THE UNIVERSITY OF SYDNEY

FACULTY OF ENGINEERING

Engineering Vacation Research Internship Program

ENGINEERING RESEARCH PROJECTS FOR WINTER 2021

AEROSPACE ENGINEERING PROJECTS

AERO2021/1 Aerial Object Detection and Localisation using Ground-Based Networked Cameras

Supervisor: A/Prof K C Wong & Zihao Wang
Eligibility: WAM>75, knowledge and/or experience in OpenCV and Python is preferred.
Project Description:
Aerial object detection and localisation is an important capability in many industries. The recent popularity surge in personal Vertical Take-off and Landing (VTOL) aircraft and small Unmanned Aerial Vehicles (UAVs) has caused concern about privacy and security. Early detection and localisation of rogue aircraft may prevent accidents around sensitive facilities, including airport and power plants. Furthermore, the primary industry may reduce crop damage by detecting pest birds and deploying deterring methods early. This project investigates the potential of using ground-based cameras to detect and localise flying objects. Using state-of-the-art computer vision algorithms, commercial-off-the-shelf (COTS) cameras can detect objects with high confidence in real-time. These cameras can also be connected to form a sensor network to triangulate the target. The goal of the project is to investigate different detection and localisation methods and implement the appropriate methods in hardware. A proof-of-concept demonstration is also required at the end of the project.
Requirement to be on campus: No

AERO2021/2 Using Super-resolution to enhance large-eddy-simulation results

Supervisor: A/Prof Ben Thornber
Eligibility: WAM>75
Project Description:
This project will focus on the application of computer graphics methods in enabling an increased resolution in the calculation of turbulent problems. Super-resolution is commonly employed in special effects packages and employs fast methods to go from a solution on a relatively coarse mesh, to a solution on a much finer mesh including finer scale flow features. Here we will explore the impact of translating this approach to turbulent problems with full fidelity, applying super-resolution to accurate computational fluid dynamics results, and comparing the result to what we get if we simply run the full calculation at a much higher grid resolution. We will also explore this approach as a means of effectively moving computational results from one grid resolution to a much higher grid resolution, and then re-initialising.

You will get experience in coding, computer graphics, computational fluid dynamics and handling large scale data generated on Australia's fastest HPC.
Requirement to be on campus: No

AERO2021/3 Fuel injection in rotating detonation engines

Supervisor: A/Prof Ben Thornber
Eligibility: WAM >75
Project Description:
This project will focus on the application of advanced computations to examine in detail the physics of fuel injection in rotating detonation engines. It will employ computational fluid dynamics codes to predict the level of fuel mixing and penetration using different injection configurations. This project will give outstanding exposure to high performance computing, the physics of rotating detonation engines and the use of advanced computational engineering tools.
Requirement to be on campus: No

BIOMEDICAL ENGINEERING PROJECTS

BME2021/1 Investigation of biomolecule surface attachment and their interactions using spectroscopic ellipsometry

Supervisors: Prof Marcela Bilek, Dr Clara Tran, Dr Aaron Gilmour
Eligibility: Experience in molecular biology and wet chemistry is desirable.
Project Description:
Surface attachment of biomolecule on medical implants and diagnostic devices play an important role in determining their performance. Ellipsometric spectroscopy is a sensitive technique to detect sub-monolayers of nanoscale molecules on a surface from the changes in polarisation of reflected light. Initial work has shown that this technique can be used to detect the formation of a monolayer of bovine serum albumin on a silicon wafer surface and test the strength of adhesion.
In the winter research program, students will study the immobilisation of biomolecules on a range of plasma modified surfaces, the nature of their adhesion, the orientation of the immobilized molecules and their interaction with complementary molecules. The project will give new insights understanding of the sensitivity of the technique and the mechanisms of biomolecule attachment on plasma activated coatings.
Requirement to be on campus: Yes (dependent on government's health advice)

BME2021/2 Real-time monitoring of changes in cerebral blood flow

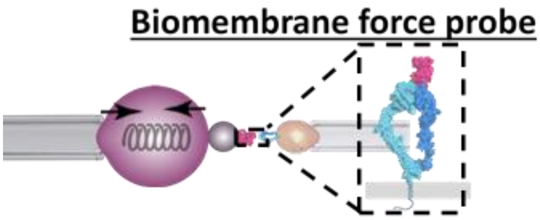
Supervisors: Dr Andre Kyme & Sam van Bohemen (PhD candidate)
Eligibility: The applicant should be confident in Python. Experience with electronics and EEG would be beneficial.
Please also note that a provisional patent has been filed to protect the EEG/ECG based method and the successful applicant will be required to sign an NDA before starting the project.
Project Description:
We are developing a novel EEG/ECG based method to monitor changes in cerebral blood flow (CBF), enabling continuous monitoring of stroke patient status during the time between major imaging scans (e.g. CT perfusion and CT follow-up). A validation study in which healthy participants are monitored using the technology during activities known to alter CBF is currently underway. The aim of this Winter Scholar project is to develop and test code for the real-time processing of streamed data from our device. Initial algorithms for this processing have been developed in Matlab, however the successful scholar will convert the processing to open-source Python and adapt the code to run in real-time, including graphical feedback to monitor real-time changes in CBF. A prototype headset device to capture EEG and ECG data will be supplied to aid in developing and testing the required processing code.
Requirement to be on campus: No

BME2021/3 Topologically induced bilateral symmetery breaking in confined pluripotent stem cell cultures

Supervisor: Prof Hala Zreiqat
Eligibility: Student that are pre-honors, or looking for research experience prior to a PhD
Project Description:
Confined cultures of human induced pluripotent stem cells (hiPSCs) can replicate the pattering of germ layer derivatives in tissue micropatterns.
Such experiments are typically completed with the culture of hiPSCs plated on 1000 μm circular adhesive templates.
This project explores how asymmetric topology of the adhesive templates can regulate hiPSC cultures, and if this is sufficient to drive bilateral symmetry breaking - the formation of cell cultures with phenotypically expressed markers for left-right.
Requirement to be on campus: Yes (dependent on government's health advice)

