EE4C5 Digital Signal Processing

Lecture 1 – An Introduction

Signal Processing?

- … is concerned with representation, transformation and manipulation of signals and the information they contain.
    - (Oppenheim and Schafer, module textbook)

Digital?

- Discrete-time?
  - What's the difference?
- Analog signals in nature?
  - Electrical, acoustic, mechanical? (name some)
- Analog Processing?
  - Linear: amplify, filter, integrate, differentiate.
  - Non-linear: Square, rectify, invert.
- Implementation
  - Circuits, mechanical devices.

Limits of analog processing

- Accuracy impacted by operating conditions (temperature, component over time).
- Dynamic range restricted.
- Noise sensitivity.
- Inflexible.
- Data storage and transmission.
- Limited speed.

Advantages of Digital Processing

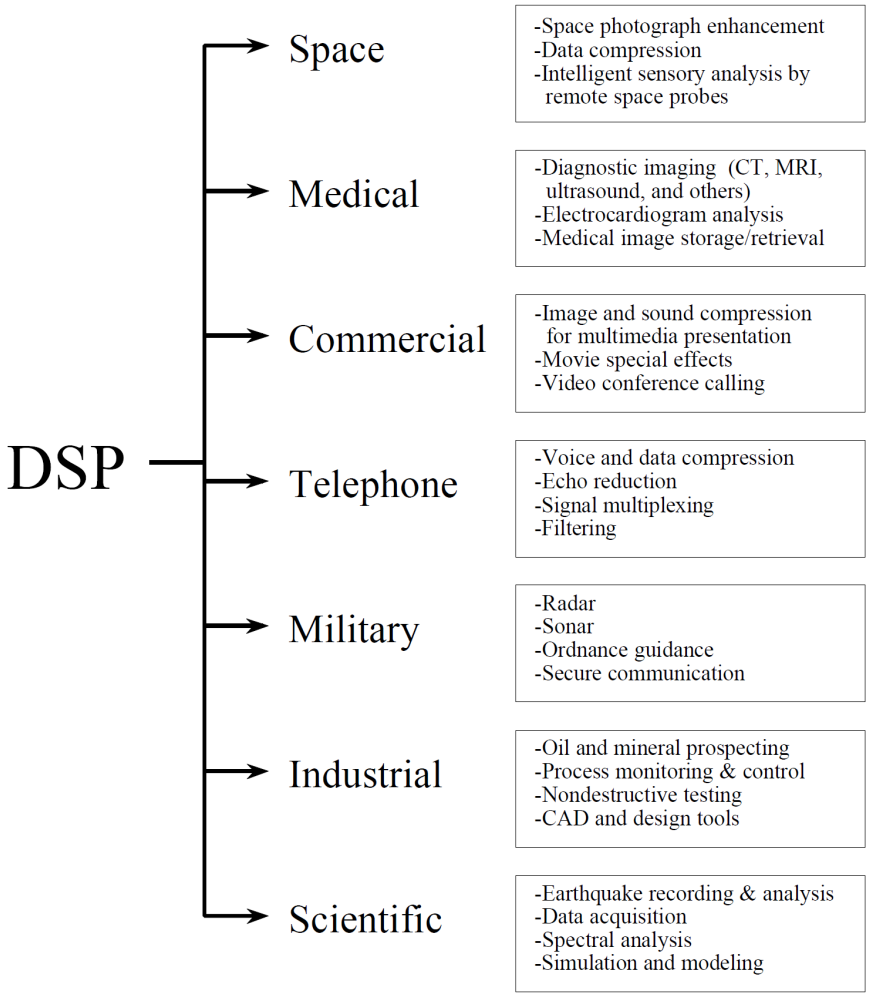
- Storage and transmission.
- Flexible.
- Can be more complex.
- Efficient implementation.
- Speed increases with technology.
- High accuracy.
- Dynamic range.
- Parallel processing.

How?

- Analog signals converted to digital (binary sequences).
- Implementation of DSP operations.
  - FPGA, ASIC, DSP Processor, CPU, GPU.

