NTNU – Trondheim
Norwegian University of Science and Technology

TTT4120 Digital Signal Processing
Fall 2021

Lecture: Course Arrangements & Introduction

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Contents and learning outcomes

- Course arrangements and general introduction
- Discrete-time signals in time-domain

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At your service

- Lecturer: 

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- Teaching assistants (click to contact):


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At your service …

- Student assistants:
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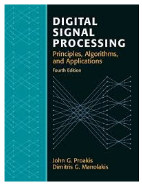
Check Blackboard for any updates

Basic course information

- Course information
  - all information through Blackboard (BB)
  - open page exists

    http://www.ntnu.edu/studies/courses/TTT4120
- Teaching:
  - lectures on Tue 16:15-18:00 and Thu 14:15 - 16:00 (EL5)
  - tutoring/exercises Thu 16:15-18:00 (KJL1)
- Course material:
  - Proakis, Manolakis Digital Signal Processing, 4^{th} Ed.
  - lecture notes on Blackboard (Norwegian/English)
  - lecture slides



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Basic course information…

- Important for Fall term 2021
  - lectures at campus, but can change abruptly to online
  - homework sessions at campus; TAs can be contacted online
  - to facilitate distance learning, most material available on BB

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Basic course information…

- Exercises:
  - 10-11 exercises, each up to 10 points
  - total of 50 points required to participate in exam (at least 25 points from exercises 6-11)
- Sessions will start next week
- Exam:
  - December 13, 9-13 (home exam)

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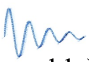
Digital signal processing (DSP)

- What is a signal? 
  - a varying (measurable) quantity
  - conveys information
- Signals can be deterministic or random
- Digital signal processing (DSP)
  - signal is a sequence of numbers
  - DSP involves transforming one signal into another signal

Signal processing is the enabling technology for the generation, transformation, and interpretation of information

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Digital signal processing (DSP)

- Definition of DSP:
  - digitalization, processing, transmission and/or representation of physical (analog) signals
  - modeling of physical signals and systems
- DSP discipline provides a toolbox of methods and algorithms
  - digitalization and analysis of physical signals
  - analysis, design, and use of linear digital systems
  - mathematical treatment of discrete versions of physical signals
  - estimation and application of mathematical models for different signals and channels

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Digital signal processing (DSP)…

- Discipline is quite theoretical

$$H(z) = \sum_{k=0}^{M-1} b_k z^{-k} =$$

$$= \sum_{k=0}^{(M-3)/2} h[k]z^{-k} + h\left[\frac{M-1}{2}\right] z^{-(M-1)/2} + \sum_{k=(M+1)/2}^{M-1} h[k]z^{-k}$$

$$= \sum_{k=0}^{(M-3)/2} h[k]z^{-k} + h\left[\frac{M-1}{2}\right] z^{-(M-1)/2} + \sum_{k=(M+1)/2}^{M-1} h[M-1-k]z^{-k}$$

$$= \sum_{k=0}^{(M-3)/2} h[k]z^{-k} + h\left[\frac{M-1}{2}\right] z^{-(M-1)/2} + \sum_{l=0}^{(M-3)/2} h[l]z^{l-(M-1)}$$

$$= h\left[\frac{M-1}{2}\right] z^{-(M-1)/2} + \sum_{k=0}^{(M-3)/2} h[k]\left(z^{-k} + z^{k-(M-1)}\right)$$

$$= h\left[\frac{M-1}{2}\right] z^{-(M-1)/2} + \sum_{k=0}^{(M-3)/2} h[k]z^{-(M-1)/2}\left(z^{-(k-(M-1)/2)} + z^{k-(M-1)/2}\right)$$

$$= \left(h\left[\frac{M-1}{2}\right] + \sum_{k=0}^{(M-3)/2} h[k]\left(z^{-(k-(M-1)/2)} + z^{k-(M-1)/2}\right)\right) z^{-(M-1)/2}$$

$$= \left(h\left[\frac{M-1}{2}\right] + 2\sum_{k=0}^{(M-3)/2} h[k]\cos[\omega((M-1)/2-k)]\right) e^{-j\omega(M-1)/2}$$

