Introduction to Robotics

METR 4202: Advanced Control & Robotics
Drs Surya Singh, Paul Pounds, and Hanna Kurniawati
Lecture # 1   July 23, 2012
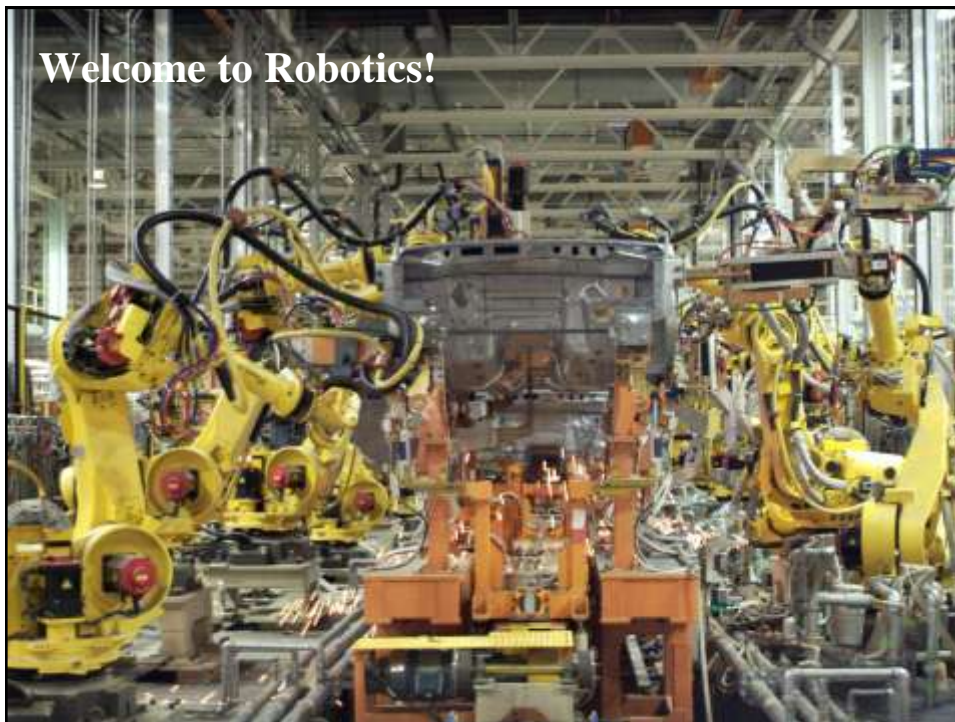
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Welcome to Robotics!

