THE UNIVERSITY OF SYDNEY

**FACULTY OF ENGINEERING**

# Engineering Vacation Research Internship Program

## DIGITAL SCIENCES INITIATIVE PROJECTS - SUMMER 2023-24

THE UNIVERSITY OF SYDNEY

**FACULTY OF ENGINEERING**

# DIGITAL SCIENCES INITIATIVE PROJECTS

## DSI2023-24/1 MEMS Gyroscope Test Setup

**Supervisor:** A/Prof. Niels Quack

**Eligibility:** WAM>75 and Undergraduate candidates must have already completed at least 96 credit points towards their undergraduate degree at the time of application.

**Project Description:**
Micro-Electro-Mechanical Systems (MEMS) Gyroscopes are widely used systems for navigation in automobile, robotics, and consumer electronics. At the University of Sydney, we have developed a demonstrator MEMS Gyroscope in Silicon-on-Insulator (SOI) Technology. To validate the operation of the Gyroscope, a test setup with rotating stage and remote readout (WiFi, Bluetooth…) is required. In this project, the student will support the design and construction of a laboratory test-setup for MEMS Gyroscopes. The performance will be validated by comparing a commercially available Gyroscope with the in-house fabricated devices.

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

## DSI2023-24/2 Opto-Electro-Mechanical Characterization of Photonic Microsystems

**Supervisor:** A/Prof. Niels Quack

**Eligibility:** WAM>75 and Undergraduate candidates must have already completed at least 96 credit points towards their undergraduate degree at the time of application.

**Project Description:**
In this project, the student will dive into the exciting world of Micro-Electro-Mechanical Systems (MEMS), with the hands-on characterization of MEMS components in cutting edge Photonic Integrated Circuits (PIC), the optical equivalent of electrical integrated circuits. After an introduction to the key features of the experimental setup, the student will measure and extract key performance metrics of the Photonic MEMS Devices, such as spectral response, optical losses, and the electro-mechanical response for a variety of components of a prototype photonic MEMS chip, such as Photonic MEMS Switches and Photonic MEMS Tuneable Filters for Fiber-Optical Telecommunication Systems.

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

## DSI2023-24/3 Design of a Micro-Electro-Mechanical Systems (MEMS) Accelerometer

**Supervisor:** A/Prof. Niels Quack

**Eligibility:** WAM>75 and Undergraduate candidates must have already completed at least 96 credit points towards their undergraduate degree at the time of application.

**Project Description:**
Micro-Electro-Mechanical Systems (MEMS) Accelerometers are widely used systems in automobile, robotics and consumer electronics. In this project, the student will develop the design of a MEMS accelerometer based on SOI technology that can be fabricated in a simple

process flow at the research and prototype foundry at the university of Sydney. The student will learn the basics of microfabrication process flow, perform hands-on finite element modelling, and transfer of the designs into a microfabrication compatible design framework.

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

### DSI2023-24/4 Mechanical Design for Attachment of Optical Fiber Arrays to Photonic Integrated Circuit Chips

**Supervisor:** A/Prof. Niels Quack; Leila Vatandoust

**Eligibility:** Familiar with SolidWorks

**Project Description:**
In this research project, the student will design and manufacture a mechanical setup to attach a commercially available array either 12, 24 or 48 optical fibers to a photonic integrated circuit chip. The alignment will be performed using a 6 Degrees of Freedom precision alignment stage. The active alignment involves coupling light from a tunable laser into the chip and maximizing the amount of power coupled to the chip by monitoring the optical power on a photodetector. Permanent attachment will be performed by ultraviolet curing epoxy. The student will develop suitable designs of fiber-array and chip holders in solidworks, manufacture prototypes by 3D Printing, and develop the experimental alignment and permanent attachment procedure.

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

### DSI2023-24/5 Design and Simulation of Electro-optic phase modulator in COMSOL Multiphysics

**Supervisors:** A/Prof. Niels Quack; Shashank Gupta

**Eligibility:** WAM>75 and Undergraduate candidates must have already completed at least 96 credit points towards their undergraduate degree at the time of application.