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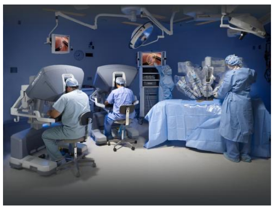
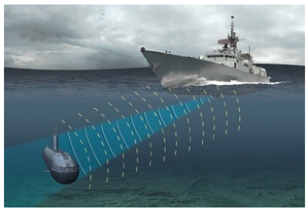
Digital signal processing (DSP)…

- … but also application oriented





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Digital signal processing (DSP)…

- Traditional areas of DSP include, e.g.,

filter design

spectrum analysis

fast filtering algorithms

signal reconstruction

multirate filters

adaptive filters

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Digital signal processing (DSP)…

- DSP influence on related disciplines

control

digital communication (TTT4130)

estimation, detection and classification (TTT4275)

multimedia signal processing (TTT4135)

machine learning for signal processing (TTT4185)

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Typical DSP intensive problems

- Signal enhancement, interference reduction
- Efficient coding for transmission or storage
- Control of industrial processes
- Navigation, positioning, surveillance
- Classification, identification, detection, and verification

- Within each problem formulation you may find many applications
- A single application may also require solving a variety of problems

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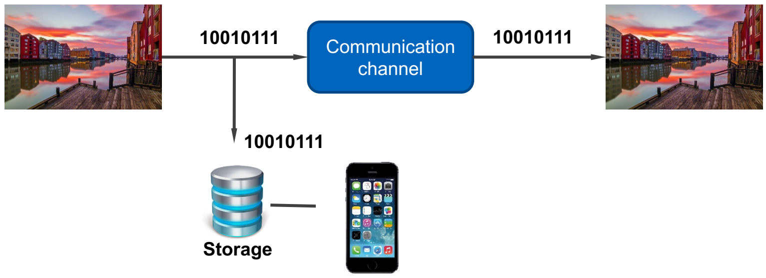
Applications



- Efficient and robust signal representation

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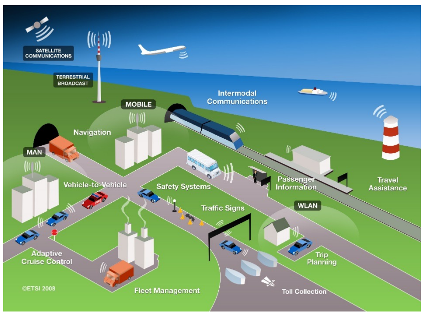
Applications…



- Digital signal transmission

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Applications…

- Speech recognition

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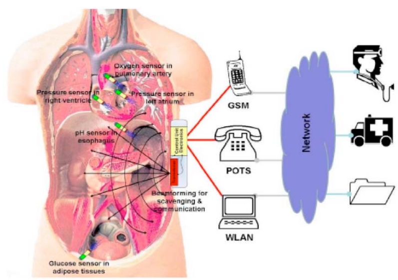
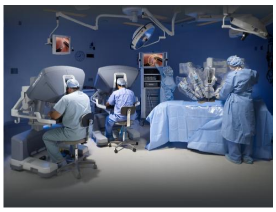
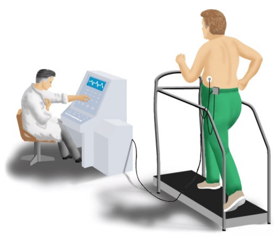
Applications…







- Medicine

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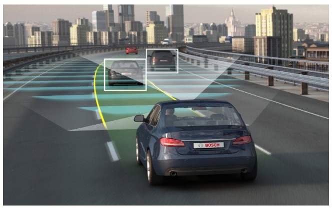
Applications…