History of Humanoids
Man's dream takes first step forward

ASIMO
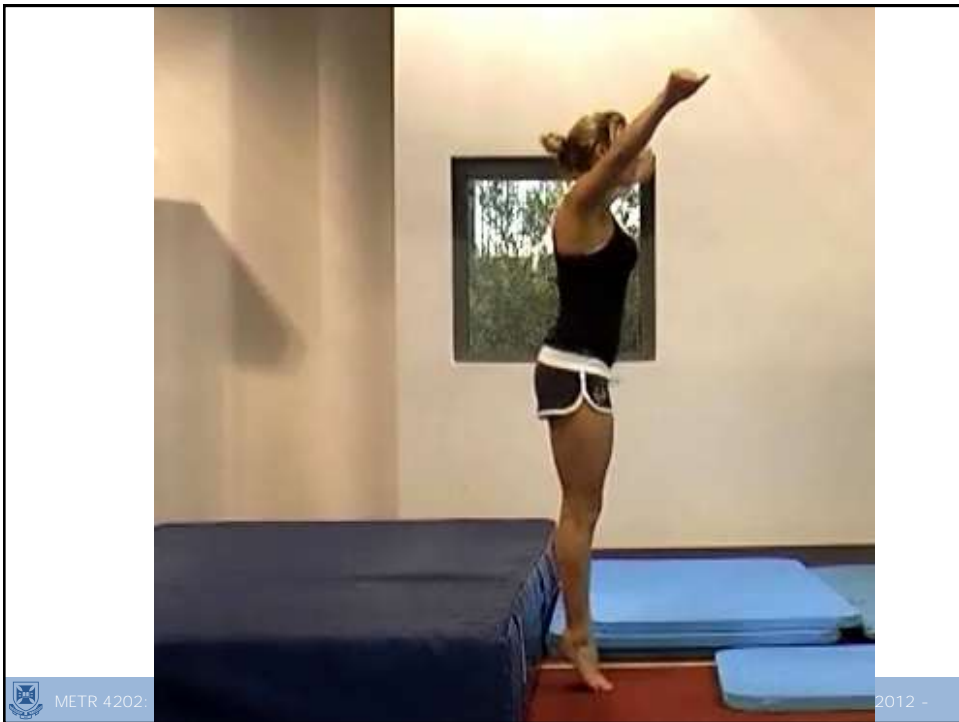The Honda Humanoid Robot ASIMO

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Agenda

- Course Objectives

- Robotics Domain Overview

- System Design Principles

Schedule of Events

Week	Date	Lecture (M: 12-1:30, 43-102)
1	23-Jul	Introduction
2	30-Jul	Representing Position & Orientation & State (Frames, Transformation Matrices & Affine Transformations)
3	6-Aug	Robot Kinematics and Dynamics
4	13-Aug	Robot Dynamics & Control
5	20-Aug	Obstacle Avoidance & Motion Planning
6	27-Aug	Sensors, Measurement and Perception
7	3-Sep	Localization and Navigation
8	10-Sep	State-space modelling & Controller Design
9	17-Sep	Vision-based control
	24-Sep	*Study break*
10	1-Oct	Uncertainty/POMDPs
11	8-Oct	Robot Machine Learning (TBA)
12	15-Oct	Guest Lecture (CSIRO-TBA)
13	22-Oct	Wrap-up & Course Review

Assessment

- Kinematics Lab (20%):
  - Proprioception
  - Arm design and operation (with Lego)

- Sensing Lab (25%):
  - Exterioception
  - Camera operation and calibration (with a Kinect)

- Systems and Controls Lab (30%):
  - All together!

- Final Exam (25%) ☺

Lectures

- Mondays from 12:00 – 1:30 pm

- Lectures will be posted to the course website
  after the lecture (so please attend)

- Please ask questions
  (preferably about the material ☺)

Tutorials & Labs

- Tutorials:
  - Tuesdays from 12:00 – 1:00 in the
    Axon Learning Lab (47-104)
  - Meeting Weeks 2-9 (not this week!)

- Labs:
  - Fridays from 11:00 – 1:00 in the
    Axon Learning Lab (47-104)
  - Meeting: Weeks 3-13 (not this week or next week!)

The Teaching Team

- Lecturers:
  Surya Singh, Paul Pounds, and Hanna Kurniawati

- Tutors:

  Mr Ashray, Doshi   Mr Jared Page
  Mr Christopher Ham   Mr Ye Tian
  Mr Adam Keyes

E-mail & website

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Please use **metr4202** e-mail for class matters!

Course Objectives

1. Be familiar with sensor technologies relevant to robotic systems
2. Understand homogeneous transformations and be able to apply them to robotic systems,
3. Understand conventions used in robot kinematics and dynamics
4. Understand the dynamics of mobile robotic systems and how they are modelled
5. Understand state-space and its applications to the control of structured systems (e.g., manipulator arms)
6. Have implemented sensing and control algorithms on a practical robotic system
7. Apply a systematic approach to the design process for robotic system
8. Understand the practical application of robotic systems in to intelligent mechatronics applications (e.g., manufacturing, automobile systems and assembly systems)
9. Develop the capacity to think creatively and independently about new design problems; and,
10. Undertake independent research and analysis and to think creatively about engineering problems.

