http://elec3004.com

An Introduction to Digital Linear **Systems: Signals & Controls**

Welcome!

ELEC 3004: **Systems**: Signals & Controls

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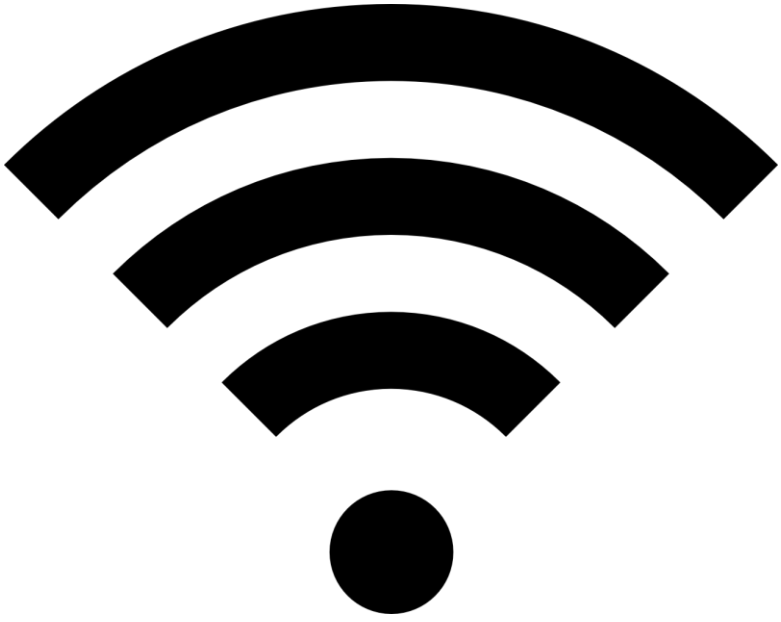
http://robotics.itee.uq.edu.au/~elec3004/

Lecture 1

February 28, 2017




M3 TO CORONATION DR
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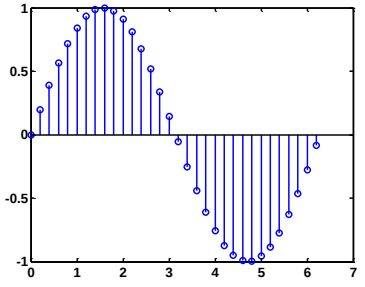
ELEC3004

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 …

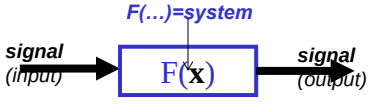
$$\begin{bmatrix} \dot{u} \\ \dot{v} \\ \dot{q} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} -.003 & .039 & 0 & -.322 \\ -.065 & -.319 & 7.74 & 0 \\ .020 & -.101 & -.429 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} u - u_w \\ v - v_w \\ q \\ \theta \end{bmatrix} + \begin{bmatrix} .01 & 1 \\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

  - 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)

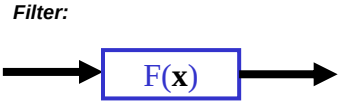
Signals and Systems Together

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

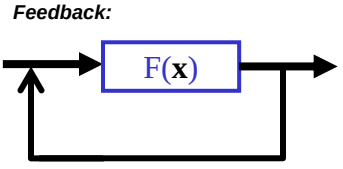


Signals and Systems Together

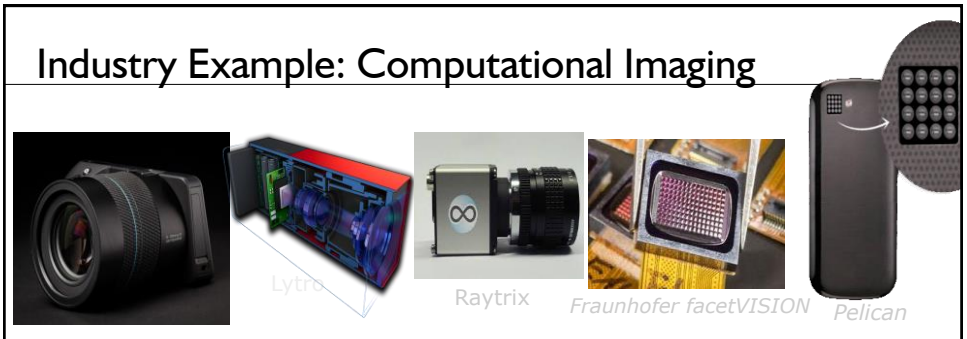
- A **signal** can be seen as that which goes in and out of a **system**
- **Signal Processing / "Filters" :** can be seen as a open-loop system

