**Supervisor: Tansu Alpcan, Tansu Alpcan tansu.alpcan@unimelb.edu.au**

**Title: Detecting Anomalous Communication Patterns using Deep Learning**

Abstract:

This project aims to detect anomalous communication patterns using deep learning methods with potential applications to disaster recovery and security. The data generated from a simulator will be used to distinguish suspicious communication from background traffic using deep learning methods. The project requires good knowledge of signal processing, communication theory as well as strong software skills. The students should be capable of installing and using simulator software and deep learning libraries, e.g., TensorFlow or PyTorch. This project is related to the PhD project listed at https://apps.eng.unimelb.edu.au/research-projects/index.php?r=site/webView&id=513

**Supervisors: Paul Beuchat paul.beuchat@unimelb.edu.au, Gavin Buskes g.buskes@unimelb.edu.au**

**Title: AI-for-Robotics platform development**

Description:

This project will focus on the development and implementation of an autonomous driving platform, both in simulation and in hardware. This platform is being developed for a new subject that is primarily targeted at students with a computer science background. The focus of the new subject is to equip students with the ability to analyse and critically examine autonomous systems from a control perspective, i.e., model fidelity, controller design methodology, sampling influences, fundamental limits, while also incorporating data-driven and reinforcement learning techniques that are relevant for autonomous driving.

In order to achieve the objectives for the new subject, the goal of this project is to package an autonomous driving platform into a 'plug-and-play' environment, where students can readily access sensor data and implement control algorithms, without requiring detailed knowledge of the underlying hardware or interfaces.

From a hardware perspective, the goal of this directed-studies project is to develop and implement low-to-medium speed autonomous-driving scenarios, for example: parking, three-point-turns, stabilisation on low-friction surfaces and intersection coordination. We will use a 1:10 scale RC racing car as a basis and build autonomous capabilities on top of that, with the F1Tenth project (https://f1tenth.org) providing guidance to accelerate development. The main sensors for feedback will be a stereo-vision camera (Oak-D-Pro). In order to protect the vehicle from damage due to a student accidentally deploying an unstable controller (i.e., a "rogue robot”), the hardware development will also include the implementation of a safety shut-down system, for example: a dedicated micro-controller board with heartbeat monitoring to the main onboard computer and time-of-flight distance sensors for local collision avoidance.

From a simulation perspective, the goal of this project is to develop and implement a high-fidelity simulation environment in the Gazebo software, with the F1Tenth project again providing a baseline to accelerate development. The simulation environment is key to the reinforcement learning objective of the subject and will need to provide an easy interface for running a batch of simulations. The simulation environment is also key to demonstrating autonomous-driving scenarios that are not possible in the real-world classroom, for example: high speed driving including recovery from slippage during cornering and lane-changing on a crowded road.

We are also open to suggestions you have for alternative autonomous-driving scenarios to implement in hardware and/or in simulation.

Programming languages: Python and C++

Software frameworks: ROS and Gazebo

**Supervisor: Jingge Zhu [jingge.zhu@unimelb.edu.au](mailto:jingge.zhu@unimelb.edu.au)**

**Title: information-theoretic analysis of machine learning algorithm.**

Information theory and statistical learning theory are closely related, as both fields are rooted in statistics. Recent works have shown that information-theoretic analysis and techniques provide useful insight to machine learning algorithms. Examples include that information measures (e.g., mutual information) provide tight bounds for generalisation errors of learning algorithms, and Fano inequalities can be used to give lower bounds on non-parametric regression problems.

In this project, we will use both information-theoretic measures and techniques to study learning algorithms from a theoretical perspective. This project is suitable for mathematically inclined students.