The Point of the Course

- Introduction to terminology/semantics

- An appreciation of how to frame problems in an engineering context

- Modeling and learning to trust the model

- Ability to identify critical details from the problem (separate information from trivia)

Grade Descriptors

Grade	Level	Descriptor
Fail	(<50%)	**Work not of acceptable standard**. Work may fail for any or all of the following reasons: unacceptable level of paraphrasing; irrelevance of content; presentation, grammar or structure so sloppy it cannot be understood; submitted very late without extension; not meeting the University's values with regards to academic honesty.
Pass	(50-64%)	**Work of acceptable standard**. Work meets basic requirements in terms of reading and research and demonstrates a reasonable understanding of subject matter. Able to solve relatively simple problems involving direct application of particular components of the unit of study.
Credit	(65-74%)	**Competent work**. Evidence of extensive reading and initiative in research, sound grasp of subject matter and appreciation of key issues and context. Engages critically and creatively with the question and attempts an analytical evaluation of material. Goes beyond solving of simple problems to seeing how material in different parts of the unit of study relate to each other by solving problems drawing on concepts and ideas from other parts of the unit of study.
Distinction	(75-84%)	**Work of superior standard**. Work demonstrates initiative in research, complex understanding and original analysis of subject matter and its context, both empirical and theoretical; shows critical understanding of the principles and values underlying the unit of study.
High Distinction	(85%+)	**Work of exceptional standard**. Work demonstrates initiative and ingenuity in research, pointed and critical analysis of material, thoroughness of design, and innovative interpretation of evidence. Demonstrates a comprehensive understanding of the unit of study material and its relevance in a wider context.

Last Year's Grade Statistics
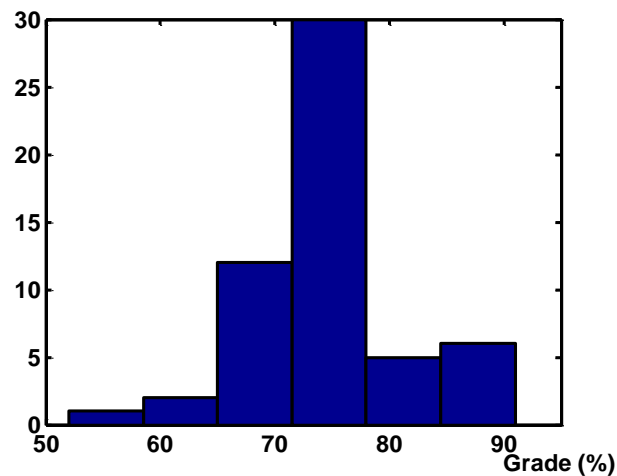
- ~ 60 % received D or HD
- Worry about **<u>learning</u>**, not about marks


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

So *What is a Robot* ?????

- A "Smart" Machine …

- A "General Purpose" (Adaptive) "Smart" Machine…

Plan→ Sense ⟶ Control → Act

"Learning"
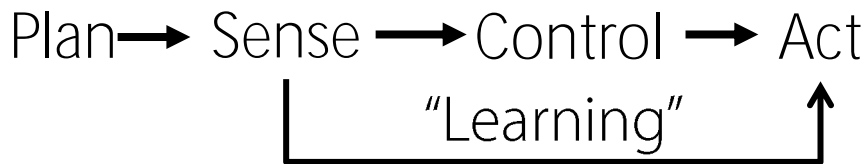
Robotics Definition

- Many, depends on context…

"A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks."
(Robotics Institute of America)

It is a machine which has some ability to interact with physical objects and to be given electronic programming to do a specific task or to do a whole range of tasks or actions.
(Wikipedia)

Programmable electro-mechanical systems that adapt to identify and leverage a **structural characteristic** of the environment
(Surya)

Types of Robotics Systems

• Manipulators	• Multiple	• Mobile

Enabling Mathematics:

- Computational Kinematics	- Behaviour based "Reflexive" control rules	-Probabilistic methods
- Operational Space		