BME2021/4 Instrumenting Biomembrane Force Probe (BFP) and micropipette based techniques to investigate red blood cell force sensing

Supervisor: Dr Lining Arnold Ju (ARC DECRA)
Eligibility: Eligible candidate should be capable of using two or more of this 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:
Haemodynamic forces are well known to play a major role in promoting blood clot formation, although the underlying molecular mechanism remains ill-defined. In this mechanobiology context, 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 develop a pico-force (10-12 Newton) nanotool—BFP (Figure 1). As the first BFP in Australia and it aims to demonstrate a novel RBC force sensing mechanism linked to the prothrombotic effect of disturbed blood flow. We will also aim to integrate micropipette techniques with cutting-edge confocal 4D imaging (3D + time) modality and driven to repetitively touch a RBC aspirated by another micropipette with controllable compressive and tensile force manipulation. The intermittent "touch and retract" cycles mimic RBC-platelet 'stop-and-go' adhesive behaviour under flow.

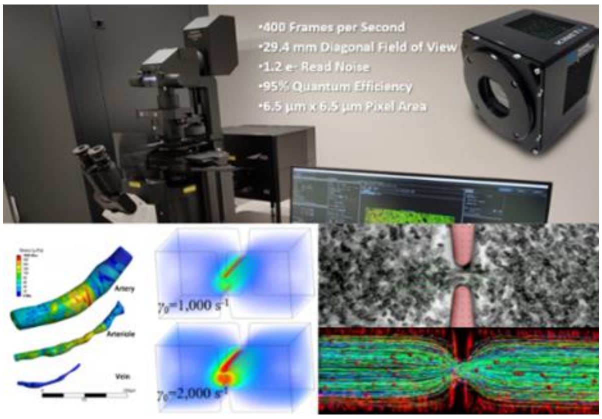


Requirement to be on campus: Yes (dependent on government's health advice)

BME2021/5 Computational fluid dynamics simulation and particle image velocimetry for blood clot-on-chip microfluidics

Supervisor: Dr Lining Arnold Ju (ARC DECRA)
Eligibility: The capability of using two or more of ImageJ, Micro Manager, ANASYS, Comsol, Labview, AutoCAD, MATLAB, and other software; Preference given to applicants who have a strong interest in the research and treatment of cardiovascular and cerebrovascular diseases such as Heart attack and Stroke.
Candidates are expected to maintain collaborations with Olympus professional microscope team and RPF soft lithography cleanroom, bridge the research results to the optimisation of microfluidics design (AutoCAD) and fabrication (soft lithography). The anticipated outcome could translate into precision medicine that facilitate physicians' decisions on diagnosis, follow disease progression, optimise treatment courses, or even bridge dependent medication strategies for individuals
Project Description:
Excessive clotting (thrombosis) leads to the cardiovascular diseases such as heart attack and stroke—the No.1 world-wide killer, killing one Australian every 12 minutes. It has long been recognized that platelets play a central role in thrombosis and are unique in their ability to form stable adhesive interactions under conditions of rapid blood flow. We have recently discovered a new 'biomechanical' prothrombotic mechanism that highlights the remarkable platelet sensitivity to the shear stress gradients of blood flow disturbance. Importantly, we found that the current anti-thrombotic drugs such as Aspirin, Plavix® or Brilinta®, have limited effect against this biomechanical thrombosis.

To address this pressing need, we are developing computational fluid dynamics (CFD) simulation and micron resolution particle image velocimetry (μPIV) techniques to correlate the haemodynamic parameters with thrombotic phenotypes.

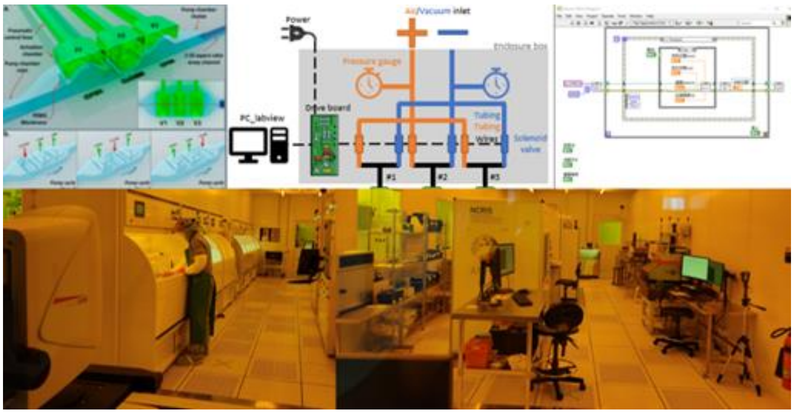


Furthermore, the results could be used for developing microfluidic biochips using soft lithography in corporation with USYD research and prototype foundry (RPF) cleanroom, to understand sequences of molecular events underlying biomechanical thrombosis (mechanobiology).
Requirement to be on campus: Yes (dependent on government's health advice)

