Mtrx 4700 : Experimental Robotics

Introduction

Dr. Stefan B. Williams

Dr. Robert Fitch

Course Objectives

- The objective of the course is to provide students with the essential skills necessary to develop robotic systems for practical applications.

Administrative Details

- Lecturers : Stefan Williams, Robert Fitch
- Lecture Time : Tuesdays 9-11
- Tutorials : Fridays, 9-12
- Contact Details :
  - E-mail : stefanw@acfr.usyd.edu.au
  - Phone : 9351 8152
  - In person : Room 206, ACFR building, dial x18152 from front door. Don't just turn up and expect to be seen. Make an appointment first, preferably by e-mail.

Administrative Details

- Details on www.aeromech.usyd.edu.au
  - Follow links to Teaching/Undergraduate/Mtrx 4700
  - Assignments, lectures and supplementary material will be posted
- Alternatively, we can set up a site on WebCT. Any preferences?

Recommended Texts

Manipulator Kinematics and Dynamics

- John J. Craig, *Introduction to Robotics: Mechanics and Control,* 3rd Edition, Prentice-Hall, 2003
- Lorenzo Sciavicco, Bruno Siciliano, *Modelling and Control of Robot Manipulators (Advanced Textbooks in Control and Signal Processing)*, Springer 2000
- Mark W. Spong, M. Vidyasagar, *Robot Dynamics and Control*, Wiley, 1989

Computer Vision

- Ballard and Brown, *Computer Vision*, Prentice Hall, 1982
- David A. Forsyth and Jean Ponce, *Computer Vision -- A Modern Approach*, Prentice Hall, 2002

Machine Learning

- Tom Mitchell, *Machine Learning*, McGraw-Hill, 1997
- Stuart J. Russell and Peter Norvig, *Artificial Intelligence, A Modern Approach*, 2nd Edition, Prentice Hall, 2002

Mobile Robotics

- Sebastian Thrun, Dieter Fox and Wolfram Burgard, Probabilistic Robotics, The MIT Press, 2005
- Greg Dudek and Michael Jenkin, *Computational Principles of Mobile Robotics*, Cambridge University Press, 2000
- Roland Siegwart and Illah R. Nourbakhsh, *Introduction to Autonomous Mobile Robots (Intelligent Robotics and Autonomous Agents)*, The MIT Press, 2004

Course Outline

Week	Date	Content	Labs	Due Dates
1	5 Mar	Introduction, history & philosophy of robotics		
2	12 Mar	Robot kinematics & dynamics	Kinematics/Dynamics Lab	
3	19 Mar	Sensors, measurements and perception	"	
4	26 Mar	Robot vision and vision processing.	*No Tute (Good Friday)*	**Kinematics Lab**
	2 Apr	BREAK		
5	9 Apr	Localization and navigation	Sensing with lasers	
6	16 Apr	Estimation and Data Fusion	Sensing with vision	
7	23 Apr	Extra tutorial session (sensing)	Robot Navigation	**Sensing Lab**
8	30 Apr	Obstacle avoidance and path planning	Robot Navigation	
9	7 May	Extra tutorial session (nav demo)	Major project	**Navigation Lab**
10	14 May	Robotic architectures, multiple robot systems	"	
11	21 May	Robot learning	"	
12	28 May	Case Study	"	
13	4 June	Extra tutorial session (Major Project)	"	**Major Project**
14		Spare		

Assessment

- Introductory Labs **(30%)**
  - Manipulator Lab: Due Week 4 (10%)
  - Pioneer Lab: Due Week 6 (10%)
  - Navigation Lab: Due Week 9 (10%)
- Major Project Presentation and Report **(40%)**
- Exam **(30%)**

Learning Outcomes

Following completion of this UoS students will:

- Be familiar with sensor technologies relevant to robotic systems
- Understand conventions used in robot kinematics and dynamics
- Understand the dynamics of mobile robotic systems and how they are modelled
- Have implemented navigation, sensing and control algorithms on a practical robotic system
- Apply a systematic approach to the design process for robotic systems
- Understand the practical application of robotic systems in applications such as manufacturing, automobile systems and assembly systems
- Develop the capacity to think creatively and independently about new design problems
- Undertake independent research and analysis and to think creatively about engineering problems

What is a Robot?

- ***Robot*** (a Slavic word for worker) was first introduced in 1921 in a play by the Czech playwright, Karel Čapek.
- A *traditional* definition of a robot is a programmable multi-function manipulator designed to move material, parts, or specialized devices through variable programmed motions for the performance of a variety of tasks.

What is a Robot?

- A robot is a machine that can help us perform a job
- They are often stronger than people
- Some are designed to go where we can't go
- They perform jobs that we can't
- Others undertake tasks we are not very good at

What is a Robot?

- Robots help us to
  - Assemble cars and other components
  - Dispense medicines and other chemical agents
  - Explore new places
  - Perform dangerous jobs like cleaning up nuclear power plants, mine fields and explosives

You might recognize these robots

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Or These…

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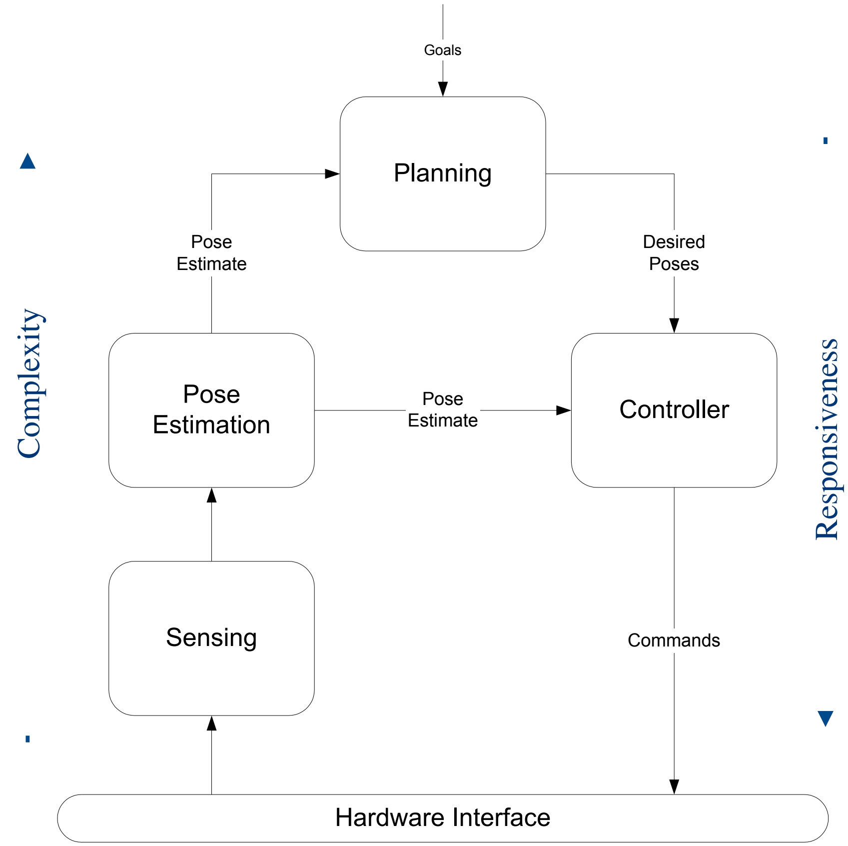
What about these robots?

What is a Robot?

- A robot system generally consists of 3 subsystems: Motion, Sensing and Control.
  - The **motion** subsystem includes *mechanisms* that function like human arms.
  - The **sensing** subsystem uses various *sensors* to gather information about the robot itself and the environment.
  - The **control** subsystem commands the motion to achieve a given *task* using the recognition information.