Sensing

Perception: Vision
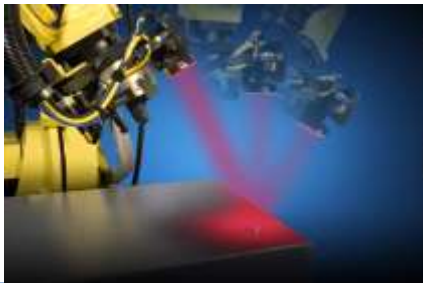
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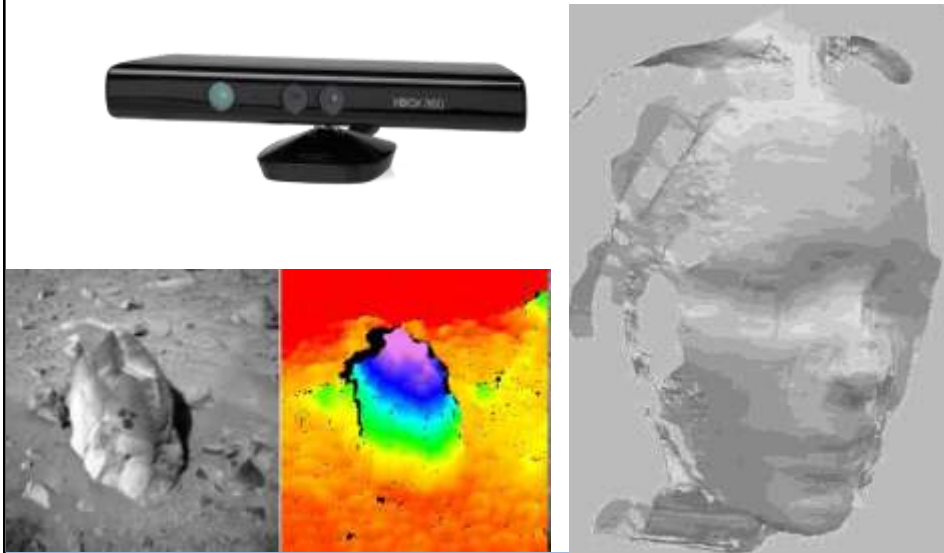
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3D Stereo Vision

Laser Sensors

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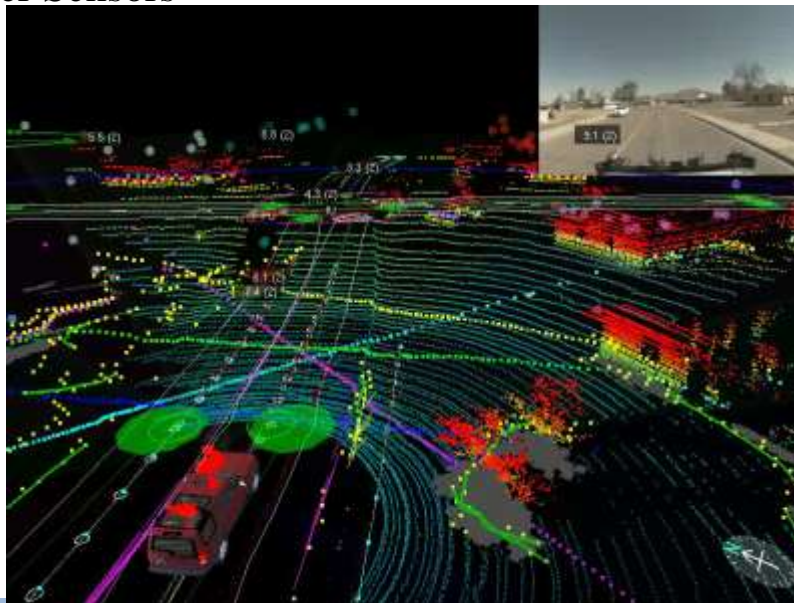
Processing …

Environment Understanding

Honda Asimov Humanoid

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Dynamic Locomotion & Balance …

