

PROJECTS FOR THE 2017 RESEARCH TRAINING PROGRAM

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Professor Ajmal Mian

Project 1:

Title: Deep Learning for RGB-D object detection

The new Kinect can acquire 3D data in High Definition at 30 frames per second. In this project, the student will train a Convolutional Neural Network (CNN) using RGB-D images of objects using labelled training data for object detection in test images. A number of public datasets are available for the student to train and test the network on such as SUN RGB-D, NYU 3D dataset etc. Further training data can also be synthesized using 3D object models and rendering them in blender or by using a simple Matlab script. As an additional step the student can also train the same or a different CNN for estimating the pose of the object.

Project 2:

Title: Deep Learning for 3D human pose estimation

The student will be required to estimate the human pose in RGB-D or simple RGB images by training a deep Convolutional Neural Network (CNN). Our lab has sufficient training data for training such networks. More data is available on the Internet and can also be synthesized. The student can choose to perform pose estimation frame by frame or for small video segments. The later approach will help in designing robust techniques. The estimated poses will then be combined to form an action descriptor to perform human action recognition.

Assistant Professor Amir Karton

See attached PDF for [Karton projects](#)

Associate Professor Chunbo Ma

Title: Agricultural Productivity in China

The project examines China's agricultural productivity in the past few decades. The 8-week program involves two parts: 1) a comprehensive literature review on the economic literature of China's agricultural productivity and a written report is expected at the end of the program; 2) data collection which may include data on agricultural inputs, outputs, weather, soil etc. ideally at the county level.

Skills/Knowledge

Relevant background in economics is essential. Knowledge of data sources related to Chinese agriculture, basic skills in ArcGIS and web crawler is preferred but not essential.

Associate Professor David Coward

Project 1:

Title: Searching for the first optical counterparts to gravitational waves

In 2015 gravitational waves were discovered for the first time from colliding black holes. In the following years LIGO is expected to detect the first binary neutron star mergers. To fully exploit these ground breaking discoveries requires finding an electromagnetic source, such as a gamma ray burst. This will enable a new probe into the most violent events in the Universe.

The project will employ the UWA Zadko Telescope (1-m fully robotic - automated) to search for the optical counterparts to neutron star mergers detected by LIGO. Zadko is also robotically linked to the NASA satellite Swift that detects gamma ray bursts. The student will be participating in new discoveries at the frontier of science.

Experience: background in programming, computing, engineering and a keen interest to learn new skills in robotic astronomy and image analysis, with the aim of making unique discoveries.

For a review of Zadko Telescope related science please go to:

<http://lanl.arxiv.org/abs/1609.06445>

Project 2:

Title: Searching for hazardous Space Junk and Near Earth Asteroids and other exotic transients using the UWA Zadko Telescope

The UWA Zadko Telescope is a 1-m fully robotic (automated) optical telescope. In 2013, more than a dozen new asteroids were discovered using the Zadko Telescope. The student will learn to schedule, manage and analyse image data, focusing on the search for hazardous Near Earth Asteroids and space junk. This project will aim for an initial exploration of the astrometric, photometric and coarse spectral parameter space of space debris in geosynchronous orbit with the one metre Zadko telescope - toward an ultimate goal of rapid object classification. Practical skills working with a metre-class robotic telescope system will be developed, together with image analysis and multivariate discrimination techniques.

Experience: background in programming, computing, engineering and a keen interest in space science and willing to learn new skills in robotic astronomy and image analysis, with the aim of making unique discoveries.

For a review of Zadko Telescope related science please go to:

<http://lanl.arxiv.org/abs/1609.06445>

Professor David Sampson

Project 1:

Title: Ultrahigh-resolution optical imaging deep in tissue – Nanoscope-in-a-Needle

Group: [Optical+Biomedical Engineering Laboratory](#)

Supervisor: Prof David Sampson, Anthony Phan and Gavrielle Untracht

Area: Biophotonics, Biomedical Optics, Biomedical Engineering

Skills: This project can take many directions from modelling and theory to optical design to experimental realisation, and so will suit physicists, electrical engineers, or mechanical engineers and can accommodate several interrelated but independent projects.

Our group is the pioneer of the Microscope-in-a-Needle, which allows an optical microscope to penetrate into opaque and scattering biological tissues via a hypodermic needle. There are many methods to “optically section” biological tissues, such as optical coherence tomography and confocal microscopy, but none can penetrate more than a few millimetres into the tissue. The needle platform we have developed makes it possible to do this in a very small, minimally invasive footprint – achieving micro-scale resolution at centimetre depths in tissue, which cannot be achieved in any other way. We now wish to evolve the Microscope to a Nanoscope, to achieve a resolution sufficient to see sub-cellular entities within intact cell clusters and tissues. These projects will contribute towards the realisation of this goal.

Project 2:

Title: Polarisation-sensitive optical coherence tomography

Group: [Optical+Biomedical Engineering Laboratory](#)

Supervisor: Prof David Sampson, Dr Karol Karnowski and Qingyun Li

Area: Biophotonics, Biomedical Optics, Biomedical Engineering

Skills: This project can take many directions from modelling and theory to optical design to experimental realisation, and so will suit physicists, electrical engineers, or mechanical engineers and can accommodate several interrelated but independent projects.

Optical coherence tomography is a three-dimensional optical analogue of ultrasound imaging. It can be extended to capture the polarisation state of light and the change in that state versus depth in the tissue, giving a measurement of the birefringence that reflects the order and geometry of a tissue’s sub-resolution microstructure. We have recently demonstrated such an approach in the [Microscope-in-a-Needle](#), and shown, for the first time, we can tell cancer from non-cancer in dense breast tissue. We are interested in using birefringence as a measure of structural and mechanical properties of tissue. In particular, we are interested in measuring contractile forces in airways associated with asthma, and in the cornea, associated with structural integrity of the cornea, which

is affected by disease and treatment, and related to glaucoma. These projects will contribute towards the realisation of birefringence as an effective label-free biomarker.

Project 3:**Title: Optical elastography – New methods of imaging stiffness in cells and tissues****Group:** [Optical+Biomedical Engineering Laboratory](#)**Supervisor:** Prof David Sampson, Philip Wijesinghe, Dr Karol Karnowski and Gavrielle Untracht**Area:** Biophotonics, Biomedical Optics, Biomedical Engineering**Skills:** This project can take many directions from modelling and theory to optical design to experimental realisation, and so will suit physicists, electrical engineers, or mechanical engineers and can accommodate several interrelated but independent projects.