BME2021/6 Micropump based automated blood clot-on-chip microfluidic devices

Supervisor: Dr Lining Arnold Ju (ARC DECRA)
Eligibility: Capability of using two or more of AutoCAD, Labview, Altium, Klayout, ANSYS, MATLAB, SOLIDWORKS, Arduino kits, C++, Python or other design/coding software; Preference given to applicants who have a strong interest in the research and treatment of cardiovascular and cerebrovascular diseases such as Heart attack and Stroke.
Candidates are expected to maintain collaborations with instrument suppliers and RPF soft lithography cleanroom, bridge the research results to the optimisation of microfluidics design (AutoCAD) and fabrication (soft lithography). The anticipated outcome could translate into point-of-care tools that facilitate physicians' decisions on diagnosis, follow disease progression, optimise treatment courses, or even deploy on ambulance to improve patient care.
Project Description:
Excessive clotting (thrombosis) leads to the cardiovascular diseases such as heart attack and stroke—the No.1 world-wide killer, killing one Australian every 12 minutes. It has long been recognized that platelets play a central role in thrombosis and are unique in their ability to form stable adhesive interactions under conditions of rapid blood flow. We have recently discovered a new 'biomechanical' prothrombotic mechanism that highlights the remarkable platelet sensitivity to the shear stress gradients of blood flow disturbance. Importantly, we found that the current anti-thrombotic drugs such as Aspirin, Plavix® or Brilinta®, have limited effect against this biomechanical thrombosis.
Excessive clotting (thrombosis) leads to the cardiovascular diseases such as heart attack and stroke—the No.1 world-wide killer, killing one Australian every 12 minutes. It has long been recognized that platelets play a central role in thrombosis and are unique in their ability to form stable adhesive interactions under conditions of rapid blood flow. We have recently discovered a new 'biomechanical' prothrombotic mechanism that highlights the remarkable platelet sensitivity to the shear stress gradients of blood flow disturbance. Importantly, we found that the current anti-thrombotic drugs such as Aspirin, Plavix® or Brilinta®, have limited effect against this biomechanical thrombosis.

To address this pressing need, we are developing simple-to-use, high-throughput and highly informative microfluidic biochips using soft lithography in corporation with USYD research and prototype foundry (RPF) cleanroom, to understand sequences of molecular events underlying biomechanical thrombosis (mechanobiology). We are also developing pneumatic and piezo driven micropumps with mechatronics design and prototyping to 1) precisely control the haemodynamic parameters inside the chips and 2) deliver and mix drugs with blood for anti-thrombotic study. We are assembling a team of bioengineers and clinicians at the Sydney Manufacturing Hub and Sydney Nano Hub.



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

BME2021/7 Modelling cardiac fibrosis using cardiac fibroblast derived micro-tissues

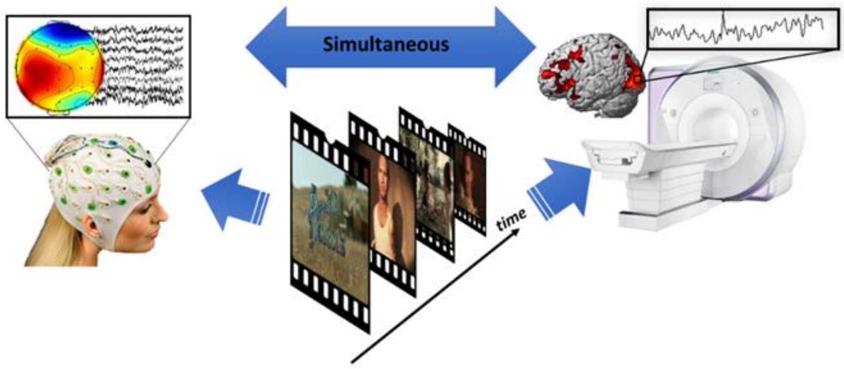
Supervisors: Dr Lining Arnold Ju, Dr Charles Cox (Victor Chang Cardiac Research Institute)
Eligibility: Eligible candidate should be capable of using two or more of these Software: Labview, SolidWorks, AutoCAD, MATLAB, 3D-max, PRO-E, ZEMAX. Also have a knowledge of Image processing tools such as ImageJ, Python and 3D illustration tools. Preference is given to applicants who have a strong interest in the biophysical instrumentation and treatment of cardiovascular diseases.
The project will be conducted at Victor Chang Cardiac Research Institute with external supervisor Dr Charles Cox.
Project Description:
Cardiac fibrosis, a process defined by excessive extracellular matrix (ECM) synthesis and remodelling, is fundamentally important in nearly all aetiologies of heart disease. Fibrotic remodelling is driven by both biochemical and biomechanical cues. While there is extensive detail regarding the biochemical pathways that govern fibroblast phenotype and function it is unclear how these cells decode biomechanical cues. This project aims to understand the role of mechanosensitive Piezo1 channels in the remodelling of the extracellular matrix that occurs under mechanical load as seen in the common abnormal heart rhythm disorder atrial fibrillation. To do this we will utilize micro-tissues made from human cardiac fibroblasts generated using custom made 3D scaffolds that enable micro-tissue stretching. This will allow us to understand how biomechanical cues, which are central to many cardiac pathologies, are sensed by cardiac fibroblasts.
Requirement to be on campus: Yes (dependent on government's health advice)

BME2021/8 Understanding Alzheimer's disease through fMRI and deep learning attention

Supervisors: Dr Mariano Cabezas & Dr Jinglei Lv
Eligibility: Knowledge about machine learning and coding skills with Python will be desirable.
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 recognized as a promising indicator for the early diagnosis of AD and its progression. Furthermore, functional magnetic resonance imaging (fMRI) together with sMRI can highlight functional differences in AD patients, when combined with sMRI. The goal of this project is to combine sMRI and fMRI with novel deep learning techniques and attention mechanisms to predict conversion to AD. The final classification model will be validated with the clinical dataset from the OASIS dataset of more than 1000 cases also with imaging and clinical data which is publicly available and free for research purposes.
Requirement to be on campus: No

BME2021/9 Record the mind with simultaneous EEG-fMRI

Supervisors: Dr Jinglei Lv, Prof Fernando Calamante & A/Prof Mayuresh Korgaonkar
Eligibility: Knowledge about signal processing, image processing, programming experience
Project Description:
We are so close to reading the mind with the modern neuroimaging technology. The electroencephalogram (EEG) records the electrical activity of billions of neurons while the functional magnetic resonance imaging (MRI) reflects the blood oxygen consumption because of neuronal firing. Now at our lab, we have the hardware setup to record both signal modalities simultaneously. We can record the brain activity during resting state as well as with cognitive tasks, even movie watching. The concurrent activity recording from both EEG and fMRI helps us not only understand how the brain works and how the mind is generated, but also suggests potential biomarkers for psychiatric disorders, such as Depression, Bipolar and Schizophrenia. It demands smart engineering to decode faithful signals among massive noise in this advanced setting. In this project, you will work with both biomedical scientists and neuroscientists to develop a pipeline of experiment design, data collection and data processing with simultaneous EEG and fMRI.



