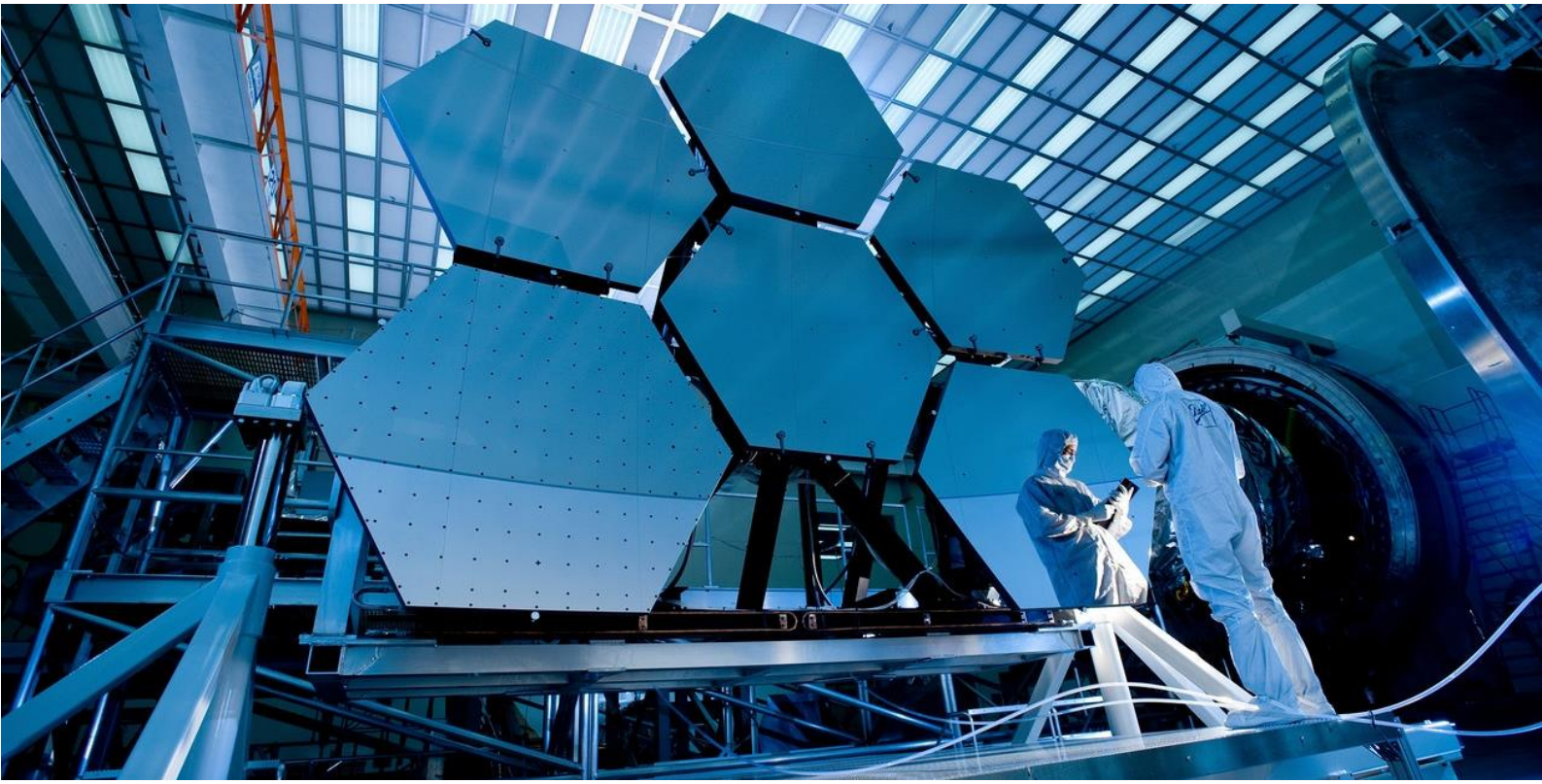
THE UNIVERSITY OF SYDNEY

FACULTY OF ENGINEERING

# Engineering Vacation Research Internship Program



## ENGINEERING RESEARCH PROJECTS FOR SUMMER 2021-22

THE UNIVERSITY OF SYDNEY

FACULTY OF ENGINEERING

# BIOMEDICAL ENGINEERING PROJECTS

## BME2021-22/1 Architecting Superior Metal-Ceramic Composites by advanced manufacturing

**Supervisors**: Dr. Xianghai An and Dr. Mohammad Mirkhalaf Valashani

**Eligibility**: High achievement in a relevant undergraduate engineering degree (a WAM of 80 or above). This summer project has the option to be combined with an honours project.

**Project Description**:
Materials come with characteristic combinations of mechanical properties. For example, ceramics have high stiffness but break easily; metals have high strength and ductility but limited ability to deform elastically. A vital requirement for all structural materials is that they possess an exceptional combination of stiffness, strength, ductility, and damage tolerance. However, these characteristics cannot currently be obtained simultaneously. Although materials with different combinations of attributes can be designed by forming composites of different materials, it is still scientifically and technologically challenging to harvest desirable combination of properties.

To address these issues, in this project, we will propose a multidesign strategy, which encompasses the deliberate modulation of the phase constitution and architecture of metal-ceramic interpenetrating-phase composites that can be enabled by the combination of advanced manufacturing techniques. The newly designed materials will push the boundaries of materials properties beyond current benchmark ranges.

**Requirement to be on campus:** Yes (dependent on government's health advice)

## BME2021-22/2 Investigation of Vroman effect of protein attachment-detachment by direct observation from Ellipsometry

**Supervisors**: Prof Marcela Bilek, Dr Clara Tran and Dr Aaron Gilmour

**Eligibility:** Wet lab experience

**Project Description**:
Ellipsometric spectroscopy has been found to be a useful tool to monitor binding events in-situ. The principle of this technique is based on the change of reflected polarized light when the biomolecules attach to a surface, adding a layer of characteristic thickness and refractive index. The technique is non-invasive and highly sensitive and thus has great potential for biosensing purposes.

In the Summer research project, we will use this technique to compare the physical adsorption of proteins on silicon surfaces against covalent binding on plasma activated coatings. The replacement of the first protein layer by a second type of protein (Vroman effect) can be directly monitored in an experiment with two proteins with known sizes competitively adsorbing. The resulting changes in layer thickness and density can be determined via the ellipsometry parameters. The presence of the second protein layer can be confirmed using an antigen-antibody pair or a fluorescent probe. The change in protein layer thickness is expected to only occur when the proteins adsorb to the surface via weak interactions. In contrast, when covalent attachment occurs, the first protein layer will not be replaced by the competition of the second protein, which will be reflected by the ellipsometry parameters remaining constant. The research will provide new insights and knowledge to the nature of protein adsorption and detachment occurring on unmodified surfaces compared with covalent

attachment on plasma modified surfaces. These processes are important as they determine physiological response to implanted biomaterials.

**Requirement to be on campus:** Yes (dependent on government's health advice)

### BME2021-22/3 Assessment of corrosion properties of next generation high entropy alloys using simulated body fluids

**Supervisor:** Dr Kostadinos Tsoutas and Prof Marcela Bilek

**Eligibility:** Students with a background knowledge of electrochemistry are encouraged to apply.

**Project Description:**
When producing metallic implanted materials, thorough understanding of corrosion properties is required so not to induce immune response while also controlling the degradation process. This material science summer project will have students investigating a high entropy alloy (HEA), a next generation, high toughness material synthesised using plasma ion deposition. Students will investigate the response of thin film HEA's using cyclic voltammetry and electrochemical impedance spectroscopy in simulated bodily fluids to assess the nature and extent of degradation. This work will pave the way for further in vitro experimentation.

Due to the uncertain nature of lab work going forward, this project also can encompass a modelling component, looking at simulating the electrochemical impedance spectroscopy of this project using a range of software packages.

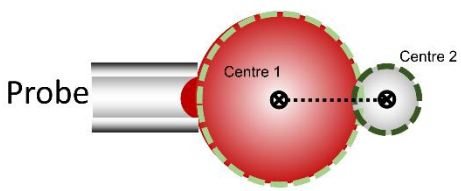
**Requirement to be on campus:** If limited campus access can be granted, the project can be undertaken with elements of both options.