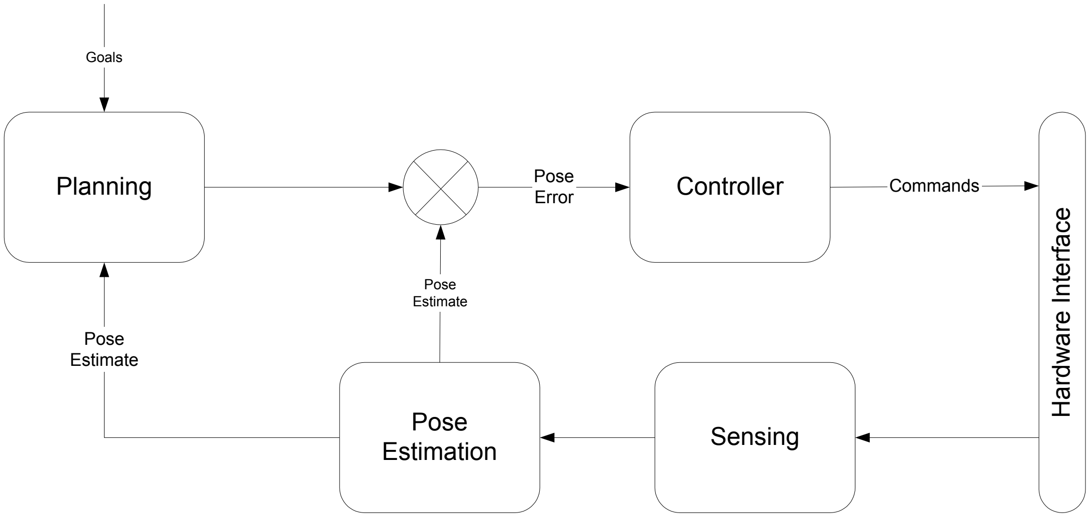
Robot Components

- The components of a robotic system can often be broken down into a hierarchy
- Sensing and interfacing to hardware is done at a low level and demands a high degree of responsiveness
- Estimation and control rely on interfaces to the mechanism
- Planning of paths and reasoning can be done at lower rates but is often more complex



Robot Components

- You may recognize the diagram recast in a traditional control layout
- There are effectively two control loops here
  - The inner loop achieves particular poses (note: there is often a rate controller in addition to the pose controller shown here)
  - The outer loop is concerned with trajectory control

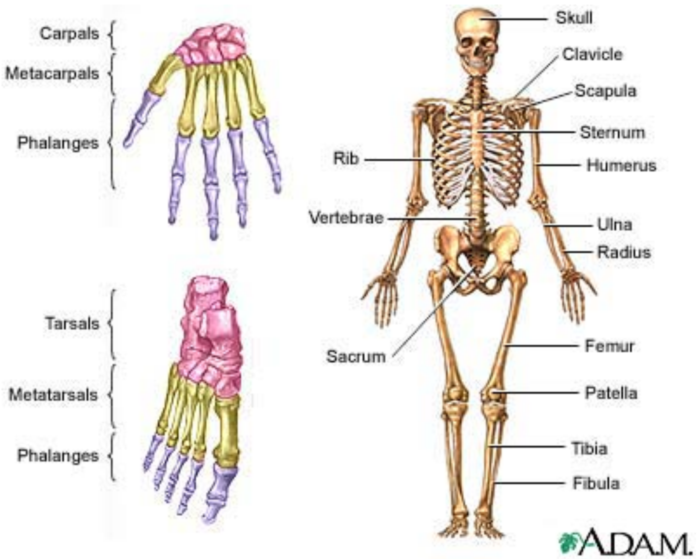


What does a robot need?

- A robotic system requires one or more of the following elements
  - Mechanics (a frame to hold everything together)
  - Actuation (something to move it)
  - Energy (something to give it power)
  - Sensing (something with which to observe)
  - Directions (a description of how to do its job)

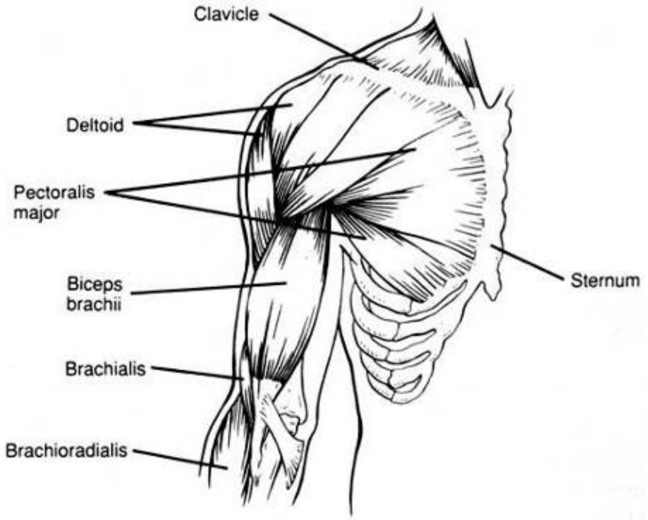
Mechanical

- Mechanical requirements are also very application dependent
- The design of a robotic system will largely be dictated by the task it will perform but may include
  - Chassis
  - Propulsion
  - Suspension
  - Locomotion



Actuators

- Actuators provide the motive power for the system
- Actuation power is usually provided by the energy system
- Careful consideration to the appropriate actuation will depend on the system requirements
- Examples include
  - Electric motors
  - Chemical engines
  - Shape memory alloy
  - Hydraulics
  - Pneumatics

