Mechatronics

Australian Centre for Field Robotics, (ACFR)

Novel methodologies using deep learning for geological data analysis

Supervisors: Dr Mehala Balamurali and Dr Katherine Silversides

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Deep Learning is a powerful new tool in data analytics. It consists of algorithms that extract high-level, complex abstractions as data representations through a hierarchical learning process. A benefit of Deep Learning is the ability to analyse and learn from large amounts of supervised data. This makes it a valuable tool for domains such as geology, medicine and ecology.

This project will explore how Deep Learning can be used to address some important problems in geology, including extracting complex patterns from massive volumes of data for domain classification and prediction of grades at unknown places. The Deep Learning results will be compared with existing geological classification methods.

Skills: Proficiency in Matlab and/or R, knowledge of machine learning/algorithms (no geological domain knowledge required).
In 2014 Mahdi made a low cost prosthetic hand and elbow and in 2015 Bas developed a haptic glove and tactile feedback for the hand. This year we would like to extend the arm by providing a stronger drive mechanism to the elbow. Additionally we would like to revise the hand actuation to a spring-tendon mechanism.

**Research Proposal**

- Design, print and build an elbow joint including actuation. A RC servo is not sufficiently strong
- Redesign the hand slightly to use spring-tendon mechanisms, print and build
- Design and print a cuff that will allow for EMG electrodes to be attached to the upper arm “stump”
- Develop electronics to allow the EMG signals to control the elbow, wrist and hand
- Consider different feedback mechanisms to allow for tactile feedback (assuming the amputee doesn’t have a hand or arm)

**Required Skills**

Good SolidWorks skills
Interest in sensors
Good electronics and microcontroller ability
We have been working for a number of years on the robotic aspects of remote operation of a CT scanner. It uses a sophisticated plastic phantom (humanoid model containing realistic bones and soft tissue) seen in the figure.

Our current requirement is to provide organs that can simulate the operation of contrast agents that are often injected into patients to provide improved images.

**Research Proposal**
- Develop a realistic organ (liver or kidneys etc) containing a simple vascular system using a 3D printer
- Develop some means to circulate different concentrations of contrast medium through the organ to simulate the introduction and subsequent dissolution of the liquid
- This will be a world first, so could make a real difference!

**Required Skills**
- Good SolidWorks skills
- An affinity for pumps
- Interest in chemistry (if possible)
Bat Detector  
Supervisor: Graham Brooker, ACFR  gbrooker@acfr.usyd.edu.au

Electronic devices to detect bat calls are fairly commonly available but generally quite expensive. Two different principles can be applied; the first is to down convert the ultrasonic signal to the audio range, and the second is to digitise and stretch the signal.

Research Proposal

- Investigate the different techniques used, and try to determine why these devices are so expensive
- Develop the electronics and the software to perform the function in a low cost manner
- Build into a robust battery powered device
- Travel around and record the calls of as many bats as you can

Required Skills

Interest in bats  
Interest in analog electronics  
Microcontroller programming skills  
Signal Processing
Speed Related Changes in the Radar Cross Section of Bullets at 77GHz

Supervisors: Graham Brooker, ACFR  gbrooker@acfr.usyd.edu.au
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Outdoor measurements have shown that the radar cross sections (RCS) of high-velocity bullets is up to 5dB higher than those obtained from static measurements of the same object. The mechanism that results in this increase is unknown.

This has implications for the RCS of the new generation of stealth aircraft when travelling at high speed.

This project aims at investigating the phenomenon by measuring the RCS of a number of different shapes under more controlled conditions using a supersonic nozzle.

Research Proposal

- Complete the integration of a 77GHz radar and a data acquisition system
- Because of the size of the bullets, it is possible to generate the appropriate supersonic airflows using a supersonic nozzle driven by a low pressure reservoir
- Assemble the compressor and reservoir coupled to the supersonic nozzle
- Confirm that the flow from the nozzle reaches the required speeds over a cross section that is sufficiently large to encompass the bullet
- Measure RCS of a number of different types of bullets at a number of different speeds and from different perspectives
- Try to determine what causes this increase in RCS
- Write a journal paper

Required Skills

- Some understanding of microwave and millimetre wave radar
- Aerodynamics etc
- Mechanical Design (SolidWorks etc)
- Electronics
- Signal Processing
- MATLAB Programming
Micro-Doppler Gait Evaluation to Infer Fatigue Levels in Long-Distance Runners (Continuing project)

Supervisor: Graham Brooker, ACFR  gbrooker@acfr.usyd.edu.au

Recent research has shown that changes in gait could be indicative of concussion, so we have speculated that similar changes could also be indicative of fatigue levels in long distance runners

This project aims at determine whether these changes in gait are consistent with fatigue levels and whether they can be measured using a Doppler radar.

**Research Proposal**

- Acquire or build a suitable data acquisition and processor that could be interfaced to one of our existing Doppler radars.
- Develop the signal processing to extract Doppler characteristics of a runner from another moving platform (probably a bicycle)
- Develop qualitative means to determine the fatigue level of the runner (distance travelled, effort, verbal feedback etc)
- Develop methods (can be classical or machine learning based) to correlate features of the micro-Doppler signature of the runner with their fatigue level
- If possible, redo on treadmill with appropriate instrumentation to produce a quantitative measure of runner fatigue

**Required Skills**

- Some understanding of microwave radar and the Doppler principle
- Low power & portable electronics
- Signal Processing
- MATLAB Programming
- Keen athlete
Integration and Testing of an Orthopaedic Measurement Device
Continuing project
Supervisors: Graham Brooker, ACFR gbrooker@acfr.usyd.edu.au
Joe Lynch and Corey Scholes, SORI CScholes@sori.com.au

If you are looking for a patient-centred project with long-term benefits for research and clinical assessment of patients suffering knee disorders, are keen to deepen your knowledge and understanding of human biomechanics and functional anatomy and would like to work directly with the “end users”, both patients and clinicians, then read on…

Students have developed a wireless accelerometer, gyro and a separate goniometer to monitor the effectiveness of orthopaedic knee surgery. These devices need to be integrated into a single product that can be easily fitted and tested at home, while still retaining sufficient accuracy to provide essential feedback on knee joint performance including shock absorbing and knee angle.

Research Proposal (Thesis for 1 or 2 students)

- Examine existing hardware (Arduino based)
- Select new processor with additional channels to accommodate all of the sensors (2 x 3axis accelerometers, 2 x gyros, 2 x goniometers)
- Examine sensor mounting methods and update as required for ease of use, repeatability and reliability
- Redevelop monitor from simple MATLAB display to enable local storage and analysis
- Integrate with telemedicine network to enable remote monitoring and analysis of measured data.

Required Skills

Mechanical Design (SolidWorks etc)
Electronics
Signal Processing
C or C++ and MATLAB Programming
Some biology
Energy Scavenging from Flying Pigeons
Continuing Project
Supervisor: Graham Brooker gbrooker@acfr.usyd.edu.au

It has become practical to harvest sufficient power from biological processes, movement, vibration or heat gradients etc to generate sufficient power to run modern low-power electronic systems.

Initial work has been conducted to obtain the acceleration profiles from a flying pigeon, and these will have been implemented on a vibration table (1 axis) to test energy scavenging options.