Our group is one of the leading groups in the world in optical elastography, which has the goal of imaging the stiffness and other mechanical properties of biological tissues, for applications in cell biology and medicine. We are involved in a pipeline of projects from the understanding of mechanical properties in soft tissue, new methods to image mechanical properties on the micro-scale, and the application of these methods in biology and medicine. Projects could involve modelling and computation to develop inverse model approaches to quantitative properties, to advanced optical systems seeking to improve the resolution of elastography into the micrometre range and depth penetration, through to biological studies on engineering cells and tissues.

Project 4:**Title: Non-invasive optical imaging of human blood and lymphatic vessels****Group:** [Optical+Biomedical Engineering Laboratory](#)**Supervisor:** Prof David Sampson, Dr Peijun Gong, Dr Danuta Sampson, and Dr Andrew Mehnert**Area:** Computer Vision, Mathematical Modelling, Biomedical Engineering**Skills:** This project will largely involve algorithm development, so it is most suited to a computational scientist.

We have been working on the development of methods for non-invasive optical imaging of blood and lymphatic vessels, which are important in assessing various diseases in the human skin and eye. These techniques are based on an optical imaging technique called optical coherence tomography angiography. Following our current work, this project will involve the further development of these techniques by focusing on designing more robust optical and mechanical hardware setups, developing better experimental methods for imaging, and improving the data processing algorithms and image processing methods. This multidisciplinary project provides with a unique opportunity to work across disciplines such as optics, computer science, engineering, medicine and biology.

The focus can be adjusted to suit the students' background and interests. Students are expected to have knowledge or interest in optics, electronics, computer programming or mathematics (familiar, or have an interest in either Matlab, C++ or Java).

Project 5:**Title: Non-invasive assessment of photoreceptor cells in human retina**

Groups: Ocular Tissue Engineering Laboratory, Lions Eye Institute, Optical+Biomedical Engineering Laboratory, UWA

Supervisor: Dr Fred Chen, Prof. David Sampson, Dr Danuta Sampson, Dr Peijun Gong, and Dr Andrew Mehnert

Area: Vision Science, Computer Science, Digital Signal Processing, Nyquist-Shannon Sampling Theorem, Fourier Transformation, Mathematical Modelling

Skills: This project will largely involve algorithm development, so it is most suited to a computational scientist.

The human retina contains a single layer of photoreceptor cell mosaic which underlies the first steps of vision; thus, even subtle alteration in the mosaic can result in severe vision loss. The retina can be examined directly using clinical tools; however these devices lack the resolution necessary to visualize the photoreceptor mosaic. In recent years, Adaptive Optics technology has been incorporated into various types of fundus cameras to enhance photoreceptor cells visualization. Despite the potential of AO imaging, much work remains in the area of signal processing and mathematical modelling of the image obtained from the camera before this technology can be fully utilized clinically.

The Ocular Tissue Engineering Laboratory in The Lions Eye Institute investigates novel cellular treatments for retinal disease and the role of commercially available AO technology in detecting photoreceptor cell loss and recovery as a tool for measuring success of cell therapy. We are now seeking new metrics (in addition to a simple density measure) to analyze AO images so that we can detect changes in mosaic arrangement before density reduces. This project involves the further development of metrics for AO images characterization as well as analysis of AO images obtained from patients suffering from various photoreceptor dystrophies. This is a translational project using computer science knowledge to impact directly on patient care.

The focus can be adjusted to suit the students' background and interests. Students are expected to have knowledge or interest in vision science, data analysis, digital signal processing, computer programming or mathematics (familiar, or have an interest in either Matlab, Labview).

Professor Erika Techera

Project 1:

Title: Enhancing Oceans Governance for the Blue Economy

Many countries in the Indo-Pacific region have adopted national agenda focused on blue economy goals. Achieving wealth from the oceans whilst maintaining ocean health is a significant challenge that necessarily involves multiple government agencies as well as industry and community engagement. Providing a good governance framework will be essential. This project will examine the different disciplines that will need to engage, explore barriers to achieving blue economy goals and areas where capacity will need to be built.

Experience: Students may come from marine science, conservation and management backgrounds, or alternatively law, policy and planning.

Project 2:

Title: Embedding remote sensing technology in oceans law and policy

Remote sensing technologies and autonomous vehicles have advanced rapidly in recent years. These technologies are often utilised to gather ocean data but have not been significantly engaged in monitoring human activities on our oceans such as fishing. The range of possible technologies needs to be explored and ways identified for them to work in combination with other resources applied to monitor ocean activities. This project will explore how these technologies could be better used to increase the effectiveness of law and policy.

Experience: Background in remote sensing technologies. Some experience in the social sciences would be valuable.

Professor Gia Parish

Title: Transistor-based chemical sensors for monitoring water contaminants

Supervisors: Professor Giacinta Parish (EECE), Professor Brett Nener (EECE), Professor Murray Baker (Chemistry and Biochemistry), Dr Matthew Myers (CSIRO).

Description:

Reliable, economically accessible technology for in-situ monitoring of contaminants in water has the power to transform health, industry, and society the world around. Applications of such monitoring range from process control monitoring and optimisation for industry, to water supply quality and wastewater monitoring, to environmental monitoring for resource extraction, and beyond. One example is contamination of environmental water bodies with heavy metal pollutants which are known to be extremely toxic metals and can lead to an irreversible damage to the health of humans and animals. In pursuit of miniaturised, robust, and ultrasensitive sensors, we are developing ion-selective field effective transistors (ISFETs) for various chemical sensing applications. We have demonstrated various sensors (pH and nitrate, mercury and calcium ions) and are currently investigating different methods to improve the sensitivity by varying the ion-selective functionalisation layer. We are also currently investigating ways to improve reliability by modifying packaging and measurement conditions. Elimination of drift will enable in situ, real-time contaminant monitoring that is accurate, reliable and low-cost.