Typical Applications

- Source of diagram: Chapter 1 "*The Scientist and Engineer's Guide to Digital Signal Processing*", Steven Smith.
- https://www.dspguide.com/
- Read Chapter 1.



My interest in DSP

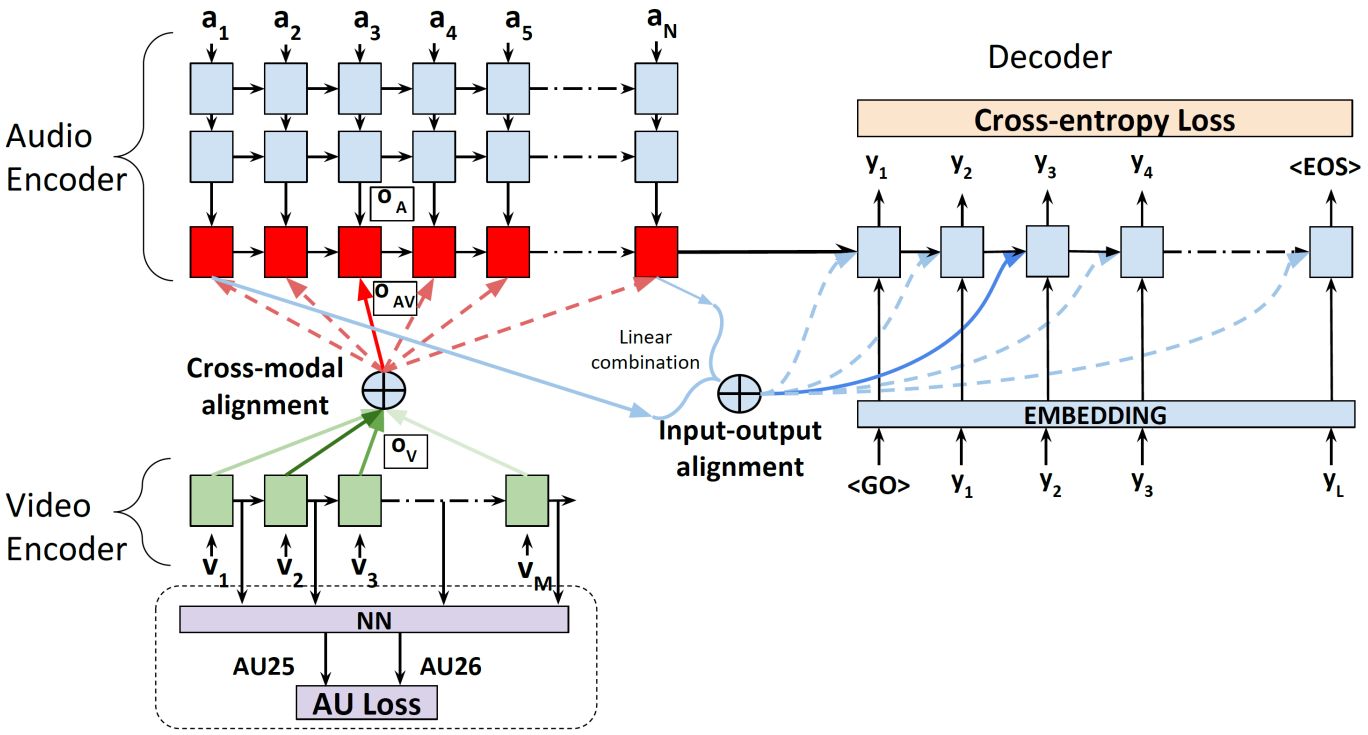
- Professor in Speech Technology.
- Speech fundamental in human communication.
- Speech science and speech technology.
  - Audio-visual speech recognition.
  - Multimodal speech analysis.
  - Speech synthesis evaluation.
  - Speech quality evaluation.
  - Birdsong.
- Wider applications
  - Capture, compression, encoding, transmission, reconstruction, recognition, synthesis…..