Requirement to be on campus: No

BME2021/10 Effect of white matter fibre architecture on human cortical properties measured by MRI

Supervisors: Dr Tonima S Ali & Prof Fernando Calamante
Eligibility: Basic programming skills
Project Description:
A whole-brain fibre-tracking dataset (tractogram) generated from diffusion MRI provides valuable insight on white matter architecture and can be exploited by track-weighted imaging (TWI) for brain mapping. TWI can incorporate various MRI contrasts to assess specific properties of brain with super resolution. Much is yet to be known about the inter-play between white matter and grey matter, and TWI provides a powerful framework to address that.

This study will focus on evaluating the influence of white matter fibre architecture on the patterns of MRI properties in the brain cortex. It will use retrospective diffusion MRI data from healthy subjects and tractograms with millions of streamlines throughout the brain. MRI parameters sensitive to tissue architecture will be studied using TWI, and those will then be projected on the cortex. Finally, the correspondence between the resulting various cortical patterns will be evaluated and compared to known patterns (eg. myelin-related patterns).
Requirement to be on campus: No

BME2021/11 A 3D printed niche for assembling synthetic embryos

Supervisor: Dr Peter Newman
Eligibility: Penultimate year
Project Description:
Methods for the generation of multilineage cell assemblies that mimic the structure and organisation of an early embryo have been developed. These synthetic embryo-like assemblies can be created by co-culturing combinations of embryonic stem cells, trophoblast stem cells, and extra-embryonic endoderm stem cells.
However, these structures are limited to assembly via a cell self-sorting mechanism that limits these structures in their architecture and composition to spheres of 50 cells of up to 3 cell-types.
This project proposes that 3D printing methods could be used to emplace cells directly into multilineage synthetic embryo structures by encapsulation in a polymer.
The project will develop a cell supporting photoresist that allows encapsulation cells without inflicting damage. We will then use 3D printing to emplace pluripotent and supporting cell types assemble a synthetic embryo.
Requirement to be on campus: Yes (dependent on government's health advice)

BME2021/12 Improving hearing outcomes with Cochlear implants

Supervisor: Dr Greg Watkins
Eligibility: Strong interest in bionics and experience in Matlab. Programming skills are an advantage, but the programming required is not extensive.
Project Description:
The sydneyBionics lab has the technology and processes to develop and manufacture advanced implantable bionic devices, such as the Bionic Eye and the Bionic Ear (cochlear implant).
Cochlear implants have restored a sense of hearing for hundreds of thousands of recipients around the world. Inspite of the enormous success of the device, the outcomes achieved by different recipients varies considerably. Recent research investigated a novel metric which was able to predict, for the first time, individual recipient speech scores in a range of listening conditions.
This project involves the investigation of the efficacy of an extension to the metric. The researcher will reproduce current results, and then evaluate a number of extensions to determine whether there is a consistent, and significant change to the accuracy of the speech score predictions.
The successful candidate will have a keen interest in bionics, and an interest in improving the outcomes achieved by cochlear implant recipients.
Requirement to be on campus: No

BME2021/13 The bionic eye: construction and evaluation of system test model

Supervisors: Prof Gregg Suaning & Dr Greg Watkins
Eligibility: Strong interest in bionics, ideally with skills in electronics, test systems, embedded and host-based software systems
Project Description:
The Sydney Bionics lab has the technology and processes to develop and manufacture advanced implantable bionic devices, such as the Bionic Eye and the Bionic Ear (cochlear implant).
This project involves the installation, commissioning, and verification of a Bionic Eye bench test system, based on the current experimental set up. The test system will be used to evaluate stimulation strategies, and advances in electrodes and electronics as applied to the bionic eye. The system includes all aspects of the implantable system including custom telemetry and stimulation chips, micro-machined electrodes, and a number of programmable controllers.
The successful candidate will have a keen interest in bionics, electronic systems and will be familiar with programmable micro controllers and software tool and want to help change the lives of people with a visual disability!

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

BME2021/14 Development and analysis of a portable hearing test system for use in early diagnosis of hearing impairment

Supervisors: Prof Gregg Suaning & Prof Melville da Cruz (Westmead)
Eligibility: Biomedical Engineer with a 'hobby level' interest in electronics and mechanical proficiency (eg. 3D printing, Arduino, etc.).
Project Description:
Hearing impairment is a global problem affecting millions of people. Accurate hearing assessment is essential to identifying hearing-related problems so that remedial actions can be taken. For example, if children are diagnosed early enough, specialised education programs can help manage the issue. For adults, hearing loss can be a symptom of other disease conditions.
Hearing tests are heavily influenced by outside sources of noise. While excellent hearing tests can readily be found as downloadable applications for smart phones, access and practicality of using the tests in a noise-free environment severely limits the number of people who can be tested.
This project seeks a solution to the access/practicality issue by constructing a body-worn, noise-free chamber for hearing testing that improves the accuracy of hearing tests over ambient conditions.
Requirement to be on campus: No

BME2021/15 The synthesis and characterisation of Ag-based nanowires for bio-applications