Places are available for multiple students to work on one or more of the following integrated project components:

1. Physical, chemical, and materials characterisation of functionalisation methods for nitrates and heavy metals
2. Electrical, chemical, and physical characterisation and optimisation of functionalised sensors
3. Mechanical, electrical and chemical characterisation and optimisation of packaging techniques

Student background:

Students are sought with backgrounds in electrical/electronic engineering, materials engineering, chemical engineering, chemistry, physics, materials science or nanotechnology/nanoscience. Prior studies/experience in semiconductor device technology or chemical sensors is desirable though not essential.

Professor Jingbo Wang

See attached PDF for [Jingbo projects](#)

Associate Professor John Bamberg

John is willing to supervise projects in the following areas:

1. Symplectic spreads

A spread of finite symplectic space is a partition of the points into maximal subspaces, and such configurations give rise to mutually unbiased bases in quantum information theory. The goal is to find, using computational techniques, more symplectic spreads with the hope of constructing an infinite family of examples. So using finite group theory will be important here, since finding symmetric symplectic spreads with a particular group of symmetries that we understand can make it possible to generalise the examples.

2. Generalised polygons

Jacques Tits famously classified the spherical buildings of rank at least 3, but the rank 2 case is still open: the generalised polygons. The most numerous are the finite projective planes, whilst we only know one family of generalised octagons up to duality. The project here is to investigate “elation generalised quadrangles” and to explore small p -groups for “Kantor families”. If a new Kantor family is found, then a new generalised quadrangle will arise. We will also look for analogous objects to find generalised hexagons and octagons, or at least to discern the structure of such a group in small examples.

3. Foundations of hyperbolic geometry

Recently, Bamberg and Penttila have produced a simpler set of axioms for hyperbolic geometry in comparison to those by Menger and Skala. The aim of this project is to push the simplification even further, or to find an alternative (but equivalent) formulation.

Associate Professor Ju Li

See attached PDF for [Ju Li project 1](#)

See attached PDF for [Ju Li project 2](#)

Professor Kadambot Siddique

Title: Efficient root system for abiotic stress tolerance in crops

Plant survival and fitness are dependent on root system architecture (RSA). In Australia, root systems of major agricultural crops are poorly adapted to soils that mostly have poor water holding capacity and nutrient deficiencies. Decreasing water availability due to drying and variable climate in the Australia's grain-belt exacerbates these soil-related stresses. Development of future crop genotypes with efficient root system for enhanced abiotic stress tolerance is essential for improved crop adaptation. Root traits that overcome abiotic constraints are critical to maintaining structural and functional properties, and are considered first order targets in breeding programmes for rainfed environments. Root traits, such as deep root systems, increased root density in subsoil, increased root hair length and density and / or xylem diameters, may contribute to enhanced water and nutrient uptake. Narrow-leaved lupin genotypes with increased capacity to take up water from deep soil horizons were linked to increased yield potential; similar relationship exists in wheat, soybean and upland rice. Modification of RSA could contribute to improvements of desirable agronomic traits such as yield, drought tolerance, and resistance to nutrient deficiencies. Wide-scale use of root related genetic information in breeding programs relies on accurate phenotyping of relatively large mapping populations. Such large-scale phenotyping of root-related traits remain the most important issue in translating recent physiological and genetic advances in understanding the role of root systems in improved adaptation to abiotic stress and enhanced productivity of agricultural crops.

The candidate will be involved in measuring root systems of crop plants using some innovative techniques during the project period.

Professor Linqing Wen

Project 1:

Title: Detecting Gravitational Waves from Coalescing Binaries of Neutron Stars and Stellar-mass Black Holes

Overview: It is an exciting time for gravitational wave research. The first gravitational wave signal from merging binary black holes was detected in September 2015 during the first science run of the Laser Interferometer Gravitational-wave Observatory (LIGO) in the United States. This not only confirmed Einstein's theory on gravitational waves but also marked the beginning of a new era in astronomy. The second LIGO science run is scheduled in October 2016. Up to tens of new detections are expected from this run and many more are expected in the next few years.

We are leading one of the online detection pipelines for gravitational waves from coalescing binaries of black holes and neutron stars using detector data. Our group was actively searching for gravitational waves online using the LIGO data during the first science run where the first discovery was made. The group will continue to be actively involved in detecting gravitational waves in science runs of LIGO as well as the Virgo detector in Europe.

Projects:

- Directly involving in the online real-time searches for gravitational wave signals in LIGO/Virgo detector data
- Speed up of gravitational wave searches using high-performance supercomputing techniques including the use of Graphics Processing Units (GPUs)
- Testing Einstein's theory of general relativity using data of discovered gravitational wave events
- Optimizing future detector network to maximize the scientific potential of gravitational wave astronomy
- Analytically and numerically investigating new binary black hole merger models with potentially observable electromagnetic counterpart

Eligibility Criteria: We are looking for highly motivated applicants with interest in gravitational wave search and multi-messenger astronomy including gravitational waves. Background with astrophysics, high-performance computing and signal processing is desirable. For applicant with interest in search pipeline development, software programming experience using C/C++, Python are required, and programming ability for Graphics Processing Units (GPUs) is a plus.

Project 2:

Title: Detecting Gravitational Waves from Binaries of Supermassive Blackholes

Overview: A passing gravitational wave will affect the local space-time metric along the travel path of a radio wave emitted by a pulsar and can lead to observable fluctuations in its arrival time at the Earth. Pulsar timing arrays provide a unique means for the detection of gravitational waves from about 1 to 100 nanohertz. The first detection in this band is possible within a decade. The Parkes Pulsar Timing Array (PPTA) in Australia observes 26 millisecond pulsars at 2-3 weeks interval with regular monitoring commenced early 2005. PPTA is the world leader in nanohertz-frequency gravitational wave science. PPTA and its international counterparts in Europe and North America have also joined together to form the International Pulsar Timing Array (IPTA) collaboration.

Projects:

- Develop new methods to detect and localize gravitational waves in pulsar timing data

- Analyze data from the Parkes telescope and from the IPTA to search for gravitational waves from binaries of supermassive black holes
- Study the capacity of future radio telescopes, including FAST in China, and pathfinders for the Square Kilometer Array co-hosted in WA and South Africa in detecting gravitational waves and constraining the galaxy evolution model.

Eligibility Criteria: Background with astrophysics, high-performance computing and signal processing is desirable. Matlab skills and software programming experience using C/C++ will be very useful.