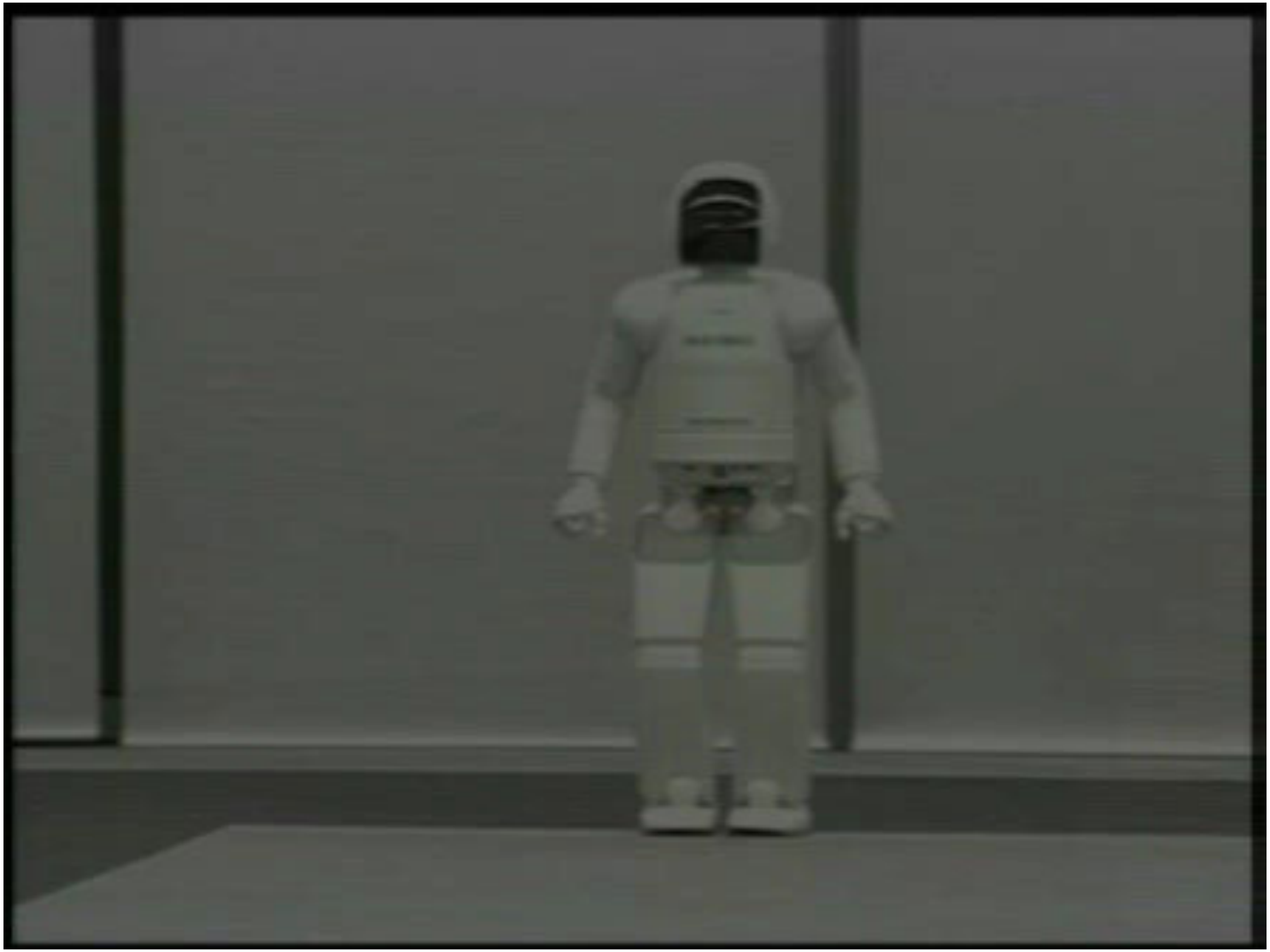


Humanoids

Humanoids – Honda Asimo

- Honda secretly began developing a Humanoid program to encourage innovation in its engineers
- The requirement for high power density in small packages provided technical challenges

Honda Asimov Humanoid



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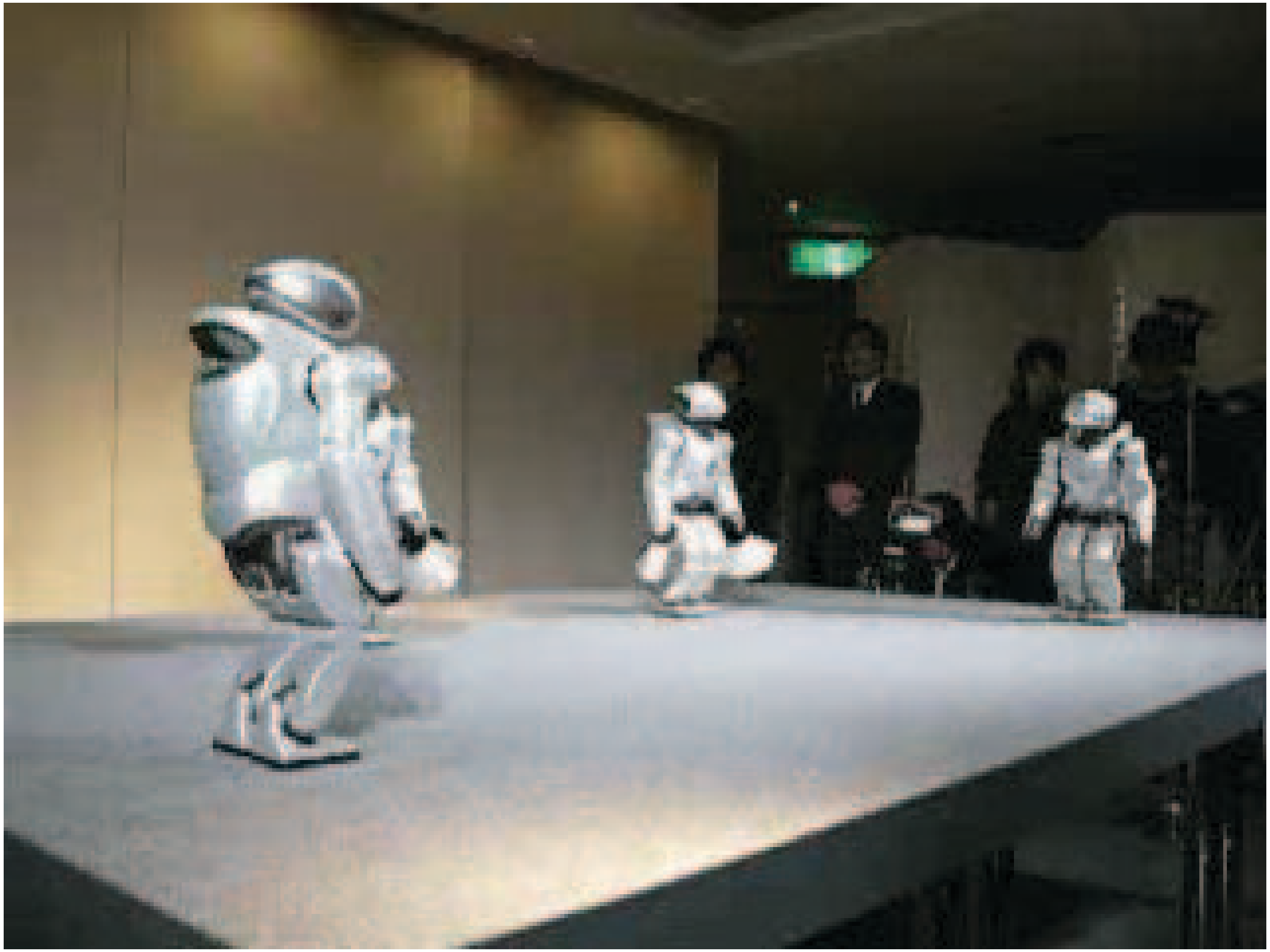
Humanoids - Sony

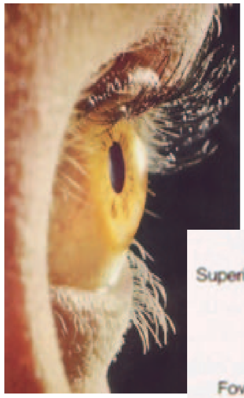


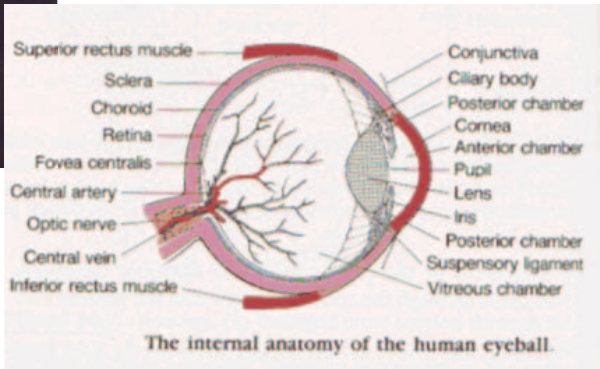
Energy

- Most robotic systems require some form of energy
- Sources depend largely on the application but may include
  - Electric (AC/DC)
  - Batteries
  - Solar
  - Diesel and gas
  - Chemical

Sensing - Vision

- Sensors measure relevant aspects of the world and convert them into signals to be processed by the system
- Once again, sensing depends on the application but may include
  - Proprioceptive sensors (encoders, resolvers, tachometers, inertial, etc)
  - External sensors (compass, GPS, inclinometer, etc)
  - Perceptive sensors (vision, sonar, laser, force and torque, proximity, etc.)

