http://elec3004.org

An Introduction to
Digital Linear Systems: Signals & Controls

Welcome!

ELEC 3004: **Digital Linear Systems**: Signals & Controls
Dr. Surya Singh

Lecture 1

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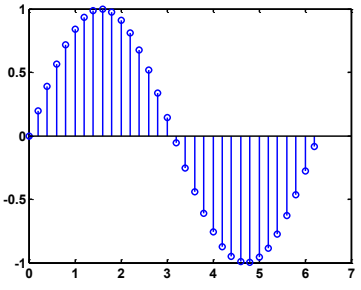
What's a Signal?

≡ *A set of data or* ***information***



- Can be a function of in **space** and/or **time**
- Various types: electrical, economics, dating, etc.
- Data → "information" is a process of understanding its structure/ forms:

$$\sin(\omega t)$$

What is a System?

≡ A **process** (function) by which information (signals) are modified so as to extract additional information from them

- Systems modify the signal(s) to yield a new result (also a signal)
- Can be of various forms: electrical, mechanical, etc.

Systems Can Be Simpler Than You Think

- B747
  - level flight,

40000 ft, 774 ft/sec …

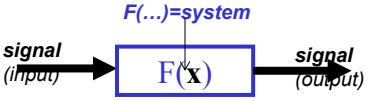
$$\begin{bmatrix} \dot{u} \\ \dot{v} \\ \dot{q} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} -.003 & .039 & 0 & -.322 \\ -.065 & -.319 & 7.74 & 0 \\ .020 & -.101 & -.429 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} u - u_w \\ v - v_w \\ q \\ \theta \end{bmatrix} + \begin{bmatrix} .01 & 1 \\ -.18 & -.04 \\ -1.16 & .598 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \delta_e \\ \delta_t \end{bmatrix}$$

  - u, w: horizontal/vertical velocity
  - q, θ: orientation & pitch rate
  - δe, δt : elevator and thrust commands

Source: Boyd, Stanford EE263 Lecture 14 (Slide 14-4)

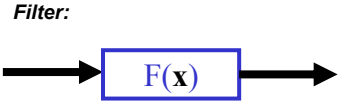
Signals and Systems Together

- A **signal** can be seen as that which goes in and out of a **system**

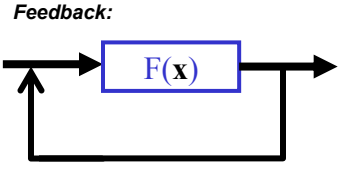


Signals and Systems Together

- A **signal** can be seen as that which goes in and out of a **system**
- **Signal Processing / "Filters" :** can be seen as a open-loop system

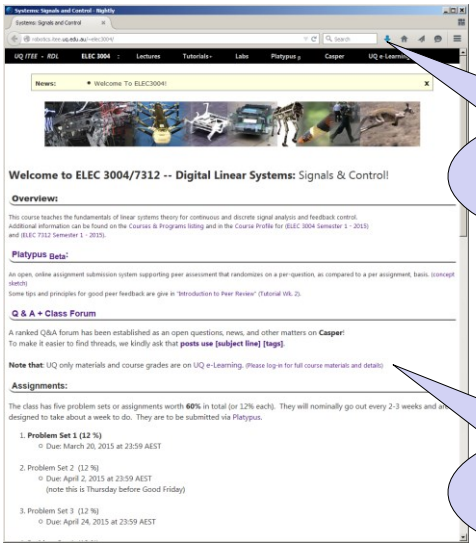


- **Feedback Control:** can be viewed as the case where the output signal **shapes** the input signal



Introducing
ELEC3004/7312

Website: http://robotics.itee.uq.edu.au/~elec3004/



http://elec3004.com

http://platypus.elec3004.com

Schedules and Locations:

- **Lectures:**
  - **Mondays** from **2:05 -- 4:00 pm**
  - Here! ☺

- **New "Open Interactive Lectures" :**
  - **Tuesdays** from **2:00 -- 3:00 pm**
  - Prentice (Bldg. 42) -- Room 216
  - Interactive: **Student Lead, Q&A, etc.**
  - ∴ **No Questions ⇒ No Answers!** ←

