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

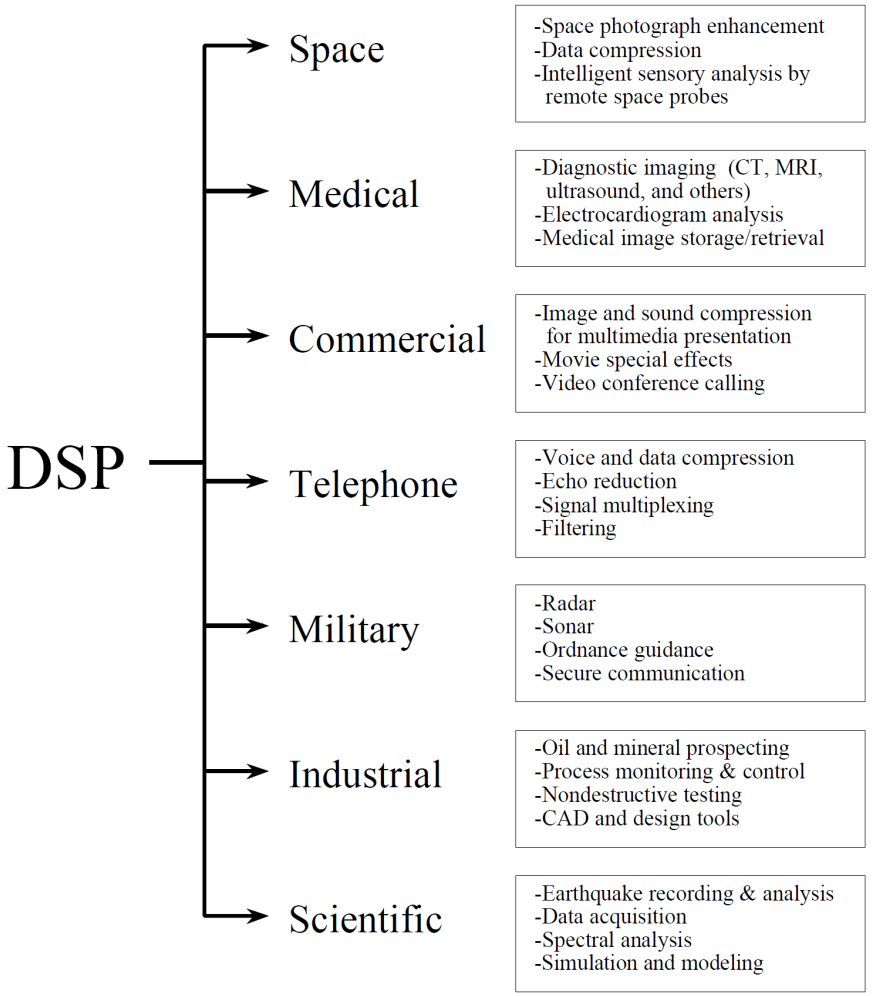
- Storage and transmission
- Flexible
- Can be more complex
- Efficient implementation
- Speed increases with technology
- High accuracy
- Dynamic range
- Parallel processing