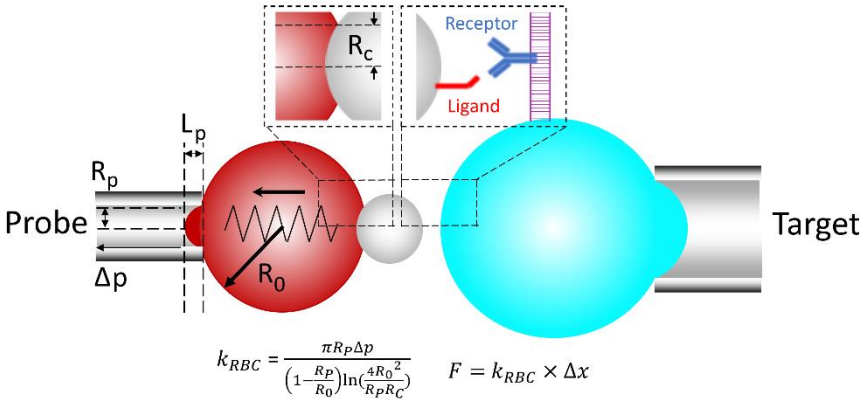
### BME2021-22/4 Instrumenting automated Biomembrane Force Probe (BFP) and micropipette-based techniques to investigate mechanosensing of living cells

**Supervisor:** Dr Lining Arnold Ju

**Eligibility:** Eligible candidate should be capable of using two or more of these software: Labview, SolidWorks, AutoCAD, MATLAB, 3D-max, PRO-E, ZEMAX. Also have a knowledge of Image processing tools such as ImageJ, Python and 3D illustration tools. Preference is given to applicants who have a strong interest in the biophysical instrumentation and treatment of cardiovascular diseases.

**Project Description:**
BFP is a powerful pico-force ($10^{-12}$ Newton) nanotool that can characteristics the single molecules bindings between living cells, which helps researchers to assess the mechanical properties of ligand–receptor interactions. With aid of the first BFP in Australia, Dr Ju has recently demonstrated a novel mechanosensing mechanism dependent on platelet and red blood cell (RBC) collision, leading to a compression force dependent thrombus formation *in vitro* and *in vivo* (Nature Commun 2018). In this context, this engineering project aims to upgrade the conventional BFP to achieve automation. We will design an image recognition algorithm to differentiate RBC, bead, and target cell respectively and live-track positions during experiment. Based on this, the feedback loop will be constructed which compensate drifting and noise during experiments. We will also aim to build a deep learning system to let the program find targeting objects to set-up the experiment without human intervention.






**Requirement to be on campus:** Yes (dependent on government's health advice)

## BME2021-22/5 Novel spheroid-on-chip model for tumor-vessel interaction

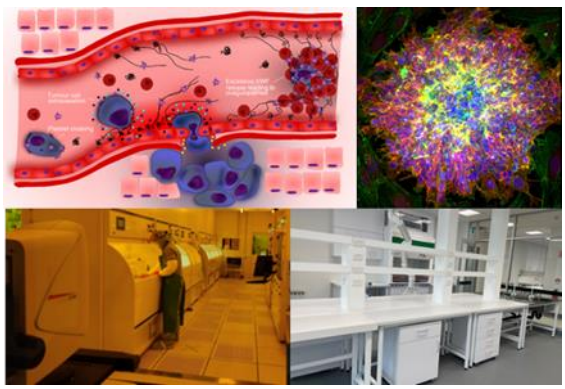
**Supervisor:** Dr Lining Arnold Ju

**Eligibility:** Candidates with experiences in cell culture and tissue culture in PC2 lab are preferred; capability of using one or more of the softwares – ANSYS, Klayout, SolidWorks, AutoCAD or other design software. Preference given to applicants who have a strong interest in the research and treatment of cancer associated cardiovascular diseases.

Candidates are expected to maintain collaborations with RPF soft lithography cleanroom, Charles Perkin Centre that bridge the research results to the cancer-endothelium crosstalk research. The anticipated outcome could translate into point-of-care tools that facilitate physicians' decisions on diagnosis, follow disease progression and optimise treatment courses.

**Project Description:**
Cardiovascular disease is one of the deadliest diseases worldwide and it affects 2/3 Australian families. Thrombosis is one of the major causes of cardiovascular disease and it's been found that cancer patients have a 5- to 7-fold increased risk of developing vein thrombosis. It was proposed that tumour cells can adjust their mechanical properties to facilitate extravasation, and the endothelial cells also have active instructive roles in the dissemination of cancer. So, it's important to know whether there's interaction between the vessel endothelium and tumour cells, and what regulate the crosstalk in between. This work will be essential to study cancer associated thrombosis and also cancer cell migration.

To address this pressing need, we are developing a novel spheroid-on-a-chip microfluidic model using tissue engineering and soft lithography in corporation with USYD research and prototype foundry (RPF) cleanroom, to understand tumor-endothelium crosstalk during cancer cell transendothelial migration. We are developing an endothelialized microfluidic platform that incorporates cancer spheroids to visualize cancer transendothelial migration and to understand the molecular event underlying the extravasation mechanism. We are assembling a team of bioengineers and clinicians at the Biomedical engineering new building J03, Sydney Nano Hub and Charles Perkin Centre.



**Requirement to be on campus:** Yes (dependent on government's health advice)

### BME2021-22/6 Development, writing and testing of tissue culture, tutorial protocols for teaching in BMET3971 Semester 1 2022

**Supervisors:** Dr Peter Newman and Prof Hala Zreiqat

**Eligibility:** Cell culture experience, completion of Tissue Engineering 3971.

**Project Description:**
The Tissue Engineering 3971 course is uniquely placed for utilisation of the new BME wet labs. Students placed in this project will help develop and test proposed tutorials for 2022 Semester 1.
This will include development of workflows for the new BME wet labs, as well as the writing and testing of protocols for:

1. The maintenance of cell culture
2. The effect of morphogens on cell culture, including fixation and staining of cells.
3. The fabrication and seeding of cells on porous CaPO4 bone ceramics, as well as fixation and staining of cells.
4. The fabrication and seeding of cells on alginate hydrogels, with microscopic analysis of cell morphology
5. The growth of cerebral organoids, their fixation and staining

**Requirement to be on campus:** Yes

### BME2021-22/7 Understanding functional differences in dementia with fMRI and deep learning

**Supervisors:** Dr Mariano Cabezas and Dr Jinglei Lv

**Eligibility:**

- Basic skills with programming. Python programming is preferable.
- Basic knowledge about medical image.
- Self-motivation, curiosity about research and passion to succeed.

**Project Description:**
Alzheimer's Disease (AD) is the most common irreversible neurodegenerative disease that results in a loss of mental function due to the progressive death of brain cells. Structural magnetic resonance imaging (sMRI) has been widely used to detect anatomical changes for AD. However, we are still unclear about mechanism of functional changes caused by dementia. Functional magnetic resonance imaging (fMRI) is promising to discover the functional differences in AD brains, that is not detectable by sMRI. The goal of this project is to analyze fMRI sequences with novel deep learning techniques and attention mechanisms (such as self-attention and attention gates) to discover functional differences between AD patients and healthy controls, so that possible new biomarkers can be defined. The developed model will be validated with the clinical dataset from the Alzheimer's Disease Neuroimaging Initiative with more than 1000 cases with imaging and clinical data which is publicly available and free for research purposes. Additionally, the models will be validated with the public available task fMRI data in the Human Connectome Project.

**Requirement to be on campus:** No

**BME2021-22/8 Open source multiphysics modelling of DNA nanorobots for early detection and treatment of cardiovascular disease**
**Supervisors:** Dr Mark Baldry and Prof Marcela Bilek

**Eligibility:** Candidates must be highly self-motivated, capable of working independently, and have coding experience. Experience with C++ and/or fluid dynamics is highly desirable.

**Project Description:**
In this project you will be involved in building, testing, and refining a model to simulate the rolling adhesion behaviour of leukocytes using the open-source modelling software OpenFOAM. This will enable the design of DNA origami-based nanorobots that can act as synthetic leukocytes to identify early-stage atherosclerotic plaques for early diagnosis and targeted treatment of cardiovascular disease.

**Requirement to be on campus:** No

**BME2021-22/9 Power-to-X and plasma catalysis: Opportunities for greening emissions-intensive industries, exporting renewable energy, and enabling self-sufficient settlements on Mars**
**Supervisors**: Dr Mark Baldry and Prof Marcela Bilek

**Eligibility**: Candidates must be highly self-motivated and capable of working independently. Experience with chemistry, energy storage, or renewable energy is highly desirable.