**Project Description:**
The electro-optic phase modulator is a crucial device in modern optical communication systems, offering the ability to control the phase of light with an applied electric field. Electro-optic phase modulators can be used to construct waveguide interferometers for effective amplitude modulation. A commonly used phase modulator is Mach-Zehnder modulator, consists of two parallel waveguides connected at the input and output ends. Each waveguide by itself functions as an electro-optic phase modulator. The light intensity at the output is the function of the phase difference between the two arms. By electro-optically controlling this phase difference through the applied voltage, the amplitude of the guided optical field at the output can be modulated. This project aims to demonstrate a phase modulator in Potassium Tantalate Niobate (KTN) waveguide and calculate pi phase shift voltage length product ($V\pi L$) using COMSOL Multiphysics.

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

### DSI2023-24/6 Corrosion in reinforced concrete structures

**Supervisor:** Dr Ali Hadigheh

**Eligibility:** WAM>75 and Undergraduate candidates must have already completed at least 96 credit points towards their undergraduate degree at the time of application.

**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. Corrosion of reinforcement is one of the main deteriorating mechanisms in reinforced concrete structures. In addition, the on-going requirement for more structurally sound infrastructures has driven the introduction and development of advanced structural health monitoring (SHM) methods. This project aims to use innovative SHM techniques for automated condition assessment and evaluation of reinforced concrete infrastructure.

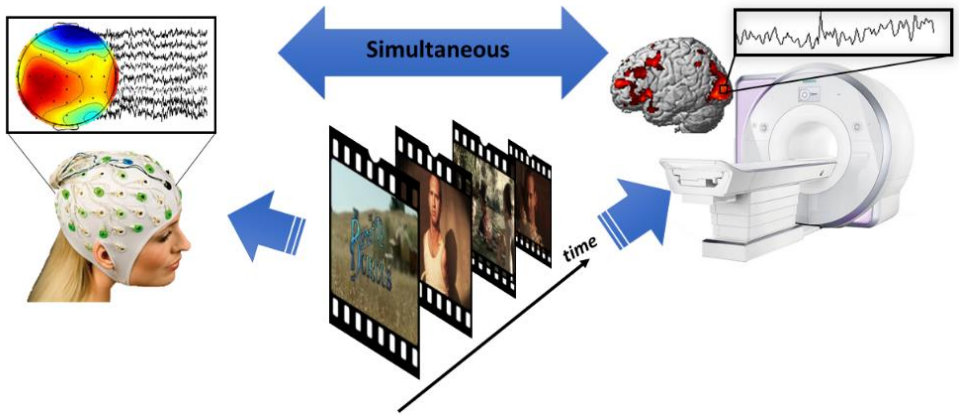
**Requirement to be on campus:** No

### DSI2023-24/7 Read the mind with simultaneous EEG-fMRI

**Supervisors:** Dr. Jinglei Lv, A/Prof. Mayuresh Korgaonkar, Prof. Fernando Calamante.

**Eligibility:**
1. Programming skills.
2. Basic knowledge about medical image.
3. Self-motivation, curiosity about research and passion to succeed.

**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 analyse simultaneous EEG and fMRI data. Together with T1w and Diffusion MRI imaging, you would explore the possibility of finding the signal sources and signal pathways in the human brain.



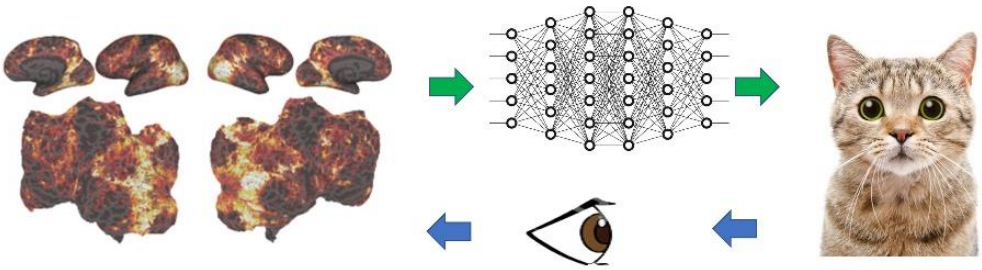

**Requirement to be on campus:** Yes **dependent on government's health advice.*

### DSI2023-24/8 Reconstructing Natural Image from Brain Activity

**Supervisors:** Jinglei Lv, Zhiyong Wang, Fernando Calamante

**Eligibility:** 1. Necessary skills with programming. Python programming is preferable.
2. Necessary knowledge and experience with deep learning.
3. Self-motivation, curiosity about research and passion to succeed.