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

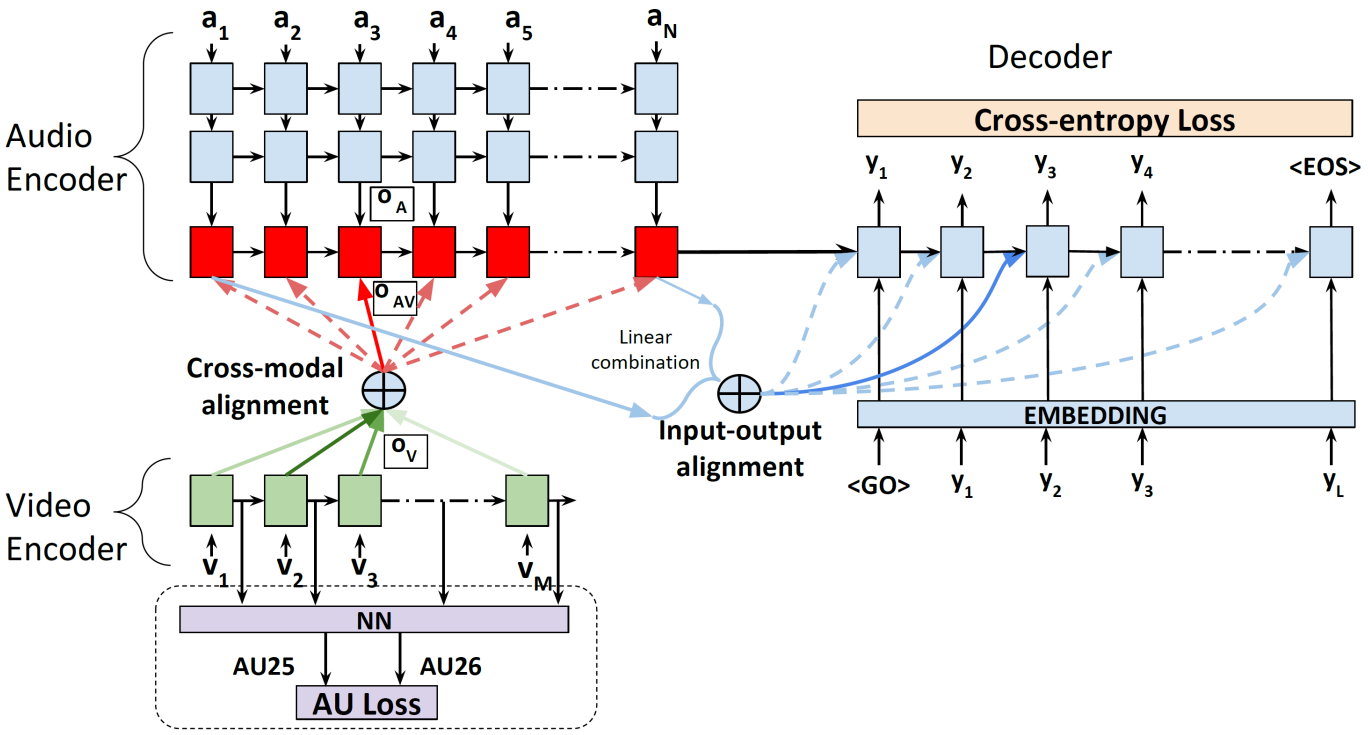
- Professor in Speech Technology
- Speech fundamental in human communication
- Speech science and speech technology
  - Audio-visual speech recognition
  - Multimodal speech analysis
  - Speech synthesis evaluation
  - Speech quality evaluation
  - Birdsong
- Wider applications
  - Capture, compression,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