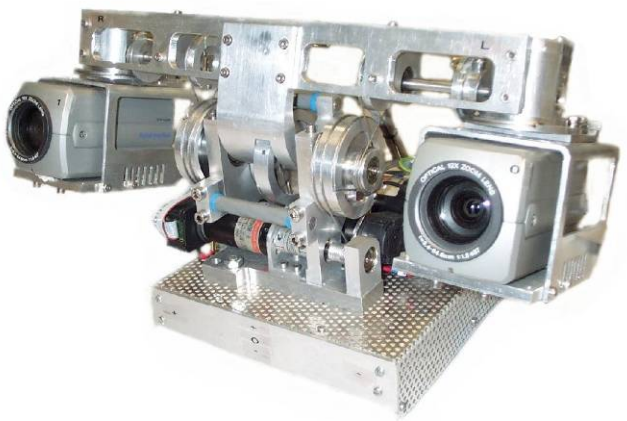


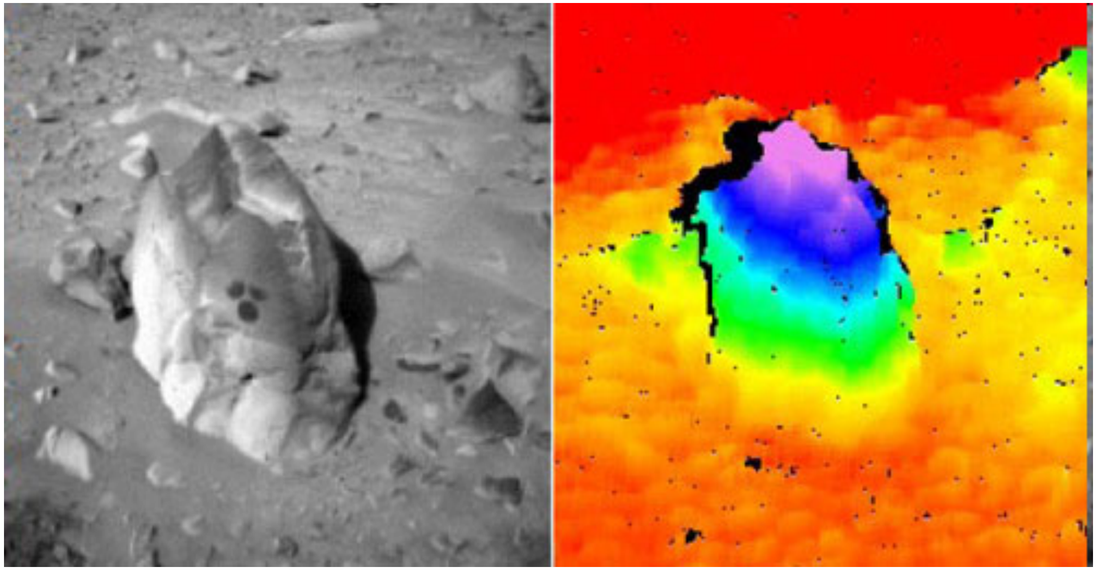


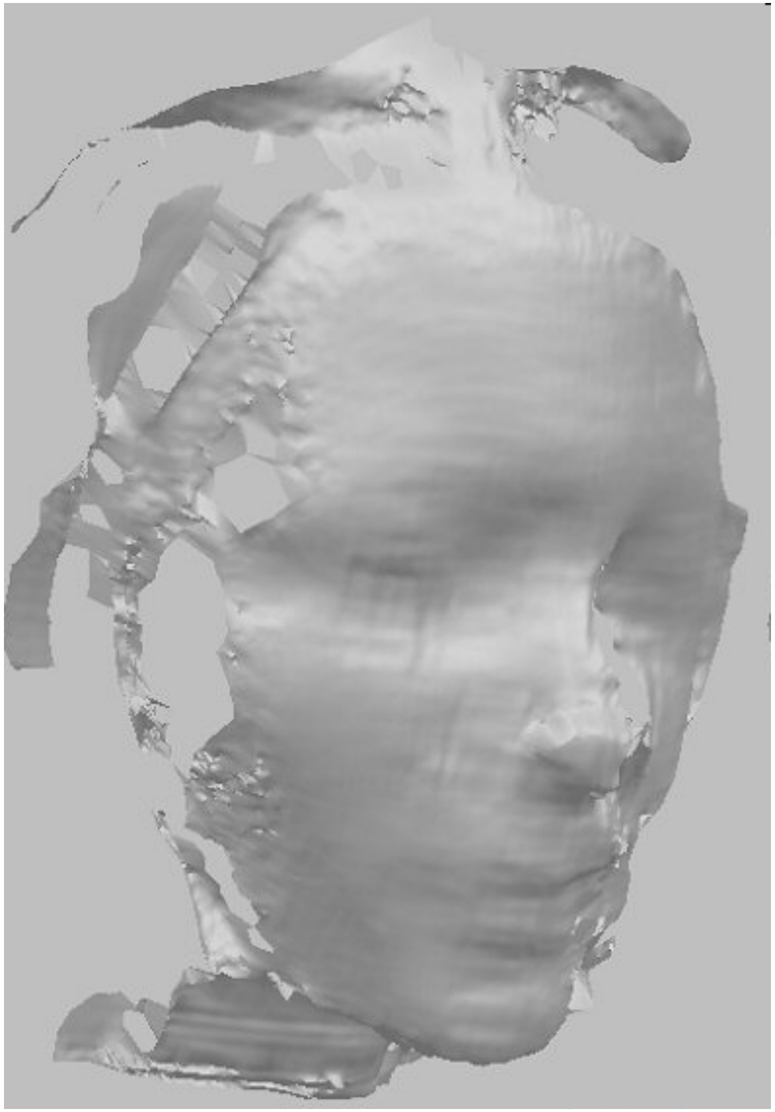
The internal anatomy of the human eyeball.