Associate Professor Mark Reynolds

Project 1:

Title: Automatic Identification of Bat Species from Recordings of Calls

Environmental impact assessments for such projects as new mines often need to gather data about the existence and numbers of animals that live in the area which might be affected. Many animals such as bats and birds can be identified from recordings of their calls (often overnight). However, it is a long and error prone process for humans to listen to recordings and identify the species heard. In this project we want to attempt to automate the process by using machine learning techniques such as Support Vector Machines and Artificial Neural Networks to identify the species from recordings. For training we have a large number of recordings already with species (manually) identified.

Experience with programming essential, and using machine learning packages with Python or Matlab is an advantage.

Project 2:

Title: Simulations with Autonomous Vehicles

There has been a lot of hype and hope on Autonomous Vehicles (AVs). However, there is little research on what impact they might have on the transport system at a macro level. For example, many are hoping for a large increase on road capacities because of the precision driving capacity of the machines. However, current research suggests that AVs are going to have limited impact if they are not connected. Other researchers have suggested that the performance is at the cost of passenger comfort. If parameters of AVs have to be tuned down to take care of the latter, then the whole system might suffer. Currently, microsimulation is the best way to answer these questions. Students will create customised AV simulation models and use those models for scenario testing.

Experience with programming essential.

Dr Matt Hipsey

Contacts: Dr Matt Hipsey and Dr Peisheng Huang

Project 1:

Title: Assessing estuary response to nutrient loading in a changing climate

Project Description: This project will first undertake training on set up and validations of an advanced 3D hydrodynamic-biogeochemical model for an estuary in Western Australia, and then run modelling scenarios to study the estuarine functional response to different nutrient loads. This will include assessing how the model is performing in terms of nutrient, oxygen and algal species predictions.

Background knowledge and skills: Familiarity with MATLAB or Python – students will need to run plotting and data processing scripts in these languages. Prior learning in the area of environmental engineering, or environmental science is necessary, and experience in hydrodynamics/hydrology and chemistry processes within river or coastal systems is desirable. Basic experience with LINUX and use of environmental models is desirable.

Project 2:

Title: The influence of wind sheltering on estuary greenhouse gas flux dynamics

Project Description: This project will first undertake training on set up and validation of a hydrodynamic-biogeochemical model for an estuary in Australia, and then assess prediction of Greenhouse Gas (GHG) fluxes to the atmosphere, including CO₂, CH₄ and N₂O. This will include comparing how GHG efflux will change depending on the surface meteorology.

Background knowledge and skills: Familiarity with MATLAB or Python – students will need to run plotting and data processing scripts in these languages. Prior learning in the area of environmental engineering, or environmental science is necessary, and experience in hydrodynamics/hydrology and chemistry processes within river or coastal systems is desirable. Basic experience with LINUX and use of environmental models is desirable.

Project 3:

Title: Modelling within the Global Lake Ecological Observatory Network

Project Description: This project will first involve training on how to use the General Lake Model (GLM) for selected lakes within the Global Lake Ecological Observatory Network. Students will then undertake ecosystem prediction and assess the results against high-frequency data from environmental sensors for the selected site.

Background knowledge and skills: Familiarity with MATLAB or R – students will need to run plotting and data processing scripts in these languages. Prior learning in the area of environmental engineering, or environmental science is necessary, and experience in limnology or reservoirs is desirable. Basic experience with calculus and the use of environmental models is desirable.

Dr. Matthias Leopold

Title: Paleosols – Life in ancient, buried soils

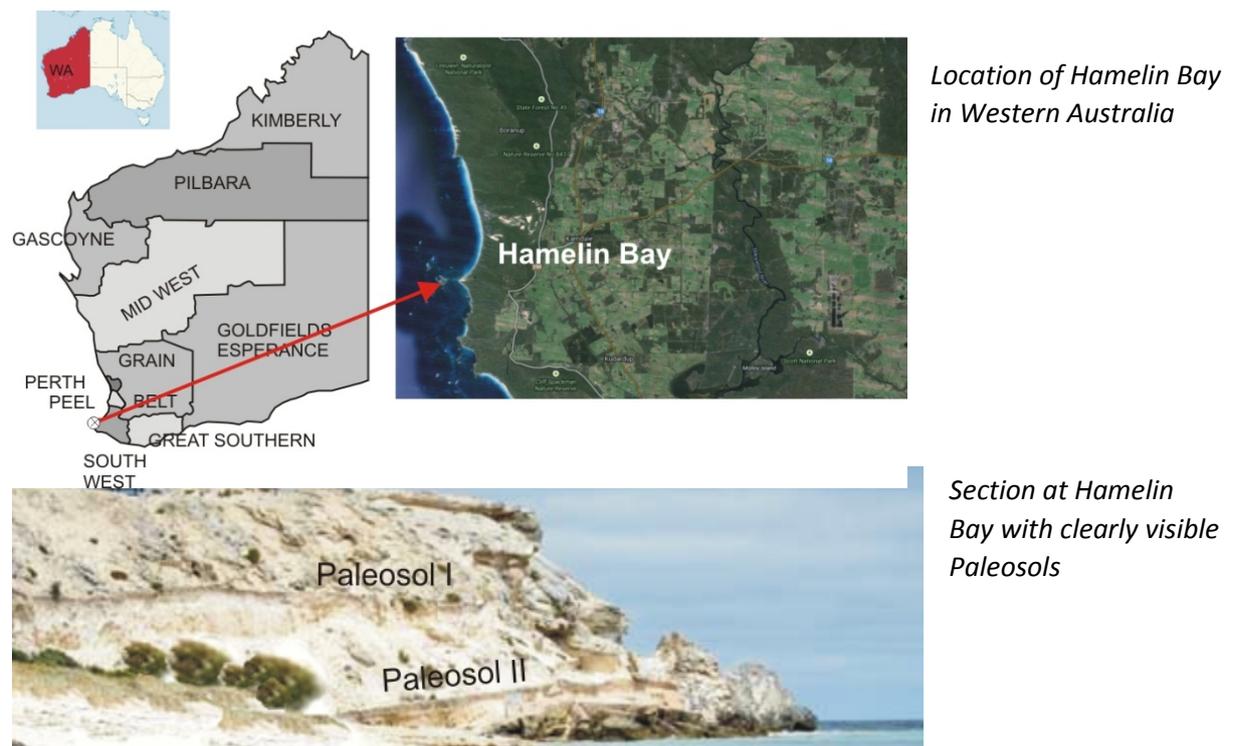
Paleosols are distinctly visible layers within sediment profiles that were once at the surface and underwent soil development processes prior to burial. Therefore, paleosols likely contain higher organic carbon and nutrient concentrations than the surrounding sediments which did not undergo soil formation. These higher levels of organic carbon will allow survival of the trapped microbial communities over geological timescales depending also on water availability.