Speech signal processing

Victor Zue, MIT, https://www.youtube.com/watch?v=j-fgbfi0W34&t=3738s

Audio-Visual Speech Recognition

- The top layer cells of the Audio Encoder take audio representations from a stack of LSTM layers (o_A) as inputs and attend to the top layer outputs of the Video Encoder (o_V , only one layer shown), producing the crossmodal alignment.
- The Decoder receives the fused Audio-Visual representations (o_{AV}), producing an input-output alignment through a second attention mechanism.

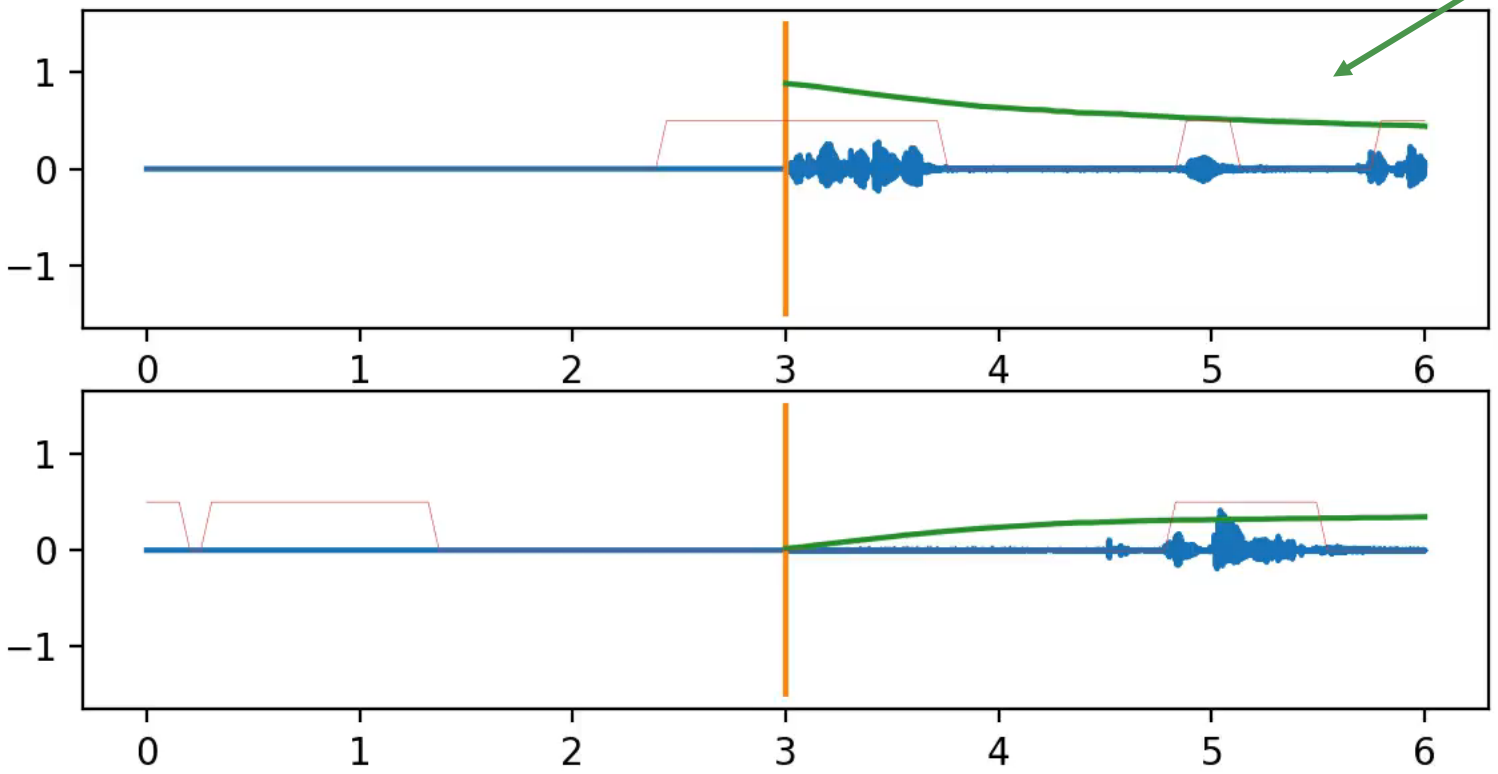


Sterpu, George, Christian Saam, and Naomi Harte. "How to teach DNNs to pay attention to the visual modality in speech recognition." *IEEE/ACM Transactions on Audio, Speech, and Language Processing* 28 (2020): 1052-1064.
https://github.com/georgesterpu/avsr-tf1