**Project Description:**
Power-to-X (P2X) describes a suite of technologies that use electricity to drive chemical processes. The simplest example is storing renewable energy by using solar or wind power to electrolyse water, producing hydrogen and oxygen. Electrocatalytic and plasma-based P2X technologies can activate stable molecules such as atmospheric carbon dioxide and nitrogen, transforming them into commodities such as net-zero emissions fuels and synthetic fertilisers. In space, P2X technology has the potential to greatly expand our capabilities of in-situ resource utilisation, enabling astronauts and future Martian settlements to be self-sufficient. In this project you will explore some of the exciting opportunities of P2X technology, with a particular emphasis on nonthermal 'cold' plasma reactors. You may also explore new reactor designs that incorporate catalyst-coated 3D printed scaffolds to exploit the unique synergies between cold plasma and catalysis.

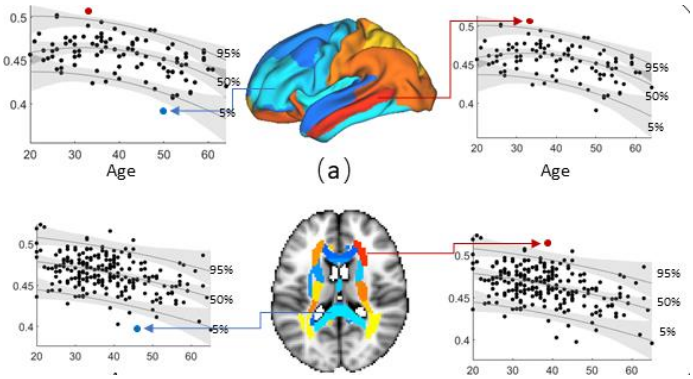
**Requirement to be on campus:** No

**BME2021-22/10 Defining the universal healthy human brain**
**Supervisors:** Dr. Jinglei Lv and Prof. Fernando Calamante

**Eligibility:**
- Basic skills with programming.
- Basic knowledge about medical image.
- Self-motivation, curiosity about research and passion to succeed.

**Project Description:**
In almost every mental health study, inference is made by case control comparison. However, it is indeed reluctant to define the healthy brain as the average of the small samples from one single study. Especially in neuroimage studies, high imaging expense and long acquisition time curse the sample number. In fact, normal is usually a statistical concept based on large population. The more sample number is included, the higher accuracy should be the model. Nowadays, more and more neuroimages, such as structural MRI and diffusion MRI, are becoming publicly available. Therefore, we can ask whether the healthy controls from one

study can serve as baseline in another study? Can we define the universal healthy brain by pooling all the control individuals to fit one reliable statistical model, against which every disordered brain can be tested to infer abnormality?




**Requirement to be on campus:** No

## CHEMICAL AND BIOMOLECULAR ENGINEERING PROJECTS

### CBE2021-22/1 Investigation of surface criteria of substrate for thin-film gas separation membranes

**Supervisors:** Dr David Wang and Dr Jia Ding

**Eligibility:** Literature review research skill and 3rd/4th year chemical engineering students are suitable.

**Project Description:**
Substrate layer is an important requirement for the production of an extremely thin and smooth, defect-free membrane for gas separation. It is critical to ascertain high-quality substrate to support the separation top-layer to obtain superior membrane gas flux and selectivity. Despite much research advancement has been made to control the top-layer membrane pore size to solve structural and performance issues, the technology transfer of thin-film gas separation membranes is continued to be hindered by the challenges of controlling the topology and structural integrity of the underlying layer. This project will critically review the substrate development in the literature and propose new requirement criteria for microporous membranes for gas separation applications.

**Requirement to be on campus:** No

### CBE2021-22/2 Structure-property criteria of substrate for polymer nanoconfinement

**Supervisors:** Dr David Wang and Mr Yi-Chen Lin

**Eligibility:** Literature review research skill and 3rd/4th year chemical engineering students are suitable.

**Project Description:**
Nanoconfined crystallization of the polymer induced by capillary forces during solvent evaporation within a porous structure has a significant impact on the thermodynamic properties of materials. The effect of nanoconfinement on the properties of polymers or glass forming liquids by nanoporous materials at <100 nm length scale is that the glass transition temperature and melting temperature become significantly different. This project will critically review the structure-property criteria of substrate in the literature and propose new

requirement for controlling the evaporative flux phenomena and polymer crystallization under nanoconfinement.

**Requirement to be on campus:** No

### CBE2021-22/3 Design, discovery, and development of Metal-organic framework-based biocatalysts

**Supervisors:** Dr. Weibin Liang and Prof. Jun Huang

**Eligibility:**

- Some background in chemical engineering, chemistry, biochemistry, biomedical, catalysis or equivalent
- The ability to work well with others in a team
- Excellent oral and written communication skills

**Project Description:**
Biocatalysis presents a significant opportunity in chemical manufacturing, due to its efficiency, selectivity, and environmental sustainability. However, the activity of many biocatalysts is compromised, or extinguished, when exposed to thermal, pH, and/or chemical stressors. This is largely due to the structural fragility of biocatalyst (e.g. enzymes) in artificial conditions. This project aims to stabilize biocatalyst in/or metal-organic frameworks (MOFs), generating a stable MOF biocatalyst with high reaction –activity and chemo-selectivity in catalyzing reaction of industrial importance.

This project involves the synthesis, characterization, and catalytic application of biocatalyst immobilized in/on metal-organic frameworks (MOFs). The student will assist in the synthesis and characterization of the MOF biocatalyst, as well as testing the catalytic performance of the materials.

**Requirement to be on campus:** Yes

### CBE2021-22/4 Design of Metal-organic Framework solid-acid catalysts for biomass transformation

**Supervisors:** Dr. Weibin Liang and Prof. Jun Huang

**Eligibility:**

- Some background in Chemical engineering, chemistry, catalysis or equivalent
- The ability to work well with others in a team
- Excellent oral and written communication skills

**Project Description:**
Recently, the synthesis and application of metal-organic framework (MOF) based solid acid catalyst has attracted wide attention in scientific and engineering aspects. This project aims to design and synthesize a series of MOF-based solid acid catalyst in the application of biomass transformation. This project will include a literature review on recent advancements in MOF-based solid acid catalyst. The student will also be involved in the synthesis and characterization of MOF materials, as well as their catalytic performance testing.

**Requirement to be on campus:** Yes

### CBE2021-22/5 Synthesis, characterization, and catalytic performance of metal-organic framework catalyst in CO2 transformation

**Supervisors:** Dr. Weibin Liang and Prof. Jun Huang

**Eligibility:**

- Some background in Chemical engineering, chemistry, catalysis or equivalent
- The ability to work well with others in a team
- Excellent oral and written communication skills

**Project Description:**
Carbon dioxide (CO2) mitigation is the most significant challenge to achieving sustainable development. Metal-organic frameworks (MOFs), as a newly discovered class of crystalline and porous materials, represent one of the most promising candidates in this application. This project targets the design and synthesis of novel MOF catalysts as multi-functional nanoreactors for efficient CO2 hydrogenation to produce valuable chemicals and fuels such as methanol and formic acid. The student will be involved in the synthesis and characterization of MOF materials, as well as testing the catalytic performance of the materials.

**Requirement to be on campus:** Yes

### CBE2021-22/6 Novel lead-free perovskite quantum dots catalysts for artificial photosynthesis of green fuels from CO2 reduction

**Supervisors:** Prof. Jun Huang and Dr. Rui Tang

**Eligibility:**
To be eligible, the candidate should:

- have basic knowledge background in either of the following: chemistry, chemical engineering, material engineering, and biomedical engineering.
- basic knowledge of semiconductors will be preferable.
- passion for pursuing research in renewable energy.

**Project Description:**
Over the past decade, achieving sustainable $CO_2$ recycling with renewable sunlight as the energy source has been viewed as crucial to meet the rising global warming issues. With Australia receiving the highest solar radiation globally, artificial photosynthesis offers an opportunity to direct convert $CO_2$ into usable chemical energy (i.e. CO, $CH_4$). Although great progress has been realized in the photocatalytic $CO_2$ reduction reactions ($CO_2RR$) fields, the photo-induced carrier generation/transfer and surface reaction kinetics of catalysts still restrict its practical application. Considering thermodynamic and kinetics issues during the $CO_2RR$ process, it is of great urgency to find novel catalysts with efficient carrier generation/transfer. This project aims to design a high-performance lead-free perovskite photocatalyst with defect engineering to realize selective photocatalytic $CO_2RR$. By tailoring the surface chemical states and semiconductor properties of the photocatalyst to invoke flexibility to control the photocatalytic $CO_2RR$ performance of the catalyst system.