We hypothesise that the paleosols contain higher organic carbon and nitrogen concentrations compared with the surrounding sediments and this allowed trapped microorganisms to survive resulting in a more diverse community and higher biomass compared with the surrounding sediment layers. We also hypothesise that the microbial communities within the paleosols differ from those in the topsoil.

To test these hypotheses, we will investigate the bacterial abundance (quantitative PCR) and community composition (next-generation sequencing) of two, several thousand year old paleosols and compare them with the surrounding sediment layers and the topsoil at Hamelin Bay (Western Australia). We will link this microbiological information with pedological (particle size, mineralogy, pedogenic oxides etc.) and chemical (pH, % C & N, etc.) soil data.

The ideal candidate has background knowledge and practical experience in either pedology or soil microbiology but more importantly should be interested in combining these two disciplines in this project. Strong knowledge of statistics and of statistical software (e.g. R project) will be required to analyse the data set.

Contact A/Prof Matthias Leopold (matthias.leopold@uwa.edu.au) or Dr Falko Mathes (falko.mathes@uwa.edu.au) to discuss aspects of this project.



Location of Hamelin Bay in Western Australia

Section at Hamelin Bay with clearly visible Paleosols

Dr. Mehrdad Kimiaei

Title: Dynamic response and fatigue design of steel catenary risers

Steel Catenary Risers (SCRs) are one of the most popular and cost effective types of risers for development of offshore fields in shallow to medium water depths. There are many engineering challenges for design of SCRs and main objective of this numerical research is to get a better understanding of dynamic response and fatigue design of SCRs. This study will be in continuation of the previous studies carried out at COFS on fatigue design of SCRs. Using Orcaflex and/or Sesam software, effects of riser-soil interaction and trench development in the touch down zone on structural response and overall fatigue life of the system will be investigated. This project suits the candidates who are interested in numerical modelling and have basic knowledge in structural and offshore engineering.

Dr Michael Considine

Project summary:

Plants have no fixed body plan and hence display a high degree of plasticity of growth in response to their environment. Underpinning this is the regulation of cell quiescence and proliferation, functions of the meristem. This plasticity is manipulated in crop production, for example the application of chemicals to stimulate and coordinate bud burst in grapevine. This study seeks to investigate the effects of chemical and physical treatments on plant growth. The project is largely directed at grapevine but uses model species such as Arabidopsis, where appropriate to advance knowledge. Your specific part of this project will be tailored by insights and data available at the time, together with your particular expertise and interests.

Expertise required:

Competence in biochemistry and/or molecular biology.

Professor Michael Small

Project 1:

Title: Singing voice detection. Essentially, we would study the methods of complex systems towards the detection of differences between human voice and an instrument, with singing voice detection as a possible application.

Singing voice detection - the task of detecting parts of a polyphonic audio containing one or several persons singing - is particularly useful for applications as audio segmentation, singer identification, real-time tracking and synchronisation or vocal extraction. A huge variety of audio features and selection methods have been proposed so far, which usually require high computational efforts making them unfeasible for real-time applications. In this project, we conjecture whether methods of nonlinear time series analysis can capture when a human voice is present (rather than an instrument) and then helping in the identification of the singing voice boundaries.

Project 2:

Title: Style-driven music composition by complex networks

In the past few years, the studied of music networks (where a music score is represented as a network of interacting notes) have helped in the modelling the note transition dynamics present in a music score. By performing random walks on those networks, one can generate new compositions that hopefully will preserve important properties of the original music while including some level of variety in the new compositions. This success of such task will basically depend on how well notes are explored during the random walk (say, as avoid preferences to hubs notes). While some variations of traditional random walks algorithms have been proposed, their applicability for style-driven generation of music content has not been explored yet. Thus, we intend to study if the random walks algorithms are suitable for the task of composing appealing music while preserving a particular style or a particular composer characteristic.

Project 3:

Title: Design of complex systems

Complex systems theory has been successful in explaining the evolution of complexity in social systems (for example, in social and evolving networks). Such explanations are inapplicable to engineering systems as this theory fails to account for the deliberately designed nature of such systems. By studying a variety of engineering systems and designs we hope to extend the approaches of statistical physics to understand such systems.

Project 4:

Title: Nonlinear diagnostic systems

Typical fault diagnosis is either statistical or linear, and relies on the decomposition of incoming data to frequency components for further diagnosis. We have developed nonlinear diagnostic methods that have been applied to physiological time series data to diagnose the imminent onset of

(among other things) cardiac arrhythmia and respiratory distress. Using the same theoretical foundation we are applying methods from nonlinear time series analysis and phase-space network analysis to identify mechanical wear and failure. Similar data analysis techniques also have potential for application in geophysical exploration and resource characterisation.

Project 5:**Title: Detecting dynamical changes in irregular sampled time series**

When observing a nonlinear system we often want to detect changes in the dynamics. Such changes might be changes in the frequency of the system or the change from periodic to chaotic dynamics. This task is often complicated by the presence of measurement noise and by irregular sampling of the dynamics, that is the time between two measurements is not fixed but random. In particular, Geological time series have gamma distributed measurement times, high levels of measurement noise and yet the main reason for collecting this data is to detect dynamical changes. Previously we used similarity measures between different sections of the observation data to detect dynamical changes. While this method successfully detects the different dynamical regimes, information theory will strengthen its foundation and hopefully allow us to develop a more sophisticated algorithm that gives us more robust results.