Turn taking prediction in action

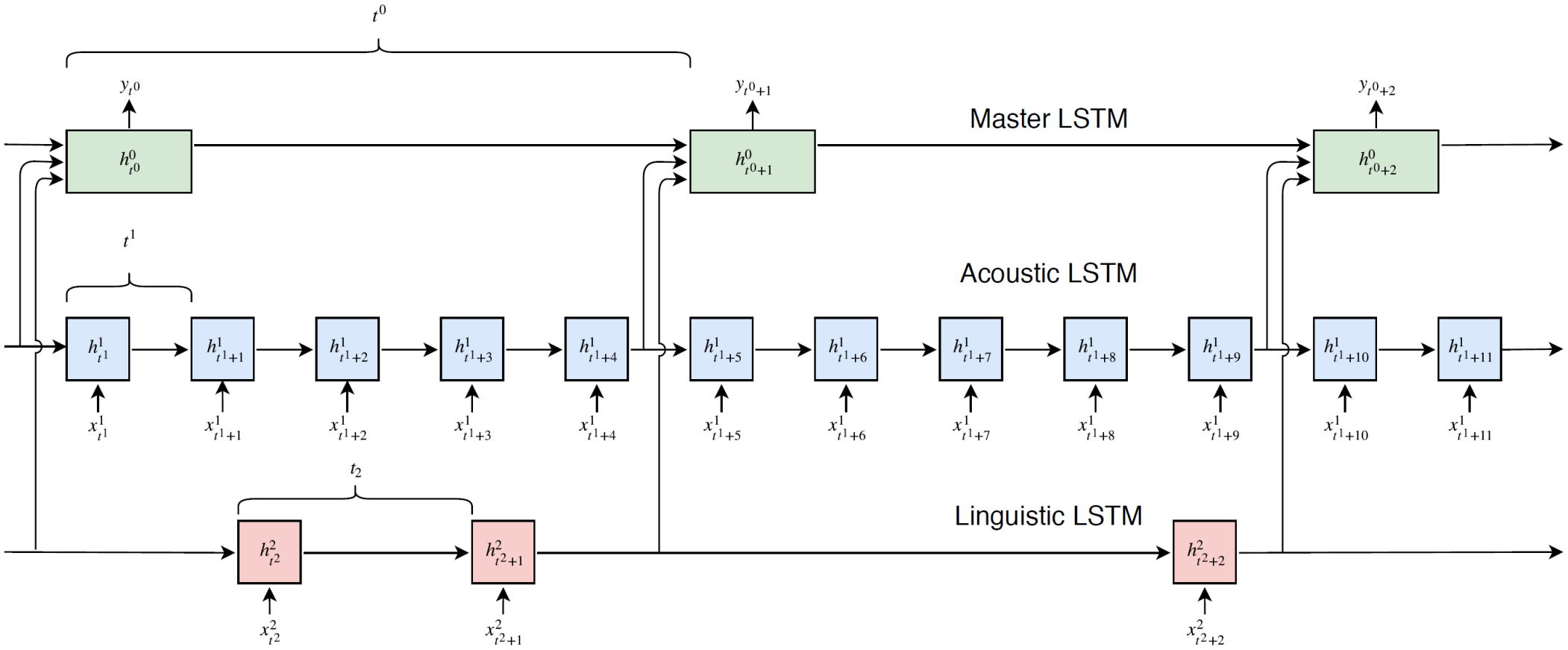
Speaker 1

Speaker 2



Green line is prediction that speaker will take a turn

Multiscale RNN architecture



Roddy, Matthew, Gabriel Skantze, and Naomi Harte. "Multimodal continuous turn-taking prediction using multiscale RNNs." In *Proceedings of the 20th ACM International Conference on Multimodal Interaction*, pp. 186-190. 2018.

www.github.com/mattroddy/lstm_turn_taking_prediction

Synthetic Speech – guess what's what?