Edges, Segments, Colour, Texture

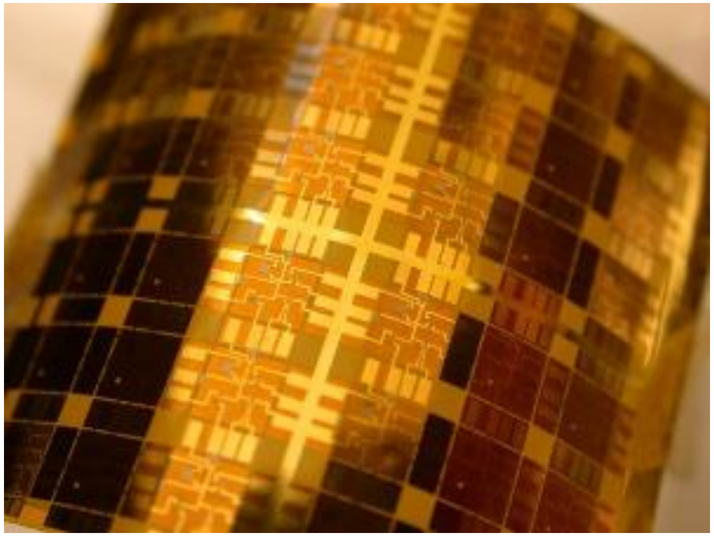
3D Stereo Vision

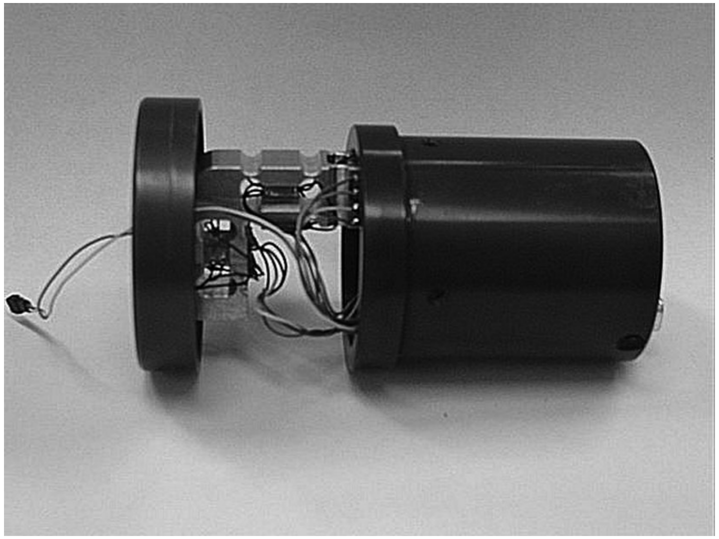






Perception: Touch





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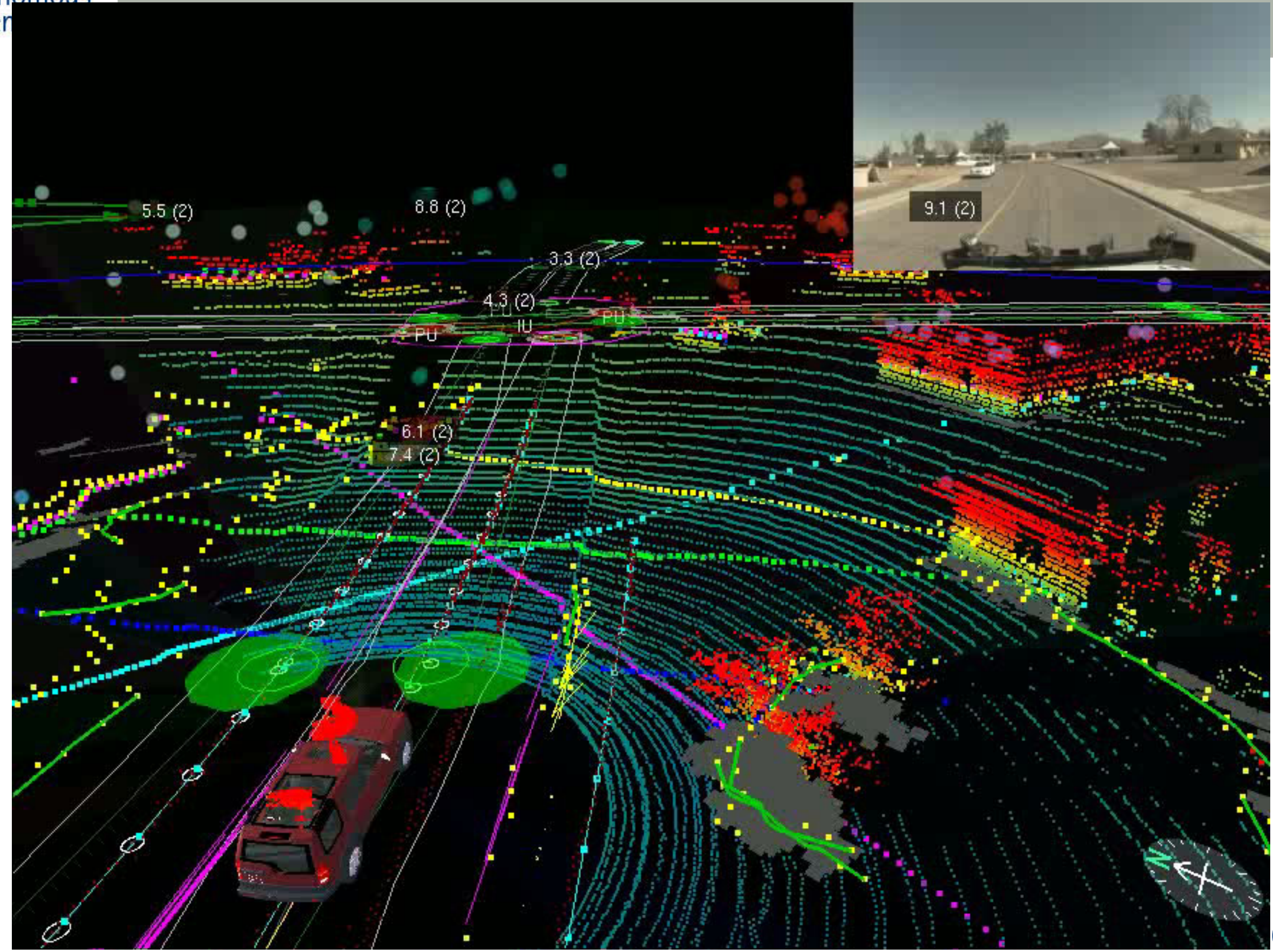
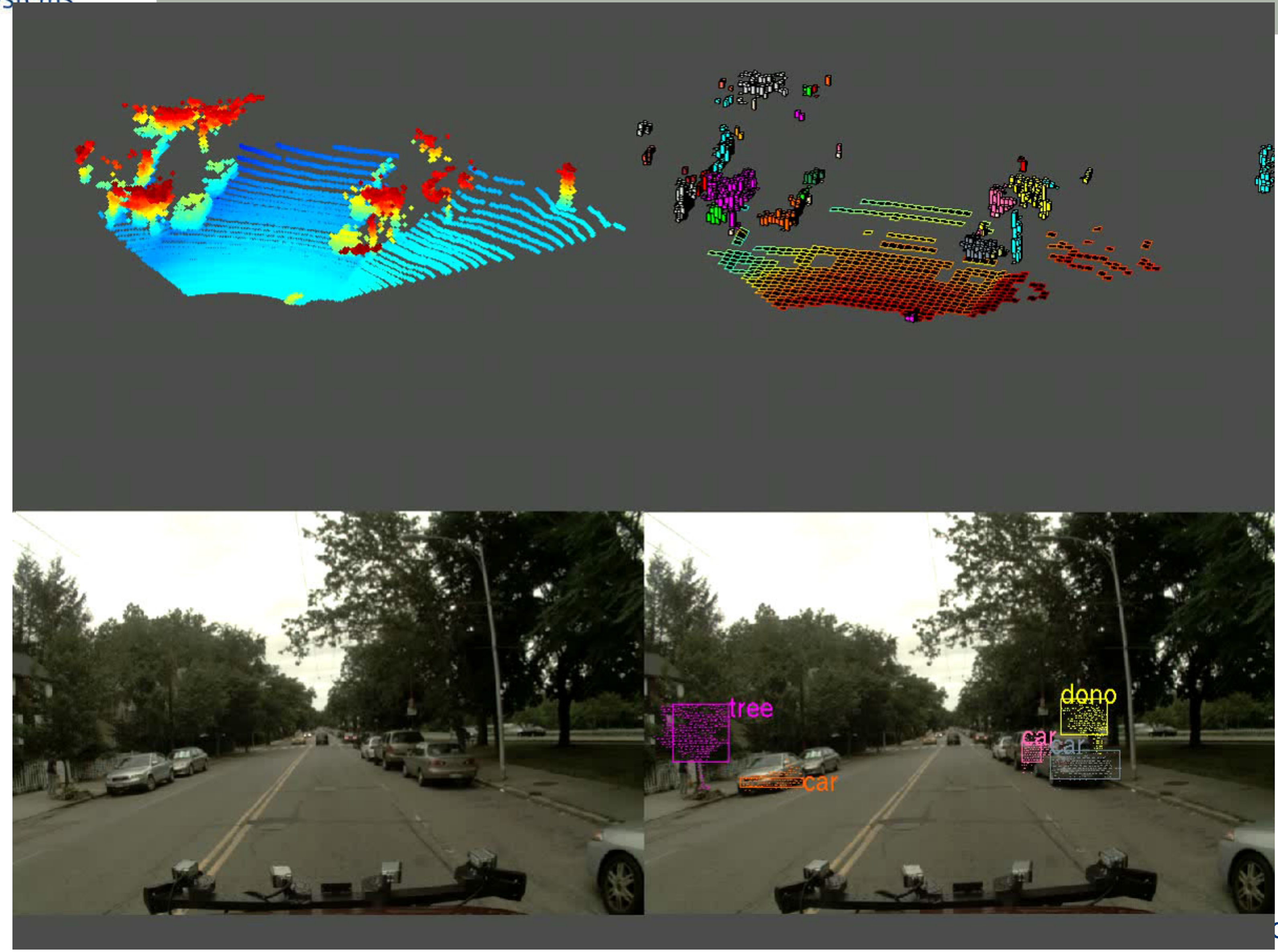
Other Sensors: Laser