Supervisors: Prof Gregg Suaning, Dr Shiyang Jia & Prof Zdenka Kuncic
Eligibility: Experience in organic synthesis
Project Description:
Silver nanowires (AgNWs) are a type of nanostructured materials with the diameter constrained to tens of nanometers or less and an unconstrained length. They have high electrical conductivity, high aspect ratios, excellent optical properties, as well as antibacterial behaviours. Upon suspension in solution, AgNWs will spontaneously form a highly interconnected network. Each junction in the network demonstrates resistive switching properties, that is, the conductivity of each junction depends on the history of the input voltage/current. This behaviour is neuromorphic in nature. Due to their intriguing electronic properties, the AgNWs become an excellent model to study and develop artificial neural networks.
This project aims to synthesize AgNWs with a range of lengths via a bottom-up method. The synthesized AgNWs will be embeded into polymer-based hydrogels for further characterisation. The neuromorphic behaviour of the AgNWs-doped hydrogels will be investigated by an Intan RHS stimulation/recording controller.
Requirement to be on campus: Yes (dependent on government's health advice)

BME2021/16 Parallel processing in neural networks inspired by anatomy of mammalian brain

Supervisors: Dr Tom Close & Dr Mac Shine
Eligibility: Strong programming skills (required), experience designing ANNs is desirable
Project Description:
A striking feature of the human brain is the ability to generalise skills and experiences to novel contexts. This capacity is often mapped onto the highly interconnected networks observed in the cerebral cortex. However, recent work (https://doi.org/10.1038/s41567-021-01170-x) demonstrates that there is a trade-off between generalisation and parallel processing in neural networks due to the risk of crosstalk between tasks. We propose that the cerebellum could facilitate parallel processing in the brain by driving patterns of neural activity in the cerebral cortex.

The project will involve designing artificial neural network (ANN) architectures loosely modelled on the thalamocortical network and analysing their network characteristics (https://www.biorxiv.org/content/10.1101/2020.09.30.321679v1). These architectures will be augmented by additional layers inspired by the structure of the cerebellum and basal ganglia. We predict that including biologically inspired circuit motifs will allow the system to minimise interference between tasks, enabling the tasks to be executed in parallel.
Requirement to be on campus: No

CHEMICAL AND BIOMOLECULAR ENGINEERING PROJECTS

CBE2021/1 Physicochemical and biological characterisation of water captured from the atmosphere

Supervisors: Dr Gustavo Fimbres Weihs, Dr Anne Mai-Prochnow & Prof Dianne Wiley
Eligibility:
Essential:
- Some background in chemical or process engineering, chemistry, microbiology or equivalent
- Strong data analysis skills
- The ability to work well with others in a team
- Excellent oral and written communication skills

Desirable:
- Experience in microbiological culturing techniques
- Ability to gather and interpret information from a range of sources

Project Description:
The stable, sustainable supply of clean water is one of this century's most significant global challenges. The Advanced Capture of Water from the Atmosphere (ACWA) team aims to develop large surfaces with incorporated nano- and micro-scale chemical patterns which can capture water passively. This project involves the characterisation, both physicochemical and biological, of the water collected by the collection materials being developed by the ACWA team. The student will assist in the collection and testing of several parameters in this captured water, as well as determining the presence and quantity of microorganisms in the samples via microbiological cultures, with the aim to determine the potential use or any treatment required for the collected water, or possible improvements for the collection devices.
Requirement to be on campus: Yes (dependent on government's health advice)

CIVIL ENGINEERING PROJECTS

CIVIL2021/1 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)

CIVIL2021/2 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

CIVIL2021/3 3D 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

CIVIL2021/4 Time dependent behaviour of Fibre Reinforced Concrete

Supervisor: Dr Ali Amin
Eligibility: WAM>75
Project Description:
This project aims to undertake the first ever study in restraining early-age cracking in reinforced concrete using fibre reinforcement. Such structures include suspended floor slabs, walls, bridge decks and shotcrete tunnel linings. This project expects to generate new knowledge in understanding, at multiple levels, how early-age behaviour at the material level in FRC translates to performance at the member/structural level. Expected outcomes of this project include the development of reliable simulation models and robust design procedures for inclusion in design standards for the control of early age cracking in FRC structures.
Requirement to be on campus: would prefer the student to be on (or close to) campus as there might be an experimental component to the project depending on the circumstances

CIVIL2021/5 3D printing technologies for development of innovative solutions in the construction industry

Supervisor: A/Prof Daniel Dias-da-Costa
Eligibility: WAM>75
Project Description:
This project will explore different possibilities of using 3D printing technologies for enhancing the construction industry. The candidate will have the freedom to propose and explore new concepts and ideas, for example, based on auxetic materials to achieve enhanced performance. Interestingly, auxetic materials can increase their size/volume when loaded in compression, which is an unexpected and instrumental behaviour for high-end structural applications. This project will include a literature review on recent advancements and the exploration of ideas through computational mechanics and possibly small testing.
Requirement to be on campus: No

CIVIL2021/6 Development of phononic crystals and metamaterials

Supervisor: A/Prof Daniel Dias-da-Costa
Eligibility: WAM>75
Project Description:
This project will explore the use of metamaterials and phononic structures for civil engineering applications. These engineered materials have been successfully used for many different applications, ranging from energy harvesting to protecting buildings and cities by capturing/filtering the propagation of seismic waves. The candidate will study those materials and develop new ideas for possible applications. The project could include the development of advanced computational models and small tests as proof of concept.