Research Proposal
- Investigate existing energy scavenging systems and select one that would be suitable to power a typical radio beacon and data logger attached to a bird
- Develop such a system and demonstrate on a vibration table that it could supply sufficient power
- Ethical approval has been obtained to test a data logger on a pigeon, and it is possible that this approval could be extended for tests of the scavenger

Required Skills
- Electronics
- Mechanical design (SolidWorks etc)
- Affinity for animals
A low cost hand orthotic driven by pneumatic artificial muscles (PAMs) that may have applications in rehabilitation and in astronaut’s gloves has been under development for some time. The initial technique (shown in the figure) relied on the flexibility of a composite material (carbon or glass fibre). However these were not sufficiently strong and flexible. Subsequent attempts to use torsion springs are under consideration but are too bulky and too complex to be effective.

**Research Proposal**
- Perform a comprehensive review of the existing methods that could be used to drive this orthotic (passive closing and active opening)
- Using the PAMs to open the orthotic, investigate alternative passive methods of closing that will be compliant and can accommodate different sized hands
- Develop a working prototype of the orthotic

**Required Skills**
- Mechanical Design & SolidWorks
- Materials
- Electronics
- Signal Processing
- C or C++ and MATLAB Programming
Scanning Millimetre-Wave Radar Foliage Penetration Study

Supervisors: Graham Brooker gbrooker@acfr.usyd.edu.au
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We have a 3D millimetre wave radar system that would be ideal to produce improved images of wooded terrain with the objective of measuring foliage penetration.

Figure: New 3D radar, existing 2D radar hardware mounted on a Segbot and a radar image showing some foliage penetration

Research Proposal

- A 3D millimetre wave radar system has been built
- This radar system needs to be commissioned
- A mounting to allow the radar to be attached to a moving platform needs to be built
- This will initially be a trolley, but ultimately it will be on one of the Segbots
- Software to produce 3D images for analysis needs to be developed
- Images in various environments and their subsequent analysis needs to be undertaken

Required Skills

- Communications and Interfaces
- Some understanding of RF
- Mechanical Design & SolidWorks
- Electronics
- Signal Processing
- C or C++ and MATLAB Programming
Scanning Millimetre-Wave Radiometer  
Supervisor: Graham Brooker  gbrooker@acfr.usyd.edu.au

Radiometry at 94GHz offers an excellent option for ground imaging during adverse weather or at dusk and dawn when visible and IR sensors suffer from poor performance.

(a) ![Existing radiometer hardware](image1.png)  
(b) ![Radiometric images](image2.png)  

Figure: Existing radiometer hardware and radiometric images

Research Proposal

- A prototype scanner and radiometer has been built that operates at 94GHz
- A new mirror must be made using the 3D printer as the old one has drooped
- Both the scanner and the millimetre wave receiver hardware need to be hardened for installation in a UAV
- Interfaces to a microcontroller to read the radiometric signal, and the mirror position as well as any aircraft INS data that is available must be developed so that images can be produced
- Software to produce strip-map radiometric images from a moving aircraft must be written

Required Skills

Communications and Interfaces  
Some understanding of RF  
Mechanical Design & SolidWorks  
Electronics  
Signal Processing  
C or C++ and MATLAB Programming
Quantification of the forces exerted during operative vaginal delivery

Continuing Project

Supervisors: Graham Brooker, ACFR  gbrooker@acfr.usyd.edu.au
Dr Jon Hyett, RPAH  Jon@fetalmedicine.com

A significant (10-15%) proportion of babies require assistance during the process of vaginal delivery. This involves application of either forceps or ventouse (vacuum), allowing the acoucher (the person who assists at a birth) to guide the presenting part through the birth canal, onto the perineum and through to delivery.

Women and babies who have an operative vaginal delivery have higher risks of traumatic injury related to the delivery process. The forces involved in delivery are poorly understood. We hypothesize that injury would be more likely in circumstances where higher forces are developed during the delivery process. Real time measurement of these forces would provide the acoucher with information about the risks associated with delivery.

Research Proposal

This project involves the development of an instrument to quantify the forces exerted during operative vaginal delivery. The point of contact between the instrument and the acoucher (i.e. handle of instrument to gloves) is sterile, and this device needs to be able to be applied in this environment. The device should be able to quantify the amount of force and record the direction of force during the delivery process. The device will first be used in simulations of the birthing process, as proof of concept, prior to being applied to clinical studies.

Required Skills
Some biology (or an interest in the subject)
Electronics & sensing
Mechanical design (SolidWorks)
Signal processing
Effect of Visual Stimulation on Standing and Walking Balance
Continuing Project

Supervisors: Graham Brooker, ACFR gbrooker@acfr.usyd.edu.au
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Quiet stance is supported by 3 sensory inputs: proprioception, vision and vestibular sensation. These 3 sources of information overlap considerably allowing subjects with the loss of one or two modalities to stand and walk safely. Here we propose to examine the effect of visual stimulation on the stability and trajectory of gait and on the stability of stance.

We hope to artificially manipulate the visual surroundings to create an illusion of movement in the pitch, yaw or roll planes.

Research Proposal

- Integrate a head mounted display (VR goggles) with a head tracker capable of measuring position and acceleration in 3D
- Use this display to create a normal visual surround which can then be manipulated
- record the subject’s standing balance using the inertial measurement unit attached to the display.
- The subjects will be tested whilst standing still and walking a straight line, and during normal visual stimulation vs abnormal visual stimulation is recorded
- Specifically, during stance, anteroposterior and mediolateral deviation during a 10 second period will be recorded.
- Whilst walking, change of trajectory produced by apparent rotation in yaw and roll planes will be explored.

Required Skills

Some biology
Electronics
Image Processing
MATLAB Programming
A Portable Test of Subjective Visual Vertical (SVV)

Supervisors:  Graham Brooker, ACFR gbrooker@acfr.usyd.edu.au
            Dr Miriam Welgampola, RPAH miriam@icn.usyd.edu.au

The SVV is a useful measure of human perception of verticality. It is abnormal in
inner ear balance disorders as well as brainstem stroke. During acute inner ear balance
disorders, the eyes tort towards the affected ear. Since the visual meridian is also
similarly torted, horizontal objects are perceived as tilted to the unaffected side. To
correct this apparent tilt, the subject will bias it towards the affected side. Conversely,
in upper brainstem strokes, the SVV is offset to the unaffected side. This non-
invasive test conveys useful diagnostic information in subjects with acute of vertigo
and is used in specialized balance clinics. We propose to develop a portable electronic
test of SVV that can be used at the bedside. This will enable the test to be used by
non-specialized centres and even in the patient’s own home.

Research Proposal

- Assemble the following hardware:
  - A pair of VR goggles capable of projecting a linear beam upon a
    circular screen at a viewing distance of 40 cm.
  - User controlled joystick.
  - A head mounted attitude heading reference system (AHRS).

- Develop the following software using LabVIEW:
  - Monitor the AHRS to ensure the head is held vertical with less than
    one degree error. Deviations outside this range will result in rejection
    of the patients SVV setting.
  - Deliver 10 consecutive presentations of the beam at random angles
    from -45° to +45° degrees.
  - Read the joystick as the subject returns the beam to his/her perceived
    vertical
  - The final position for each presentation will be logged, and averaged to
    produce the mean and SD for SVV.