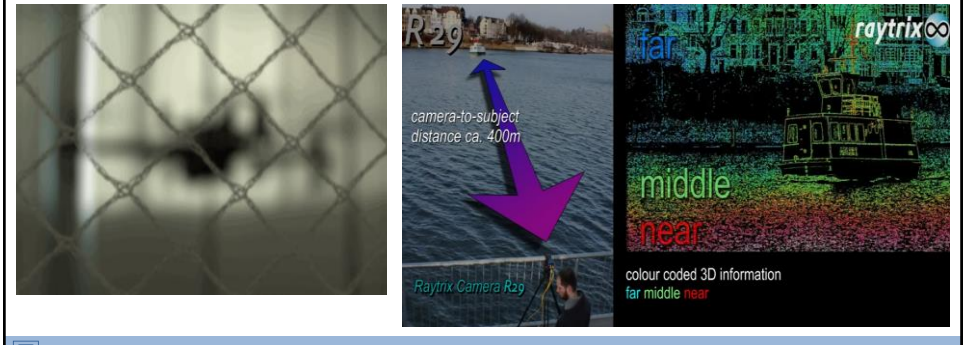


- **Feedback Control:** can be viewed as the case where the output signal **shapes** the input signal

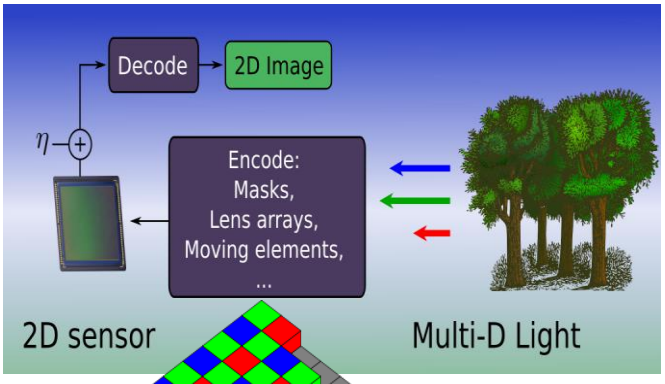


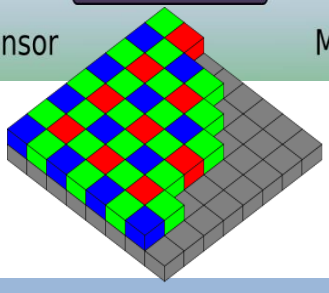
Industry Example: Computational Imaging





Another Example: Computational Imaging



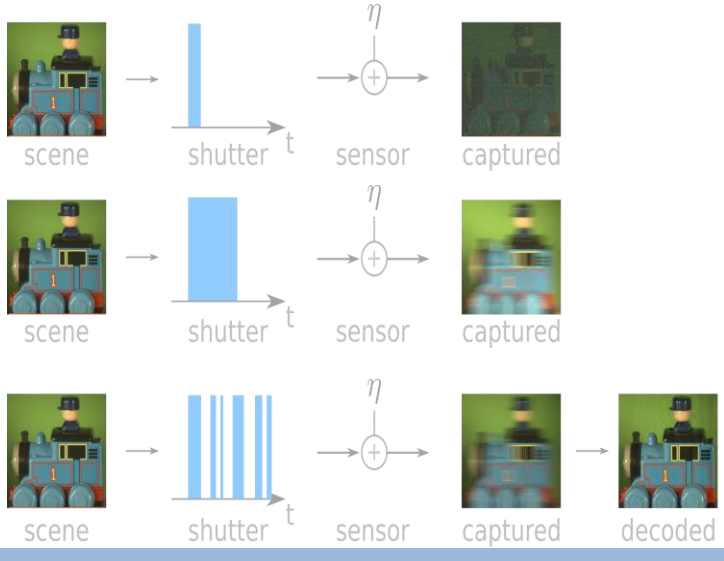


Intensity $\mathcal{L}(.)$
- Position (3)
- Direction (2)
- Time (1)
- Wavelength (1)
- Polarization (1)