**Requirement to be on campus:** Yes

### CBE2021-22/7 Polymer-based flexible humidity sensor

**Supervisors:** Dr. Syamak Farajikhah and Dr. Sina Naficy

**Eligibility:** Previous lab work experience will be an advantage. Science and engineering background students.

**Project Description:**
Humidity is defined as the concentration of water vapor present in air. It is known that humidity plays a significant role in every part of the Earth in biology and automated industrial processes. So, it is essential to design a sensor for continuous and reliable humidity monitoring. Recently, flexible humidity sensors emerged as great candidates for the potential applications in electronic skin, wearable electronic systems, soft robotics, and noncontact sensation.

This project will focus on the design and fabrication of a cost-effective flexible polymer-based humidity sensor. Conductive hydrogel composites with tunable moisture uptake and consequently swelling ratio will be designed and used for humidity measurement. Concentration of the conductive fillers, ionic compounds, and initial electrical resistivity will be optimised to get the best sensor performance. Humidity sensors will be fabricated using different techniques, e.g., casting, fibre spinning and 3D printing, and their reproducibility, accuracy and response time will be evaluated.

**Requirement to be on campus:** Yes

### CBE2021-22/8 Creating meat-like flavours and textures from plant-based systems

**Supervisors:** Prof. Roman Buckow, Damian Frank and Ciara McDonnell

**Eligibility:** We are looking for a motivated honour or Master students with good knowledge of Food Technology principles and interest in plant-based meat research.

**Project Description:**
The next generation of successful plant-based meat mimetics will need to deliver more realistic flavours and textures than currently available. Raw meat has bland flavour and poor texture until it is thermally processed. In meat mimetics, hydrocolloids (e.g. methylcellulose) and flavour precursors (e.g. amino acids) are regularly used to entrap water and generate characteristic meaty aroma profiles. But there is need to improve quality and understand complex interactions of ingredients.
In this project, beef meat will be systematically compared with vegan meat mimetic systems upon heating. The students will use state-of-the-art texture analysis, scanning electron microscopy and low-field molecular resonance as well as solid phase microextraction (SPME) and gas chromatography mass spectrometry (GC-MS). This work will be partly conducted at an industry partner's research lab. This research could lead to increased consumption of plant-based meats, thus supporting the UN's sustainable development goals.

**Requirement to be on campus:** No

### CBE2021-22/9 Polymer-based flexible energy storage devices

**Supervisors:** Dr. Sina Naficy and Dr. Syamak Farajikhah

**Eligibility:** Previous lab work experience will be an advantage.

**Project Description:**
Smart garments are clothes with embedded functional electronic componentry including sensors and antennas. They may be used for physiological measurement and monitoring, hazard detection, and/or wireless communication. This approach has found widespread application in personalised wearable medical monitors, and even in the military field. Wearable energy storage devices are the essential parts of such applications and must be seamlessly integrated into such garments.

This project will focus on the design and fabrication of porous conductive fibres electrochemically active to serve as electrodes in energy storage devices. Conductive polymer composites with tunable porosity will be designed and fabricated. Concentration of the conductive fillers, ionic compounds, and initial electrical resistivity will be optimised to get the best electrochemical performance. Flexible capacitors will be then fabricated by assembling different electrodes and solid electrolytes. Finally, the ability of incorporating such capacitors into a garment will be demonstrated.

**Requirement to be on campus:** Yes

### CBE2021-22/10 Biomaterial development from biopolymers

**Supervisor:** Dr. Yi Shen

**Eligibility:** Students with background of biopolymer, protein and microfluidics will be preferred.

**Project Description:**
Biomaterials derived from natural components, such as proteins, have been widely explored in many applications for their excellent biocompatibility and degradability. In particular, protein-based microgels has great potential to be engineered as an alternative to synthetic microplastic in food, personal care and cosmetic applications. However, the bottleneck of the development of protein-based microgels has always lied in the poor stability and high cost of the synthesis methods. Taking advantage of protein phase behaviour, microgels with high stability and low cost can be generated. In this project, functional proteins and peptides will be screened and investigated as building blocks of the new biomaterials through their phase behaviour. Key research in this project will focus on two ways of generating biomaterials through phase transitions to produce stable/dissolvable microgels and macroscopic biomaterials.

**Requirement to be on campus:** No

### CBE2021-22/11 Engineering hydrogel microparticles for cell therapy

**Supervisors:** Dr. Sepehr Talebian and Prof. Fariba Dehghani

**Eligibility:** We are looking for a motivated honour or Master student with a strong academic track record in chemical or biomedical engineering or chemistry or pharmacy.

**Project Description:**
There are many challenges for the delivery of biologically active compounds for therapeutic applications. One of the critical steps will be protection of these compounds from surrounding environment to preserve their efficacy. For instance, orally administered drugs may lose their bioactivity in gastrointestinal track due to exposure to low pH and enzymes. Stem cell transplantation is also impaired by complex immune cell responses causing clearance of 90% of donor cells. We aim to design a new class of biocompatible material for encapsulation of active compounds to address existing challenges. Hydrogels will be ideal materials as they are benign-water-swollen polymeric networks. We will engineer hydrogels with desirable properties suitable for target or non-invasive delivery. The outcomes of this project will reduce the health care cost and reduce drug side effects. The candidate will acquire various skills by engaging with a team of expert in materials science, chemical and biomedical engineering.

**Requirement to be on campus:** Yes

## CIVIL ENGINEERING PROJECTS

### CIVIL2021-22/1 Structural application of recycled fibre reinforced polymer (rFRP) composites

**Supervisor:** Dr Ali Hadigheh

**Eligibility:** Basic knowledge about composite materials.

**Project Description:**
Carbon fibre reinforced polymer (CFRP) composites are being increasingly used in lightweight structures due to their unique combination of high strength and low weight. These superior properties promoted high usage growth rates observed in aerospace, defence, construction,

automotive and renewable energy. This research will aim to produce recycled composites for structural applications.

**Requirement to be on campus:** Yes (dependent on government's health advice)

### CIVIL2021-22/2 Service life prediction of infrastructures with machine learning

**Supervisor:** Dr Ali Hadigheh

**Eligibility:** Basic knowledge of programming.

**Project Description:**
Structures are subject to gradual and progressive deterioration over time, and are likewise prone to damage due to accident, misuse, or extreme natural events. The on-going requirement for more structurally sound infrastructures has driven the introduction and development of advanced machine learning methods for structural health monitoring. This project aims to use machine learning methods for automated condition assessment and evaluation of infrastructure.

**Requirement to be on campus**: No

### CIVIL2021-22/3 Continuous structural health monitoring of bridges using advanced fibre optics

**Supervisor:** Dr Ali Hadigheh

**Eligibility:** Basic knowledge of programming and bridge design.

**Project Description:**
This project will aim to apply fibre optics for structural health monitoring of a pedestrian post tensioned concrete bridge.

**Requirement to be on campus:** No

### CIVIL2021-22/4 Road safety, infrastructure, and design: what are the attributes of unsafe intersections?

**Supervisors:** Dr Emily Moylan, Prof David Levinson, Dr Mohsen Ramezani, Prof Judy Kay

**Eligibility:** Experience with or willingness to learn Python or similar language. Experience with or willingness to learn GIS.

**Project Description**:
The design of transport infrastructure can incentivise positive or negative behaviours in users. Some behaviours are associated with crashes and near misses. When designing road infrastructure, engineers are tasked with numerous decisions including widths, alignments, signalling, signage and paint, speed limits and location of transit stops. This project uses the attributes of road intersections across New South Wales from diverse publicly available data sources to explain safety outcomes focusing on pedestrian safety and the elements of intersection design that are most likely to influence behaviours associated with pedestrian crashes. Due to the scope of the project from civil infrastructure to human-technology interaction, the student will be working with a team of researchers across Civil Engineering and Computer Science. This project would be suitable for continuation as an honours topic.