Required Skills

Some biology
Electronics
Signal and Image Processing
LabVIEW Programming (or learn on the job)
A Micro-mechanical Testing System for Biological Tissues

Supervisors:  Graham Brooker, ACFR  gbrooker@acfr.usyd.edu.au
  Elizabeth Clarke, RNSH  elizabeth.clarke@sydney.edu.au

Engineering studies of biological tissues often involve controlled loading of very small or very soft tissues. This thesis involves expansion and optimisation of a micro-mechanical testing apparatus that is currently used for biomechanics studies of soft tissues. Some examples of the potential applications of this apparatus include 3-point-bending of mouse bones, tensile strength of a human hair or mouse tendon, and cyclic loading of joint cartilage.

Note: the apparatus is located at RNS Hospital at St Leonards, and the student will be expected to perform the integration and testing at the Murray Maxwell Biomechanics Laboratory there.

Research Proposal

- Develop a custom LabVIEW program for precision control of a linear motor to provide maximum flexibility in a range of testing regimes:
  - cyclic loading
  - threshold conditions
  - force control
- Develop data acquisition system to acquire and log data from displacement and force sensors
- There is scope within this thesis project to include optional mechanical design and manufacture:
  - miniature 3-point-bending apparatus
  - mechanical testing of synthetic or biological tissues (e.g. Silicone gels, mouse bones or soft biological tissues)

Required Skills

Some biology
Control
LabVIEW Programming (or learn on the job)
SolidWorks (for phase 2)
Ultrasound Phased Array Imaging
Continuing project
Supervisor: Graham Brooker gbrooker@acfr.usyd.edu.au

The object of this thesis is the extended development of an ultrasound phased array imaging system. Previous work has provided core signal processing electronics and software algorithms for imaging. Advanced topics in signal processing and end applications are now possible.

Potential Research Areas

Signal Processing:
High fidelity coherent signal processing techniques:
- synthetic aperture
- coherent motion detection
- multiple-pulse integration & fusion.

Applications:
- Incorporation onto a mobile platform
- 3D Volumetric visualisation methods
- 3D Object analysis
- Ground texture analysis

Required Skills
- Communications and Interfaces
- Electronics
- Signal Processing
- C or C++ and MATLAB Programming
4th Year Thesis Topics – 2016

Supervisor: Dr. Ali Haydar GÖKTOĞAN

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Paramotors are motorised paragliders. They offer one of the easiest forms of flying. In this thesis, you will be given an airfoil, a motor, remote control equipment and a set of sensors and a small embedded microcontroller board to construct an Unmanned Autonomous Paramotor (UAP).

There is a significant body of knowledge and many open projects on the internet about low-cost small flight controllers and UAP systems. For this project, initially you will fly the UAP in manual radio control (RC) mode. After that, you will acquire flight data for the system identification. The characterisation of the UAP will help you to develop a set of flight control algorithms. You will demonstrate autonomous way point navigation, precision landing, operations.

**Required Skills:**
- Linux, ChibiOS
- Matlab/Simulink
- C/C++
- Math
- Electronics
- RC
In this thesis, you will design and build a scaled model of a motorized trike hang glider. In order to acquire flight data for the system identification, you will initially fly the trike using radio control (RC) system. The system identification of the trike will help you to develop the flight control algorithm for the platform.

In order to make your motorized trike an autonomous platform, you will develop a flight control algorithm in Matlab/Simulink. Using Matlab Coder, the developed flight control algorithm will be converted into C/C++ code to run on an autopilot module. The completed system will perform autonomous way point navigation and precision landing.

Required Skills:
- Hands-on-mechanical building skills
- Linux, ChibiOS
- Matlab/Simulink
- C/C++
- Electronics
- RC
A multi-rotor Unmanned Aerial Vehicle (UAV) is a type of vertical take-off and landing (VTOL) vehicle with independently controlled propellers. Its simplistic airframe design makes them attractive for demonstration of UAV various control algorithms. Multi-rotor UAVs can be operated in both an indoor and outdoor. There is a significant body of knowledge and open source projects on the internet about multi-rotor airframe design, as well as low-cost small flight controller projects for autonomous flight.

This project requires student to design and build the mechanical structure and then develop flight control algorithms on an existing flight control computer (i.e. autopilot). If you are looking for an interesting, technically challenging project with significant outdoor time, and if you want to acquire some RC (Radio Control), flight experience and basic flight control theory, then this project is for you.

Required Skills:
- Linux
- Matlab/Simulink
- C/C++
- Math
- Electronics
- Hands-on-mechanical building skills
Visual Servoing of a VTOL UAV

Visual servoing process utilises feedback from vision sensor(s) to control the motion of a robot. In this project student will build a Vertical Take-Off and Landing (VTOL) Unmanned Aerial Vehicles (UAVs) and develop control algorithms utilising IR tracker or fiducial based visual servoing to demonstrate autonomous take-off and landing maneuvers.

If you are looking for an interesting, technically challenging project and if you want to acquire some RC (Radio Control), flight experience basic flight control theory, visual servoing and pose estimation then this project is for you.

Required Skills:
- Linux, ChibiOS
- Matlab/Simulink
- C/C++
- Math
- OpenCV
- Electronics
- Hands-on-mechanical building skills
This platform is about development of a Vertical Take-Off and Landing (VTOL) Unmanned Aerial Vehicles (UAVs) capable of landing on a moving platform. System will use live video stream from the camera on board the UAV for visual servoing. In this project student will build a UAV platform and develop the flight control algorithms in Matlab/Simulink. Using Matlab Coder, the developed flight control algorithm will be converted into C/C++ code to run on a given autopilot hardware. Complete system will perform autonomous way point navigation, precision landing on a moving platform.

If you are looking for an interesting, technically challenging project and if you want to acquire some RC (Radio Control), flight experience basic flight control theory, visual servoing and pose estimation then this project is for you.

**Required Skills:**
- Linux, ChibiOS
- Matlab/Simulink
- C/C++
- Math
- OpenCV
- Electronics
- Hands-on-mechanical skills
Navigation system of many Unmanned Aerial Vehicles (UAVs) relies on the fusion of the Global Positioning System (GPS) and inertial sensors. A precise estimation of UAV’s position, velocity, acceleration and attitude is important for the control of the UAV. Reliance on the availability and accuracy of the GPS is considered as vulnerability for the UAV.

This thesis about developing a terrain aided navigation system for a Vertical Take-Off and Landing (VTOL) UAVs. The Digital Terrain Elevation Map (DTEM) of the flight area will be given. The VTOL UAV will be equipped with a scanning laser range finder. You will use the DTEM data along with the inertial sensor and laser scan data for the navigation of the UAV.

In this project student will build a UAV platform and develop the navigation system in Matlab/Simulink. Using Matlab Coder, the developed algorithm will be converted into C/C++ code to run on a given autopilot hardware. Complete system will perform autonomous way point navigation, precision landing. If you are looking for an interesting, technically challenging project and if you want to acquire some RC (Radio Control), flight experience basic guidance, navigation and flight control, then this project is for you.

Required Skills:
- Linux, ChibiOS
- Matlab/Simulink
- C/C++
- Math
- Electronics
A returning boomerang is a spinning aerial device that displays interesting flight behaviour once it is launched. Despite its simple physical construction and shape, its flight characteristic is complex.