Another Example: Computational Imaging

- Flutter Shutter

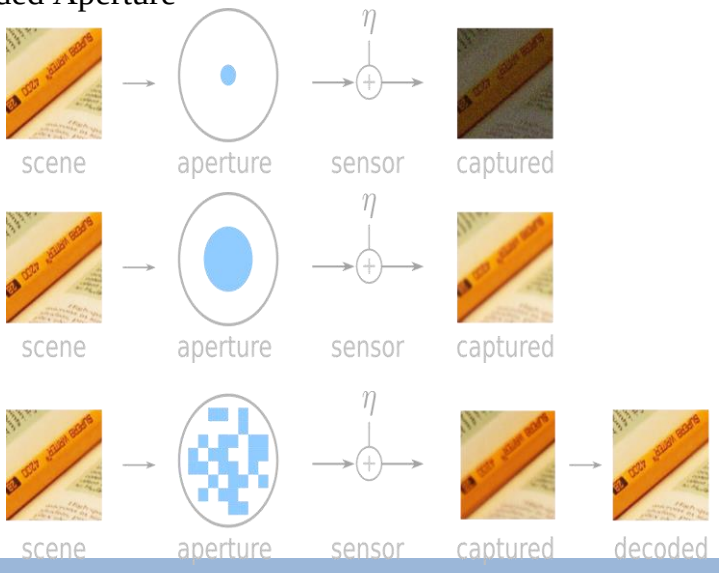
[raskar2006]



Another Example: Computational Imaging

- Coded Aperture

[gottesman89, levin2007, zhou2009 and others]



Introducing
ELEC3004/7312

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

Schedules and Locations:

- **Lectures:**
  - **Tuesdays** from **2:05 -- 3:30 pm**
  - Goddard Biological Sciences (8) -- Room 139
  - **[**Here! ☺**]**

&

  - **Thursdays** from **4:05 -- 5:30 pm**
  - Physiology Building (63) -- Room 348

- It starts at 2:05 (or 4:05 on Thursdays) – **Relax!**

Schedules and Locations: **Tutorials**

- **Tutorials: EVEN Weeks (Starting on Week 2)**
  SIX parallel sessions -- **Please come to your assigned one**.
  - Alternate attendance is at tutor discretion and must be arranged in advance

- Sessions are:
  - **Tuesday 4:00p--6:00** in Hawken - Room S202
  - **Wednesday 11:00a--1:00** in Hawken - Room S202
  - **Wednesday 2:00p--4:00** in Hawken - Room S202
  - **Wednesday 4:00p--6:00** in Hawken - Room S202
  - **Thursday 9:00a--11:00** in Hawken - Room S202
  - **Thursday 11:00a--1:00** in Hawken - Room S202

- ~ 90 min- 2 hours

Schedules and Locations: **Labs**

- **Prac / Lab Sessions: ODD Weeks (Starting Week 3)**
  - Six parallel sessions -- **Please come to your assigned one**.
  - Alternate attendance is at tutor discretion and must be arranged in advance

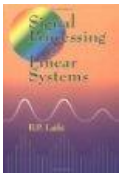
- Sessions are:
  - **Tuesday 4:00p--6:00** in Hawken - Room S202
  - **Wednesday 11:00a--1:00** in Hawken - Room S202
  - **Wednesday 2:00p--4:00** in Hawken - Room S202
  - **Wednesday 4:00p--6:00** in Hawken - Room S202
  - **Thursday 9:00a--11:00** in Hawken - Room S202
  - **Thursday 11:00a--1:00** in Hawken - Room S202

- ~ 2 hours

Lecture Schedule:

Week	Date	Lecture Title
1	28-Feb	Introduction
	2-Mar	Systems Overview
2	7-Mar	Systems as Maps & Signals as Vectors
	9-Mar	Data Acquisition & Sampling
3	14-Mar	Sampling Theory
	16-Mar	Antialiasing Filters
4	21-Mar	Discrete System Analysis
	23-Mar	Convolution Review
5	28-Mar	Frequency Response
	30-Mar	Filter Analysis
5	4-Apr	Digital Filters (IIR)
	6-Apr	Digital Windows
6	11-Apr	Digital Filter (FIR)
	13-Apr	FFT
	18-Apr	
	20-Apr	**Holiday**
	25-Apr	
7	27-Apr	Active Filters & Estimation
8	2-May	Introduction to Feedback Control
	4-May	Servoregulation/PID
10	9-May	Introduction to (Digital) Control
	11-May	Digitial Control
11	16-May	Digital Control Design
	18-May	Stability
12	23-May	Digital Control Systems: Shaping the Dynamic Response
	25-May	Applications in Industry
13	30-May	System Identification & Information Theory
	1-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

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…

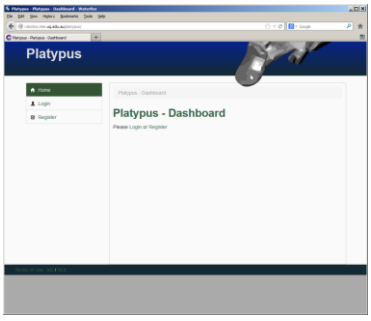
- Systems
- Signal Abstractions
- Signals as Vectors / Systems as Maps
- Linear Systems and Their Properties
- LTI Systems
- Autonomous Linear Dynamical Systems
- Convolution
- FIR & IIR Systems
- Frequency domain
- Fourier Transform (CT)
- Fourier Transform (DT)
- Even and Odd Signals
- Likelihood
- 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

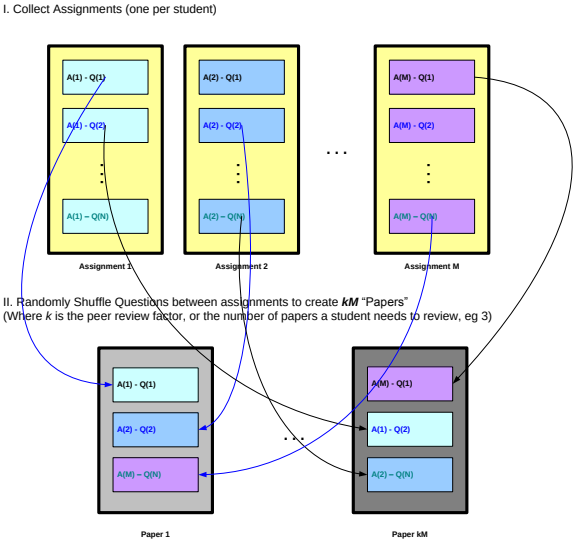
Assessment Task	Due Date	Weighting
Problem Set 1	24/03/2017 23:59	20%
Problem Set 2	28/04/2017 23:59	20%
Computer-based Assessment Online Quiz	5-May-17	EXTRA CREDIT
Problem Set 3	26/05/2017 23:59	20%
Final Exam		40%