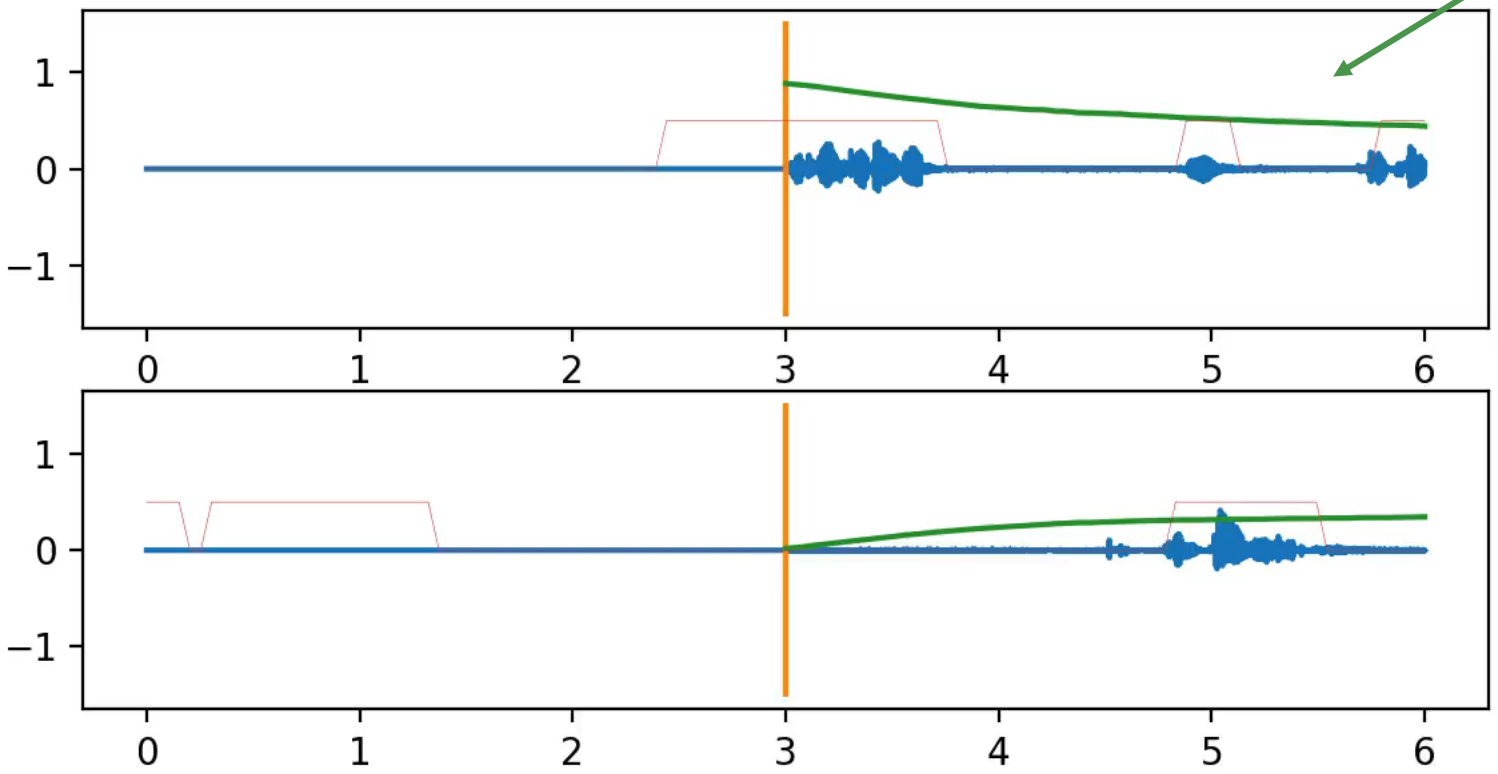


Sterpu, George, Christian Saam, and Naomi Harte. "How to teach DNNs to pay attention to the visual modality in speech recognition." *IEEE/ACM Transactions on Audio, Speech, and Language Processing* 28 (2020): 1052-1064.
https://github.com/georgesterpu/avsr-tf1

