Directed Studies Projects

Semester 1 2023

Project Title	Project Description	Supervisor and contact email
Detecting Anomalous Communication Patterns using Deep Learning	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	Tansu Alpcan tansu.alpcan@unimelb.edu.au
AI-for-Robotics platform development	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	Paul Beuchat paul.beuchat@unimelb.edu.au Gavin Buskes g.buskes@unimelb.edu.au

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	Jingge Zhu jingge.zhu@unimelb.edu.au
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.	James Bullock james.bullock@unimelb.edu.au
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.	Dragan Nesic dnesic@unimelb.edu.au
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	Glenn Bradford glenn.bradford@unimelb.edu.au

	• Depending on progress make in the above tasks, support to develop curriculum materials may also fall in scope.	
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.	Ye Pu ye.pu@unimelb.edu.au
Vision-Based trajectory planning and following for underwater autonomous vehicles (AUVs)	This project aims to develop advanced control and learning strategies for trajectory planning and following for underwater autonomous vehicles (minimise lap time/power consumption and guarantee collision avoidance) based on local cameras and demonstrate the proposed algorithms on a real underwater robot. Particularly, this project aims to combine a vision-based simultaneous localization and mapping (VSLAM) algorithm with advanced control and learning strategies for motion planning and control. Specifically, the project includes the following steps: 1. Survey techniques for VSLAM and optimal trajectory-planning / following and obstacle avoidance, with emphasise on model predictive control and reinforcement learning. 2. Test existing VSLAM algorithms on the robot (based on the results of our previous projects) 3. Investigate possible model predictive control and reinforcement learning techniques for optimal trajectory-planning / following for AUVs using camera data and demonstrate the algorithms in simulation. 4. Develop novel control and learning strategies for trajectory planning and following. Particularly, we aim to take the performance of the VSLAM algorithm is taken into consideration in the design of the strategies. 5. Test the developed control/learning algorithms in simulation and on the real underwater robot. Skills required: 1. Programming skills: Knowledge of MATLAB, Python, and C++/C. Knowledge of using ROS, Gazebo, and OpenCV. Knowledge of Unreal Engine. 2. Mathematical and electronics skills: Knowledge of dynamic modelling. Knowledge of control theory and machine learning. Knowledge of using embedded systems (Raspberry Pi, Arduino and etc.).	Ye Pu ye.pu@unimelb.edu.au
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.	Chris Manzie manziec@unimelb.edu.au
Implementation and Evaluation of Control Algorithms of a Quadruped Robot	The control of a quadruped robot is an active research area in the field of control, robotics and artificial intelligence due to its capability of operating independently in various environments that a human can access. The aim of this project is to test and evaluate an autonomous quadruped robot system, leveraging the robot dog available in the CSP lab, with optimal control algorithms to complete some simple tasks, e.g. obstacle avoidance and path following. The project will focus on implementing an existing algorithm, such as model predictive control, to enable autonomous navigation and ensure obstacle avoidance. Through this project, valuable insights will be gained into the implementation and control of autonomous quadruped robot systems, contributing to the advancement of interdisciplinary fields and providing opportunities for real-world applications. **Skills:** 1. Required: H1 Mark. Basic Knowledge of Control Theory; Experience with Python and ROS. 2. Preferrable: Basic Knowledge of Optimisation Algorithms.	Dr Ye Wang ye.wang1@unimelb.edu.au Prof Chris Manzie manziec@unimelb.edu.au

Photonic metasurface modelling	By controlling the way that light interacts with these structures, metasurfaces can be engineered to display a wide range of optical properties, including negative refractive index. This means that light going through the metasurface will bend in the opposite direction to what would be expected based on Snell's law. This behaviour presents new opportunities for the design of optical devices and systems, such as highly efficient lenses and cloaks that can make objects invisible to specific wavelength of light. In this direct study, we will use photonic simulation tools to design metasurfaces."	Sejeong Kim sejeong.kim@unimelb.edu.au
Online Learning with Side Information	Summary: Online learning is a type of machine learning problems in which one wishes to make decision (e. g. prediction) about data in a sequential and online manner. For example, how to predict tomorrow's US stock market value (or the weather in Melbourne) given the past data, where minimal assumptions on the underlying data-generating mechanism is made. In this project we will explore the role of side information for online learning. Take the stock market example: if you knew the Australian stock market information, will that help you to make a better prediction for the US stock market? In this project we aim to design efficient online prediction algorithms with side information and to study its performance limitation theoretically. Prior knowledge on machine learning/online learning is not required but would be a plus. Solid knowledge in probability theory and good programming skills are useful for this project.	Dr Jingge Zhu, jingge.zhu@unimelb.edu.au
Transparent Displays for Augmented Reality	Augmented Reality (AR) is an emerging technology that enables the seamless overlay of the real world with computer generated virtual images in such a way that the virtual content is aligned with real world objects (examples: Google glass, HoloLens etc). AR is now being targeted in a wide range of application domains such as new AR motor cycle visor, medical surgery, education, entertainment, AR tourism and storytelling by recreating past scenes through AR in a historical site. Despite AR promising to provide breakthrough visual experience in numerous applications, widespread adoption is limited due to discomfort, eyestrain and cumbersome devices. This is mainly caused by the physical form of current AR see-through display-combiners, which require the viewer to look through thick cube reflectors, inability to focus the virtual images on the retina while seeing the real-world scenes, a limited field of view (FOV), and a small eye box that limits area where virtual image is visible. This project will investigate a Meta AR: a new thin and flat AR see-through display-combiner technology using dielectric metasurfaces using computational techniques to exploit the full potential of the AR technology. The student will give necessary training on finite element methods to carry out the design and simulation work. Please get in touch with Ranjith Unnithan if you require more information.	A/Prof. Ranjith R Unnithan r.ranjith@unimelb.edu.au and Prof. Christina Lim