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

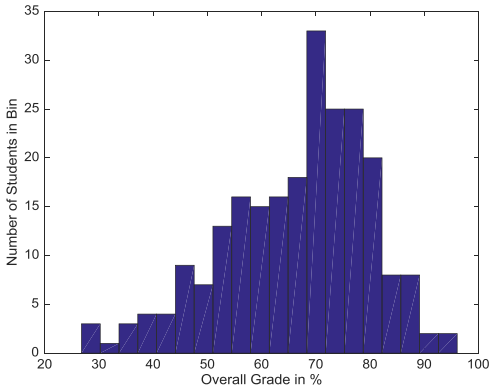


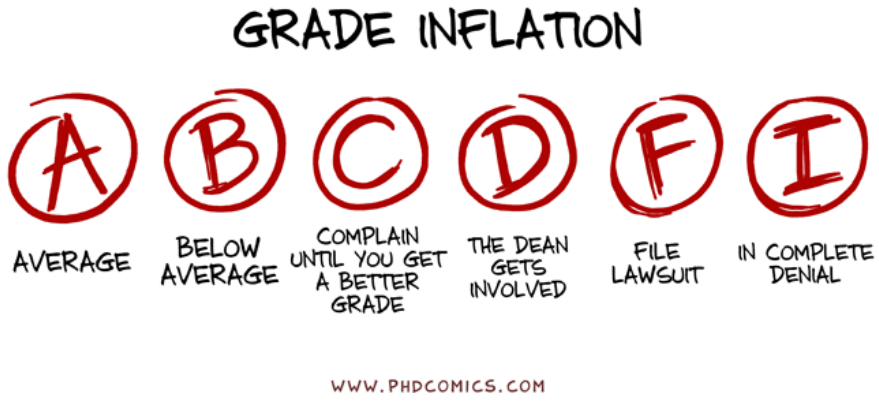
Platypus: How does it work?



Last Year's Grade Statistics

- ~ 62 % received >4 and ~30% received D or HD
- Worry about **learning**, not about marks





I need a "7" for a Job!

The New York Times | http://nyti.ms/1jTJavh

SUNDAYREVIEW | OP-ED COLUMNIST

How to Get a Job at Google

FEB. 22, 2014

Thomas L. Friedman

MOUNTAIN VIEW, Calif. — LAST June, in an interview with Adam Bryant of The Times, Laszlo Bock, the senior vice president of people operations for Google — i.e., the guy in charge of hiring for one of the world's most successful companies — noted that Google had determined that "G.P.A.'s are worthless as a criteria for hiring, and test scores are worthless. … We found that they don't predict anything." He also noted that the "proportion of people without any college education

Information: Size and Rate

A short novel	1 megabyte	1,000,000
All undergraduate textbooks	100 MB	100,000,000
An iPod	100 GB	80,000,000,000
A library floor of academic journals	100 GB	100,000,000,000
Print collections of Library of Congress	10 TB	10,000,000,000,00

Copying notes by hand	32 bits/second	32 bps
Speaking	230 bits/sec.	230 bps
Reading text	360 bits/sec	360 bps
Home internet connection	1-10 Mb/sec.	5,000,000 bps
Single optical fiber	40 Gb/sec.	40,000,000,000 bps

A short novel ≅ 1 Mbyte
- 70 hours to copy
- 6 hours to read
- Less than 10 seconds to download

Taken from: *http://burikmodeldesign.com/search/How_Many_Bytes.htm*

Changes from 2016

1. Three Assignments (Peer-reviewed, Marks from Tutor)
2. Online Quiz ("Mid-Semester" Review/Recap)
3. Labs remain optional
   1. Concepts still overlap with class
   2. May be assessed on Assignments/Final Exam
4. No State-Space Control "crammed" in the end
5. I am still inspired by, but little less of,
   Boyd's EE263: *Introduction to Linear Dynamical Systems*

My Goals Are

To teach you the skills and knowledge required to:

- Pass this course;
- Work towards meeting the needs of the world's population sustainably, working across technical, research and strategic roles

What you can expect from me:

- Lectures: theory, examples, expert guest lecturers, notes posted on webpage
- Try to make lectures interesting
- Participate in tutes, post solutions on Platypus
- Answer ALL questions respectfully
- Available for consultation immediately before and after lectures, during tutes and Thurs 4-6 pm.
- Guidelines for exam

Your goals in ELEC3004:

- To learn the skills and knowledge required to:
- Pass this course;
- Work towards meeting the needs of the world's population sustainably, working across technical, research and strategic roles

What I expect from you:

- Attend and participate in lectures, tutes, pracs
- Set out calculations clearly, with diagrams, units, interpretation
- Make sure you understand the fundamentals: keep up
- Ask questions if you:
  - don't understand
  - can't see/hear
  - suspect/find an error
- Complete all assessment on time
- Use email sparingly
- All email to be courteous and polite
- If you have a problem,
  - let me know **early** and propose a solution if possible