Schedules and Locations: Tutorials & Practicals

➔ All in Hawken -- Room S202 ➔

- **Tutorials: ODD Weeks (Starting on Week 3)**
  - **Please come to your assigned session**.
  - Sessions are:
    - **Monday 4:00 – 5:00p**
    - **Tuesday 12:00 – 1:00p**
    - **Thursday 11:00 – 12:00n**
    - **Thursday 4:00 – 5:00p**
    - **Friday 11:00 – 12:00n**
  - ~ 1 hour (unless extra time is needed)

Schedules and Locations: Tutorials & Practicals

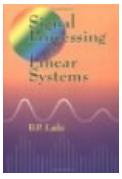
➔ All in Hawken -- Room S202 ➔

- **Prac Sessions: EVEN Weeks (Starting Week 4)**
  - **Please come to your assigned session**.
  - Sessions are the **same** as the Tutorial Sessions
  - That is:
    - **Monday 4:00 – 6:00p**
    - **Tuesday 12:00 – 2:00p**
    - **Thursday 11:00 – 1:00p**
    - **Thursday 4:00 – 6:00p**
    - **Friday 11:00 – 1:00p**
  - ~ 2 hours

Lecture Schedule:

Week	Date	Lecture Title
1	2-Mar	Introduction
	3-Mar	Systems Overview
2	9-Mar	Signals as Vectors & Systems as Maps
	10-Mar	[Signals]
3	16-Mar	Sampling & Data Acquisition & Antialiasing Filters
	17-Mar	[Sampling]
4	23-Mar	System Analysis & Convolution
	24-Mar	[Convolution & FT]
5	30-Mar	Frequency Response & Filter Analysis
	31-Mar	[Filters]
0	6-Apr	Holiday & Holiday
	7-Apr	Holiday
6	13-Apr	Discrete Systems & Z-Transforms
	14-Apr	[Z-Transforms]
8	27-Apr	Digital Filters
	28-Apr	[Digital Filters]
9	4-May	Digital Control Design
	5-May	[Digitial Control]
10	11-May	Stability of Digital Systems
	12-May	[Stability]
11	18-May	State-Space
	19-May	Controllability & Observability
12	25-May	PID Control & System Identification
	26-May	Digitial Control System Hardware
13	31-May	Applications in Industry & Information Theory & Communications
	2-Jun	Summary and Course Review

Reference Texts:



B. P. Lathi
Signal processing and linear systems
1998
TK5102.9.L38 1998

João Hespanha
Linear Systems Theory,
2009
[UQ Ebooks]

- Yes!
  You may use the Internet!!
  - Khan Academy
  - Wikipedia
  - YouTube
  - & **Google Scholar** Too!
- This field is vast & there are countless references present

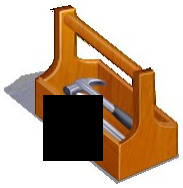
E-mail

- **elec3004@itee.uq.edu.au**
- Casper!
  - https://casper.ceit.uq.edu.au/courses/elec3004/
- [That's it!]
- {Not the instructors/tutors personally}

The Point of the Course

- Introduction to terminology/semantics
- An appreciation of how to frame problems in a linear systems engineering context
- Modeling and learning assumptions/when to trust the model
- Ability to identify critical details from the problem

➔ It's a **shortcut** …
Once you see that a system is **"linear"**
you can then apply the raft of
"linear systems" tools
(time & frequency analysis) to them
without having to do all the analysis from scratch



Not the Point of the Course

- Get good grades
- Just do homework
- Memorize pointless facts
- Rote "learning" of material with no comprehension
- Ask yourself, is the wonder still there?

Lots of Stuff To Cover…

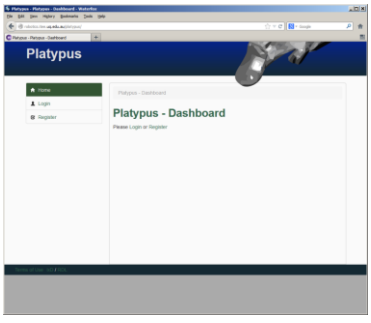
- Systems
- Signal Abstractions
- Signals as Vectors / Systems as Maps
- Linear Systems and Their Properties
- LTI Systems
- Autonomous Linear Dynamical Systems
- Convolution
- FIR & IIR Systems
- Frequency domain
- Fourier Transform (CT)
- Fourier Transform (DT)
- Even and Odd Signals
- Likelihood
- Causality
- Impulse Response
- Root Locus
- Bode Functions
- Left-hand Plane
- Frequency Response
- Discrete Time
- Continuous Time
- Laplace Transformation
- Feedback and Control
- Additional Applications
- Linear Functions
- Linear Algebra Review
- Least Squares
- Least Squares Problems
- Least Squares Applications
- Matrix Decomposition and Linear Algebra
- Regularized Least Squares
- Least-squares
- Least-squares applications
- Orthonormal sets of vectors
- Eigenvectors and diagonalization
- Linear dynamical systems with inputs and outputs
- Symmetric matrices, quadratic forms, matrix norm, and SVD
- Controllability and state transfer
- Observability and state estimation
- And that, of course, **Linear Systems are Cool!** ☺