The following papers provide some examples of research problems related to this project (but by no means must the student work on these topics)

https://arxiv.org/abs/2205.03131

https://arxiv.org/abs/2205.04641

https://arxiv.org/abs/2109.01377

**Supervisor: James Bullock james.bullock@unimelb.edu.au**

**Topic: Silicon solar cell photoluminescence as a proxy for device voltage.**

When illuminated with visible light, silicon will emit photons with an energy around 1.1eV. This process is called photoluminescence and its magnitude is proportional to the concentration of excess electrons/holes generated from the visible light illumination. Conveniently, a solar cell's operating voltage is also proportional to the excess electron and hole concentration and thus photoluminescence can be used as an excellent proxy for device voltage. This provides us with way to estimate a solar cell's device voltage during the fabrication process without having to finish the device. This directed studies module will consist of both a practical and theoretical component. The practical component will be focused on helping to build an experimental set-up for measuring photoluminescence on large area silicon wafers. The theoretical component will involve building models to convert the measured photoluminescence into an estimate of device voltage.

**Supervisor: Dragan Nesic dnesic@unimelb.edu.au**

**Title: Hybrid systems: source seeking with a mobile robot**

Hybrid dynamical models provide a very general and flexible framework for modeling, analysis and design of a broad range of systems ranging from mechanical systems with impacts, power electronics, multi-agent systems with switched topology, networked control systems, event-triggered control, and so on. The goal of this project is that you learn about this powerful methodology and apply it on an example of source seeking control with a mobile robot. The goal is that you understand the methodology and flexibility of design and simulate the robot behaviour different scenarios (e.g. with obstacle avoidance). Source seeking is a problem where you aim to find the source of a signal (e.g. a gas leak, source of radiation, or the location of an airplane's black box that emits a radio signal) by using only a sensor mounted on the robot. The robot is able to find the source of the signal in an autonomous fashion and only by using the measured signal at its current location.

**Supervisor: Glenn Bradford glenn.bradford@unimelb.edu.au**

**Title: FPGA-based hardware acceleration**

Hardware acceleration for computationally intensive applications is of growing importance to improve workload performance in cloud data centres, the network edge, and IoT embedded devices. A diverse set of algorithms can benefit from such acceleration, including in the areas of artificial intelligence, machine learning, networking, cryptography, and multimedia signal processing. This directed studies position will involve formulating and prototyping FPGA-based design projects for use within a new master's level hardware acceleration subject to first be offered in 2023.

This new subject seeks to attract an interdisciplinary cohort of students from computing and engineering, and so candidate design projects will need to incorporate relevant concepts across both disciplines. Responsibilities for this directed studies position include: reviewing relevant literature to identify algorithms of interest and their corresponding hardware acceleration proposals; prototyping design project solutions on embedded FPGA platforms and/or cloud-based FPGA solutions; and evaluating the feasibility and appropriateness of projects for use within the subject. A range of industry design software and tools will be used.

- Low-level synthesis using VHDL or Verilog and design suites such as Xilinx Vivado ML or Intel Quartus Prime
- High-level synthesis using C/C++/OpenCL and industry tools such as Xilinx HLS
- Cloud-based computing services such as Amazon AWS

Depending on progress make in the above tasks, support to develop curriculum materials may also fall in scope.

**Supervisor: Ye Pu ye.pu@unimelb.edu.au**

**Title: Safe control and learning for underwater robots**

Autonomous underwater vehicles (AUVs) have been proven very useful in ocean-based industrial applications, including making accurate seafloor maps and searching for wreckage in disaster response scenarios. Compared to ground and aerial robots, AUVs are facing different challenges such as extremely limited communication resources, unknown and complex environments, and strong underwater disturbances. The goal of this project is to develop safety-guaranteed control and learning algorithms for AUVs against strong disturbances in complex environments. Particularly, this project aims to draw on techniques from the domains of optimal control, reinforcement learning, and optimisation to design novel control strategies for real-time motion control with safety guarantees.

**Supervisor: Chris Manzie manziec@unimelb.edu.au**

**Title: Coordinated control of heterogeneous vehicle swarms**

This project will look to develop and demonstrate a distributed control method(s) incorporating collision avoidance for leader-follower control in a swarm of unmanned (and potentially heterogeneous) vehicles tasked to achieve a common overall objective (for example source seeking or monitoring an area). In particular, the method should be able to seamlessly adapt to follower agents intermittently joining or leaving the swarm of followers.