- Natural
- HMM Synthesis (I)
- DNN + WORLD
- DNN + NSF

- Hybrid System (M)
- FastPitch + WaveRNN
- FastPitch + WaveNet

Synthetic Speech – guess what's what?

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5. HMM Synthesis (I)
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3. Hybrid System (M)
7. FastPitch + WaveRNN
6. FastPitch + WaveNet

Required Reading & other material

- Chapter 1 “The Scientist and Engineer's Guide to Digital Signal Processing”, Steven Smith.
- Discrete-Time Signal Processing. Oppenheim & Schafer, Chapter 1, Intro.
- Introduction to Matlab.
  - https://matlabacademy.mathworks.com/details/matlab-onramp/gettingstarted (2-hour intro if your Matlab is rusty)
- Future of Signal Processing.
  - https://futureofsp.eecs.mit.edu/videos/

The 4C5 Module

Course Content

- Signals and Properties, LTI systems – review (3C1 or equivalent background).
- Sampling and reconstruction, Decimation, interpolation, quantisation.
- Digital Filters, Linear Phase systems.
- Filter design methods – IIR, FIR.
- Optimum FIR Filter Design.
- Practical Filter Design in Matlab.
- Discrete Fourier Series, Discrete Fourier Transform, Discrete Fourier Transform Properties.
- Computation of FFT.
- Random Processes.
- Spectral analysis of signals with DFT.
- Filter realisations.
- DSP in an era of Deep Learning.

Module Descriptor

- Online, Engineering School website.
- Learning Outcomes.
  - LO1. Outline and use a variety of approaches to sampling and reconstruction of signals .
  - LO2. Describe, appraise and implement filter design methods for IIR and FIR filters, identifying trade-offs and evaluating outcomes.
  - LO3. Appreciate and illustrate the role of linear phase.
  - LO4. Elaborate on the relationship between the Continuous Time Fourier Transform and the Discrete Fourier Transform.
  - LO5. Discuss the importance and relevance of properties of the DFT.
  - LO6. Illustrate fast algorithms for implementation of the DFT and their practical use and advantages.
  - LO7. Interpret and analyse signals using spectral analysis techniques derived from the DFT.
  - LO8. Appreciate the role of signal processing in current approaches to system design.
  - LO9. Exploit assigned reading and lab exercises to deepen insights into module content.

5 ECTS Course

- 1 ECTS = 20-25 hours student effort.
- 4C5 – 100-125 hours.
  - 33 hours lecture.
  - 4X 1-hour labs.
  - 9 hours tutorials.
  - Rest from you!

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} 46 hours

54-79 hours???

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46 hours

  - Rest from you!
  - 4 X prep lab at home of 2hr (8).
  - 1 hour study per hour of lecture (33).
  - 1 hour per tutorial/homework (9).
  - 12 hours for intense exam prep.

62 hours

Lectures

- Notes shared on Blackboard.
- Sparse.
- Take notes!
- Lecture Slots: Mon Tues Wed mornings.

Tutorials

- Will assign problems from module textbook 1 week in advance.
- Weekly Tutorial slot.
  - Friday.
- Attendance will be sampled.
- Interactive.

Labs

- 4 labs.
- Largely self-guided.
- Will get one 1-hour slot in CadLab as clinic per lab (Tuesday afternoon).
- You do the lab BEFORE you attend clinic.
- Clinic slots assigned to Labgroup 1/2.
  - Week 3,4,5,6, 8,9,10,11 , e.g. [1 2 2 1 2 1 1 2]
  - Check “myGroups” in Blackboard
- Submit required evidence via Blackboard (before clinic and once complete).
- Attendance optional but gets recorded.
- No submission = no marks.
- More on submission requirements later (important).