Requirement to be on campus: No

CIVIL2021/7 Strengthening of composite cementitious materials using carbon polymers and state-of-the-art machine learning

Supervisor: A/Prof Daniel Dias-da-Costa
Eligibility: WAM>75
Project Description:
Many existing structures are approaching the end of their service life. As such, innovative solutions are being sought to upgrade them for further use. This may require the development of strengthening techniques, for example, based on carbon polymers, that can quickly establish the necessary strength and serviceability. This project will explore advanced optimisation and machine learning to achieve the best possible performance of structures.
Requirement to be on campus: No

ELECTRICAL AND INFORMATION ENGINEERING PROJECTS

EIE2021/1 Wireless sensor network for solar 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 (dependent on government's health advice)

EIE2021/2 Use of phase change materials in building insulation for energy management applications

Supervisors: A/ Prof Gregor Verbic
Eligibility: Proficiency in high-level programming language (such as Matlab or Python).
Project Description:
The electricity demand due to the heating and cooling of residential buildings is one of the main drivers of the electricity cost. However, using phase change materials (PCM) to improve building insulation can turn the air conditioning load into a flexible system resource, particularly in buildings with rooftop solar. The PCM can serve as thermal energy storage that can soak up excessive solar generation in the middle of the day to either precool or preheat the building to avoid using the air conditioner in the afternoon when the electricity is the most expansive. The project will use machine learning for residential buildings' energy management to schedule the air conditioner's operation to reduce electricity cost and maximise the self-consumption of solar generation. The case studies will use real-life demand and solar generation data from Australian capital cities to determine the effectiveness of PCMs for energy management.
Requirement to be on campus: No

EIE2021/3 Pro-active tennis: Learning best actions

Supervisor: Dr Wibowo Hardjawana
Eligibility: Experience in Python and knowledge of neural networks tools such GNN
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 graphical neural networks (GNN) research in telecommunications 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

EIE2021/4 Development of an OTFS detector for 6G wireless networks

Supervisors: Dr Wibowo Hardjawana & Prof Branka Vucetic
Eligibility: Strong experience in Python and/or C/C++ and knowledge about deep neural and wireless communication networks
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 for OTFS systems on top of the system model developed in our current research.
Requirement to be on campus: No

EIE2021/5 Radio intelligence controller for O-RAN alliance based 5G NR networks

Supervisors: Dr Wibowo Hardjawana & Prof Branka Vucetic
Eligibility: Experience in NS-3 and knowledge about deep neural net works
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. One of the RIC features deal with the lower layer, namely the adaptive Modulation Coding Scheme (MCS) algorithm for adjusting uplink and downlink transmission rates according to the wireless channel condition and quality of service requirements. This is done by 5G base stations (gNodeB) based on the feedback received from user equipment (UEs). The most common algorithm is running long pre-simulations and interpolation to create the mapping between SINR and MCS. As the system complexity increases, coupled with latency issues, this approach becomes infeasible. This project will develop for RIC, a Deep Neural Network (DNN) function that can predict the MCS for 5G NR base stations, extending the current research work that has been applied into WiFi networks. To create extensive training data, we will be using NS-3 based 5G NR network simulator. We will then implement the DNN in NS-3 to test the performance in a simulated environment.
Requirement to be on campus: No

EIE2021/6 Development of Open-Source Wireless Cellular Networks

Supervisors: Dr Wibowo Hardjawana, Dr Phee Yeoh & Prof Branka Vucetic
Eligibility: Strong experience in C/C++ and 4/5G wireless communication networks
Project Description:
This project is a multi-disciplinary project involving researchers in power (microgrid) and telecommunication domains. The school has developed a microgrid test-bed to replicate renewable energy generation systems, including wind, photovoltaic, biomass, fuel cells, energy storage, and local loads. In this project, students will develop communication infrastructure to support microgrid test-bed applications, leveraging existing research work at the Centre of Telecommunications and IoT. Students will first use open source 4G communications stacks and software-defined radio (SDR) kits to construct their own 4G cellular networks consisting of base stations and core gateway. The student will then program SIM cards according to the

configured 4G network to be used by microgrid devices. They will be used to facilitate communications between microgrid devices and microgrid controllers in the cloud.
Requirement to be on campus: No

EIE2021/7 Theoretical analysis of communication-efficient federated learning

Supervisors: Dr Mahyar Shirvanimoghaddam

Eligibility: Solid background in mathematics and machine learning with good 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, both projects can run remotely, but the preference is for the on-campus mode.

EIE2021/8 Novel decoding techniques for short channel codes

Supervisor: Dr Mahyar Shirvanimoghaddam

Eligibility: Solid background in mathematics and machine learning with good programming skills

Project Description:
Channel coding has been developed for many applications and is now an integral part of any communication systems. Towards 6G, new applications will arise which requires packets of small sizes, less than 1000 bits, to be sent to meet the desired level of reliability and latency. New channel coding and decoding techniques should be developed to guarantee the performance at short block lengths. This project aims at investigating ordered statistics decoders and proposed improvements to reduce the complexity and enable real-time implementation.
Requirement to be on campus: No, both projects can run remotely, but the preference is for the on-campus mode.

EIE2021/9 Optimizing hardware for machine learning on the edge through the use of variable precision

Supervisor: Dr David Boland
Eligibility:

- Bachelor’s Degree in electrical engineering
- Outstanding transcript (WAM>75)

Either:

- Confidence with hardware design (VHDL/Verilog/High-level synthesis) or embedded systems.
- Knowledge training machine learning algorithms
- Research experience with publication record in electrical engineering (preferred)

Project Description:
Recently, machine learning techniques are being used across an increasing range of application domains. Examples include driverless cars, surveillance, radio signal analysis and

medical uses such as cancer detection. However, to enhance their capability on the edge, for example on a drone, there is a continual drive for faster and lower power implementations. One important research direction has been the development of low precision machine learning algorithms, and modification of computer architectures to support this. For example, modern GPUs and CPUs are increasingly supporting new custom number systems for machine learning. This project aims to extend this by exploring how to optimise machine learning algorithms to use variable precision at run-time: high precision when needed for accuracy, and low precision elsewhere because it is faster. This project will also explore the development of novel computer architectures to support this.
Ideally this project will be tackled by a team of students combining machine learning and hardware design experience. You will test your developments on a range of benchmark applications to demonstrate its advantages over existing solutions.
Requirement to be on campus: No