**Project Description:**
The ability to decode neural activity patterns associated with visual perception is a major goal in the field of neuroscience. Recent advances in machine learning and neuroimaging techniques have shown promising results in reconstructing images from brain activity data. In this project, we propose to develop a deep learning-based approach to reconstruct natural images from functional magnetic resonance imaging (fMRI) data. Specifically, the fMRI data was collected while the participants were viewing 10,000 images. Our aim is to train a neural network to learn the mapping between fMRI data and visual stimuli, allowing us to reconstruct images that match the content of the original visual stimulus. This research helps understand the mechanism of human visual system. It will potentially inspire new directions for artificial intelligence and bionic eyes.



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

## DSI2023-24/9 AI and NLP: Collaborative Intelligence for Crowdsourcing

**Supervisor:** Dr. Jonathan K. Kummerfeld

**Eligibility: Experience with the Python programming language**

**Project Description:**
Many AI systems rely on labelled data for training. Creating those resources is usually a laborious process performed by experts. For some tasks, methods have been developed for non-experts to label data, e.g. for identifying objects in images. This project aims to push the boundaries of what non-experts can do by taking advantage of AI.

There are several possible focuses for this project, including:

- Building an adaptive labelling system, where people do most of the work at first, but then the system automatically shifts over time to use more AI input and less human input.
- Creating human-AI collaborative systems that can do tasks faster, e.g., perfect real-time speech recognition.
- Enabling people to do new, more complex tasks.

R**equirement to be on campus:** No

## DSI2023-24/10 AI and NLP: Playing Diplomacy

**Supervisor:** Dr. Jonathan Kummerfeld

**Eligibility: Experience with the Python programming language**

**Project Description:**
Games have been a focus of AI for decades, from Checkers, to Chess, and Go. Diplomacy is a particularly challenging game, with seven players, simultaneous turns, and extensive discussion

between players. This project is part of an ongoing effort to develop AI to play the game and to act as an advisor to human players.

There are several possible focuses for this project, including:

- Developing alliance-specific tactical AI models.
- Exploring different forms of human-AI collaboration in the game.
- Improving models for automatic interpretation of messages.

**Requirement to be on campus:** No

### DSI2023-24/11 AI and NLP: Code Generation

**Supervisor:** Dr. Jonathan K. Kummerfeld

**Eligibility:** Experience with the Python programming language

**Project Description:**
Large language models have dramatically improved the quality of AI-generated code, but they aren't perfect. In particular, they struggle with more complex tasks or when context changes the nature of the task. This project aims to understand and address these limitations with novel models, systems, and studies.

There are several possible focuses for this project, including:

- Identifying the strengths and weaknesses of LLM-based code-generation models.
- Creating tools that help non-expert users understand the output of these models and avoid errors.
- Improving code-generation with new models that build on LLMs to address their limitations.

**Requirement to be on campus:** No

### DSI2023-24/12 AI and NLP: Healthcare

**Supervisor:** Dr. Jonathan K. Kummerfeld

**Eligibility:** Experience with the Python programming language

**Project Description:**
Clinical notes contain key information about patients, but they are difficult to interpret. The style of writing is a challenge even for large language models (LLMs), because the writing is unlike the training data for LLMs (text online and in books). One possible focus of this project is creating an AI-based system for clinical coding: identifying key insurance-related information in clinical notes.

The project involves a multi-disciplinary team across Computer Science and Medicine, developing novel AI methods with the goal of applying them to real patient data.

**Requirement to be on campus:** No

### DSI2023-24/13 System identification and control of Autonomous Underwater Vehicles (AUVs)

**Supervisor:** Professor Stefan Williams

**Eligibility:** Control systems knowledge (e.g. AMME3500/AMME5520). C++, Matlab, Python recommended.

**Project Description:**
Autonomous Underwater Vehicles (AUVs) are utilised within the Australian Centre for Field Robotics (ACFR) for visual seafloor surveys. This involves the AUV traversing close to the seafloor over complex terrain, aiming to hold a consistent altitude of 2 meters. Optimising the AUV's control system for both manoeuvrability and power efficiency is necessary for operating in these conditions.