Boston Dy...
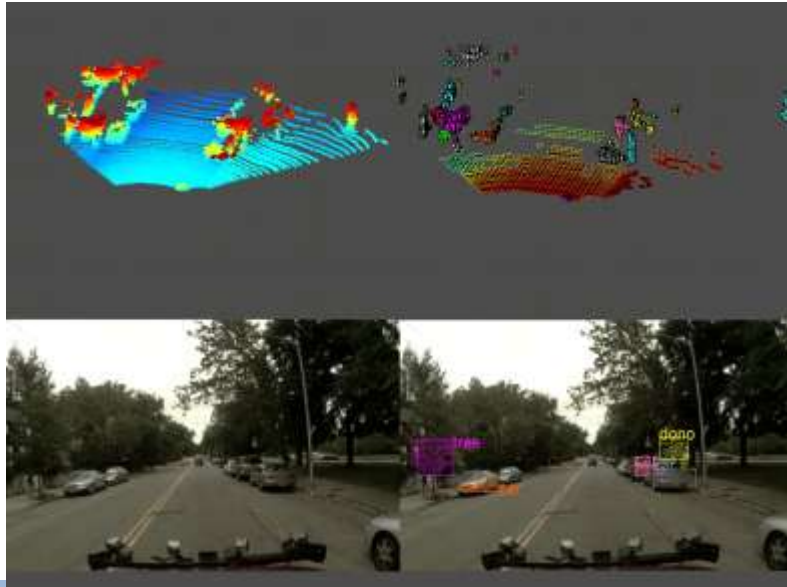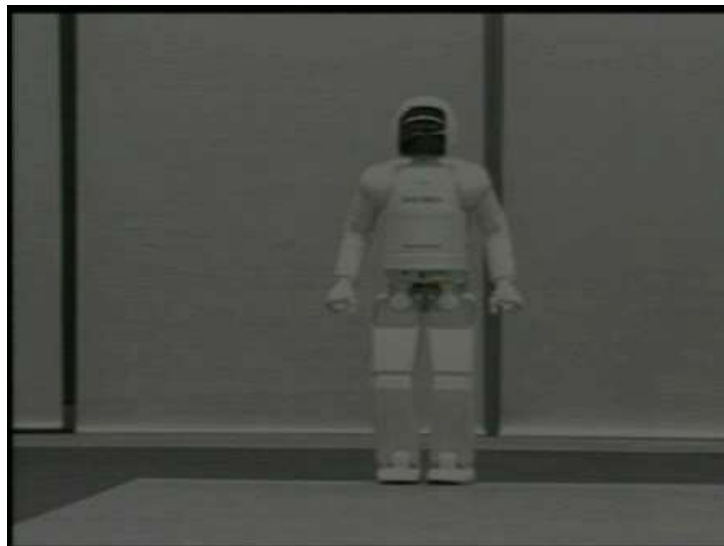
Action

Driving a Robot

Field Testing Nov 2003

Spinner
Unmanned Ground
Combat Vehicle

Driving Many Robots

Robot Submarines For Marine Biology

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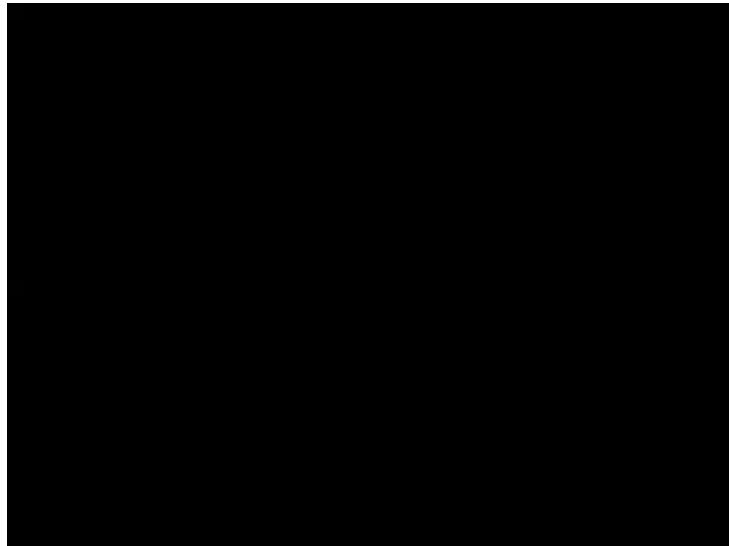
Robot Sniper Training Robots

What's the Structure?