In this thesis project you will build an instrumented boomerang and launch it using our robotic boomerang launcher apparatus. During its short flight, the instrumented boomerang will collect flight data. You will use this data for flight characterisation of the boomerang.

This is a unique project requires extensive electronics, programming and math skills.

Required Skills:
- Physics
- Linux
- Matlab/Simulink
- C/C++
- Math
- Electronics
Video recording of a fast moving UAV manually from the ground is a challenging task even if the camera is mounted on a fluid head tripod. Tracking the UAV to keep it at a desired point in the video frame is particularly difficult when a high zoom lens is used. Furthermore, pointing the camera to UAV when the UAV flies straight over the camera (i.e. 90 degree elevation angle) may not be possible even for high-end fluid head tripods.

This project is about designing, building and testing of a high-speed tracking system to be mounted on a tripod. The tracking system will be capable of carrying a DSLR (or similar) video camera with a zoom lens. The system will receive the GPS data from the UAV and be able to control the pan-tilt angle to keep the UAV in a desired spot in the video frame.

**Required Skills:**
- Linux
- Matlab/Simulink
- C/C++
- Math
- Electronics
- Hands-on-mechanical building skills
Impact acoustic is a versatile Non-Destructive Testing & Evaluation (NDT&E) technique. It is based on the characterisation of time-frequency features of the acoustic signals obtained from the impact on the surface being tested. Impact acoustic is used in many different areas; such as medical examination, classification of kernels, detection of metal fatigue etc. However, in this thesis, impact acoustic will be used for the analysis of tile-wall/floor bonding strength.

You will design, build and test a compact, hand-held NDT&E tool capable performing impact acoustic analysis on tiles. This is a challenging project and requires strong maths, programming and mechatronic design skills.

**Required Skills:**
- Linux
- Matlab/Simulink
- C/C++
- Math
- Electronics
- CAD
- Hands-on mechanical skills
Civil engineering applications of robots are rapidly increasing. This thesis topic is about designing and building a wall climbing robot that can be used on different types of walls. There are many different techniques for wall climbing, abseiling, vacuum adhesion, electroadhesion etc.

Your robot will be equipped with a Non-Destructive Testing & Evaluation (NDT&E) sensor to detect faults in the wall. The robot will be teleoperated by an operator using a tablet. This is a challenging project and requires strong maths, programming and mechatronic design skills.

**Required Skills:**

- Linux
- Matlab/Simulink
- C/C++
- Math
- Electronics
- CAD
- Hands-on mechanical skills
Robots and other autonomous mobile platforms can be used in many environmental monitoring applications. These platforms need to be able to operate in real, unstructured environment. Performing data gathering missions in real, outdoor environment brings its own challenges.

This thesis topic is for you; if you feel that you want need to do something positive about the environment. This thesis project will focus on the development and operation of an autonomous boat on lakes and irrigation channels. You will design and build the boat and develop guidance, navigation and control codes for it.

**Required Skills:**
- Linux
- Matlab/Simulink
- C/C++
- Math
- Electronics
- CAD
Development of an Autonomous Forklift

Autonomous Guided Vehicles (AGV) is becoming increasingly popular in material handling in warehouse and in modern industrial environments. They use a variety of navigation and guidance techniques including magnetic tapes, inductive guidance wires, laser scanners, omni-directional cameras etc..

This thesis is about designing, building and testing a scaled model of an autonomous forklift. The autonomous forklift will be able to localise itself in a mock-up warehouse and transport pallet loads while avoiding obstacles.

This is a challenging mechatronics project and requires strong maths, programming and mechatronic design skills.

**Required Skills:**
- Linux
- Matlab/Simulink
- C/C++
- Math
- Electronics
- CAD
- Hands-on mechanical skills
In a nutshell, a telepresence robot is a mobile platform with bidirectional audio-visual interface and it is operated from a remote location. In a typical operational scenario, user connects to a telepresence robot and teleoperates it to move in its environment while getting live feedback from the robot. Communication bandwidth, packet loss rate, latency, type of human-machine-interface (HMI) presented to user, mechanical properties of the robot and many other factors affect the telepresence experience, hence the user satisfaction.

This thesis is about designing and building a telepresence robot with different levels of autonomy, including obstacle avoidance, assisted autonomy by providing to “go to destination”, “follow a person” types of functions. This project requires strong, hands-on mechanical, electronics and software design and development skills and experience. Furthermore, experience in web-technologies, such as PHP, HTML5, CSS3, JQuery, C/C++ on embedded Linux platforms are essential.

**Required Skills:**

- Matlab/Simulink
- Math
- Electronics
- Linux, ChibiOS,
- PHP, HTML5, CSS3, JQuery, C/C++
- IOS, Swift
- Android, Java
- CAD
Ever increasing popularity of mobile devices has created an unprecedented market for innovative mobile apps. Although the overwhelming majority of mobile apps are using only the hardware of the mobile device and some web services, there is an increasing interest in directly linking mobile devices with external physical platforms. AR-Drone mobile app is an example in which an external physical platform (an AR-Drone multicopter) is controlled by a mobile device (such as iPhone or iPad, etc.).

This thesis is focused on mobile app development for robotics platforms in which student will design, develop and demonstrate a teleoperated robotic platform using a mobile. This project requires strong, hands-on electronics and software design and development skills and experience. Furthermore, experience in IOS and/or Android along with their app development environments as well as experience in web-technologies (PHP, HTML5, CSS3, JQuery on embedded Linux platforms) are essential.

Required Skills:
- Math
- Electronics
- IOS, Objective-C, Swift
- Android, Java
- Linux, PHP, HTML5, CSS3, JQuery, C/C++
Path Planning and Control of a Microrobot Team

Microrobotics is a rapidly developing field deals with robots smaller than 1mm. Applications of microrobotics range from in-vivo medical operations, to micro-fabrication, to micro-scale particle manipulation. Recently we have developed an experimental setup in which multiple microrobots have been operated on a 2D test arena using combination of magnetic field and mechanical surface waves. The size of these microrobots varies between 200-2000 microns.

This thesis is focused on developing a path planning and control system for a team of microrobots on a 2D test arena. This project requires knowledge and interest in physics, particularly in the fields of electricity and magnetism, oscillations and waves. Furthermore hands-on experience in electronics circuit design, programming in Simulink, C/C++ and Python are essential.

Required Skills:
- Physics
- Math
- Matlab/Simulink
- Electronics
- Linux
- OpenCV
- C/C++, Python
Vision Based Closed-Loop Control of Microrobots

Microrobotics is a rapidly developing field deals with robots smaller than 1mm. Applications of microrobotics range from in-vivo medical operations, to micro-fabrication, to micro-scale particle manipulation. Recently we have developed an experimental setup in which multiple microrobots have been operated on a 2D test arena using combination of magnetic field and mechanical surface waves. Size of these microrobots varies between 200-2000 microns.

This thesis is focused on the development of a vision-based closed loop control system for the microrobots. This project requires knowledge and interest in physics, particularly in the fields of electricity and magnetism, oscillations and waves. Furthermore hands-on experience in electronics circuit design, programming in Simulink, C/C++ and Python are essential. As the microrobots moves very fast on the 2D test arena, the vision system has to be fast to track the microrobots. Therefore hands-on experience on OpenCV would be helpful.

