous-time Fourier series and transform*
Sampling theorem
Fourier representation of discrete signals Discrete-time Fourier Series and Fourier Transform; z transform*
Discrete Fourier Transform (DFT) Definition; Properties of DFT;
Frequency response of LTI systems
Frequency selective filtering Specifications of frequency-selective filter; IIR and FIR filters; Properties of IIR and FIR filters; Design of IIR and FIR filter.
Introduction to Spectral Analysis
Short-time Fourier transform
Introduction to Wavelet Transforms

Resources

The following are some of the suggested references for the topics covered in the course. For each lecture, the relevant reading materials will be from one or more of the following books.

- Oppenheim, Alan V., Ronald W. Schafer, and John R. Buck. Discrete-time signal processing. Vol. 2. Englewood Cliffs: Prentice-hall, 1989.
- Proakis John, G., and G. Manolakis Dimitris. Digital Signal Processing, principles, algorithms, and applications. Pentice Hall, 1996.

A more advanced book that goes into the mathematical foundations of signal processing, which also gives a geometric view of signal processing, is the book,

- Vetterli, M., Kovacevic, J., Goyal, Vivek K., Foundations of Signal Processing.

Grading

The final grade for the course will consider the performance on the assignments, quizzes, mid-term, and the final exam.

Assignments	15
Quizzes	10
Mid-term	20
Final	55
Total	100

An absolute grading scheme will be followed for the course:

S: >=90; **A**: >=80; **B**: >= 70; **C**: >= 60; **D**: >=50; **E**: >=40; **F**: <40

Lectures Schedule (August – December 2024)

Lecture timings:
Friday: 10:00 – 11:30 AM

Week	Date	Vidoes	Discussion
1	2/8/24	Orientation/Math prelims	Introduction
2	9/8/24	Introduction to Python Programming	Programming problems
3	16/8/24	What are signals?	Signals tutorial
4	23/8/24	Geometric Signal Theory, Sampling Theorem	Sampling theorem tutorial
5	30/8/24	What are Systems?	Systems tutorial
6	4/10/24	LTI Systems1, 2	LTI Systems tutorial
7	11/10/24	Fourier Representation	FT tutorial
8	18/10/24	Fourier Representation	FT tutorial
9	25/10/24	Revisiting Samping, Z-transform 1	Sampling, Z transform tutorial
10	1/11/24	Z-transform 2, Freq. Domain LTI	LTI Systems tutorial
11	8/11/24	Discrete Fourier Transform	DFT tutorial
12	15/11/24	Discrete Fourier Transform	DFT tutorial
13	22/11/24	Frequency selective filters	Filter design tutorial
14	29/11/24	In class: Introduction to Spectral Analysis	Spectral analysis tutorial
15	6/12/24	In class: Short-time Fourier Transform	STFT tutorial
16	13/12/24	In class: Introduction to Wavelet Transforms	Wavelets tutorial

Midsem Exam: 7:30 – 8:30 AM, 22 October 2024
Final Exam: 7:30 – 10:30 AM, 23 December 2024

Assignment Schedule

Assignment	Details	Due on
1	Math Preliminaries	30/9/24
2	Python Programming	
3	Signals	
4	Systems	
6	LTI systems	31/10/24
7	Fourier Representation	
8	Z transform	30/11/24
9	DFT	
10	Frequency selective filter	
11	Spectral analysis	15/12/24
12	STFT and Wavelet	