Robotics: All about structure…

- Robot working in an "unstructured" environment

→ Does not have to be dirty to use "field robotics" technology …

→ Robotics is about exploiting the **structure** …

  Either by:

  - Putting it in from the design (mechanical structure)

  - "Learning" it as the system progresses (structure is the data!)

To Create Something "Smart"…
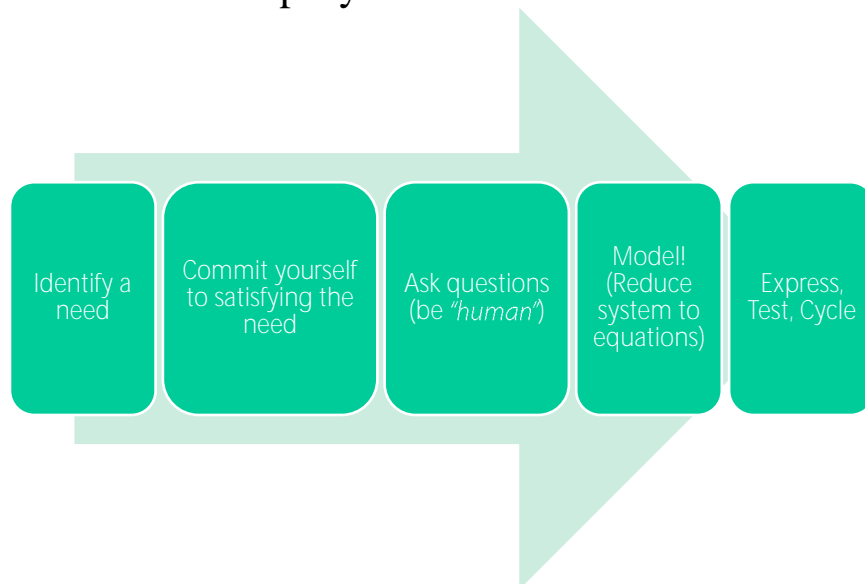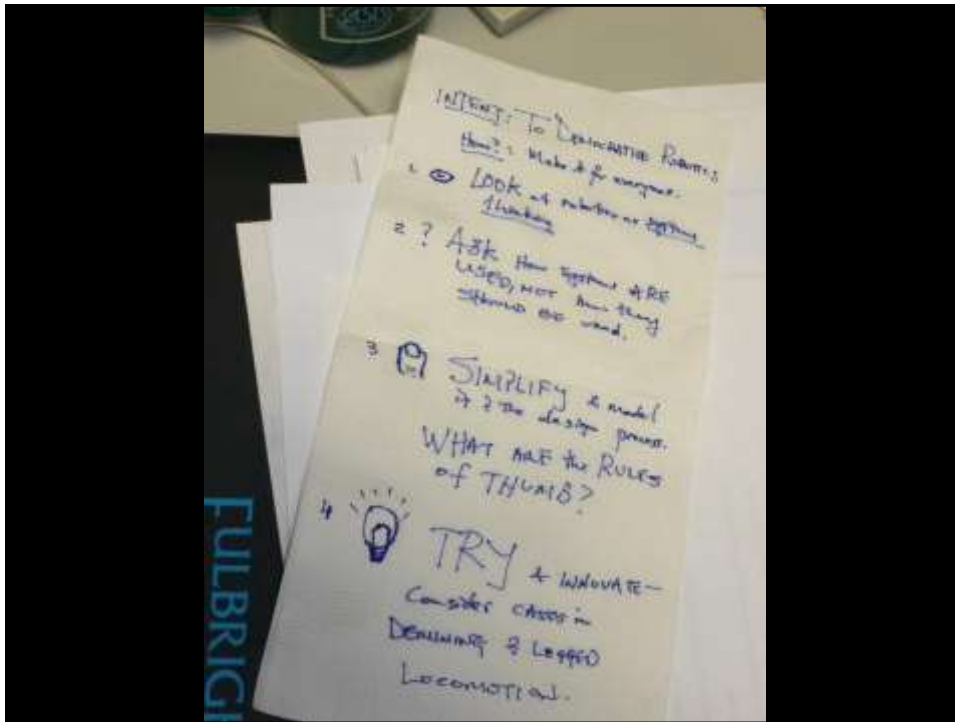& Design is a Disciplined Way To Do Just That

Be Stupid!