**Requirement to be on campus:** No

## CIVIL2021-22/5 Strategic scheduling and deployment of random breath and drug testing operations

**Supervisors:** Dr. Mohsen Ramezani, Prof. David Levinson, Dr. Emily Moylan, Dr. Mike Bambach

**Eligibility**: Competency in Modelling, Data analytics, Optimization, and Programming. Interested students should contact mohsen.ramezani@sydney.edu.au before applying.

**Project Description**:
Evidence-based research has shown random breath testing (RBT) and mobile drug testing (MDT) are effective at deterring drink driving and driving under the influence (DUI). RBT is the primary drink driving countermeasure implemented in all Australian jurisdictions. Evaluations of RBT and MDT have been with largely positive outcomes. The potential for drink driving and driving under the influence does not occur uniformly over time and place. Given the considerable impact of RBT and MDT, while being resource-intensive and considering the operational constraints (equipment, location capacity, workforce requirements, etc.), the strategic deployment of RBT and MDT should remain unpredictable and ubiquitous. The aim of this project is to find answers to where and when RBT and MDT should occur to achieve a more significant impact. The impact can be measured by sustained deterrence, long-term reduction in positively identified tests, exposure to RBT and MDT (directly and indirectly) and ultimately drop in drug- and alcohol-related road trauma (fatalities and injuries).

**Requirement to be on campus**: No

## CIVIL2021-22/6 Video processing techniques for observing pedestrian interactions with intersections

**Supervisors:** Dr. Emily Moylan, Prof. Judy Kay, Prof. David Levinson and Dr. Mohsen Ramezani

**Eligibility**: Familiarity with human-technology interaction. Familiarity with common video processing techniques.

**Project Description**:
The design of transport infrastructure can incentivise positive or negative behaviours in users. Some behaviours are associated with crashes and near misses, and we should choose designs that minimise these. This project focuses on extracting information about pedestrian and driver behaviour from video footage. Existing off-the-shelf products provide trajectory and delay metrics but no insights into hesitations, trajectory adjustment, near-misses or distraction. The student will review the approaches in the literature, assess the unmet needs for the intersection design application and develop customised algorithms to record the relevant behaviours. Due to the scope of the project from civil infrastructure to human-technology interaction, the student will be working with a team of researchers across Civil Engineering and Computer Science. This project would be suitable for continuation as an honours topic.

**Requirement to be on campus**: No

## CIVIL2021-22/7 'Take the next left': Processing drone footage to understand lane change behaviour

**Supervisors:** Dr Emily Moylan and Dr Mohsen Ramezani

**Eligibility: Experience with or willingness to learn video processing is important. Some familiarity with traffic simulation software is desirable.**

**Project Description**:
Most traffic simulations portray lane change behaviours related to turning vehicles, but these changes usually trigger a set distance before the intersection. In reality, experienced drivers

may anticipate lane changes well in advance, particularly during congested conditions in order to navigate difficult mergers caused by queuing.
This project uses drone footage of a set of adjacent intersections to understand how far in advance cars tend to change lanes. Existing software will be used to extract vehicle trajectories within each intersection, but additional processing will be required to match vehicles between the intersections.

The outcome of the project is useful for calibrating microsimulations of traffic conditions that might be used for road design and travel demand management. Moreover, the heterogeneity of driver behaviour is an important attribute of the system and a contrast with future Autonomous Vehicle Systems.

**Requirement to be on campus:** No

### CIVIL2021-22/8 Global groundwater asset – an uncertainty analysis

**Supervisors:** A/Prof Federico Maggi and Dr Chiara Pasut

**Eligibility**: Basic knowledge of or willingness to learn hydrology; Good knowledge of MATLAB; Current knowledge of or willingness to learn high-performance computing (HPC) methods; Intermediate level of programming skills.

**Project Description**:
Groundwater is the world's largest accessible source of freshwater, with over 2 billion people relying on it as their primary source of water supply. Regional and global scale modelling assessments of soil-water dynamics are needed to forecast possible drought under climate change. Although many studies have already been conducted, there is high uncertainty in the output due to the presence of inaccuracies in global scale soil physical datasets and external driving forces (e.g., precipitation) that feed the models. The aim of this project is to quantify the uncertainty in the global soil water saturation and water table depth with varying soil hydraulic properties. This is to be achieved by modelling soil water dynamics at a global scale with an advanced computational environment that solve the Richards' equation.

**Requirement to be on campus:** Yes Occasionally for large dataset download/manipulation (>1 TB)

### CIVIL2021-22/9 Infrastructure flood vulnerability assessments for climate change adaptation

**Supervisor:** Aaron Opdyke

**Eligibility**: Familiarity with or willingness to learn GIS software.

**Project Description**:
Climate change poses a significant threat to global development and poverty reduction. In low and middle-income countries, understanding disaster risk can be challenging in data scarce environments. This project will use open and crowdsourced data for vulnerability assessments of infrastructure in Indonesia, examining the exposure of assets to shifting flood hazards under climate change. Working with a cross-national research team, this research will contribute to understanding where and how buildings and roads will be impacted by climate change in the province of Aceh. Results will inform strategies to improve resilience of resource-constrained communities.

**Requirement to be on campus:** No

### CIVIL2021-22/10 Systems dynamics of climate change migration

**Supervisor:** Dr Aaron Opdyke

**Eligibility**: Familiarity with or willingness to learn system dynamic modelling.

**Project Description**:
Millions of people will be displaced because of climate change in the decades ahead. Decisions to migrate (forced or voluntary) stem from complex relationships between environmental, social, political, economic, and demographic drivers. Understanding these relationships is vital to improving infrastructure planning, design, and construction. This project will use survey data from experts to model the relationships between migration factors. System dynamic modelling will be used to develop causal loops of drivers that lead to climate change migration. Results will inform climate change adaptation policies for infrastructure.

**Requirement to be on campus:** No

### CIVIL2021-22/11 Advanced analysis of steel frames under elevated temperature

**Supervisors:** A/Prof Hao Zhang

**Eligibility**: Knowledge about steel design and finite element modelling.

**Project Description**:
This project aims to use the advanced analysis which accounts for both material and geometric nonlinearity to evaluate the performance of steel frame structures exposed to natural compartment fire. The role of connections in the response of steel frames to fire will be studied. Natural fire curve will be used and compared with the ISO standard fire.

The project will be purely numerical, using finite element analysis (e.g. Strand7, ABAQUS).

**Requirement to be on campus:** No

### CIVIL2021-22/12 Intelligent Compaction

**Supervisor:** Prof David Airey

**Eligibility**: 2 years of study

**Project Description**:
Compaction occurs on almost all construction sites but the methods of specifying and assessing the success of compaction have not changed significantly for over 50 years. Recent attempts have been made to use various sensor technologies to assist with the process and these are generally lumped under the heading of intelligent compaction. However, the lack of suitable mechanistic models has meant the potential of the sensor information has not been realised. This project will investigate whether a recently developed constitutive model can be adapted to capture the behaviour during compaction. The project will involve setting up a spreadsheet and performing analyses to investigate the model capability.

**Requirement to be on campus:** Yes

## ELECTRICAL AND INFORMATION ENGINEERING PROJECTS

### EIE2021-22/1 Deep Graph Learning for 6G Wireless Networks

**Supervisors:** Dr. Changyang She and Prof. Yonghui Li

**Eligibility:** Students should strong math and programming skills.

**Project Description:**
Graphs have been widely used to represent complex data in many applications, such as e-commerce, social networks, and bioinformatics. Efficient and effective analysis of graph data is important for graph-based applications. However, most graph analysis tasks are combinatorial optimisation (CO) problems, which are NP-hard. Recent studies have focused a lot on the potential of using machine learning (ML) to solve graph-based CO problems.

The project aims to solve two types of CO problems. The first type of problems belongs to link prediction that determines the sequential order of actions on a graph, including routing problems in communication networks, the travelling salesman problem, and molecular generation. The second type of problems are permutation invariant/equivariant, where the sequential order of actions has no impact on the final performance, such as user association, interference management and resource allocation in wireless networks, coding and decoding algorithms, and anomaly detection of a sensor network.

**Requirement to be on campus:** No

### EIE2021-22/2 iPhone App Development – TrueDepth, Avatars, and 3D Audio

**Supervisor:** A/Prof Craig Jin

**Eligibility:** App software development, some experience with Unity a plus.

**Project Description:**
We are developing an iPhone app that uses captures video images and TrueDepth images from the front facing phone camera. We are using these to create 3D shape models for avatars and 3D audio filters. We are also developing demonstrators for the iPhone using the Unity game engine that compiles down to the iPhone.