Required Skills:
- Physics
- Math
- Matlab/Simulink
- Electronics
- Linux
- OpenCV
- C/C++, Python
Microrobotics is a rapidly developing field that deals with robots smaller than 1mm. Applications of microrobotics range from in-vivo medical operations, to micro-fabrication, to micro-scale particle manipulation. There are various methods to move the microrobots in the test environment, including thermal, optical, chemical, electrostatic, electromagnetic, bacteria propelled systems.

This thesis is focused on designing, building and testing an experimental setup in which microrobots will be moved in 3D space using accurately controlled magnetic field vectors generated by multiple electromagnets. This project requires knowledge and interest in physics, particularly in the fields of electricity and magnetism, oscillations and waves. Furthermore, hands-on experience in electronics circuit design, programming in Simulink, C/C++ and Python are essential.

**Required Skills:**
- Physics
- Math
- Matlab/Simulink
- Electronics
- Linux
- OpenCV
- C/C++, Python

**CONTACT**
Dr. Ali Haydar GÖKTOĞAN
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Embedded super-computing for robotic applications

The NVIDIA Jetson TK1 development kit is a full-featured platform for Tegra K1 embedded applications. It allows you to unleash the power of 192 CUDA cores to develop solutions in computer vision, robotics, medicine, security, and automotive. Buy the Jetson TK1 DevKit below and make sure to check out the Jetson TK post from our Parallel Forall blog.

NVIDIA provides the BSP and software stack which includes the CUDA Toolkit, OpenGL 4.4 drivers, and support for the OpenCV library for Tegra. Get software downloads and find additional documentation on the Jetson Support Page.

DevKit Includes

- Jetson TK1 development board
- AG adapter with power cord
- USB Micro-B to USB A adapter
- Quick Start Guide

Jetson TK1 Board Features

- Tegra K1 SOC
  - Kepler GPU with 192 CUDA cores
  - 4-Plus-1 quad-core ARM Cortex A15 CPU
- 2 GB x16 memory with 64 bit width
- 16 GB 4.51 eMMC memory
- 1 Half mini-PCIe slot
- 1 Full-size SD/MMC connector
- 1 Full-size HDMI port
- 1 USB 2.0 port, micro AB
- 1 USB 3.0 port, A
- 1 RS232 serial port
- 1 ALC6639 Realtek Audio codec with Mic in and Line out
- 1 RTL8111GS Realtek GigE LAN
- 1 SATA data port
- SPI 4MBbyte boot flash

The following signals are available through an expansion port:

- DVI/LVDS
- Touch SPI 1x4 + 1x1 CSI-2
- GPIOs
- UART
- HSIC
- i2c

Embedded GPUs will enable not only on-board vision processing but also allows a number of parallel-processing algorithms to be run online in a small form-factor.

This project will need to start by getting the Jetson dev board equipped with all the appropriate linux and Nvidia CUDA/Optix libraries to allow such algorithms to be ported most easily.

What you do with it next is up to you, but might include:

- Optical-flow based obstacle detection/classification.
- Adaptive Lidar/radar/sonar processing.
- Integration with one of the ACFR’s UGVs or UAVs.

Supervisor: Dr David Johnson, ACFR


Required Skills:

- Strong programming skills (particularly C++)
- Knowledge of Linux would be a bonus.
- An interest in embedded systems, perception and machine-learning would also be a benefit.
Semi-autonomous FPV racer

This project will be made up of a number of steps

1. Build an FPV racer (with capacity for additional on-board processing) and learn to fly it.
2. Develop (or re-use) an FPV-racing simulator for developing vision, EM or sonar based obstacle avoidance algorithms, e.g. MORSE/BlenSor.
3. Integrate your software onto the FPV racer to allow the equivalent of autonomous emergency breaking in three dimensions for UAVs.
4. Determine metrics for improved performance and analyse results.

**Supervisor: Dr David Johnson, ACFR**

Required Skills:
- Strong programming skills (particularly C++).
- Electronics skills and the desire to build stuff.
- An interest in embedded systems, perception and control algorithms would also be a benefit.
Counter-UAV system development

Micro-UAVs capable of relaying high-resolution video across long distances are no longer limited to defence research labs – they are now on every small (and big) child’s Christmas List.

The fact that they have not yet been widely used for criminal activities is quite surprising, as they are certainly well suited to many infiltration tasks and can be both difficult to detect and trace back to the user. It is therefore an area of great commercial and academic interest.

This project will investigate means to locate and disable such systems by non-kinetic methods, i.e. shooting them out of the sky is cheating (although potentially a future sport).

**Supervisor: Dr David Johnson, ACFR**

Required Skills:
Strong programming skills (particularly C++).
Electronics skills and the desire to build stuff.
An interest in embedded systems, perception and control algorithms would also be a benefit.
Robotic electronic warfare and countermeasures

Supervisor: Dr David Johnson, ACFR d.johnson@acfr.usyd.edu.au

Research Proposal (Thesis only, 1 or more students)

We have built many robots and sensors over the years and have learnt one important lesson:

There are many more ways for a robot not to work than for it to work correctly!

Even the robots that do work may fail under certain known conditions. It is likely that there are many unknown conditions under which they may also fail, particularly if someone, i.e. you, is going out of their way to find that ‘unknown’ failure mode and exploit it. The most interesting case is when the failure mode goes undetected and is then used for nefarious purposes.

In a world where autonomy is increasing along with the accessibility of cheap, almost throw-away systems, which could be turned to doing naughty things, we need to know where the weak points are so that we can do something about it.

Required Skills

Electronics

Signal Processing

C or C++ and MATLAB Programming

You should have done (or be planning to do) the Sensors and Signals course.

An interest in pursuing this topic at postgraduate level would also be a benefit.
Radar hardware design for 3D printing

Supervisor: Dr David Johnson, ACFR d.johnson@acfr.usyd.edu.au

Research Proposal (Thesis only)

At high frequencies, radar hardware design becomes a lot like plumbing, except with rather tighter tolerance constraints. The shape and structure of the cavity can make these devices difficult to machine, but may present an excellent opportunity for 3D printing techniques. One drawback is the low electrical conductivity of the majority of additive-printing or SLS materials, however this may be overcome by novel electro (less) plating methods. I am keen to pursue this idea further, as it has great possibilities, particularly for airborne millimetre-wave radar systems for UAVs, but I need someone to do the time-consuming mechanical design and electromagnetic simulation.

Required Skills

Mechanical design (Solidworks)

Electronic design

You should have done (or be planning to do) the Sensors and Signals course.

Some prior knowledge of electro-magnetic wave theory would be a distinct benefit.
Cognitive radar development

Supervisor: Dr David Johnson, ACFR d.johnson@acfr.usyd.edu.au

Research Proposal (Thesis only, 1 or more students)

At the ACFR, we have recently completed development of a 94GHz millimetre-wave radar testbed with extremely high resolution and the ability to be reprogrammed on the fly. One of the interesting applications of this technology involves changing the transmitted waveform dynamically to maximise information about the environment. This may be to balance the requirements for range/angular resolution vs maximum range or available communications bandwidth. It might also be to mitigate (or employ) multipath or other interference sources.

There are a number of possible approaches to tackling this problem, including, but not limited to:

- Developing a closed-loop control algorithm that adapts to existing data in order to improve signal-to-noise in subsequent scans, by changing register values through the xml datalink.
- Looking at non-linear-phase waveforms (of which the simplest is a chirp) to provide multipath target discrimination at the FPGA-fabric level.