EIE2021/10 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

EIE2021/11 Circuits design and signal processing for advanced sensors

Supervisor: Prof Xiaoke Yi & Dr Liwei Li
Eligibility: Year 3/4 or Master students
Project Description:
The state-of-the-art sensing technology is rapidly growing and will play a critical role in the near future. For instance, smart phones, which play a significant role in our daily life, have a fingerprint identity sensor that makes it easy for us to access the device, and they also use an ambient brightness sensor to adjust the display brightness, etc.
The project is to deliver the superior, advanced sensing platforms that arise with cutting-edge solutions to address the important challenges across a diverse range of applications in various fields, particularly in lab-on-chips, Internet of Things, aerospace and biomedical applications. The internship project focuses on electrical circuits design and data processing as well as machine learning and software programming. The aim is to realize ultra-sensitive, high resolution and extreme-range sensing. The intern will closely work with a research team including PhD students and postdoctoral research associates. Innovative signal processing and design in both hardware and software will be carried out during the project.
Requirement to be on campus: Yes (dependent on government's health advice)

EIE2021/12 CMOS-compatible integrated photonics devices

Supervisor: Prof Xiaoke Yi & Dr Liwei Li
Eligibility: Year 3/4/5 or Master students

Project Description:
The vast capability offered by photonic technologies for the transmission and processing of broadband signals has been widely recognized. Photonic signal processor applications can be found in broadband wireless access network, sensor networks, satellite communications, scientific instrumentation and radio-astronomy. The convergence of photonics and CMOS electronics empowers photonic integrated circuits to meet the ever-increasing demand for data throughput in information systems.
The project is focused on simulation and testing of photonic integrated circuits. The aim is to achieve high performance, low costs and high yields chips permitted by the integration via CMOS compatible fabrication. The photonic chip will be tested in harsh operating environments.
Requirement to be on campus: Yes (dependent on government's health advice)

EIE2021/13 Forecast of PV Power Generation and Consumer Power Demands for Optimal Energy Management of Microgrids based on Machine Learning and Data Analytics

Supervisors: Prof. Jian Guo (Joe) Zhu and A/Prof. Jin Ma
Eligibility:

- Bachelor's degree in electrical engineering
- Outstanding transcript (WAM>75)
- Good knowledge of AI and data analytics
- Skilful with MATLAB/Simulink/Python programming
- Research experience with publication record in electrical engineering (preferred)

Project Description:
Microgrids are considered as an effective means to integrate renewable and/or non-renewable distributed energy resources, energy storage units, and consumer loads for better efficiency, power quality, reliability, and economical benefits. For optimal energy management of microgrids, it is essential to predict/forecast the PV power generation and consumer power demands so as to determine the best charging and discharging set points of the battery energy storage unit. This project aims to develop algorithms for accurate forecasting the PV power generation and consumer power demands based on AI and data analytics techniques for the purpose of effective microgrid energy management.
Requirement to be on campus: No

EIE2021/14 A high sensitivity probe for remote detection of active ac power cables

Supervisor: Prof Jian Guo (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:
Active ac power cables can be dangerous when the conductors are exposed. This project aims to design a high sensitivity probe for remote detection of active ac power cables. The project work includes a comprehensive study of detecting principles, probe materials, and feasible structures of the probe through a thorough literature, comparative study and design exercise. The feasibility can be demonstrated by analytical calculation and/or numerical simulation of the probe performance.
Requirement to be on campus: No

MECHANICAL ENGINEERING PROJECTS

MECH2021/1 Designing a coughing machine

Supervisors: Dr Agisilaos Kourmatzis & Prof Assaad Masri
Eligibility: Have completed at least 1 Fluid Mechanics unit and have an HWAM>75.
Project Description:
COVID-19 has reminded those of us who work in multiphase fluid mechanics, how poorly we understand the airborne transport of droplets. Part of the reason for this is due to the lack of engineering tools available to replicate a range of "practical" conditions. In this project, you will work on designing a machine that is capable of closely replicating the dynamics of a human cough or sneeze. You must have a keen interest in fluid mechanics, design work, computational modelling and/or experimental analysis.
Requirement to be on campus: No

MECH2021/2 The multiphase fluid mechanics of energy conversion devices

Supervisor: Dr Agisilaos Kourmatzis
Eligibility: Have completed at least 1 Fluid Mechanics unit and have an HWAM>75.
Project Description:
The Thermo fluids &Combustion groups in the School of AMME work on a broad variety of applications which require application of multiphase and multi physics flows. One area we are very active in is the design of systems to provide better control over the delivery of turbulent sprays. Key projects in this area include delivery of fuel sprays for use in gas turbine combustors, water sprays for fire suppression, and spray injection over the Great Barrier Reef for "marine cloud brightening". Whilst these applications are all very different, at the core of all of them is analysis of highly turbulent, and extremely complex transient sprays. We use a variety of advanced experimental methods to probe these flows mainly using high speed imaging systems. We are looking for an outstanding candidate interested in working on one or more of injector design, advanced experimental technique development, image processing methods, or computational modelling.
Requirement to be on campus: Yes (dependent on government's health advice)

MECH2021/3 Fluid mechanics of inhalation drug delivery devices

Supervisor: Dr Agisilaos Kourmatzis
Eligibility: Have completed at least 1 Fluid Mechanics unit and have an HWAM>75
Project Description:
Pertinent to recent events, the use of intranasal drug delivery as a means of effective self-vaccination has a lot of interest, but so many questions remain with regards to how aerosol is transported through the human nasal channels and what the mechanisms of drug transport are once the drug has made contact with human tissue. Similar questions persist in our understanding of more traditional inhaler devices. These inhalers are not only used for treatment of common respiratory diseases such as asthma and COPD, but also for delivery of inhaled antibiotics. At the core of controlling the efficacy of these delivery systems, is a need to understand the turbulent fluid mechanics of droplets in complex geometries. In this project you will work on either experimental work, computational modelling, or in the design of new devices, to improve our ability to deliver drugs for specific applications.
Requirement to be on campus: No