Plagiarism! Common causes: ignorance, desperation, wilful disregard of the rules

- Ignorance can result in plagiarism through:
- working too closely with other students
- failing to reference properly
- Solutions:
- Talk about your assignments together, but write them separately
- If quoting directly, use " "
- Check with lecture and/or UQ guidelines if unsure:

- http://www.library.uq.edu.au/how-to-guides/avoiding-plagiarism

Plagiarism! Common causes: Ignorance, desperation, wilful disregard of the rules

- Desperation can result in plagiarism through:
- Students under pressure due to uni work or external circumstances, working against a deadline, fail to take proper care in referencing, or copy someone else's work
- Solutions:
- Ask for extension
- Had in late assignment or no assignment:
- LIKELY TO GET A BETTER RESULT THAN FACING A PLAGIARISM INVESTIGATION

Plagiarism! Common causes: ignorance, desperation, wilful disregard of the rules

- Wilful disregard of plagiarism rules is very serious.

- Common indicators:
- Using formatting and minor changes to hide similarities with published work or the work of other students.

- Consequences:
- See UQ plagiarism policy.
- Solutions:
- Do your own work!
- CONSEQUENCE FOR PLAGIARISM ARE VERY SERIOUS

E-mail

- **elec3004@itee.uq.edu.au**

- Casper!
  - https://casper.ceit.uq.edu.au/courses/elec3004/

- [That's it!]
- {Not the instructors/tutors personally}

Communications: Some Expectations

- **Think carefully before using email**

- Please keep communication concise and polite

- Let me know if there are problems
  - During tutorials, before and after lectures
  - Student reps (Teaching and Learning Committee)
  - Consultation period: 4-6pm Thursday

Communications: Examples

- Email 1:

  To [ELEC3004],

  I am currently signed up for the Tuesday afternoon tutorial, T1, but this clashes with another subject in which I have no movement. Is it possible for me to be changed into the Wednesday morning tutorial, T2?

  Thank You for your time.

  Name signed,

  student number

- Email 2:

  S'up!! ☺

  all T classes be the full, can't sign on ☹

Communications: Examples of useful emails

- Email 1:

  I think that there is an error in the solutions to Question 4: the second Eqn has 2D, but I think it should be D.

- Email 2:

  My friends and I are unsure what air temperature to use in Q2a on the assignment. Could you please explain this in the next lecture.

- Email 3:

  Would I be able to have an X day extension to assignment 1 because I am ill? I have submitted my medical certificate to the school.

- Email 4:

  I am having trouble keeping up in the course. Could I make a time to meet with you to discuss.

  Yours sincerely, [My Name]

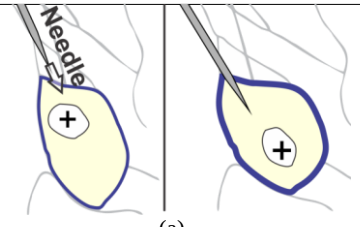
What I expect from you

- 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

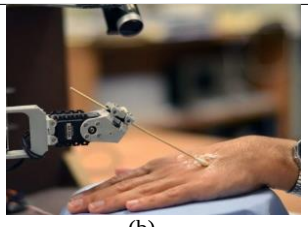
In Summary: Some Philosophy

- 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)

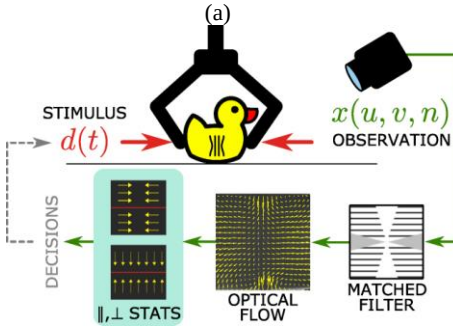
About What I Do



(a)



(b)



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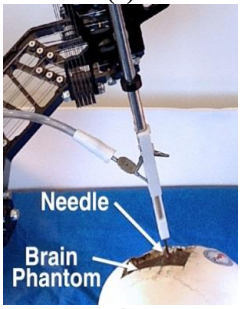

(d)

(a) Lesion targeting **(b)** DermBot **(c)** Visual Deformable Object Analysis **(d)** Neurosurgical Robotics

Next Time…

Signals & Systems: A Primer!