PROJECTS FOR THE 2016 UWA-USTC & NANJING RESEARCH TRAINING PROGRAM

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# Assistant Professor Amir Karton

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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 pubic 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 chose 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.”

# Dr. Barbara Catinella and Dr. Luca Cortese

**The gas cycle of galaxies - paving the way to FAST & SKA**

Hydrogen gas is a key component of galaxies - it is the fuel out of which new stars are formed, hence it plays a crucial role in the formation and evolution of galaxies. The next-generation radio surveys with the Square Kilometre Array (SKA) and its pathfinders will usher in a new era for extragalactic studies, allowing us to measure the gas content for millions of galaxies. In addition to measuring the 21 cm emission from atomic hydrogen (HI), improvements in radio instrumentation open the exciting possibility of detecting emission from other molecules, such as hydroxyl (OH), in large numbers of "normal" galaxies, thus providing further insights into the link between interstellar medium and star formation.

This project will explore the feasibility of detecting OH emission from galaxies observed by ALFALFA, the state-of-the-art HI survey carried out with Arecibo, the largest single-dish radio telescope currently available. The student will construct the best sample for this task by identifying the galaxies within the survey volume (with HI detections or not) whose OH emission would fall within the frequency interval probed by ALFALFA. Although the OH signal from individual galaxies is not detected by ALFALFA, the ensemble signal of a large sample of galaxies might be.

In addition to addressing an intriguing scientific question, this project will allow the student to familiarize with single-dish HI data. This expertise will be important to scientifically exploit the upcoming HI surveys with the Five-hundred-meter Aperture Spherical Telescope (FAST) being built in southern China, which will essentially be a scaled-up version of Arecibo.

# Dr. Britta Bienen

**Foundation capacity under combined vertical, horizontal and moment loading in layered soils**

Almost half of the offshore drilling activity in the oil and gas industry worldwide is performed by jack-up rigs (rigzone 2014). These platforms (Fig. 1) are not custom-designed for one particular location but rather rated for water and drilling depths. Therefore, a site-specific assessment is required prior to each relocation to demonstrate that the rig can withstand the storm loading at that location. Predictive methods are available for relatively simple soil conditions comprising of either sand or clay, which are predominant in the areas of early offshore development in the North Sea and the Gulf of Mexico, respectively. However, in most offshore regions including Australasia, soil profiles typically consist of layered deposits of different strengths. No prediction models exist for these conditions, which exposes these US$200M rigs to significant risk. The lag of fundamental science to support guideline recommendations became evident in the joint industry project InSafe (Osborne et al. 2009, 2011), which aimed to benchmark state-of-the-art predictive methods against field data – the vast majority of which featured layered soil strata.

*Figure 1: From site investigation to prediction of foundation response under VHM loading.*



The development of predictive methods that can capture the effects of soil layers has been hampered by the complexity of the problem and limitations in research techniques. The proposed research will establish fundamentally new scientific understanding as it will, for the first time, reveal the failure mechanisms that govern foundation capacity in layered soils (Fig. 1). These insights will have impact far beyond the example application selected here but advance knowledge in a classical area of geotechnical engineering: foundation response under general loading.

The research will rely on numerical analyses, such that skills in finite element modelling are desirable. Over the course of the project, the foundation response will be established under a variety of load paths and for a number of soil layering systems. The results will form the basis of capacity envelopes for foundations under combined loading, with previous research in this area (Fig. 1) now forming part of international guidelines (ISO 2012).

# Professor David Coward

**Project 1:**

**Title: Gamma ray bursts as probes to the distant Universe.**

Gamma ray bursts are the brightest explosions in the Universe and there is growing evidence that there are several types of bursts that relate to their progenitors. There is still many outstanding questions that remain unsolved. The project will investigate various observed correlations between the optical and high energy emissions of gamma ray bursts. This could lead to confirmation of models that predict some GRBs are related to the merger of massive stars as opposed to the collapse of single stars.

Experience and skills: background in astrophysics and computational/astrophysical and statistical modelling and a keen interest to explore new ideas.

