Introduction to Digital Signal Processing

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Duration: 14-16 weeks, 3hrs of lecture/tutorials per week

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 heard of the term frequency spectrum of a signal? Have you wanted to know what is a frequency spectrum? How does one obtain or compute a frequency spectrum? How is all this stuff implemented on a computer?

If these are some questions that have popped up in your thoughts at some point and you are keen to find out some 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, along with regular quizzes, a mid-term, and a final exam.

Detailed Course Content

There will be topics in the course which might require familiarity with abstract mathematical ideas not covered in the course. These topics can be safely ignored by students 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.

Short-time Fourier transform

Introduction to Wavelet Transforms

Course textbook

The following are some of the suggested references for the topics covered in the course. For each lecture, the releveant 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 geometric view of signal processing is the book,

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