Project 6:**Title: Converting Time Series to Complex Networks**

Time Series measurements occur everywhere in Science and Society — electrocardiograms, financial market indicators, weather and climate patterns, seismic activity and laser dynamics are all typical examples. In many cases the system underlying the observed time series is a nonlinear deterministic dynamical system (and this is where we depart from statistical linear time series analysis). Such nonlinear and deterministic systems may give rise to chaotic dynamics. We are developing new methods to construct, from the time series, a network structure that represents the underlying system dynamics. There are a variety of different ways to do this, and right now we are trying to determine which is best. Roughly, each of these methods constructs a network where the nodes of the network are representative of distinct dynamical states. The question then is what can the quantitative measures of network science tell us about the underlying deterministic dynamics? How are measures such as assortativity, and betweenness (the Google page-rank algorithm — for example) related to properties such as bifurcation and unstable periodic orbits.

As well as exploring these properties on fundamental test systems (the usual chaotic dynamical systems undergoing bifurcation) we are also applying these methods to a variety of real experimental systems: electronic circuits and chaotic lasers, electrocardiogram dynamics and measures of seismicity. An interesting open question is how to extend these methods to look for synchronisation between signals or when one possess multi-dimensional time series.

Professor Michael Tobar

Project 1:

Title: Transfer of quantum encoded information between microwave and optical frequencies

Supervisors: Prof. Michael Tobar, Dr. Maxim Gorychev plus others TBA

In the future quantum communication networks will distribute entangled states over a large scale computing architecture [1,2]. The core elements of future quantum networks, i.e., quantum repeaters [3] as well as network nodes, can be realized by using qubits and quantum memories of diverse physical nature [4,5]. Today, elementary quantum networks linking two remote single atoms have been demonstrated [6,7]. Solid-state systems such as superconducting quantum circuits [8], nanomechanical devices [9], and spin doped solids [10] potentially offer larger scalability and faster operation time compared to systems based on the single atom approach. However, such solid-state devices operate at microwave and radio frequencies, which are less suitable for long-range quantum communication than optical channels due to losses in cables and the high noise temperature of antennas of about 100 K for radio-relay communication. To establish a fiber-optical link between them, one has to use a quantum media converter, i.e., a device, which coherently interfaces matter and photonic qubits. One of the promising ways towards implementation of such a converter relies on using optically active spin ensembles in a hybrid quantum architecture [15–17]. Among these, rare-earth (RE) ion doped crystals are very attractive for application in hybrid systems due to their high spin tuning rate [18] and long optical and spin coherence time [19–21]. Yet only erbium ions offer a unique opportunity of a coherent conversion of microwave photons into the telecom C band at 1.54 μm , which is used for long distance fiber-optical communication.

This project will see the expertise of FQM group on microwave whispering gallery mode resonators combine with German expertise in optics at Saarland University in Saarbrücken, create one of the first quantum microwave---optical convertor using Erbium spins in crystals, which will be developed as both microwave and optical whispering gallery mode resonators. The research will investigate different crystal hosts such as YAP and YSO, which are yet to have the dielectric properties characterized in the microwave. The end goal will be to resonantly couple to both the microwave and optical transitions simultaneously, achieving strong coupling. The FQM group has funding for the necessary exchange between institutes, with equipment funding existing through the ARC CoE in Engineered Quantum Systems.

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Project 2:

Title: Vibration isolation for cryogenic optomechanics experiments

Supervisors: Dr. Jeremy Bourhill, Prof. Michael Tobar, Dr. Maxim Goryachev, Prof. Eugene Ivanov

Optomechanical experiments produce coupling between mechanical motion and electromagnetic radiation (light). By measuring the frequency shift of the latter, produced by the mechanical motion, one can infer the mechanical state of the device. In fact, these measurements can be made so sensitive as to enter the quantum regime - becoming limited by Hysenberg's uncertainty principle, if the thermal noise of the motion is removed via conventional cryogenics. With this level of accuracy, a plethora of fascinating fundamental and applied experiments can be performed, such as tests on quantum gravity, and microwave to optical conversion.

This project would focus on the construction and design of a vibration isolation system to be fitted inside the lab's existing dilution refrigeration units. This piece of infrastructure is essential for the removal of seismic and vibrational noise in optomechanical experiments.

This project is funded by a \$600,000 AUD ARC Discovery Project and by the ARC Centre of excellence in Engineered Quantum Systems.

Project 3:

Title: Rotating Lorentz Invariance Experiment using Precision Frequencies

Supervisors: Prof. Michael Tobar, Dr. Maxim Goryachev, Prof. Eugene Ivanov

Despite the remarkable advances made in physics during the 20th century, several major unsolved mysteries continue to perplex scientists. One of the significant problems is the incompatibility between our understanding of particle physics and gravitational physics. Attempts to unite these two sectors in to one comprehensive theory often predict that miniscule deviations from current physical laws could occur. Extremely sensitive measurements are required to probe different areas of physics to search for hints of these new effects and help shape the direction of theoretical research.

One of these potential effects is a violation of Lorentz invariance. Recently in collaboration with UC Berkeley, we undertook the FIRST test of Lorentz Invariance of phonons [1]. This is the analogue to a Michelson-Morley test of photons to test the constancy of the speed of light. The oscillating phonons allow us to test the Lorentz Invariance of neutrons rather than photons. This first test was implemented using "off the shelf" room temperature quartz oscillators. In our laboratory we have oscillators, which are at least an order of magnitude better than these. Furthermore, we will

investigate cryogenic versions of the experiment, with the potential to improve on these results by four orders of magnitude, which result in a sensitivity range where new physics may be detected at the Planck suppressed electro-weak scale [2].

This experiment will involve generating precise frequencies in the lab at room temperature and cryogenic temperatures, as well as building a rotating table to test the isotropy of the phonons. The student will need to use Python, matlab, etc, to control the experiment and take data. The student will learn how to analyse data to search for new physics, with important publications resulting from this work.

This project is funded by a \$600,000 AUD ARC Discovery Project

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Project 4:

Title: Direct Detection Dark Matter Experiments in the Lab

Research Group: Frequency and Quantum Metrology

Supervisors: Prof. Michael Tobar, Prof. Eugene Ivanov, Mr. Ben McAllister

The composition of dark matter is one of the greatest outstanding issues in physics.

One of the most promising dark matter candidates is a hypothetical family of particles referred to as the Weakly Interacting Slim Particles (WISPs). These particles have origins in particle physics yet also make excellent dark matter particles. They are extremely light (sub-eV masses) and interact gravitationally and very weakly with current standard model particles.

