49274 - Advanced Robotics

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Course Outline

• **Mobile Robots**
  - Sending
  - Mapping
  - Navigation
  - Control

• **Industrial Robots**
  - Kinematics
  - Dynamics

• **Series of lectures on fundamental techniques – with a broad range applications outside robotics domain**

• **Project – Group or individual project selected from a list of topics to be provided by week 3**

• **Assessment – Project (100%)**
Mobile Robotics

• Rapidly maturing technology
• Potential in both indoor and outdoor applications
Industrial Robotics

- Mature technology
- Large range of applications
- Integrated packages
  - Robot
  - End-effector and Fixtures
  - Sensors
- Large Market
  - About 50% in automotive industry
  - Consumer goods, Electronics
Centre for Autonomous Systems

Gamini Dissanayake

University of Technology, Sydney
Autonomous Systems
Research and Development

Machine Intelligence: Perception, Learning and Control

Autonomous Systems: Sensing, Computing, Platforms

Applications

Research and Development

Advanced Robotics - Introduction

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Automated Container Handling

- **The Simplest Problem:**
  - A structured environment
  - Well defined task
  - Well defined pay-off

- **Research Challenges:**
  - Control a large, fast platform
  - Guarantee performance
  - Ensure Safety
Enhanced Straddle Carrier (ESC)

- **Objectives:**
  - Best manned performance
  - 24/7 operation
  - Safe, low-maintenance

- **Innovations:**
  - Navigation Integrity
  - Control Performance
  - Multi-vehicle optimisation
Berth 7 Fisherman’s Island

- Operational automated terminal
- Located in Brisbane, run from Sydney
- The world's most technically advanced container terminal
- A new start-up company producing automation systems
Automated Mining Systems

• A Harder Environment
  ○ Less structure
  ○ Diverse information
  ○ Environment Interaction

• Research Challenges
  ○ Sensing/Perception
  ○ Platform Control
  ○ Systems Design
Automated Haulage

- **Objectives:**
  - Safety
  - Efficiency

- **Innovations:**
  - Sensing
  - Environment Modelling
  - Control
Mine Visualisation

- **Objectives:**
  - Improve efficiency and safety
  - Steps toward automation

- **Innovations:**
  - Multi-Sensor Data Fusion
  - Modelling unstructured environments
Defence Applications

• **Autonomous Systems Roles:**
  - Wide-Area Surveillance
  - Situational Awareness
  - Air/Land/Sea Operations
  - Tactical Strike

• **Research Challenges:**
  - Multi-Sensor Data Fusion
  - Multiple Platform Control
  - Autonomous Operations
  - Systems of Systems
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
The Current Challenge: Complex Environments

- **Environments:**
  - Complex, remote operations
  - Dynamic and changing world
  - Tasks: “Dull, Dirty, Dangerous”

- **Autonomy:**
  - Perception
  - Navigation
  - Control
Sub-Sea Systems

- **Constraints**
  - No GPS
  - Low cost IMU
  - No *a priori* Terrain Model

- **Research Challenges**
  - Sensing and Perception
  - Localisation and Mapping
  - Control
Reef Transect Monitoring

- Project with Barrier Reef Authority
- Precise Mapping of Flora
- Autonomous Navigation over Long Time Periods
Land Vehicle Systems

- **Constraints**
  - No GPS
  - No \textit{a priori} terrain model
  - Rough, Dynamic Terrain

- **Research Challenges**
  - Multi-Modal Sensor Fusion
  - Learn Feature Structures
  - Platform Control
Jungle Operations

- Project for Singapore
- Autonomous High-Speed Navigation in Foliage
- Fusion of mm-Wave Radar and Infra-red
Future Challenge Problem: Bush Fire Fighting

- **Environment:**
  - Dynamic, Time-Critical
  - Heterogenous Platforms
  - The Human Dimension

- **Approach:**
  - Sensing and real-time “picture” compilation
  - Mixed autonomous/remote operation in dangerous areas
  - Working with fire-fighters
Sensors For Fire Fighting

- Imaging Radars
- Sensors which see through smoke and foliage
- Provide pictures for platforms and fire-fighters
Future Challenge Problem: Working with People