**Project 2:**

**Title: Searching for hazardous Space Junk, 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. Because the Zadko Telescope is directly linked to NASA satellites, the student will also have the opportunity to work on analyzing gamma ray burst optical afterglows using nearly real-time data from the Zadko Telescope.

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.

# Dr. Du Huynh

Note: Below are 3 projects but Dr. Du can only take up to 2 students.

**Project 1:**

**Title: Assessment of Fundamental movements using the Kinect Sensor**

Supervisor: Dr Du Huynh

The aim of this project is to obtain objective estimates of 7 to 11 year old children’s movement proficiency using the Microsoft Kinect Sensor. We propose to develop a software driven tool that can interpret movements from videos captured by the Kinect Sensor while children perform four fundamental movements. The innovation behind the Kinect hinges on advances in skeletal tracking. In computer generated skeletal tracking, a human body is denoted by a number of joints representing body parts, each of which is further characterised by its 3D coordinates. The Kinect Sensor captures the positions of 20 body joints every 30 seconds in three-dimensional space, providing an accurate representation of the major body segments. The Kinect Sensor’s skeletal tracking ability is designed to work for every person on the planet, in every household, without any calibration. We have already developed software capable of capturing Kinect Sensor data to count the range and frequency of different movements (for example, jumping, throwing and sidesteps) while children play movement-based video games. However, the current software is unable to process the more complex task of determining the quality of children’s movements. Taking on this project, the student is expected to apply machine learning and computer vision techniques with the software development phase of the research. The results of this project will contribute towards a validated objective measurement tool for determining children’s movement proficiency using off-the-shelf hardware and tailored software.

Prior skills required: Knowledge on the Matlab programming language is essential. Basic understanding of image processing and computer vision is desirable.

**Project 2:**

**Title: Visual tracking using sparse appearance models**

Supervisor: Dr Du Huynh (CSSE)

The aim of this project is to track an object in videos. The focus is on how to represent the object to be tracked so as to better handle partial occlusion and changes in appearance of the object. One of the techniques is to have a number of canonical representations of the object (in the form of templates) and adaptively update the representations along the way. Other issues to research on include how to minimize the number of templates and the update criteria and frequency. This project suits those students having some background in optimization techniques.

Prior skills required: Knowledge on the Matlab programming language is essential. Basic understanding of image processing and computer vision and knowledge in C/C++ are desirable.

**Project 3:**

**Title: Evaluation of state-of-the-art object tracking methods**

Supervisor: Dr Du Huynh (CSSE)

The aim of this project is to evaluate many state-of-the-art object tracking method. The performance of these methods under change of illumination, partial occlusion of the tracked target over a number of video frames, and whether object detection is required in the tracking process will be studied and compared using standard benchmark datasets. You will need to have some basic knowledge on image processing. It is essential that you have good Matlab programming skills. Basic knowledge in C/C++ is also desirable.

Prior skills required: Knowledge on the Matlab programming language is essential. Basic understanding of image processing and computer vision and knowledge in C/C++ are desirable.

# Associate Professor Duncan Wild

**Photoelectron spectroscopy of gas phase anion-molecule complexes**

This project will be undertaken in the research group of Dr Duncan Wild and involves spectroscopy of gas phase anion-molecule complexes. The rate and direction of chemical reactions are determined by the potential energy surface governing the interactions between the species. Using photoelectron spectroscopy of gas phase anion-molecule complexes allows us to probe the neutral potential energy surface. In this project, you will be involved with studies of fundamental species with Nitrogen and Sulfur containing molecules attached to an anion. These species have relevance for the chemistry occurring in our atmosphere, and that of distant celestial bodies. This project is flexible in that you can choose the systems to investigate! The idea behind the experiments is:

1) Create exotic gas phase anion-molecule clusters.

2) Mass select a specific cluster using TOF mass spectrometry

3) Record a photoelectron spectrum using laser radiation.