Required Skills

Electronics

Signal Processing

C, C++, MATLAB and/or Python Programming

Unix skills

A willingness to learn FPGA (VHDL) design

You should have done (or be planning to do) the Sensors and Signals course.

An interest in pursuing this topic at postgraduate level would also be a benefit.
Acoustic localisation, control and interaction of a robot

Supervisor: Dr David Johnson, ACFR d.johnson@acfr.usyd.edu.au

Research Proposal (Thesis only, 1 or more students)

For robots to operate in a human-centric environment, they need to be able to communicate efficiently with us. One obvious way of doing this is through speech. Voice-recognition algorithms (such as Siri or Utter) have significantly improved in recent years, so it may be time to revisit this problem and all the research pathways it may lead too. For instance:

- Can a robot infer operator intent or other additional information from what is said to it?
- Can a network of robots share acoustic information to localise themselves and the operators, either through speech or other noises?
- Does a mechanically actuated pinna (that’s earlobe) aid localisation accuracy?
- What 2-way interactions lead to more efficient dialogue?

There are many more directions this topic could take and I am open to ideas.

Required Skills

Electronics

Signal Processing

C or C++ and MATLAB Programming

An interest in human psychology
Collaborative projects with the ARC Centre for Excellence in Engineered Quantum Systems (Quantum Nanoscience Laboratory)

Supervisor: Dr David Johnson, ACFR d.johnson@acfr.usyd.edu.au

Research Proposal (Thesis only, 1 or more students)

The eQus group is rapidly expanding within the Physics department and a number of interesting projects requiring an engineering perspective are up for grabs under the general theme of “Custom electronics for control of quantum systems”. These projects represent a great opportunity for solving the real-world engineering problems that will extend the science of quantum computing. While an interest in the underlying physics would be beneficial, it is not a pre-requisite. There are a number of topics that may be of interest, including:

- Multi-frequency readout of quantum systems
- Real-time optimisation of quantum control circuits
- Simulation of 2D arrays of quantum dots
- Mixed signal analysis of high power RF devices
- Nano-fabrication for quantum computation

These topics would particularly suit students studying for a combined science/engineering degree.

**Required Skills**

Mechanical design (Solidworks)

Electronics

Signal Processing

C or C++ and MATLAB Programming

A willingness to learn FPGA (VHDL) design

An interest in pursuing this topic at postgraduate level would also be a benefit.
Modelling of spiking dynamics of live neurons
(Honours Thesis)

Vertical nanowire arrays are a new technology for electrical probing and biomolecular delivery to individual live neurons in a slice of a rat’s brain (liberated from the rat’s body and kept alive in a bath of bovine serum). This thesis project is based on collaboration with MIT and Harvard University exploring the possibilities of this new technology for rapid-throughput neuroscience.

A neuron’s electrical dynamics are highly nonlinear and difficult to understand, but are extremely important as the key to understanding intelligence. Our role is to rapidly create a high-fidelity computational model of the neuron from the signals recorded via nanowires, so that an accurate simulation can be built of the entire neuronal network, i.e. “reverse engineering the brain” – one of the grand challenges of science in the 21st century.

Above: a live neuron from a rat’s hippocampus being probed with a patch clamp.

This thesis topic would be suitable for Biomedical and Mechatronic students. Advanced topics are available for those doing a double degree with Mathematics or Computer Science, including the use of graphics processing units (GPUs) for rapid neuron modelling.

Interested students should contact Dr Ian Manchester via email ASAP: i.manchester@acfr.usyd.edu.au
Design and control of dynamic walking robots (Honours Thesis or Engineering Project)

As robots move out of the factories and into the wider world, many creative methods of locomotion are being proposed. Legged robots in particular are suitable for traversing terrain too rough or irregular for wheels to be useful. Recently, a new type of biped robot called “dynamic walkers” has been invented. These robots are based on co-design of the physical mechanism and the feedback control to generate highly efficient motions, much like a human. They are far more efficient than well-known robots such as Asimo or Big Dog. Some are so efficient they can walk down a shallow slope without any powered actuation at all!

At the Australian Centre for Field Robotics (ACFR) we are designing new experimental biped systems which will be able to walk over rough terrain in a highly naturalistic and efficient manner. There are several options available for thesis or project work, covering mechanical design and construction, physical modelling and simulation, implementation of real-time feedback control, and computational analysis.

Above: one of our biped experiments at ACFR.

These thesis and project topics would particularly suit Mechanical and Mechatronic students with an interest in dynamics and control, state of the art robotics, or design of energy-efficient mechanisms.

Interested students should contact Dr Ian Manchester via email ASAP:

i.manchester@acfr.usyd.edu.au
Advanced nonlinear control and optimization
(Honours Thesis)

Engineered systems are getting more and more complex, and increasingly the design process relies on advanced mathematical and computational methods. A particular focus recently has been using methods from semialgebraic geometry and semidefinite optimization to design and guarantee performance of highly nonlinear dynamical systems.

Above left: a rotary inverted pendulum (“Furuta pendulum”): a nonlinear, underactuated mechanical system and a popular test-bed for advanced nonlinear control theory.

Above right: a graphical representation of a three-dimensional spectrahedron, an important object for proving stability of nonlinear dynamical systems.

There are many challenging opportunities available in this area, both with experimental and theoretical focus. This project would suit ambitious and creative students from any stream, with extra possibilities for those doing a combined degree with mathematics or computer science.

Interested students should contact Dr Ian Manchester via email ASAP to discuss concrete project proposals:

i.manchester@acfr.usyd.edu.au
Control and Motion Planning for an Underwater Manipulation Robot (Honours Thesis)

Underwater robots are already being used extensively for biological surveys, archaeology, and inspection of communications, oil and gas infrastructure. The next step is to develop robots that are capable of intervention. That is, interacting with the environment rather than just observing it. Typical examples include biological or geological sample collection, and repair of underwater infrastructure (e.g. a leaking oil pipe).

At the Australian Centre for Field Robotics (ACFR) we have recently purchased a remotely-operated vehicle with a manipulation arm (pictured below) which we are modifying for autonomous operation. There are many challenges to developing autonomous manipulation systems: object detection and localisation, vehicle motion modelling and control, precision force control, etc. Any of these would make a good thesis topic.

Interested students should contact Dr Ian Manchester or A/Prof Stefan Williams via email ASAP: i.manchester@acfr.usyd.edu.au, s.williams@acfr.usyd.edu.au
Dextrous Robot Manipulation
(Honours Thesis or Project)

The Baxter robot (pictured below) is a low-cost robot platform designed to work alongside humans in small to medium sized businesses. We have a Baxter at the Mechatronics Teaching Laboratory. This thesis project involves designing the “brain” of this robot, i.e. its perception, motion planning, and control systems.