Environment Understanding



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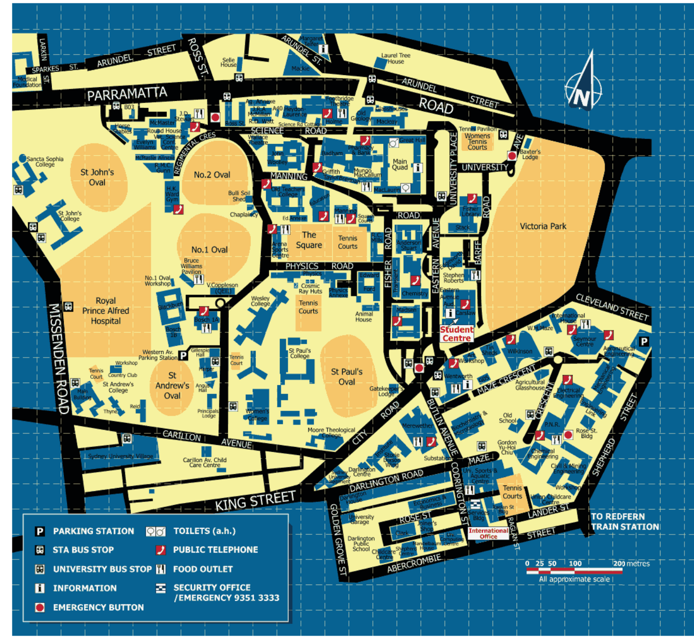
Control

- Control systems are used to enable a robot to perform its allocated task
- These days many controllers are implemented as digital systems, although analogue systems can often be used
- Control systems may include
  - Velocity control
  - Position control
  - Trajectory control
  - Environmental control




```
get destination
while not at destination
        sample sensors
        calculate movement
        send commands
end
```

Controlling a Robot

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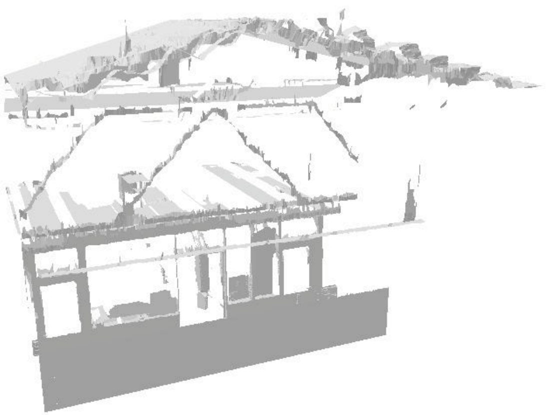
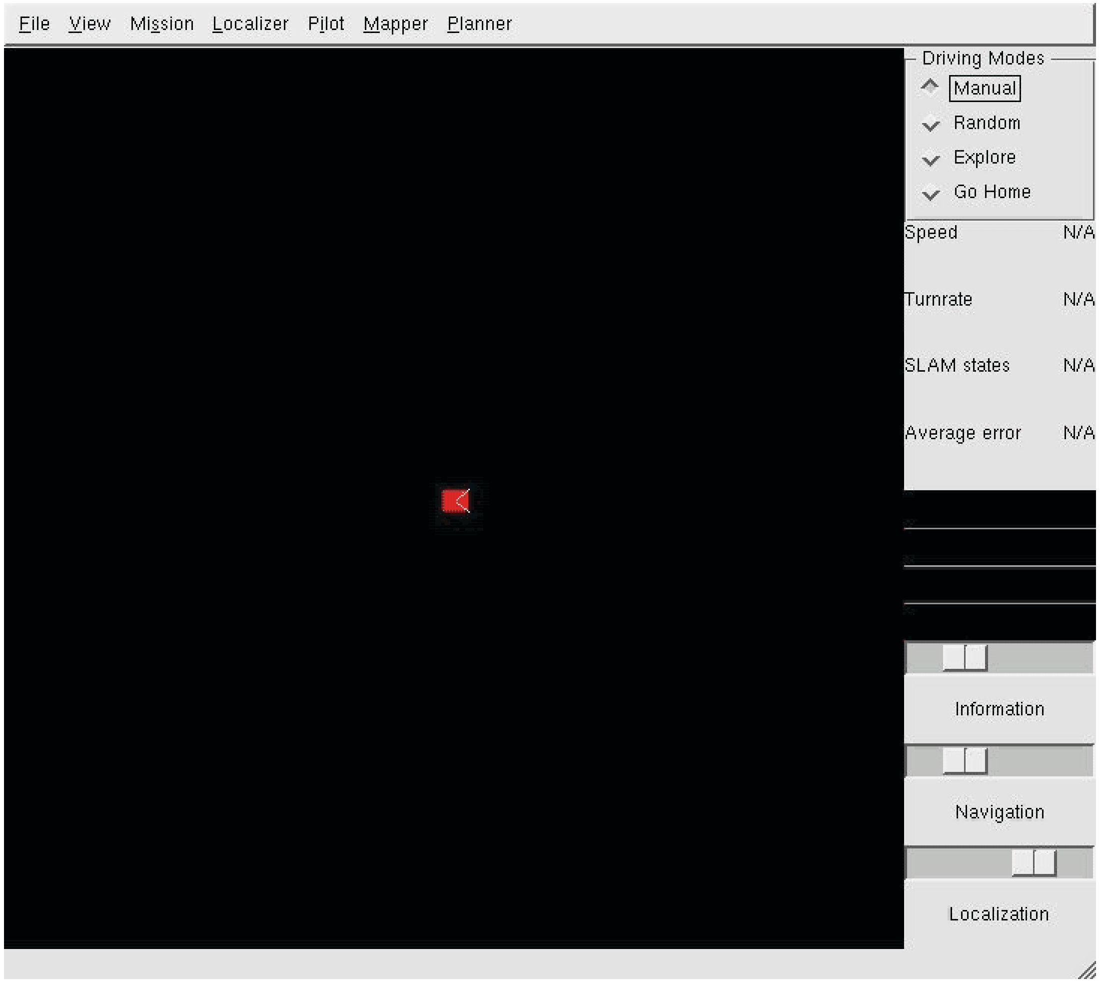
Controlling Many Robots