We have built up our own spectrometer which incorporates a mass spectrometer (time of flight) and a magnetic bottle photoelectron spectrometer, and you will be able to work on this apparatus alongside other students in the group. You can also be involved with quantum chemical calculations on the experimental targets.

Please look to our group website for more information, or Facebook page.

http://laser.scb.uwa.edu.au

https://www.facebook.com/UWALaserSpectroscopyGroup

Required skills: Good basis in Chemistry, Physics, Mathematics.

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

**Transistor-based biosensors for disease identification and drug discovery**

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

Description:

The ability to monitor biological and chemical signals with an electronic device is a tremendously innovative approach for cell research and process control in pharmaceutical and microbiological production. Biofriendly, chemically inert and stable III-Nitride-transistor based biosensors are under development to detect specific biological markers to indicate processes such as disease markers or drug interactions. The successful development of this electronic biosensor technology has the potential to improve health and disease treatment through major improvements in throughput, precision, quality, speed and simplicity of, for example, drug and disease testing methods. Places are available for multiple students to work on the one or more of following integrated project components:

1. Physical, chemical, materials and biological characterisation of functionalisation methods, particularly surface and cell studies
2. Electrical, chemical, biochemical and physical characterisation and optimisation of functionalized 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, chemistry, physics or nanotechnology/nanoscience. Prior studies/experience in semiconductor device physics, biosensors or chemical sensors is desirable though not essential.

# Professor Jingbo Wang

**See attached PDF for** [**Jingbo Wang projects**](file:///P:\OVC\ovc_share\INTERNATIONAL%20RELATIONS%20(N&SE%20ASIA)\WORKING%20FILES%20-%20JERLINE%20CHEN\UWA-China%20Research%20Training%20Program\Projects_Jingbo%20Wang_2016.pdf)

# Professor Kadambot Siddique

**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-leafed 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(s) to be confirmed

# Associate Professor Michael Giudici

Research projects in the Centre for the Mathematics of Symmetry and Computation

Members of the Centre conduct research in group theory and combinatorics. Group theory is the mathematical abstraction of symmetry and one can use groups to understand combinatorial structures such as graphs or geometries, or one can use combinatorial structures to understand groups.

Members of the Centre are willing to supervise a project on the topic of group theory or combinatorics, or some combination of the two. Possible projects include:

* Graphs with certain symmetry properties, such as Cayley graphs or vertex-transitive graphs;
* Configurations in finite geometries;
* Permutation groups;
* Algebraic graph theory.

Projects have the potential to involve the use of computation through computer algebra packages such as GAP or Magma. They will also involve learning the research and publication process including the use of tools such as Math-SciNet to search the literature, LATEXto typeset mathematical papers, and arXiv for their distribution.

We are looking for students with a mathematics major with some evidence of coursework in group theory or combinatorics.

More information about research in the centre can be found at <http://www.cmsc.uwa.edu.au/research>

# Professor Michael Small

**Project 1:**

**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 2:**

**Title: What does a Random Complex Network "look" like?**

Complex networks are becoming increasingly prevalent. From online and real social networks, to disease propagation networks, transportation networks, gene expression and metabolic networks, and communication networks. Our aim is to understand how such systems work by studying their fundamental structural properties.

A complex network is nothing more than a mathematical graph. Vertices (or nodes in the nomenclature of complex systems science) are connected via links (or edges). These edges can be either directed or undirected and weighted or unweighted. For simplicity we usually consider the case of unweighted and undirected edges. Hence, the structure of the network can be represented by a symmetric binary matrix. Several specific network structures have attracted particular interest. Among these are the small-world network (where nodes are typically connected so that the neighbours of a node are often neighbours themselves — and yet the average path-wise distance between random nodes is small) which is an embodiment of the "Six-degrees of Separation" phenomenon; and, scale-free networks (where the probability of a node having k links follows a power law — it is proportional to kγ for some exponent γ>0).

