Mtrx 4700 : Experimental Robotics

Introduction

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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**

**Computer Vision**
- Ballard and Brown, *Computer Vision*, Prentice Hall, 1982

**Machine Learning**

**Mobile Robotics**
## Course Outline

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<th>Week</th>
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<td>1</td>
<td>5 Mar</td>
<td>Introduction, history &amp; philosophy of robotics</td>
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<td>2</td>
<td>12 Mar</td>
<td>Robot kinematics &amp; dynamics</td>
<td>Kinematics/Dynamics Lab</td>
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<td>3</td>
<td>19 Mar</td>
<td>Sensors, measurements and perception</td>
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<td>4</td>
<td>26 Mar</td>
<td>Robot vision and vision processing.</td>
<td>No Tute (Good Friday) Kinematics Lab</td>
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<td>5</td>
<td>9 Apr</td>
<td>Localization and navigation</td>
<td>Sensing with lasers</td>
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<td>6</td>
<td>16 Apr</td>
<td>Estimation and Data Fusion</td>
<td>Sensing with vision</td>
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<td>7</td>
<td>23 Apr</td>
<td>Extra tutorial session (sensing)</td>
<td>Robot Navigation Sensing Lab</td>
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<td>8</td>
<td>30 Apr</td>
<td>Obstacle avoidance and path planning</td>
<td>Robot Navigation</td>
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<td>9</td>
<td>7 May</td>
<td>Extra tutorial session (nav demo)</td>
<td>Major project Navigation Lab</td>
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<td>10</td>
<td>14 May</td>
<td>Robotic architectures, multiple robot systems</td>
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<td>11</td>
<td>21 May</td>
<td>Robot learning</td>
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<td>12</td>
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<td>Case Study</td>
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<td>4 June</td>
<td>Extra tutorial session (Major Project)</td>
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<td>Spare</td>
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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
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.
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
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
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.)
Edges, Segments, Colour, Texture
3D Stereo Vision
Perception: Touch
Other Sensors: Laser
Environment Understanding
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

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get destination while not at destination sample sensors calculate movement send commands end
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Controlling a Robot

Field Testing Nov 2003

Spinner
Unmanned Ground Combat Vehicle
Control: Search and Exploration
Control: Sensing and Planning
Control: Making Iced Tea
Throwing and Catching

Throwing

Throwing

Regrasping

Regrasping
Learning to Walk and Play
Big Dog: Walking by Balancing
Entertainment
Androids
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
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
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
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