The task of the student will be to help us characterise the dynamic system of the AUV, with the goal to integrate this into the AUV's control system and improve the simulation of the vehicle. This involves both analytical and experimental techniques to estimate the buoyancy and drag coefficients of the vehicle.

R**equirement to be on campus:** Yes *dependent on government's health advice.

### DSI2023-24/14 Accelerated Real-Time Image Processing Pipeline for Embedded Systems on Marine Robots

**Supervisors**: Dr. Stefan Williams, Dr. Gideon Billings

**Eligibility:** Coding proficiency (preferably C++), Experience with ML libraries like TensorFlow is a plus

**Project Description:**
The aim of this project is to develop an accelerated image processing pipeline, tailored for underwater scenes and capable of operating at real-time framerates on embedded systems. The project would explore the use of a Google Edge TPU combined with an NVIDIA Jetson device to accelerate an image feature encoding network that would pipe into a GPU accelerated feature extraction and matching stage. This accelerated image processing pipeline will be the backbone for visual methods, such as Simultaneous Localization and Mapping, semantic segmentation, and object detection, that will run onboard underwater vehicles.

The student will explore machine learning models that are optimized for edge devices in conjunction with GPU accelerated feature descriptors to determine a processing pipeline that balances computational performance and accuracy.

R**equirement to be on campus:** Yes *dependent on government's health advice.

### DSI2023-24/15 Cross-modal medical image generation

**Supervisor**: Prof. Jinman Kim

**Eligibility:** WAM>75 and Undergraduate candidates must have already completed at least 96 credit points towards their undergraduate degree at the time of application

**Project Description:**
Computer-aided diagnosis has been revolutionized by deep learning. However, deep learning necessitates substantial data, which is a hurdle given the scarcity of curated medical images.

The aim for the project is to develop a model to generate medical images conditionally, that is, to produce images in accordance with user-specified criteria, such as particular diseases or symptoms. This will increase dataset for the training process for deep learning algorithms in CAD.
There are two predominant frameworks in medical image generation: diffusion models and Generative Adversarial Networks (GANs). These types of generative AI models have made strides and are being widely deployed. However, there's growing recognition that these types of models often generate images that defy logic, particularly in medical image generation (e.g. creating deformed structures). To overcome this, we will refine existing generative

algorithms with the aim of enhancing the accuracy and reliability of the synthesized medical images.
R**equirement to be on campus:** Yes *dependent on government's health advice.

### DSI2023-24/16 3D Printing Smart Wearable Sensors

**Supervisor**: Dr Anusha Withana

**Eligibility:** You will work with the supervisor and a PhD student, and we expect you are a fast learner. Excellent skills in programming, , 3D design tools, 3D printing or fabrication, and human computer interaction are added benefits.

**Project Description:**
Wearable sensors are very popular, for instance, your smartphone or smartwatch has tens of sensors. But their functionality is limited by design. In this project, we aim to make 3D printable sensors, and look at how their functionality can be changed based on the design. We will use computational design tools to help customising sensors. And they will be able to fit different parts of our body including cloths we wear.

R**equirement to be on campus:** Yes *dependent on government's health advice.

### DSI2023-24/17 Predictive Gesture Classification in Virtual Reality (VR)

**Supervisor**: Dr Anusha Withana

**Eligibility:**
You will work with the supervisor and a PhD student, and we expect you are a fast learner. Excellent skills in programming, , machine learning, and human computer interaction are added benefits.

**Project Description:**
Can we predict a player's next move in a VR game? Gestural input, for example, using your hand movements as input has become one of the most popular input technologies for rapidly developing virtual reality (VR) and augmented reality (AR) applications (eg.GearVR, HTC Vive, etc.). Gestures, such as hand movements and poses in space, are an essential part of our daily communication (ie. body language) and thus create an intuitive modality for interacting with these immersive new computer applications. In this project we focus on predicting hand movements for the purpose of pre-recognising user activities in VR. The project will build our existing work on continuous hand movement recognition (See video in the link) and the data we have collected.
https://dl.acm.org/doi/10.1145/3472749.3474753

R**equirement to be on campus:** Yes *dependent on government's health advice.