Efforts to search for WISPs typically involve exploiting WISP-to-photon coupling mechanisms, which provide a powerful portal to detection with minimal model dependency. Cosmological constraints restrict the generated photon frequencies to a regime focused on the RF and microwave spectrum. Such low energy signals are well suited to lab-based precision measurement.

Here at UWA we are working on direct detection experiments searching for cold dark matter WISPs. We are looking for capable and motivated students to join our team and work at the forefront of this exciting field of modern physics. There will be opportunities to develop skills in a variety of areas, including microwave electronics, low noise measurement techniques, low temperature (sub-mK) systems, quantum-limited measurements and electromagnetic simulations and theory.

Contact michael.tobar@uwa.edu.au for further information or to discuss any aspects of the projects.

Professor Mikhail Kostylev

Project 1:

Title: Investigation of spin wave scattering from nanometre-size non-uniformities (theoretical)

Spin waves (or magnons in quantum picture) are waves of magnetisation in magnetic materials. Technologically important are materials in the form of multilayered films containing layers made from magnetic and non-magnetic metals with thicknesses 0.5-100 nm. They are mostly studied because of their importance for future applications in magnetic logic [1], microwave nano-oscillators, microwave meta-materials and in novel sensing applications [2,3].

Many of those applications will rely on scattering of spin waves from uniformities of magnetic environment of a film, as, for instance, in [1]. So far, the problem of calculation of spin wave scattering has been solved in 1 dimension only[4]. The goal of the proposed project is to attempt to solve a two-dimensional problem rigorously and (quasi)-analytically. It is anticipated that very interesting effects, such as formation of spin wave caustics [5] from the scattered spin wave field will follow from this solution.

In the framework of this project the student will first derive analytical expressions which govern the two-dimensional magnetisation dynamics. Once the equations have been obtained, the student will produce a numerical code to implement this model. A choice of different programming environments will be available for this purpose – MathCAD, Matlab or Wolfram Mathematica.

If successful, this project will result in a publication in a high-impact physical journal, such as Journal of Applied Physics. Required background knowledge: good command of electrodynamics, some idea of magnetism.

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Project 2:

Title: Investigation of a perfect microwave shielding effect in multilayered ferromagnetic films (experimental)

Broadband stripline ferromagnetic resonance (BSFMR) [1] is an emerging powerful tool with which to study magnetic films for various applications, such as magnetic memory, logic and microwave signal processing.

In our previous work [2] we unexpectedly found that BSFMR response of metallic ferromagnetic multilayered films is strongly affected by the effect of microwave electromagnetic shielding by eddy currents circulating in the film, although the thickness of the films we studied was significantly smaller than the microwave skin depth.

Recently, we constructed a complete theory of this effect for the case of single-layer films [3]. (This was a work by a visiting student from Nanjing University.) Currently we are working on extending this theory to the case of multilayered films.

The goal of the proposed will be experimental validation of the theory. The student will fabricate a number of multilayered ferromagnetic films, such as NiFe/Co, NiFe/Ni, Co/NiFe/Co, Ni/NiFe/Ni, Co/NiFe/Ni etc., measure their ferromagnetic resonance response with our BSFMR setup, fit the data with the theory for the multilayered films whose construction will be completed by the time of commencement of this experimental project and interpret the experimental findings in this way.

If successful, this project will result in a publication in a high-impact physical journal, such as Journal of Applied Physics. Required background knowledge: understanding of electrodynamics, some idea of magnetism.

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Professor Murray Baker

See attached PDF for [Murray Baker project](#)

Professor Paul Low

See attached PDF for [Paul Low project](#)

Professor Reto Dorta

See attached PDF for [Reto Dorta project](#)

Dr Shiaohuey Chow

Title: Triaxial investigation of undrained behaviour of carbonate sand

Offshore renewable energy devices are typically located in shallow water (<30 m) with sandy sediment. In order to produce cost effective foundations for these devices, correct identification and prediction of the sediment behaviour are essential. The behaviour of these sandy sediments is governed by their drainage condition (how well water drains from the soil pores), which can be categorised into three regimes: drained, partially drained and undrained. For an offshore foundation, the soil drainage condition has been found to depend on the hydraulic conductivity of sand, size of the foundation and loading (shear) rate. The sand behaviour will move from drained to undrained regime as the hydraulic conductivity reduces, and as the foundation size and shear rate increase. Due to the relatively high hydraulic conductivity of sand, existing works have focused on their drained behaviour. However, undrained behaviour is mostly expected under transient (wave-induced) loading offshore, where the sandy sediment is typically at least medium dense with lower hydraulic conductivity, in combination with the large foundation size and high shear rate. Hence this study will investigate the undrained behaviour of sand and the factors affecting this behaviour (e.g. sand density and stress level) using triaxial tests. In particular, this study will focus on studying the behaviour of carbonate sand, which is commonly found in Australian waters (e.g. North West Shelf) and international waters (e.g. North Sea, Arabian Gulf).

Background knowledge and skills

- Civil engineering/geotechnical engineering
- Laboratory/experimental skills

Professor Ryan Lowe

Project 1:

Title: Numerical modelling of oscillatory (wave-induced) flow in coastal canopies

Over the past decade a number of studies have investigated how coastal canopies formed by aquatic vegetation (e.g. salt marshes, seagrasses, etc.) can modify nearshore hydrodynamic processes. Coastal canopies are found to attenuate wave energy and reduce the turbulent flow inside the canopy that interacts with the underlying seafloor. This latter effect is believed to be crucial for a number of important coastal processes, such as sediment and nutrient transport. However, most numerical models used in coastal engineering / oceanography do not incorporate this effect yet.

In this project two state-of-the-art coastal models will be applied to study the wave-induced flow in and above coastal canopies: XBeach and SWASH. XBeach (www.xbeach.org) is a two-dimensional, horizontal (depth-averaged, 2DH) process-based coastal engineering model that is able to simulate waves, currents, sediment transport and coastal evolution. Recently, XBeach was extended with a vegetation module that includes a coupling with a canopy flow model. SWASH (<http://swash.sourceforge.net/>) is a state-of-the-art three-dimensional (3D) nearshore model for simulation of waves and currents. SWASH also includes a recently developed vegetation module.