Assessment

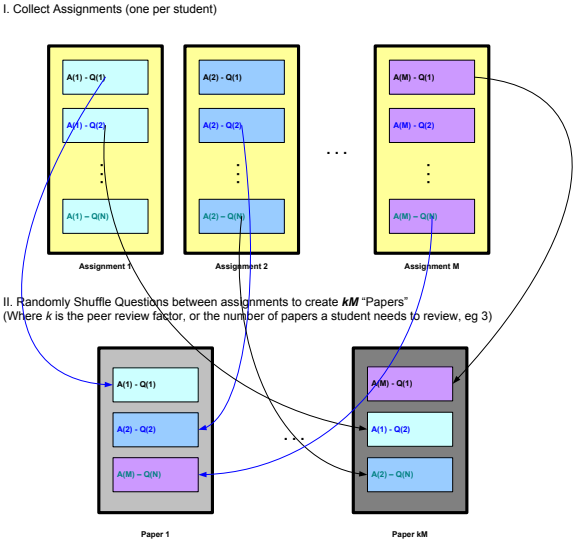
Assessment Task	Due Date	Weighting
Computer-based Assessment Challenge Practice Problems	TBA	EXTRA CREDIT
Laboratory Practicals Part I, II, III & IV	TBA	EXTRA CREDIT
Problem Set/s Problem Set 1	**20 Mar 15 23:59**	**12%**
Problem Set/s Problem Set 2	**2 Apr 15 23:59**	**12%**
Problem Set/s Problem Set 3	**24 Apr 15 23:59**	**12%**
Problem Set/s Problem Set 4	**8 May 15 23:59**	**12%**
Problem Set/s Problem Set 5	**22 May 15 23:59**	**12%**
Exam - during Exam Period (Central) Final Examination	Examination Period	40%

Platypus: Peer-review for Deliberate Practice/Learning

- **Peer-Review**
  - A **key** part of Engineering is being able to critically evaluate peer work (and give **good** feedback on it)
  - We **will** help teach you good habits of peer feedback
- **Question** (not Assignment) based random shuffling

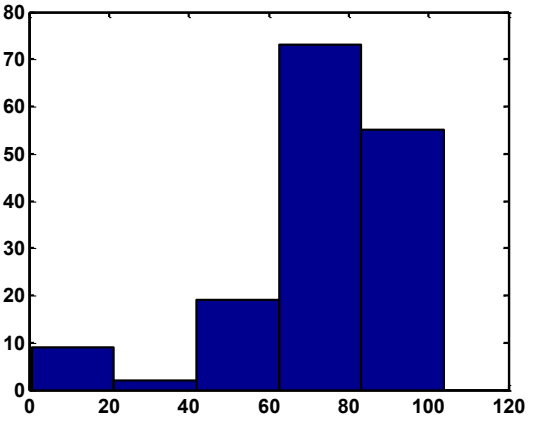


Platypus: How does it work?



Last Year's Grade Statistics

- ~ 45 % received >5
- Worry about **learning**, not about marks



What I expect from you

- Lectures:
  - Participate - ask questions
  - Turn up (hence the attendance marks)
  - Take an interest in the material being presented
- Tutorials:
  - Work on questions before tutorials
  - Use tutorials to clarify and enhance
  - Assignments to be submitted on time

Some Philosophy

- Let's start with Why …
- To learn something is to teach it
  - The function of a teaching is not so much to cover the topics, but more to discover them
- It is actually **more** work for us!
  - We have to teach you how to reflect & then assess this as well as how to do the assignment
- It helps you understand it by giving you a different perspective
- We're a community
  - You (alone) can't do everything … that's why we work together
  - The notion of "free speech" ➔ Trust emerges → efficiency (η)