Slide 34

Control: Search and Exploration





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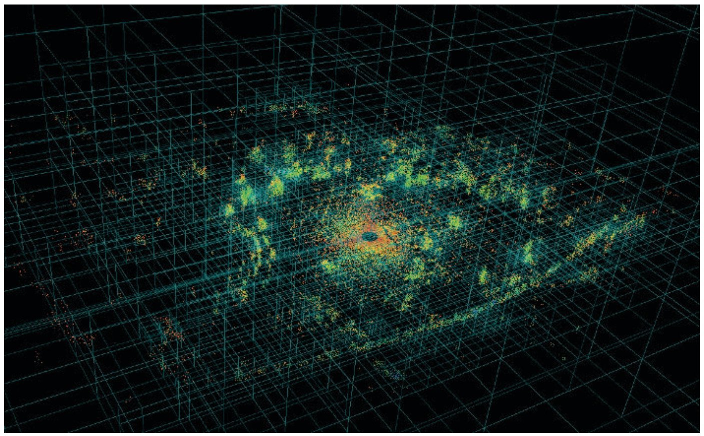
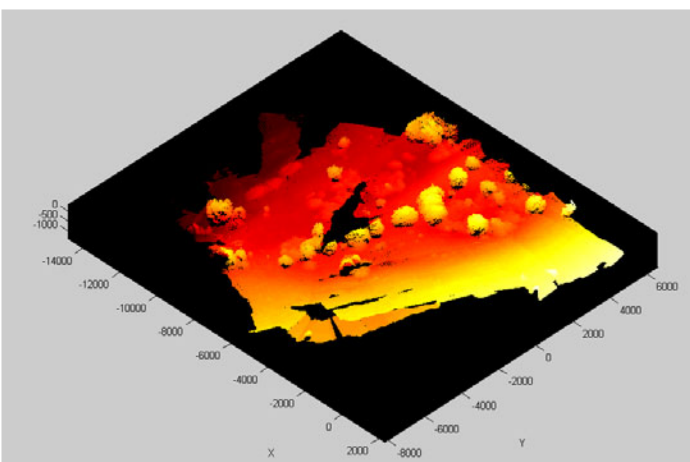
Control: Sensing and Planning





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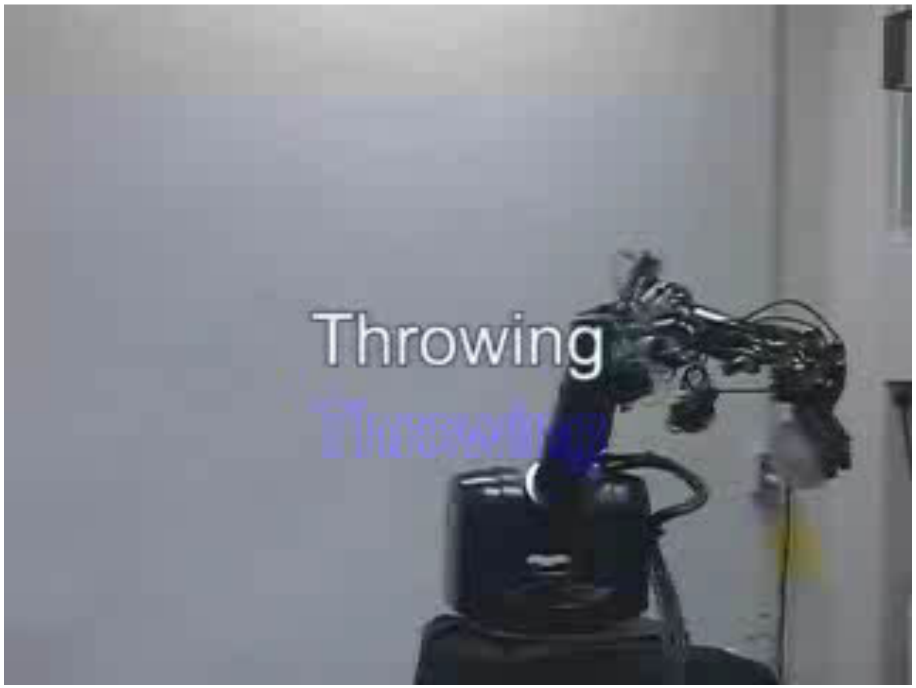
Control: Making Iced Tea

Throwing and Catching



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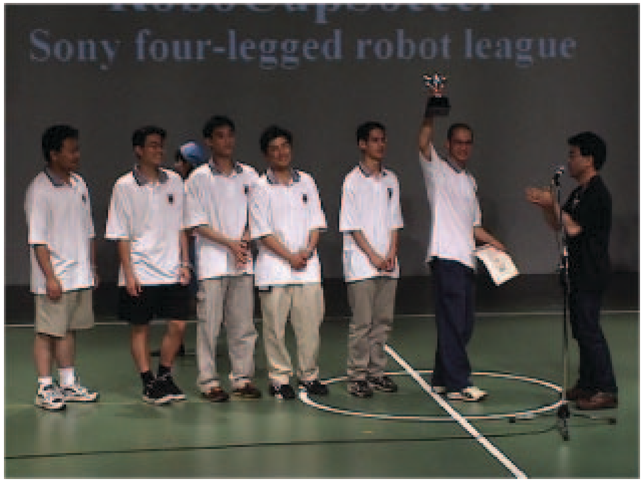
Learning to Walk and Play



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Big Dog: Walking by Balancing

Entertainment

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Androids

Slide 42

Space Robots

- NASA has been using robotic systems to explore Mars
- Many satellites can be considered robots
- Voyager recently became the first manmade object to leave the solar system

Space Robots

Opportunity

Spirit

Transport – CMU Navlab

- Navlab is an on-going program that investigates the application of robotic technologies in the transport arena
- One of the most ambitious demonstrations was entitled “No Hands Across America” in which a robotic vehicle drove from Pittsburgh to San Diego with little human intervention

DARPA Grand Challenge

- **DARPA Grand Challenge** is a field test intended to accelerate research and development in autonomous ground vehicles
- An autonomous ground vehicle to finish designated route most quickly within 10 hours will receive $2 million.
- Route will be no more than 175 miles over desert terrain featuring natural and man-made obstacles.
- Exact route will not be revealed until two hours before event

DARPA Urban Grand Challenge

Autonomous Systems

Automated Container Handling

- Relatively Simple Problem:
  - A structured environment
  - Well defined task
  - Well defined pay-off
- Research Challenges:
  - Control a large, fast platform
  - Guarantee performance
  - Ensure Safety
- Objectives:
  - Best manned performance
  - 24/7 operation
  - Safe, low-maintenance
- Innovations:
  - Navigation Integrity
  - Control Performance
  - Multi-vehicle optimisation

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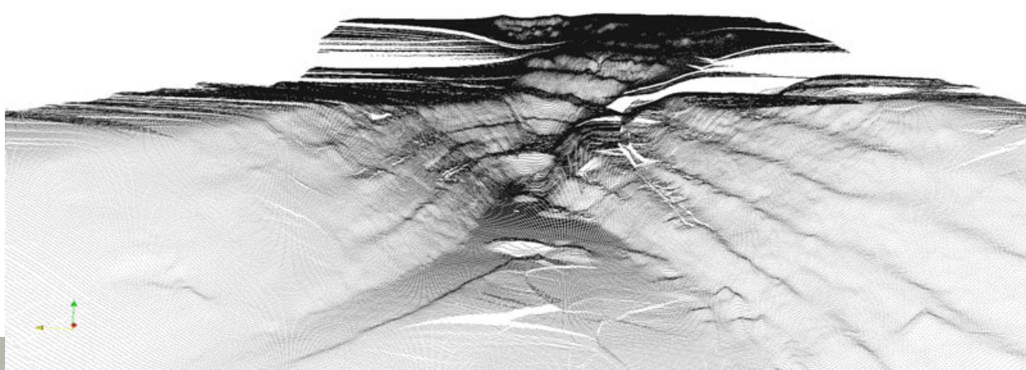
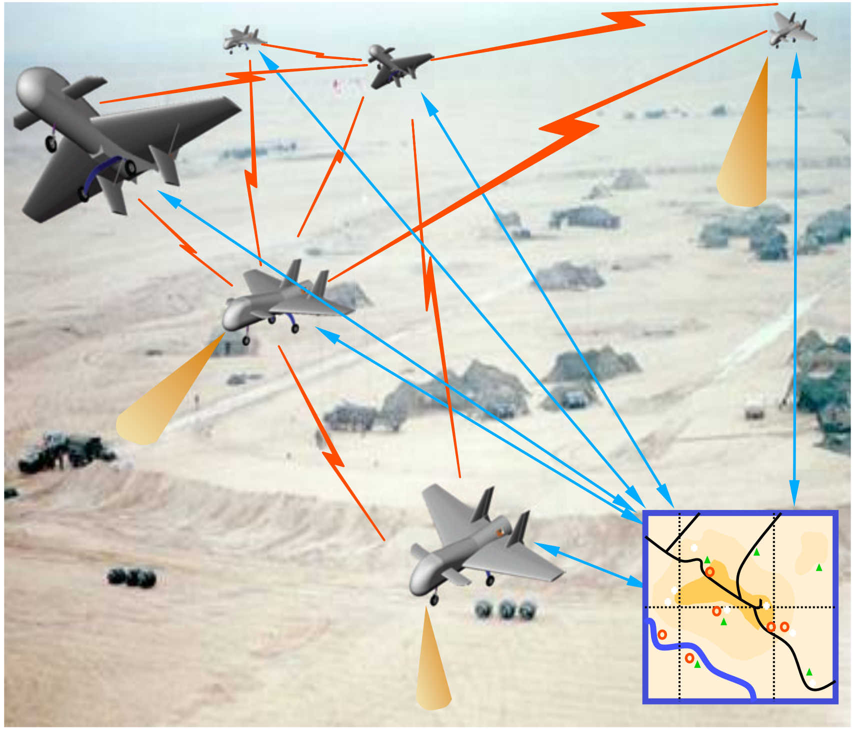
Systems