• Environment
  - Interaction with humans
  - Built-in and mobile autonomous systems
  - Security, Health care, smart buildings

• Approach
  - Ubiquitous Sensing
  - Cooperative Learning
  - Human-Centred Control
Algorithms for Mapping and Exploration

• **Building Maps**
  - Unknown Environment
  - Sensing and navigation
  - Locating areas of interest

• **Applications**
  - Security
  - Tour Guide
  - Domestic
Outreach

- **Autonomous Systems:**
- **Have wide appeal:**
  - Researchers
  - Industry
  - Children
- **Play an important role in**
  - Publicising Engineering and Science
  - Developing advanced technology skills
  - Adding value to industry
Autonomous Systems

• **Autonomous systems are on the verge of a revolution in understanding and application:**
  - Emerging applications have been demonstrated
  - Many key scientific problems have been resolved

• **A new generation of autonomous systems can now be envisioned:**
  - Operation in unstructured, dynamic worlds
  - Posing key research challenges in perception, learning and control
  - Leading to the development of true intelligent systems

• **Australia stands to reap a huge benefit from the development and application of autonomous systems**
Mobile Robotics

Key Competencies

• Sensing
• Mapping
• Navigation
• Control
Mobile Robot Architecture
Transport/Logistics
System Architecture

- **Navigation**
  - Navigation System
  - Navigation Sensors
  - Position Estimates

- **Control**
  - Control System
  - Drive, Steer, Brake
  - Status
  - Path Data
  - Enable

- **Pilot**
  - Pilot
  - Status
  - Task Data

- **Safety and Condition Monitoring**
  - Safety and Condition Monitoring System
  - Process Sensing
  - Condition Sensing
  - Collision Sensing

- **Base Station**
  - Task Data
  - Status
Aerospace/Defence
Civilian/Domestic
Mining / Materials Handling
Mining / Construction
Collision Sensing

- Ultrasonic Sensors
- Collision Lasers
Museum Tour-Guide Robot
Commercial Cleaning
Helpmate Hospital Delivery Robot
Automatically Guided Vehicles (AGV)
2D Mapping
3D Mapping

Real Time Autonomous Robotic Mapping

The Robotic Volumetric Mapping Project
Carnegie Mellon University    Sponsored by: DARPA ITO
In and Around the Home
Entertainment

![Robot Diagram]

- Head touch sensor
- Camera (CMOS image sensor)
- Stereo microphone
- Speaker
- Tail (equipped with LEDs)
- Back touch sensor
- Acceleration sensor
- PC card slot
- Lithium ion battery pack
- "Memory Stick" slot for AIBO
- Chin touch sensor
- Pause button
- Chest light

Dimensions:
- Width: 274mm
- Height: 266mm
Entertainment
Security and Tele-presence
Underground Mining

- Laser Guidance
- Mapping and Localisation
- Control
Undersea

- Embedded CompactPCI
- 2 Sonars
  - Tritech SeaKing
  - Imagenex
- Gyro
- Compass
- Pressure Sensor
- Camera
- Five Thrusters
Maintaining Altitude

- Depth measured using pressure sensor
- Imagex sonar is used to set depth set-point
- Compute the error in altitude
- Command to thrusters to achieve desired altitude
Reef Transects

- Australian Institute for Marine Sciences (AIMS) is surveying the Great Barrier Reef
- Divers record visual transect information
- This information is used to monitor coral diversity and growth patterns
Visual Servoing

- Images of the sea floor from the camera
- Compute the direction of the rope
- Desired heading for the AUV is computed
- Control signals to thrusters in order to track the rope
Future
Typical Industrial Robot

- In a robot, the gripper is positioned by rotating joint motors by a desired amount.
- In the robot shown, the joints are driven by DC motors through reduction gear boxes.
- Position of the motor is sensed using an encoder. Velocity of the motor is measured by a tacho-generator.
Applications
Applications
Applications
Applications
Mobile Manipulators

Useful Compliant Motion Tasks
Typical Robot Structures – 6 DOF
Typical Robot Structures - SCARA