**Requirement to be on campus:** No

### EIE2021-22/3 Automatic Segmentation for Real-Time Vocal-Tract MRI

**Supervisor:** A/Prof Craig Jin

**Eligibility**: Familiarity with image processing and deep networks.

**Project Description:**
Real-time MRI is a new imaging paradigm, and we are exploring vocal-tract imaging. We are working to develop Deep Network algorithms that can extract contours of the vocal tract. In this project, we explore automatic region extraction to provide labelled data for Deep Network training.

**Requirement to be on Campus:** No

### EIE2021-22/4 Audio-Video Emotion Recognition using Deep Networks

**Supervisor:** A/Prof Craig Jin

**Eligibility:** Familiarity with Deep Networks.

**Project Description:**
This project explores emotion recognition from audio-video data using deep networks. The starting point is the AFF-Wild database and the AVEC2019 baseline code.

**Requirement to be on campus**: No

## EIE2021-22/5 Efficient Deep Learning Reasoning in Mobile/Edge Computing

**Supervisor:** Dr Dong Yuan

**Eligibility:** Family with Python and Pytorch

**Project Description:**
Recent advances in deep neural networks (DNNs) have made AI applications popular, e.g., data analytics for autopilot. A self-driving car can generate up to 750 megabytes of sensed data per second, but the average uplink rate of the cellular network is only 5.85 Mbps. In order to avoid the effects of network delay and put the computing at the proximity of data sources, edge computing emerges. However, edge computer itself is limited by its computing capacity and energy constraints. Different approaches were proposed to reduce the needs of computing resources for DNN inference (reasoning), e.g., partition allows one portion of DNN inference is processed at the edge and the rest is processed at the cloud; compression allows the design of small DNN according to the applications' requirements. In this project, you are expected to design and implement the latest solutions to accelerate DNN inference in the edge computing environment.

**Requirement to be on campus:** No

## EIE2021-22/6 Capacitive wireless power transfer for bio-implantable and underwater devices

**Supervisor:** Professor Joe Zhu

**Eligibility:**
- Bachelor's degree in electrical engineering
- Outstanding transcript (WAM>75)
- Good knowledge of electromagnetics
- Skilful with MATLAB/Simulink
- Research experience with publication record in electrical engineering (preferred)

**Project Description:**
Inductive wireless power transfer has been widely employed for power supply to various devices and systems, including bio-implanted devices, such as heart pacemaker and artificial hearts, and other applications, like mobile phone charger, and EV charging. However, the transmitting and receiving coils must be well aligned in order to achieve good transmission effects. Also, when the high frequency electromagnetic power is transmitted wirelessly through a lossy media, the power loss can be significant, resulting in low power efficiency.

This project aims to develop an alternate wireless power transfer method based on the capacitive coupling mechanism to achieve high efficiency power transfer for bio-implantable and underwater devices. The project work includes the study of electric coupling principle, numerical electric field analysis, and electronic circuit analysis and design.

**Requirement to be on campus:** No

## EIE2021-22/7 Improve automatic medical report generation with auxiliary information

**Supervisor:** Dr Luping Zhou

**Eligibility:**
- Have basic knowledge in machine learning, especially in deep learning
- Have good programming skills in pytorch and tensorflow
- Have experience in writing deep learning models

**Project Description:**

Radiological imaging data grow at a disproportionate rate against the supply of trained readers, leading to a dramatic increase in radiologists' workloads. Automatic generation of diagnostic reports from medical images is therefore in high demand, which could help reduce workload, mitigate diagnostic errors, and speedup clinic workflow. Recently, with the development of deep learning techniques, great progress has been witnessed in this field. However, such research is still in its early stage. This project aims to develop deep learning models that could explore auxiliary information to improve medical report generation. This could establish baselines for model evaluation and facilitate the advancement of research in this field.

**Requirement to be on campus**: No

### EIE2021-22/8 Theoretical Analysis of Communication-Efficient Federated Learning

**Supervisor:** Dr Mahyar Shirvanimoghaddam

**Eligibility:** Background in telecommunications and machine learning and Strong programming skills.

**Project Description:**
Current machine-learning techniques are complex which inhibit their deployment on many devices due to restricted memory and computational power. This project aims at designing simple learning tools to enable on-the-device analytics via federated learning. In federated learning, each device performs local learning and send only the model parameters to the edge device. The edge device will aggregate the local model parameters and send it back to the devices. A few rounds of message exchange are required to achieve convergence. Most current work in this area assume perfect communication channels between the devices and edge node, which is not realistic. In this project, we consider wireless channel between the nodes and model the convergence of the federated learning under noisy channel conditions. We will also devise novel algorithms to guarantee convergence in presence of channel impairments.

**Requirement to be on campus:** No

### EIE2021-22/9 Novel channel coding-based Machine Learning approached for on-the-device computation

**Supervisors:** Dr Mahyar Shirvanimoghaddam and Prof. Yonghui LI

**Eligibility:** Background in telecommunications and machine learning and Strong programming skills.

**Project Description:**
Edge computing has evolved in recent years to enable processing of data closer to its sources and transmitting only the necessary data to remote servers. Performing computations at the network edge has several advantages including, the volume of data needed to be transferred to the cloud is reduced; therefore, the communication cost decreases, the physical proximity of edge devices to the data sources (i.e. IoT devices) makes it possible to achieve lower latency which improves real-time data processing performance, decentralization can make systems more robust by providing transient services during a network failure or cyber-attack. To enable edge computing one need to either reduce the complexity of the ML algorithm which may reduce the learning accuracy or distribute the learning tasks over several layers of the computing hierarchy, which significantly increases communication overhead. The fact that most learning algorithms have been designed and optimized for large data sets with usually unrestricted memory and computation power, makes them not suitable for application in resource-constraint settings. Accordingly, most existing edge computing solutions which rely on these approaches suffer from either low accuracy or high communication overhead.

This project aims at designing simple yet effective machine learning algorithms which can be effectively implemented on IoT devices for analysing data. We will utilize our expertise in information theory, channel coding techniques, and machine learning to design fundamentally better and simpler learning algorithms, so simple devices can run analytic, which reduces the need for seamless connectivity to the cloud services.

**Requirement to be on campus:** No

### EIE2021-22/10 FPGA-based radio frequency machine learning

**Supervisor:** Prof Philip Leong

**Eligibility:** Undergraduate students with an interest in hardware design.

**Project Description:**
FPGAs enable the integration of radio and machine learning on a single device, allowing latency to be minimised and making them an excellent platform for physical layer radio frequency (RF) applications. In this internship, you will develop a high-performance machine learning system which interfaces to a software defined radio. This will be an improved version of http://phwl.org/2020/rtamc/. This project would be suitable for students with strong proficiency in computer architecture and digital design and an interest in real-time machine learning.

**Requirement to be on campus:** No

### EIE2021-22/11 Advanced Polar Coding

**Supervisors:** Dr. Vera Miloslavskaya and Prof. Branka Vucetic

**Eligibility:** Good knowledge of Matlab/C++, mathematics (linear algebra and probability theory); algorithms and data structures knowledge; English skills (reading, writing, listening, and speaking).

**Project Description:**
Error-control coding is one of the key enabling technologies for reliable data transmission. 5G employs the low-density parity-check (LDPC) and polar codes, while 3G and 4G rely on the turbo codes. Advanced error-coding techniques are ought to be developed to meet the stringent requirements of 6G. The gap-to-capacity should be minimized to ensure an acceptable reliability. In this project, students will have the opportunity to review the error-control coding literature and implement advanced polar coding techniques such as parallel encoding of 5G polar/LDPC codes, probabilistic Hamming weight distribution of polar codes, reinforcement learning based HARQ for 5G polar codes, SCL/sequential decoding with neural network-based list size profile for 5G polar codes, and genetic algorithm for polarization-adjusted convolutional (PAC) code design.

**Requirement to be on campus:** No

### EIE2021-22/12 Machine learning in wireless networked control for industry 5.0

**Supervisors:** Wanchun Liu and Prof Yonghui Li

**Eligibility:** Background in mathematics; telecommunications or control; Python programming; Experience in machine learning frameworks; TensorFlow or PyTorch.