Robot Mining (Western Australia)



Multi-UAV Data Fusion

- ANSER Project
- Research:
  - Data Fusion
  - Information Networks
  - Time-Critical Data
- Demonstration:
  - Ground Picture Compilation
  - Multi-Platform
  - Multi-Sensor
  - Network Centric



ANSER Flight Trials

- Outcomes
  - World-First Cooperative UAV demonstrations
  - Shows fully autonomous network-centric operations
  - Received BAE Systems Chairman Gold Award
- Follow-on Programs:
  - BAE Systems
  - UK MOD
  - US Air Force and Navy

Land Vehicle Systems

- Research
  - Long term, autonomous navigation in unstructured environments
  - Perception
  - Cooperative data fusion and control
- Applications
  - Defence
  - Agriculture
  - Mining
  - Firefighting

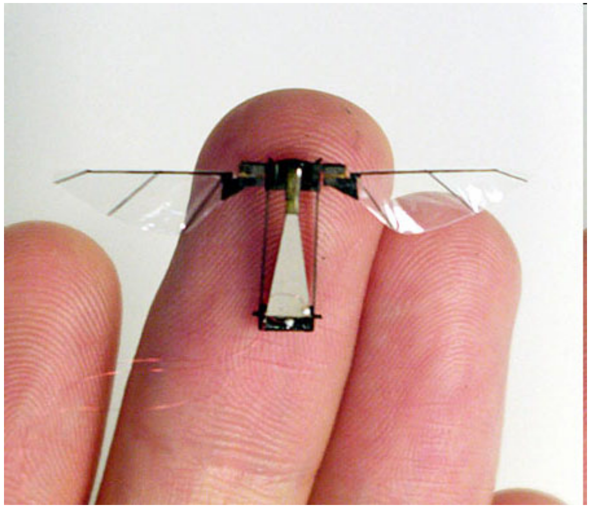
Robot Sniper Training Robots

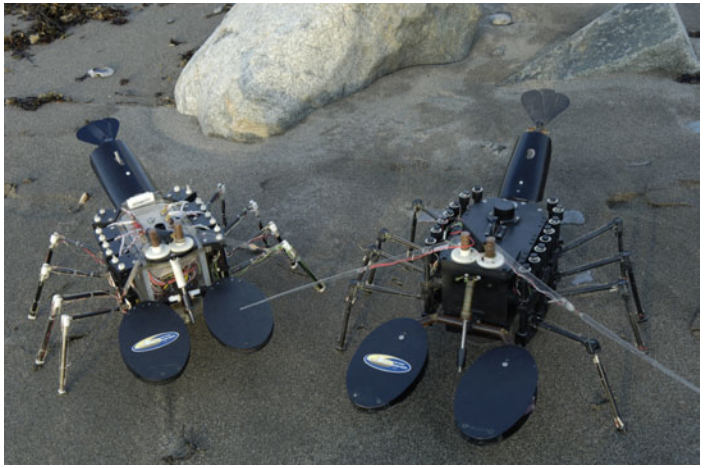
Unmanned Underwater Vehicles (UUVs)

- Constraints
  - No GPS
  - Low cost IMU
  - Unstructured Terrain
- Research Challenges
  - Sensing and Perception
  - Localisation and Mapping
  - Adaptive Control

Terrain Models

Biomimetic Robots





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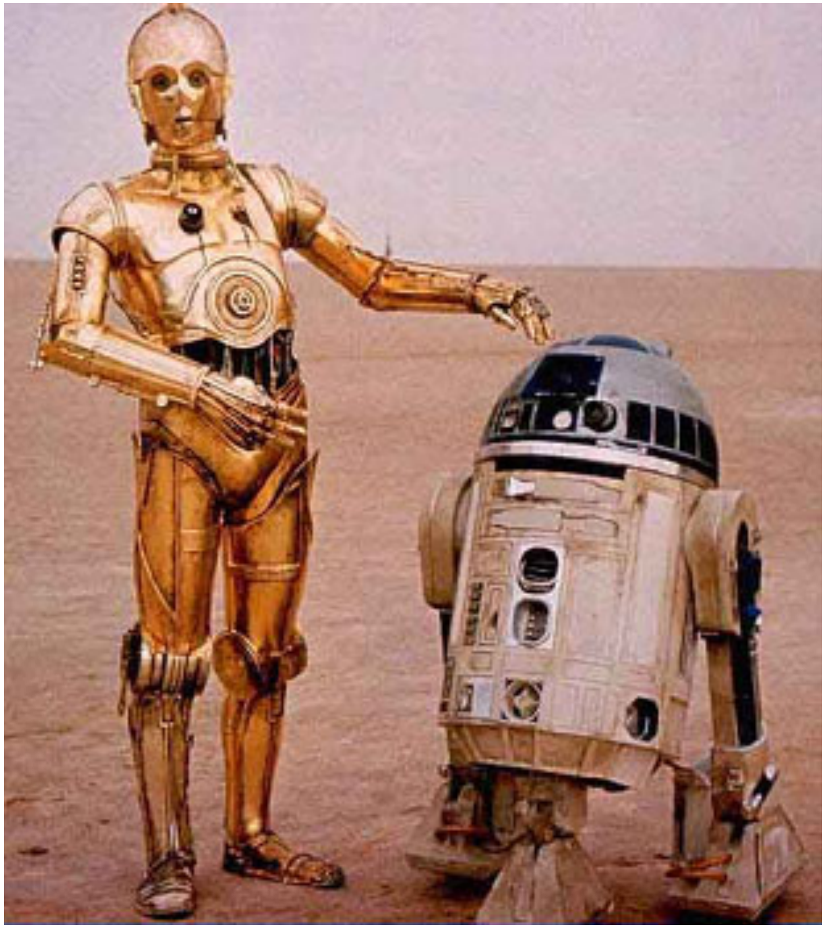
Many More Robot Applications

Maybe this isn't so far away…



Conclusions

- Robotic systems are playing an increasingly important, and diverse, role in our society
- The study of robotics involves an integration of a number of different areas including hardware, electronic and software

Further Reading