The objective of this project is to better understand the dynamics of wave-driven canopy flows that is relevant for many coastal ecosystems around the world. One of the key research questions is whether a 2DH approach may be sufficient to capture the relevant physical coastal processes in these systems, or that a 3D approach is required to obtain accurate results. The 3D model will also be used to study the velocity profile in coastal canopies in more detail. To validate the models, the student will make use high resolution wave data that was collected during a number of experiments in the Hydraulics Lab of the University of Western Australia.

For this project, previous experience with MATLAB/PYTHON and numerical modelling is preferred. The project will be supervised by Prof Ryan Lowe, Arnold van Rooijen (PhD student), and Dr Dirk Rijnsdorp.

Project 2:

Title: Modelling the coastal impact of wave energy converters

With increasing energy demand in most countries and the growing concerns for climate change, governments worldwide are aiming to transition from fossil fuels towards renewable energy resources. Wave energy, being one of the most concentrated and consistent forms of renewable energy, forms one of these potential new energy sources. To efficiently harness the power of the sea, the optimal location of wave energy converters (WECs) is thought to be in a nearshore region, where they will be clustered in large arrays (forming so-called WEC farms). Several studies hypothesised that such WEC farms can act as a coastal defence as they will reduce the wave height near the coast. Although their coastal impact has received increasing attention in the past decade, it remains unclear if such farms actually serve as a coastal defence or, to the contrary, can have detrimental coastal impacts.

To date, such studies relied on spectral (phase-averaged) wave models like SWAN, which do not account for all relevant physical processes that affect the wave field in the coastal region. Therefore, we still lack a detailed understanding of the coastal impact of such WEC farms. In this project, the more advanced (state-of-the-art) non-hydrostatic wave model (SWASH) will be used to tackle this challenging problem. This model provides a powerful tool to resolve the evolution of the waves at the scale of a realistic coastal region (intrinsically accounting for wave processes like shoaling, refraction, diffraction, nonlinear wave-interactions, and wave breaking). Furthermore, it was recently extended to account for the wave-structure interactions. Conceptually, this is one of the first models that can resolve both the nonlinear wave evolution and the wave-structure interactions at the relevant spatial and temporal scales. The project will be supervised by Professor Ryan Lowe and Dr. Dirk Rijnsdorp

Professor Tim Colmer

Title: Waterlogging tolerance in chickpea – assessment of anoxia tolerance

Chickpea is sensitive to soil waterlogging. Survival of root tips and of lateral roots during anoxia (zero oxygen) needs to be assessed. Anoxia occurs in soils when waterlogged, since microorganisms consume any oxygen and the water impedes the inwards diffusion of oxygen from the air. Root tip survival likely depends on the capacity for ethanol fermentation to produce energy (ATP produced in glycolysis), but the capacity for ethanolic fermentation in chickpea roots should be evaluated. Evaluation of responses of root respiration and growth to declining oxygen supply would also enhance our understanding of the stress faced by the roots. Identification of genotypes with contrasting tolerance would be an important outcome.

Who will this project suit?

Students interested in plant physiology wanting to understand how plants function and to develop high-level skills in laboratory research techniques.

Supervisors

Prof. Tim Colmer (timothy.colmer@uwa.edu.au) and Dr. Lukasz Kotula (lukasz.kotula@uwa.edu.au)

Tim Colmer collaborates with Prof. Nakazono and Prof. Ashikari at Nagoya University. He has visited Nagoya for 2 weeks each year for the past few years.

Reading *(We have previously worked on wheat and rice, but currently have a project on chickpea. The papers below are on wheat, but we now need to test some of these processes in chickpea)*

Goggin DE, Colmer TD. 2007. Wheat genotypes show contrasting abilities to recover from anoxia in spite of similar anoxic carbohydrate metabolism. *Journal of Plant Physiology* 164: 1605-1611.

Herzog M, Striker GG, Colmer TD, Pedersen O. 2016. Mechanisms of waterlogging tolerance in wheat - a review of root and shoot physiology. *Plant, Cell & Environment* 39: 1068-1086.

Professor Thomas Braunl

Project 1:

Title: Embedded Robotics

Suitable for: Computer Science, Software Eng., Electrical Eng., Mechatronics Eng.

Required: Good programming skills in C or C++ are a prerequisite for this project.

See details: <http://robotics.ee.uwa.edu.au/eyebot7/Robios7.html>

We are using a more advanced version of the lab-robots you know from Embedded Systems. These are based on a Raspberry-3 controller, using vision, PSD distance sensors and a color display. For this project we are looking at implementing practical robot applications in the following areas:

- Autonomous navigation and path planning software
- Establishment of Robotics image processing library for visual navigation

Project 2:

Title: Visual Hardware Design

Suitable for: Computer Science, Software Eng., Electrical Eng., Mechatronics Eng.

Required: Good programming skills in Java and some digital hardware skills are a prerequisite for this project.

See details: <http://robotics.ee.uwa.edu.au/retro/>

Retro is a hardware simulation system on register-transfer level; including registers, function units, memory units. Working CPUs can be created by using a graphics editor from library components. System has been designed for educational purposes and is routinely used in teaching labs at a number of universities.

Project goals:

- Add new components to hardware simulation system
- Build simulated SIMD parallel processing system using simple processing elements

Associate Professor Vincent Wallace

Title: Terahertz Biomedical applications

Description: Terahertz (THz) typically refers to the electromagnetic waves with the frequency ranging from 0.1 to 10 THz and the wavelength is between 30 to 3000 mm. Due to the lack of coherent sources, these frequencies, situated in the spectrum regime between optical and electronic techniques, were referred to as a THz gap. Nowadays, more and more techniques have been investigated to bridge this gap, and the applications of Terahertz cover a wide range from astronomy, security check to chemical and biomedical applications. Terahertz is strongly attenuated by water, thus very sensitive to the change of water content in biological tissues. Unlike X-ray, the photon energy of terahertz is very low that it does not pose any ionization hazard for human beings. Moreover, some collective inter-molecular vibrational modes lie in the terahertz frequencies. These unique features have made it a potential tool in biomedical research field. The student will work with a team of researchers on developing THz technology for biomedical applications which can involve data collection and processing, development of analysis and software interfaces.

Background: Students with electronics, physics, biomedical engineering or other related backgrounds are welcomed.

Skills: General knowledge in electromagnetic wave theory, physics and optics, signal processing, MATLAB or other coding language.