MECH2021/4 Experimental investigation of mixed mode combustion

Supervisors: Dr Matthew Dunn & Prof Assaad Masri
Eligibility: WAM>75
Project Description:
This project will involve working in the clean combustion laboratory at The University of Sydney

exploring mixed mode combustion. Mixed-mode combustion is the dominant mode of combustion in most combustion devices. Yet despite being ubiquitous in practical systems, understanding and predicting mixed mode combustion remains a fundamental challenge. There is simply no existing universal model that can adequately and accurately account for all modes of combustion. The development of such an understanding of mixed mode combustion is necessary to develop next-generation renewable green fuels and clean combustion processes. The successful candidate will be involved in experiments using state of the art optical and laser techniques and subsequent data analysis. The suitable student will have performed at a high level in all subjects with a particular interest in fluid mechanics and thermal engineering.
Requirement to be on campus: Yes (dependent on government's health advice)

MECH2021/5 Experimental investigation of flame inhibition

Supervisors: Dr Matthew Dunn, A/Prof Matthew Cleary & Prof Assaad Masri
Eligibility: Must be an Australian citizen
Project Description:
This project will involve working in the clean combustion laboratory at The University of Sydney to develop a new experimental capability to understand flame inhibition. The project will evaluate replacements to toxic halogenated gaseous compounds with finely dispersed solid phase powders that act as radical inhibitors and scavengers. The suitable student will have performed at a high level in all subjects with a particular interest in fluid mechanics and thermal engineering. The project will also involve a literature search to identify state of the art solid-phase dispersible inhibitors to be included in the experimental inhibitor trial in a laboratory-scale turbulent flame.
Requirement to be on campus: Yes (dependent on government's health advice)

MECHATRONICS ENGINEERING PROJECTS

MECHATRON2021/1 Lunar robotics

Supervisors: Prof Stefan B. Williams, Prof Ian Manchester, Dr Viorela Ila & Dr Donald Dansereau
Eligibility: Students should have a strong background in programming, robotics, space systems and/or mechatronic design. Prior experience working with machine learning tools or robotics will be considered an asset.
Project Description:
We have a number of projects related to our new lunar robotics program related to developing sensing, perception and planning methods suitable for deployment on extra-terrestrial rover systems. This might include studying the terra mechanics of wheeled systems, proposing new sensing modalities suitable for modelling the environment around the rover, path planning methods that guarantee safe passage around obstacles and machine learning algorithms suitable for semantic understanding of extra-terrestrial scenes. We will work with successful students to further develop project topics.
Requirement to be on campus: No

MECHATRON2021/2 Marine robotics

Supervisors: Prof Stefan B. Williams, Dr Oscar Pizarro, Dr Hao Wu & Dr Lachlan Toohey
Eligibility: Students should have a strong background in programming, robotics and/or mechatronic design. Prior experience working with machine learning tools or robotics will be considered an asset.
Project Description:
We have a number of projects related to our marine robotics program:

- Develop a model predictive controller for an AUV to build local maps of seafloor obstacles and explore high level planning methods like Behaviour Trees that can be used for an AUV to navigate in the littoral environment. This work will access

navigation sensor data collected from AUVs and utilise underwater simulators to model and test the controllers.
- Calculate target direction of a Lagrangian float from a hydrophone array, implement real-time navigation when the array is on a moving surface vessel and post-process the trajectory using depth and speed data from the float, and bathymetry maps.
- Develop and train a supervised/unsupervised machine learning model to automatically detect and identify marine life forms or classify benthic habitat cover using underwater imagery data collected by AUVs around Australia.

We will work with successful students to further develop project topics.
Requirement to be on campus: No

MECHATRON2021/3 3D Dynamic robotic vision in the dark

Supervisor: Dr Donald Dansereau
Eligibility: Image processing in Matlab, Python or C++; Experience with ROS and motion planning for robotic arms would be an asset.
Project Description:
Autonomous robots do not perform well in low light and this impedes applications spanning autonomous driving, drone delivery, and underwater survey.
In this project we will explore how carefully planning a robot's motion can help it see better in the dark. This involves developing information-preserving motion strategies, implementing algorithms to make the most of the resulting imagery, and characterisation and validation on physical hardware.
Depending on interest and capability, students can focus on motion planning and execution on a robotic arm, or image enhancement and vision algorithms in Matlab, Python, or C++.
Requirement to be on campus: Yes (dependent on government's health advice)

SCHOOL OF MEDICAL SCIENCES PROJECT

MS2021/1 The application of botulinum toxin type A (BTXA) in burn scar prevention and skin tissue engineering

Supervisor: Prof. Peter Maitz, Dr. Joanneke Maitz
Eligibility: Cell culture experience preferred but not required
Project Description:
Advances in burn injury management over the last decades has made survival of severe and large burns achievable, significantly increasing the incidence of burn injury scarring and its associated morbidity. Patients suffer from long-term functional and psychological effects of their scars; the bushfire victims from 2019-2020 are currently experiencing the realisation of their permanent memorandum.
Burn scars are thickly packed, collagen dense scars, with minimal elasticity and pliability. Based on previous studies of BTXA on collagen formation and its potential effect on myofibroblast differentiation, it has been suggested as a treatment to reduce scarring. We are examining the effect of BTXA in an in-vitro cell culture model and in-vivo animal model to be used for the development of new therapies and delivery systems to reduce burn wound scarring. Based on preliminary data, we will design an electrospun dermal template for the delivery of BTXA and set up a clinical trial to advance its translational potential. If successful, this will be the first dermal template developed to improve the quality of burn scar tissue using a novel drug delivery.
Requirement to be on campus: Yes (dependent on government's health advice)