Some potential topics include:

- Using vision to analysing object shape to plan grasping motions
- Control of arms to cooperate with a human partner
- Learning precise control by demonstration and experience

This project would particularly suit Mechatronics students, especially those doing a combined degree with computer science. Interested students should contact Dr Ian Manchester via email ASAP to discuss concrete project proposals:

i.manchester@acfr.usyd.edu.au
The Intelligent Vehicles and Safety Systems Group (IVSSG: its.acfr.usyd.edu.au) is part of the Australian Center for Field Robotics (ACFR). Our research is related to improving the safety and performance of vehicles with a range of projects related to sensing, perception, user interfaces and automation. This is a very important area of research with the potential of improving safety, minimizing environmental impact and increasing performance for the transportation of people and goods. We are offering positions for undergraduate theses in a range of topics related to intelligent vehicles including (but not limited to):

**Determining Position**

Most projects involving vehicles require a good estimate of position. The most common way to do this is using a GPS sensor, though these have well understood limitations. In vehicles, problems arise when driving near tall buildings (urban canyon effect) as well as in tunnels and covered areas.

We are currently looking into new methods of using sensors such as gyroscopes, accelerometers and odometry incorporated with GPS and GLONASS to improve the estimation of position. There is an opportunity for several undergraduate theses in this area, with great potential in exploring both the experimental and theory behind estimating position.

*Dead Reckoning (red dots) uses sensors to estimate position without GPS*
Mobile Phone Positioning / Pedestrian Intent

Mobile phones are ubiquitous in today’s society, in particular phones with a spectacular range of on-board sensors. Most phones (even low end models) have gyroscopes, accelerometers, GPS, cameras, magnetometers and other sensors. With appropriate algorithms, these sensors have the potential to provide a high quality estimate of position for people, bicycles as well as vehicles. At the same time we can use this information to estimate pedestrian intention, activities etc. We have already developed basic software that currently run in Android and IOS platform.

There is an opportunity for one or more students to work in this area for the undergraduate thesis. There is a broad scope for working with this platform, including estimating activities, intention, position and broadcasting this information to vehicles for safety applications. The student are required to have a good background in programming.

Thermal Imaging – Working with Infrared

Thermal imaging from infrared cameras can be used for a range of applications, particularly the detection of vehicles, people and animals during the day or night. Even more, the infrared camera is less sensitive to light conditions such as shadows and can operate to some extent through dust and fog.

We have a commercial infrared camera which can be mounted on a vehicle and can be used in a variety of applications. There is scope for undergraduate thesis work in processing the information from the camera and investigating the use in the detection of obstacles.
Monocular Vision
Embedded microcontrollers such as the raspberry pi have the capability of capturing video and performing complex image processing on board. For vehicle applications, this can be used to track the position of the vehicle in the lane, perform visual odometry, detect people or bicycles, detect road signs and a host of other applications. A project in this area would focus on using open source tools such as scikit-image.org or opencv.org to process images in an embedded system to solve problems in the area of intelligent transportation systems.
Cooperative Robot Localisation/Tracking
(Honours Thesis or Engineering Project)

Supervisor: Dr. Mao Shan, ACFR, m.shan@acfr.usyd.edu.au

Research Proposal

Localising and tracking mobile nodes in an industrial environment is necessary for many autonomous and manned system applications. At present, cooperative localisation/tracking has attracted a growing interest in the research community. In conventional localisation/tracking, robots without self-localisation capability have to be localised by a sufficient number of reference nodes using trilateration/triangulation algorithms. In a large environment, however, the reference nodes usually fail to cover the whole area, which makes the global localisation/tracking ineffective.

In the cooperative localisation/tracking scenario, a mesh network is formed to connect all robots, and these position unknown robots can communicate and help localise each other in the use of pairwise range and/or bearing measurements. Overall, cooperative localisation/tracking brings higher robustness, scalability and localisation/tracking accuracy.

I am looking for a few students studying the cooperative localisation/tracking of robots in indoor/outdoor environments. The theory part is based on a state-of-the-art nonparametric cooperative tracking algorithm that has been published in two well-developed papers.


Each student could pick one of following research directions:
1. In-depth research into the fundamental cooperative tracking framework
2. Algorithmic optimisation for higher efficiency
3. GPU acceleration in algorithm implementation
4. Extending with ultra-wide-band (UWB) wireless communication
5. Adding other types of sensors for higher accuracy/reliability

We would have good opportunities of publication on top journals/conferences at conclusion of research.

Interested students should contact Dr. Shan to discuss detailed topics as per their interests and skills.

Required Skills

Statistics
Matlab programming
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<th><strong>MX or MXSpace</strong></th>
<th><strong>Aero, Aerospace, MX or MXSpace</strong></th>
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| Mawson is an all terrain rover that has been in operation over the last two years as part of a space robotics program. It needs to be overhauled. We are looking for a student who has an interest in advance computer hardware and software. The objective of the thesis is to give Mawson a whole new lease on life. The thesis would comprise of:  
  - Selection of new computer hardware  
  - Software to drive motors and read sensors already on board.  
  - Code for teleoperation  
You will work closely with our engineers as part of the design and implementation process. | Continuum now has an arm that will give this rover the ability to look closely at objects and generate detail models of the object and of the terrain. Code is written in Matlab/Simulink. We are looking for 3 students for the following thesis topics:  
1) Use the laser scanner on the arm to build a 3D model of a target rock given multiple viewpoints. Challenges include object segmentation from the laser data and motion planning for the arm.  
2) Use the laser scanner on the arm to create an elevation map of the environment and then use this map to develop a path planner for Continuum.  
3) Develop a energy model for the arm. e.g for a given trajectory calculate the energy used based on joint torques, etc. As an extension perhaps plan energy-optimal collision free trajectories for a given initial and final poses.  
You will work closely with our engineers as part of the design and implementation process. |
**Aero, Aerospace, MX or MXSpace**  
Mammoth is a wheel-legged robot. Code is written in Matlab/Simulink. We have a number of thesis topics including:

1) A student looking at how to create a rapid map of the Mars Yard using onboard laser sensors and generating traversability maps for Mammoth.
2) A student working on novel User Interfaces for tele-operating Mammoth including low-level control to high-level planning.
3) A student working on the planning problem, in particular to look at clambering gaits.
4) A student to investigate building a more effective force sensor unit to identify if Mammoth's wheels are touching the ground reliably.

You will work closely with our engineers as part of the design and implementation process.

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**MX or MXSpace**
Ladybird is an electric powered robot designed for vegetable industry. We are looking for students to advance Ladybird with the following thesis topics:

1) To estimate and map the yield and vigour of leafy vegetable crops during the growing cycle, using geometry from lidar and stereo vision.
2) To develop and demonstrate fast (<500ms) planning for precision weeding using the Universal Robots UR5 arm mounted under Ladybird’s skirt.

You will work closely with our engineers as part of the design and implementation process.
**MX or MXSpace**
Shrimp has been used in a number of trials for the tree-crop industry. We are looking for student to work on the following thesis topics:

1) To investigate the use of machine learning to model the geometric characteristics of an orchard, for the purpose of automatic tree detection and segmentation in three dimensional lidar data.

2) To improve camera based yield estimation algorithms by using images of trees taken from multiple view-points.

You will work closely with our engineers as part of the design and implementation process.

**Aero, Aerospace, MX or MXSpace**
We have an Astec Falcon 8 that will be used in agriculture. We are looking for students interested in thesis topics on:

- Developing novel systems and sensors that can catch bugs.
- Optimal path planning given terrain characteristics and energy constraints.
- Search algorithms and path planning for detecting moving invasive pests.