**Project Description:**
Different from the 1st to the 5th generation (5G) of cellular communications, which are communications performance-focused, a primary driver behind 6G is the imminent deployment of Connected Robotics and Autonomous Systems (CRAS). To make CRAS come true, advanced

wireless networked control technology needs to be developed. In particular, communications and control codesign will be a crucial research topic. This project will develop a novel deep reinforcement learning-based algorithm for communications and control codesign to achieve high-performance networked control.

**Requirement to be on campus:** No

### EIE2021-22/13 Object Detection for the blind

**Supervisor:** Dr Wanli Ouyang

**Eligibility:** Solid background in deep learning. Background knowledge in ELEC5304, ELEC5306, ELEC5308 are preferred. Strong interest in developing practical machine learning algorithm for practical data.

**Project Description:**
Object detection is a critical computer vision and artificial intelligence technology for finding the locations of objects using cameras. Object detection, like identifying the location of people, sign, door, will help to the blind. This project aims to develop object detection methods for helping the blind.

**Requirement to be on campus:** No

### EIE2021-22/14 Wireless sensor network for solar irradiance forecasting

**Supervisor:** A/Prof Weidong Xiao

**Eligibility:** Background in microprocessor programming and wireless communication.

**Project Description:**
The objective is to create a low-cost but effective ground-based sensor network, which shall provide accurate solar irradiance information faster than the existing forecasting systems. The sensor network targets the application of solar cells to monitor the cloud and irradiance variation. The sensing network shall cover a large area that requires a distributed implementation. The development shall be based on the latest IoT technologies and 5G wireless network. The first setup of the ground-based forecasting system will cover the campus area.

**Requirement to be on campus:** Yes

### EIE2021-22/15 Adaptive Rate Control Design for IEEE 802.11ah systems

**Supervisor:** Dr. Wibowo Hardjawana

**Eligibility:** Strong knowledge in C/C++; network simulators (preferably NS-3) and lower layers communications protocol stacks (MAC and PHY) for either 5G NR or IEEE 802.11.

**Project Description:**
IEEE 802.11ah targets long-range IoT applications where a large number of low power wireless sensor stations are connected to an access point (AP). Rate adaptation (RA) algorithm plays a prominent role in adaptively selecting an appropriate transmission rate to maximize throughput in that. Minstrel RA algorithm that uses a random sampling approach has been the defacto RA in industry. In our research and collaboration with industry, we have improved Minstrel RA algorithm for the 802.11ah system by using artificial neural networks. designing shallow neural networks (SNNs). The project aims to improve the Minstrel RA algorithm further. The research outputs of this project can be extended for further postgraduate research study at The University of Sydney.

**Requirement to be on campus:** No

### EIE2021-22/16 Pro-active Tennis: Learning Best Actions

**Supervisor:** Dr Wibowo Hardjawana

**Eligibility:** Knowledge on Tennis; Strong knowledge in C/C++/Python and Deep Neural Networks toolboxes such DGL, Pytorch or TensorFlow.

**Project Description:**
Big data is changing how NSW junior tournament tennis players train and play. The key to success is taking all that information and turning it into something players can use to win. In this project, we will use open-source tennis data, capturing professional matches stroke-by-stroke statistics to predict what a player should do for a given observation of his state (e.g., position) and opponent states (e.g., position, type of strokes, etc.). This project will extend our supervised graphical neural networks (GNN) research in telecommunications into un-supervised GNN for sport analytic. The graph's edges represent the correlation between states, while the vertices will represent states/features of the current players. The neural network is used to learn the best outcomes/actions of the positions.

**Requirement to be on campus:** No

### EIE2021-22/17 Development of MIMO OTFS Detector for 6G Communications

**Supervisor:** Dr Wibowo Hardjawana

**Eligibility:** Strong knowledge in C/C++, Python; Deep Neural Networks toolbox such DGL, Pytorch or TensorFlow. Strong knowledge in physical layer of wireless cellular and WiFi communications.

**Project Description:**
Recently, orthogonal-time-frequency space (OTFS) modulation has been proposed as 6G waveforms for wireless cellular networks to address high mobility transmissions. OTFS represents the wireless signal regarding users' channel delay and Doppler effects, leading to constant representation for long channel durations. The user does not move at all from a signal processing perspective. We have currently developed a Bayesian OTFS detector that outperforms other work in the existing literature. This comes at the cost of signal processing computational complexity. The project will continue our research in this area by developing fast and reliable symbol detectors based on the denoising concept in Image Signal Processing for OTFS systems on top of the system model developed in our current research.

**Requirement to be on campus:** No

### EIE2021-22/18 Radio Intelligence Controller for O-RAN Alliance based 5G NR Networks

**Supervisor:** Dr Wibowo Hardjawana

**Eligibility:** Strong knowledge in 5G NR communications (Physical and MAC layers) and Python; Deep Neural Networks toolbox such DGL, Pytorch or TensorFlow.

**Project Description:**
Radio Intelligence Controller (RIC) framework has been proposed by Open RAN Alliance as the new standard to implement machine learning in open radio resource management for 5/6G cellular networks. Current RIC depends on the closed-loop channel feedback in form of 5G Channel Quality Index (CQI) from the receivers prior making resource decisions. This introduces latency into the system making it not suitable for low latency communications. This

project will prototype CQI predictor for RIC based on the Artificial Intelligence, allowing it to operate as an open-loop system.

**Requirement to be on campus:** No

### EIE2021-22/19 On-chip photonic signal processing and sensing

**Supervisors:** Prof Xiaoke Yi and Dr Liwei Li

**Eligibility:** Year 3/4 or Master students in Engineering and Science.

**Project Description:**
The rolling out of the internet of things which seeks to connect and integrate billions of devices together, and the increasing need for intelligent systems continually demand more bandwidth, higher speed signal processing. Direct signal processing in optical domain has the potential to realize orders of magnitude increase in instantaneous bandwidth, and a very high sampling frequency ability (over THz in comparison to around GHz with electronic technology), which lead to diverse applications for tackling problems of processing wideband signals, and for providing essential interference immunity. This project focuses on light weight, small size and low power consumption integrated photonic circuits for processing wideband and high-speed signals, which applications in data centres, neurophotonics, quantum information processing and space.

**Requirement to be on campus:** Yes, (dependent on government's health advice)

### EIE2021-22/20 Miniaturised LIDAR sensor

**Supervisor:** Prof Xiaoke Yi

**Eligibility:** Year 3/4 or Master students in Engineering and Science.

**Project Description:**
The project will focus on research and innovative thinking to explore the potential opportunities for commercial exploitation of a small low power solid state scanning LIDAR (Light Detection and Ranging) sensor. Professor Xiaoke Yi currently leads a research effort together with Professor Robert Minasian, supported by Thales & the Australian Research Council, on a photonic based silicon chip that implements a solid-state beam steering capability. The intern will work with the team to further study the capability, identify applications, and develop specific target performance measures such as: Operating range, Optical power levels, Beam scan rate, Electrical power consumption, etc.

**Requirement to be on campus:** Yes, (dependent on government's health advice)

### EIE2021-22/21 Coordination and control of distributed energy resources over mobile networks

**Supervisor:** A/Prof Gregor Verbic and Dr Wibowo Hardjawana

**Eligibility:** At least a D average (WAM>75). Good knowledge of Python. Willingness to learn new things on the fly.

**Project Description:**
The project will develop a 4G/5G communications infrastructure for a microgrid testbed. The testbed consists of several prosumer models implemented either as hardware prototypes using industry-grade equipment or software on a single-board computer (Raspberry Pi). Each prosumer has an energy management system (EMS) for managing local distributed energy resources (DER), including a PV-battery system and flexible loads. The testbed is designed as a simulation platform to model and simulate, in a realistic environment, several approaches for

DER coordination and control. To that end, prosumer EMSs communicates with the local battery inverter over a Modbus protocol on one side and a DER coordinator over a wireless network. Several prosumers are connected via a 4G/5G mobile network to form a prosumer microgrid where they will trade energy in a peer-to-peer (P2P) energy market.

**Requirement to be on campus:** Yes

## MECHANICAL ENGINEERING PROJECTS

### MECH2021-22/1 Computational modelling and simulation of mobile active and passive swimmers in turbulent flow

**Supervisor**: Dr Nicholas Williamson

**Eligibility:** Prefer BE Mechanical with excellent grades in Fluid Mechanics subjects.

**Project Description:**
This project focuses on the development of a computational model to simulate the motion of millimetre scale zoo-plankton and algal clusters in a turbulent flow field. A new particle model would be implemented within an existing computational fluid dynamics code written in Fortran and parallelised using MPI. The new tool would be used to investigate how these active swimmers respond to turbulence at difference scales. The work would lead to better understanding of a wide range of physical and biological phenomena including how and when algal blooms form.