Turn taking prediction in action

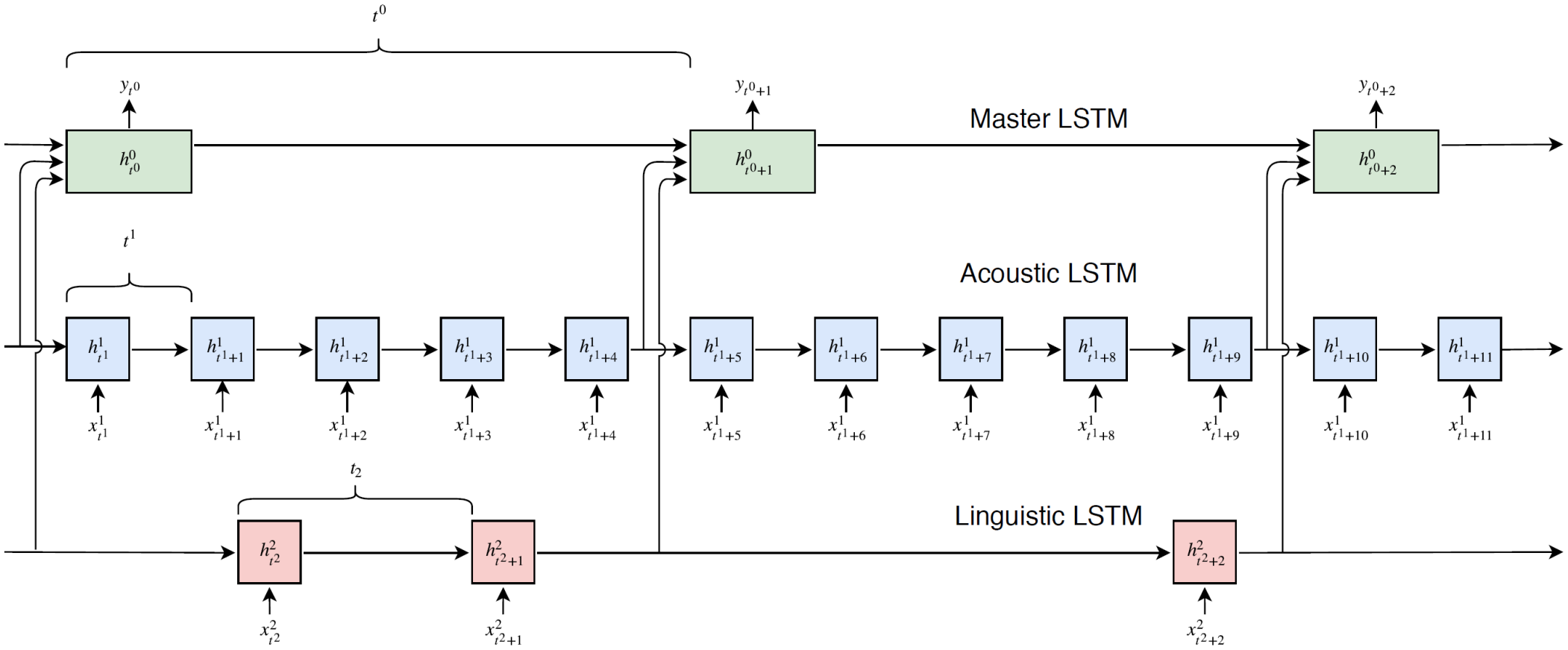
Speaker 1

Speaker 2



Green line is prediction that speaker will take a turn

Multiscale RNN architecture

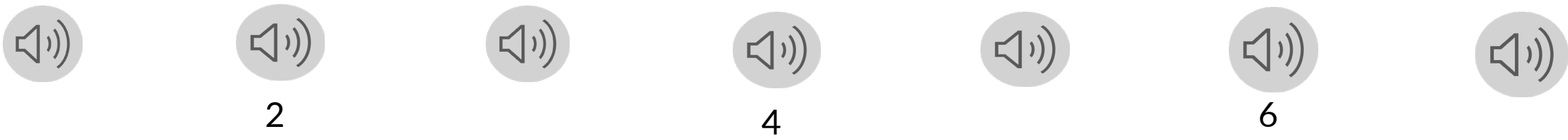


Roddy, Matthew, Gabriel Skantze, and Naomi Harte. "Multimodal continuous turn-taking prediction using multiscale RNNs." In *Proceedings of the 20th ACM International Conference on Multimodal Interaction*, pp. 186-190. 2018.

www.github.com/mattroddy/lstm_turn_taking_prediction

Synthetic Speech – guess what's what?

1 2 3 4 5 6 7



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

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

Synthetic Speech – guess what's what?

1. Natural
5. HMM Synthesis (I)
2. DNN + WORLD
4. DNN + NSF

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 you 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

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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  - 33 hours lecture
  - 4X 1-hour lab clinics
  - 9 hours tutorials
  - 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

46 hours

62 hours

Lectures

- Notes shared on Blackboard
- Sparse
- Take notes!
- Slots:

Tutorials

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

Labs

- 4 labs
- Largely self-guided
- Will get one 1-hour slot in CadLab as clinic per lab
- You do the lab BEFORE you attend clinic
- Clinic slots assigned to Group 0/1
  - Week 3,4,5,6, 8,9,10,11 [0 1 1 0 1 0 0 1]
- Submit required evidence via Blackboard
- Attendance optional but gets recorded
- No submission = no marks
- More on submission requirements later (important)

Marking

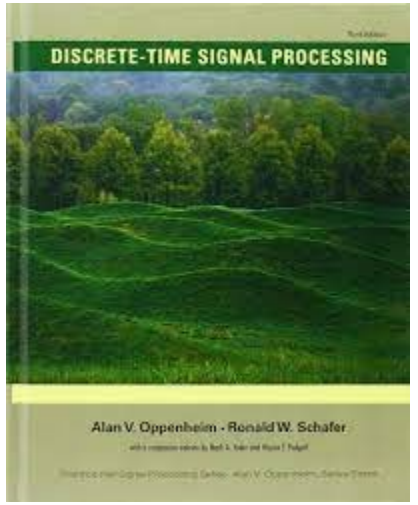
- 85% End of year Exam
- 15% CA
  - Based on lab submissions
- Note supplemental based 100% on exam

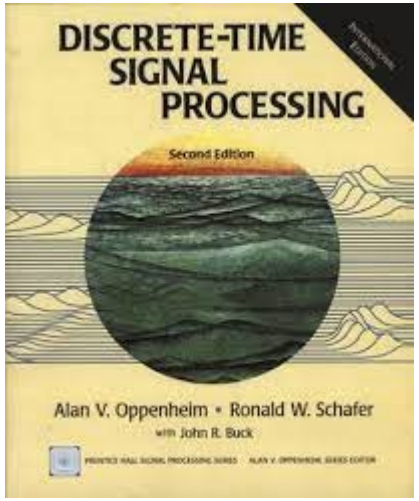
Announcements

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

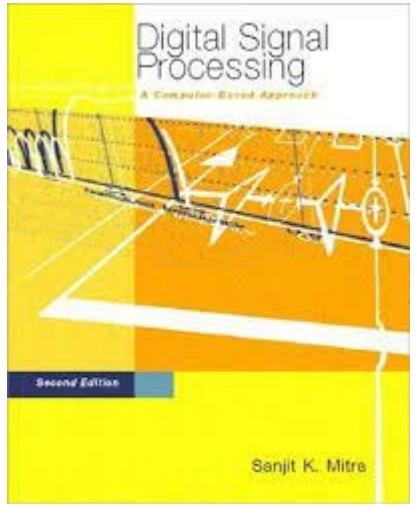
Module Texts

- 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!