You will work closely with our engineers as part of the design and implementation process.
Hybrid fuel-cell-based systems are gaining importance across a range of disciplines including, but not limited to, aeronautics, automotive, renewable energy, ... Whereas fuel-cell technology has matured considerably in the last decade, significant research into the system dynamics of still required. A range of thesis topics are available in this domain to support projects funded by US Navy and the Australian Defence Science and Technology Group (DSTG)

**Fuel Cell Controller Design**

Fuel cell performance during transients is significantly impacted by the controller design. This thesis will consist of the design of a fuel cell controller and an assessment of its impact on the transient performance of the fuel cell.

*1 Honours thesis*

**Battery Prognostic Health Management**

Battery life and endurance estimates are critical for the performance prediction of electric vehicles. In this thesis a NASA developed battery health management model will be extended and applied to a range of mission profiles. The predicted performance will be compared with measured performance to assess the validity of the model.

*1 Honours thesis*

**Electronic Speed Controller Efficiency**

Electronic speed controllers are needed to drive brushless DC motors. However, efficiency data for these electronic devices is not widely available. In the current thesis electronic speed controller efficiency will be measured and a model will be developed that allows accurate prediction of speed controller efficiency.

*1 Honours thesis*

**Modelica Dynamic System Modelling**

Modelica is the leading object-oriented modelling tool for dynamic systems and is used in a range of industries and research institutes. Whereas various open-source models are available in Modelica validation and improvement of those models is needed. In this series of thesis projects modelica models will be developed for a range of hybrid fuel-cell-based applications:

- fuel cell and battery dynamic models
- fuel cell controller models
- automotive drivetrain analysis
- ...

*2-3 Honours thesis*

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**Supervisor Details:** Dries Verstraete Dries.Verstraete@sydney.edu.au, Rm N316, Aero Eng Bldg J11
Autonomous Marine Systems

The Australian Centre for Field Robotics’ marine systems group undertakes fundamental and applied research in a variety of areas related to the development and deployment of autonomous marine systems. We have a number of thesis projects available that will support studies in the fields of engineering science, ecology, biology, geoscience, archaeology and industrial applications. More details of our research can be found at http://www.acfr.usyd.edu.au/research/subsea.shtml.

Title: Underwater Intervention using ROVs
Supervisors: S. Williams and I. Manchester

We have a small Remotely Operated Vehicle (ROV) designed for underwater inspection and intervention tasks. The ROV serves as a testbed for new methods in motion planning, control and nonlinear system identification. We are working towards fully autonomous underwater manipulation capability for the next generation of ROVs and AUVs. Optimising control strategies that account for the disturbances induced by the tether and interaction with its environment will lead to improved controllability of these platforms. Dynamical forces that act on these platforms are a combination of nonlinear mechanical interaction through the manipulator arm and tethering cable, as well as forces on the body induced by ocean currents. These effects may be large, time-varying, and difficult to model and must be properly accounted for in order to maintain precision control of these platforms. Students will be expected to research current trends in underwater manipulation and intervention, propose and implement control systems for the ROV and validate novel manipulation techniques in underwater trials.

Title: Dynamics and Control of Autonomous Underwater Vehicles
Supervisors: S. Williams, O. Pizarro, and M. Bryson

We have a pair of Autonomous Underwater Vehicles (AUV) that are used for surveying the seafloor in depths well beyond those that can be reached by a diver. We are looking for one or two motivated students to undertake a study of the dynamical properties and control design of these vehicles. These studies will result in improvements to the real time control of the vehicle, including its ability to hold depth and follow tracklines in energetic environments. Based on the outcomes of previous student theses in the area, there is also scope for completing the design of optimised propellers, fabricating them and demonstrating enhanced endurance. Students will be expected to research
current trends in long-term AUV design, propose design modifications to our existing vehicles and validate their designs in simulation and during engineering trials held periodically throughout the year.

Title: **Image classification in reef environments**  
Supervisors: S. Williams, O. Pizarro

This project will explore the classification of seafloor type based on visual and sonar information collected by an Autonomous Underwater Vehicles. The volume of data being collected by these systems precludes detailed manual analysis of the data. Machine learning algorithms have recently been shown to be effective at identifying patterns within this data that can help to guide further analysis. We are also interested in developing methods capable of recognizing particular organisms within the highly unstructured marine environments we work in. Students interested in this project should have strong software skills. One or two students will be accepted for this project.

Title: **Unmanned Surface Vessel navigation, control and mapping**  
Supervisors: S. Williams and F. Ramos

Unmanned Surface Vessels (USV) are increasingly being used for tasks such as seafloor mapping using acoustic sensing. We have recently begun a project to look at the design and implementation of such vehicles. Projects will focus on aspects of navigation, control and sensing for USV systems. One of the key aspects of such survey work is the ability to modify plans while the vehicle is underway and to respond to disturbances such as wind, waves or strong currents. This work represents a crucial step in the development of autonomous technologies capable of long-term, reliable deployment. Students interested in this project should have strong software skills and some experience with electronics and hardware design. Tasks will include interfacing to the existing vehicle path planner as well as exploring novel methods of responding to sensed data. One or two students will be accepted for this project.
Title: **Real-time Visual Simultaneous Localisation and Mapping (SLAM)**  
Supervisors: S. Williams, O. Pizzaro and M. Bryson

We operate an imaging autonomous underwater vehicle (AUV) that takes stereo photographs of the seafloor. Currently these data are used in post-processing to refine the vehicle's navigation using algorithms from recent robotics research collectively known as simultaneous localisation and mapping (SLAM). By enforcing loop closures where images are seen to contain the same features, such visually-augmented navigation can dramatically improve our ability to geo-reference the location of the vehicle and the data it has collected. Research in our group has led to efficient implementations of SLAM that are suitable for real time operation; however, the image processing required to generate the visual features used for identifying loop closures is too computationally intensive to run in real time on our existing hardware. We seek a motivated student with strong programming skills and an interest in SLAM to research hardware/software options for real-time feature extraction and to implement a system suitable for real time use on our AUV.

Title: **Unmanned Aerial Shark Patrol**  
Supervisors: Stefan B. Williams and Mitch Bryson

There is a growing interest in the use of Unmanned Aerial Vehicles (UAVs) in a variety of domains. One area of potential growth is in the patrol of beaches, with a particular focus on aerial visual identification of sharks. However, this can be hindered by surface reflection and attenuation through the water column. Attenuation reduces contrast, limiting the depth to which objects can be effectively imaged through water. Specular reflection of sunlight at the water's surface exacerbates the situation by adding interference, often bearing more energy than the signal of interest. As a result, both human and automated visual systems become overwhelmed by the stronger interfering signal. We have recently completed a study demonstrating that specifically tailored multispectral cameras are suitable for enhancing through water visibility for aerial shark detection. This project will seek to develop a compact multispectral camera system for aerial flight. One to two students projects will be available to build a prototype imaging system and demonstrate algorithmic methods for contrast enhancement.
UAV Motion Planning

Motion planning for unmanned aerial vehicles (UAVs) is a challenging problem that must consider a variety of considerations, including winds, thermals, obstacles and safety. Mathematically, this motion planning is an optimisation problem that comprises both discrete and continuous decisions. In this thesis, you will apply state-of-the-art sampling based motion planning algorithms to UAV motion planning. You will be interested in development of optimisation and/or graph search algorithms.

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