**Requirement to be on campus**: No

### MECH2021-22/2 Three-phase turbulent fluid mechanics

**Supervisor**: Dr Agisilaos Kourmatzis

**Eligibility**: The successful student will be very self-driven, motivated and take initiative. You will also have an outstanding academic track record. Preference to final year students with excellent grades in fluid dynamics (Distinction++), however all students from year 3 onwards are welcome to apply.

**Project Description**:
One of the most complex fields in turbulent flows is that of 3-phase, or gas-liquid-solid flows. Despite how critical understanding these flows is to our everyday lives, from food production, to pollutant control and pharmaceuticals, the physics of these flows remains poorly understood. This results in high inefficiency and waste in a range of industrial systems because our ability to physically model the underlying mechanisms is too rudimentary. In this project, you will work on developing a new 3-phase flow experiment which will make the first steps towards helping us understanding this critically important field.

**Requirement to be on campus:** Yes, preferably

### MECH2021-22/3 Do sunscreen sprays really provide the protection we think they do?

**Supervisor:** Dr Agisilaos Kourmatzis

**Eligibility:** The successful student will be very self-driven, motivated and take initiative. You will also have an outstanding academic track record.
Preference to final year students with excellent grades in fluid dynamics (Distinction++) and/or experience in CFD modelling or experimental work, however all students from year 3 onwards are welcome to apply.

**Project Description:**

There is a lack of understanding of the true efficacy of certain sunscreen delivery systems (Cancer Council Victoria, ARPANSA). One reason for the poor understanding is because we do not really know how the droplet size/dynamics ejected from a sunscreen aerosol can influence the final SPF rating. In this project, you will work on either CFD modelling or experimental development focused on improving our understanding of the dynamics of aerosols from sunscreen spray systems.

**Requirement to be on campus:** Yes, preferably

### MECH2021-22/4 Can we change clouds to save the Great Barrier Reef?

**Supervisors**: Dr Agisilaos Kourmatzis and A/Prof Matthew Cleary

**Eligibility:** The successful student will be very self-driven, motivated and take initiative. You will also have an outstanding academic track record. Preference to final year students with excellent grades in fluid dynamics (Distinction++) and/or solid modelling (solidworks or equivalent), however all students from year 3 onwards are welcome to apply.

**Project Description:**
Marine Cloud Brightening has been proposed as a method to prevent coral bleaching (https://www.savingthegreatbarrierreef.org/cooling-the-reef). To achieve this, it is necessary to generate very small droplets at very high flowrates, and it is unclear what technology would be best suited for this. You will work with us in researching available nozzle technologies as well as assisting in developing an optically accessible nozzle system to help us better understand the most efficient way to generate the aerosols we need. This is a very ambitious multi-phase fluid mechanics project.

**Requirement to be on campus:** No

### MECH2021-22/5 Deformation behaviour of ultra-strong but ductile steels

**Supervisor:** Dr Xianghai An

**Eligibility:** High achievement in a relevant undergraduate engineering degree (a WAM of 80 or above). This summer project has the option to be combined with an honours project.

**Project Description:**
Steel is the workhorse of our infrastructure. Stronger, tougher steels are always needed to reduce weigh and improve safety in transportation, enhance architectural flexibility in construction, and improve performance in heavy machinery. Recently, the third-generation advanced high strength steels (AHSS) have been developed. These steels have lower alloying cost and less difficulty on manufacturing than those of first- and second-generation AHSS but exhibiting better tensile properties.

With respect to the perspective engineering applications of these strong materials, their cyclic deformation response and cryogenic properties are also essentially crucial concerns owning to safety issues, which will be explored in this project by applying fatigue testing, cryogenic tensile experiments, and advanced characterisation techniques. Timely exploiting the knowledge of the fatigue behaviour and cryogenic properties of the AHSS is important both scientifically, for the in-depth comprehension of their deformation behaviour, and technologically, for assessing their service utilities in safety-critical structural components.

**Requirement to be on campus:** Yes

### MECH2021-22/6 Architecting Superior Metal-Ceramic Composites by advanced manufacturing

**Supervisors:** Dr. Xianghai An and Dr. Mohammad Mirkhalaf Valashani

**Eligibility:** High achievement in a relevant undergraduate engineering degree (a WAM of 80 or above). This summer project has the option to be combined with an honours project.

**Project Description:**
Materials come with characteristic combinations of mechanical properties. For example, ceramics have high stiffness but break easily; metals have high strength and ductility but limited ability to deform elastically. A vital requirement for all structural materials is that they possess an exceptional combination of stiffness, strength, ductility, and damage tolerance. However, these characteristics cannot currently be obtained simultaneously. Although materials with different combinations of attributes can be designed by forming composites of different materials, it is still scientifically and technologically challenging to harvest desirable combination of properties.

To address these issues, in this project, we will propose a multidesign strategy, which encompasses the deliberate modulation of the phase constitution and architecture of metal-ceramic interpenetrating-phase composites that can be enabled by the combination of advanced manufacturing techniques. The newly designed materials will push the boundaries of materials properties beyond current benchmark ranges.
**Requirement to be on campus:** Yes

## MECHATRONICS ENGINEERING PROJECTS

### MECHATRON2021-22/1 3D Hyperspectral Sensing

**Supervisors:** Dr. Donald Dansereau

**Eligibility:** Experience with one or more of image processing, image optimisation, and/or computer vision in Matlab or Python.

**Project Description:**
Working with researchers at the Australian Centre for Field Robotics, this project will develop a unique 3D hyperspectral camera that simultaneously measures the 3D shapes and spectral signatures of objects. Hyperspectral sensing gives us rich information about the health of forests, crops, and reefs and this work has the potential to advance the state of how robots use this technology to perceive their world. In this work you will advance the imaging software pipeline used to make sense of the data collected using a unique 3D hyperspectral camera. The resulting tools will enable real-time hyperspectral sensing, by combining measurements over time and summarising them in a compact representation. COVID-permitting, students will have an opportunity to make use of the ACFR's Robotic Imaging Lab and its facilities.

**Requirement to be on campus:** Yes

### MECHATRON2021-22/2 Inspection and mapping with an advanced underwater drone

**Supervisors:** Dr Donald Dansereau and Dr Viorela Ila

**Eligibility:** Depending on focus, experience with one or more of imaging; image processing, computer vision, and/or robotic mapping. Hands-on experience with robotic platforms, ROS, Python and/or C++ would be an asset.

**Project Description:**
Working with researchers at the Australian Centre for Field Robotics in collaboration with industry partner Hullbot, this project will develop techniques for improving underwater inspection and mapping with a small, advanced underwater drone. Depending on interest and ability, students will focus on either designing or characterising robotic imaging systems,

low-level vision algorithms, or high-level mapping and change detection techniques. COVID-permitting, students will have an opportunity to work on-site at Hullbot's headquarters located at the Sydney Superyacht Marina, as well as making use of the ACFR's extensive robotic imaging and test tank facilities.

**Requirement to be on campus:** Yes

## SCHOOL OF PHYSICS PROJECT

### PHY2021-22/1 Plasma technology for energy storage

**Supervisor:** Prof Marcela Bilek and Seyedeh Khadijeh Alavi

**Eligibility:** At least at 3rd year of Engineering, basic knowledge of chemistry and competent knowledge of physics, time management, problem-solving and analytical skills.

**Project Description:**
Due to global warming concerns, renewable electricity production from variety of energy sources such as solar, wind, hydro, wave, and other resources is growing rapidly. The main challenges along this way are the efficient storage/usage and transport of this electricity. Considering the intermittent character of the raised energy sources the technologies which are flexible enough to switch on/off easily to follow the supply are more favourable. The plasma technology would provide the suitable process that would be able to use the renewable electricity in a flexible way and convert it to fuels or useful chemicals. Gas plasma discharge could be created by applying electrical energy to a gas and operate at low temperature close to room temperature. In this project you will investigate and compare plasma reactors most often used for gas conversion to be able to suggest a new/modified design that could be made in the lab for further research required to bring this technology closer to industrial application.

**Requirement to be on campus:** No