Be stupid!

- When creating something new it is impossible to be an expert – so don't act like one.

- Keep your ego out of it, be a professional idiot.

- If you are stupid people will teach you everything they know about the problem.

- If you are smart, they will not volunteer information.

- Question conventional wisdom.

Look – Ask – Simplify - Test

Identify a need → Commit yourself to satisfying the need → Ask questions (be *"human"*) → Model! (Reduce system to equations) → Express, Test, Cycle

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1. Identify a need

- *Find a problem you are interested in working on.*
(It doesn't not have to be a problem, it can be an opportunity.)

- Learn everything you can about the need (problem).
 (Understand the context)

- Get clear what the problem really is.

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2. Commit to satisfying the need

- Question your motivation

- Don't expect financial rewards if there is no need being satisfied

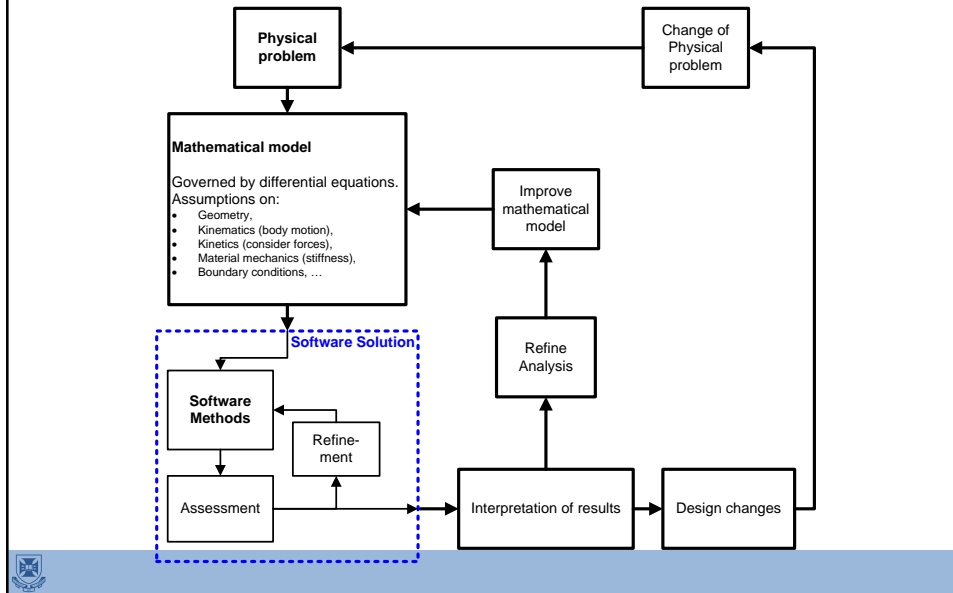- Trust your "gut"; follow "wants" not "shoulds."

3. Ask Questions

- Consider this from the users perspective…
  - Try **"*you*"** instead of **"*me*"**…

- How to all the parts fit together
  - Think about the "system"

- Identify "root" causes of angst
  - What's really going on…
  - Why was the "error" there to begin with

- Be wary of a fixed methodology.

4. Model

- Abstraction from Design to Analysis Tools

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5. ETC: Express, Test, Cycle

- Start generating solutions immediately.

- Save research efforts for parts you can't make work.

- <u>Express</u> as many ideas as you can.

- <u>Test</u> the ones you are not sure about.
  (Do it cheaply, use "crap-ups".)

- <u>Test</u> your prototype.
  Abuse your prototype …
       check it under the worst imaginable conditions.

- Modify, test and rebuild, modify, test and rebuild, …..
  (keep iterating until time is up.)

This week's Tutorial …

- ## **NOT being held this week**

Summary

- An outline of the course structure – details are in the Unit of Study Outline
- Considered and presented a basic definition of a mechatronic system
- A look at the courses which will fulfil the requirements for a Mechatronic Engineering Degree
- Some examples of common mechatronic systems