- Self-driving cars

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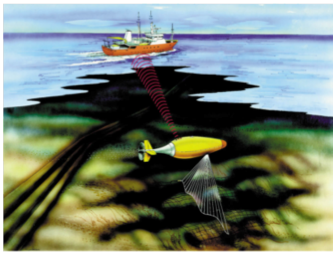
Applications…



- Underwater communication
- Environmental monitoring

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Digital versus analog signal processing

- Advantages:
  - easy to design and modify
  - possible to build complex systems
  - accuracy easier to control (word lenght of ADC)
  - errors in transmission and storage can be corrected
  - can be implemented in software
  - size decreases and less energy needed
  - same processor can time share different tasks
- Limitations:
  - signals with high bandwidth may require too fast processing and too high sampling rate

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Prerequisites

- Vary with the study programme: 2-3 first weeks will be devoted to make sure all have a common understanding of basics
  - could be a lot of new things for “KYB,” and some repetition for “ELSYS”
- Central concepts during first few weeks:
  - sampling
  - signals and systems in time and frequency
  - math: Fourier analysis, Laplace transform, complex numbers, partial fractions
  - statistics: probability density functions, expectations
  - MATLAB (or Python)

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Course contents

- Introduction to discrete signals and systems
- Analysis of discrete systems/filters using z-transform
- Sampling of analog signals, Nyquist rate and reconstruction
- Sampling in frequency domain, DFT and FFT
- Correlation and energy spectral density
- Stochastic signals, basic estimation theory, spectral estimation, and signal models, prediction
- Filter design and implementation
- Quantization and quantization noise
- Multirate signal processing

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Example questions

- Consider the following two operations

$$y[n] = \frac{1}{4}x[n] + \frac{1}{4}x[n-1] + \frac{1}{4}x[n-2] + \frac{1}{4}x[n-3]$$
$$y[n] = \frac{1}{4}x[n] - \frac{1}{4}x[n-1] + \frac{1}{4}x[n-2] - \frac{1}{4}x[n-3]$$

- Amplifies low/high frequencies? What is digital frequency?
- What about the following two operations (feedback)

$$y[n] = 0.6y[n-1] + x[n]$$
$$y[n] = 1.1y[n-1] + x[n]$$

- Stability issues.
- How to figure out these things for more complicated signals?

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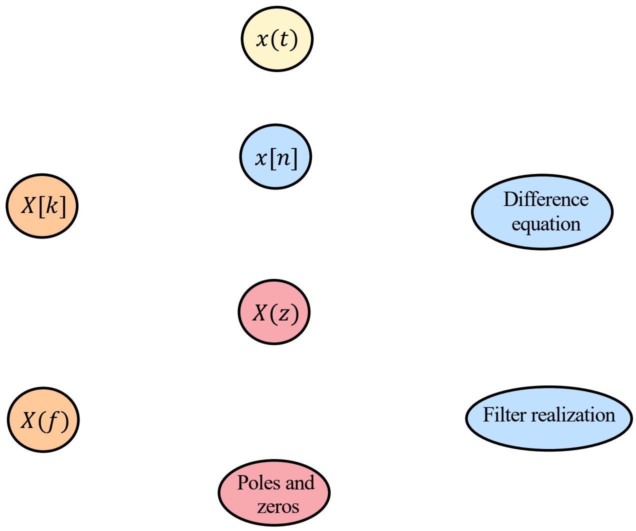
First couple of weeks



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What you should do

- Be active:
  - important to work throughout the whole semester
  - check lecture/homework material before sessions
  - ask questions
  - try to solve homeworks (not blindly copy someone else)
- Matlab/Python will replace pen and paper when dealing with physical signals
- Try to understand subject rather than only focus on rehearsing exam questions

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Reference group

- Quality control and feeback
  - few students from course (one from each programme)
  - be contact person/link to the students in your programme
  - three meetings during the course

- Volonteers?
- More information found here*

* https://innsida.ntnu.no/wiki/-/wiki/English/Reference+groups+-+quality+assurance+of+education

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