Plagiarism

- Plagiarism is the act of presenting the work or ideas of others as your own without due acknowledgement.
- Individual assignments.
- Difference between helping each other and plagiarising the work.
- New Engineering School system on plagiarism.

Marking

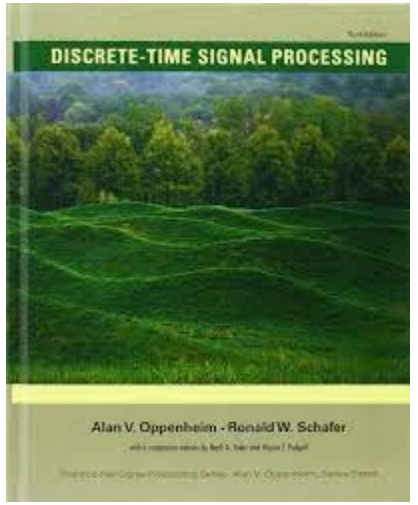
- 85% End of year Exam.
- 15% CA.
  - Based on lab submissions.
- Note supplemental based 100% on exam.

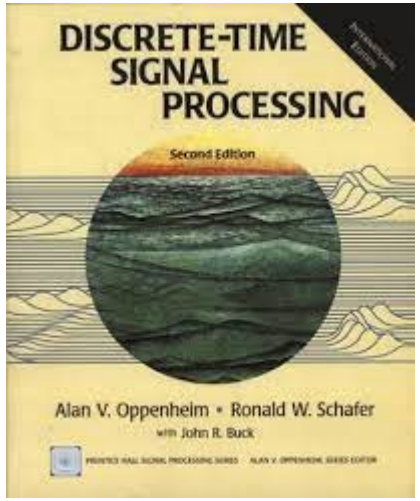
Announcements

- Module run via Blackboard.
- Check there for announcements in between classes.
- Set your email preferences.
- Other announcements will be made in lectures.
  - (I assume you are here ☺)

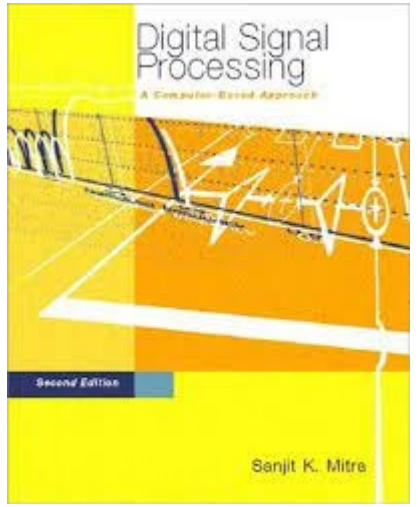
Module Texts

- Discrete-Time Signal Processing, Alan V. Oppenheim, Ronald W. Schafer (3rd edition).
- Online via library, or 7 S-LEN copies.
- [The Library of Trinity College Dublin: Stella Search -- Discrete-time signal processing / Alan V. Oppenheim, Ronald W. Schafer. (tcd.ie)]





- Other material:
  - The Scientist and Engineer's Guide to Digital Signal Processing, Steven W. Smith, Ph.D. (free online).
  - Digital Signal Processing: A Computer-based Approach, Sanjit K. Mitra (out of print).
  - https://ocw.mit.edu/courses/res-6-008-digital-signal-processing-spring-2011/pages/introduction/ (videos from Alan Oppenheim)



Contacting me

- Happy to take questions…
  - During class.
  - TA/TF at tutorials, TF/TA at lab clinics.
  - Office hours if demand there.
- Happy to take feedback.
  - Class reps.
- Please email me at:
  - nharte@tcd.ie
  - Always put 4C5 in the subject line as I filter emails.
  - Ensure it comes from your @tcd.ie email address.
  - I won’t respond to non-college email.
  - Allow 2-3 working days for a response!