Algorithms exist to construct complex networks of these types. Scale-free networks, for example, can be constructed by the growth process of preferential attachment. New nodes are added with links linking to existing nodes with probability proportional to the number of links the existing nodes already have. This process lead to the rich (highly connected) nodes becoming richer still — this is the so-called Pareto principle. While constructing networks in this way asymptotically converges to the required power-law it is not necessarily the most likely way of doing so. A natural question is what to typical networks look like? And, how do their properties differ?

We are currently developing algorithms based on maximum likelihood principles to address both these issues. Our results, to date, indicate that in many ways the preferential attachment procedure is actually rather atypical. Application of these methods arise in all areas of science ond engineering where complex interacting systems occur — communication systems, power grids, complex mining operations, social systems and the internet.

**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: Distributed control of autonomous vehicles: Autonomous, or remotely controlled**

Autonomously or remotely controlled vehicles are an increasingly common feature of engineering for remote operations in the resources sector. However, these machines are usually scaled to ensure cost efficiency of the (now possibly absent) human operator. Moreover, entirely remote operations are neither efficient nor desirable. In all situations, some level of local autonomous control is required both for reasons of safety and efficiency — by removing the assumptions of scale inherited from human operators, autonomy of individual agents in a larger fleet of smaller vehicles is also necessary. Using concepts from agent based-modelling, collective dynamics and emergent behaviour, we are applying modelling and analysis methodologies from flocking behaviour of complex systems to mining operations. There is also increasing realisation that resource collection at mine-site is not thoroughly tracked and information (concerning quality or grade) should be feedback from the processing stage to inform and optimise collection – an integrated and system-level understanding of the operation and the effect of geological control on downstream performance will allow for improvements in dynamic control and optimisation.

# Professor Michael Tobar

**Project 1:**

**Title: Coherent Microwave to Optical Converter using Magnetic Materials**

Transferring coherent quantum limited signals between microwave and optical frequencies has become very important for the future transfer of quantum-encoded information. This project will see the FQM group team up with UQ to investigate a completely new way of achieving this through the implementation of low-loss magnetic materials coupled to unique resonant cavity designs.

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]. The latter potentially offers 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 spins and photonic qubits.

This work is based on a new idea to use low-loss magnetic material to achieve this. Magnetic material is used at both optical and microwave frequencies, and we will combine both of these properties to realize this device. For example yttrium iron garnet (YIG) is in high use as a frequency determining element for filters and resonators for oscillators, YIG is a ferrite with very high resistivity and a sharp ferrimagnetic resonance. These properties allow YIG resonator oscillators to achieve DRO-like phase noise performance and very wide tuning ranges, for example 2-20 GHz tunable oscillators are available. High performance, with unloaded Q factors of greater than 1000 is achieved and demands that a resonator that is a highly polished sphere or ellipsoid made from a single crystal of YIG.

Also YIG is used in optical, and magneto-optical applications i.e. optical isolators through the implementation of the Faraday effect, so is polarization dependent. It is transparent for infrared light wavelengths over 600 nm. It also finds use in solid-state lasers in Faraday rotators, in data storage, and in various nonlinear optics applications. Thus, we propose to use both these microwave and optical properties to engineer the microwave to optical conversion. The conversion must be implemented in the strong coupling regime. Recently the FQM group combine with the group of Mikhail Kostylev in the School of physics have achieved the Ultra-Strong Coupling regime at microwave frequencies at low temperatures. This work has been patented and describes a new innovative way of designing the microwave resonant cavities using a multiple-post reentrant cavity technique [11]. The next step will to be to utilize this result to create a converter by adapting a resonant device to work simultaneously at optical and microwave frequencies. This new technique offers many advantages.

The types of cavities we will look at include our newly invented two post reentrant cavities [12] and Whispering Gallery Mode resonators, which we have already used for spin doped measurements [13-15]. Magnetic materials have a significant advantage over systems which utilized doped spins in a crystal host [13-15], namely that the majority of the host ions contribute to the magnetism, rather than a low concentration of impurity spins. This has allowed us to recently obtain the ultra-strong coupling regime [12], this paper has been held up while a patent application has been under submission.

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**Project 2:**

**Title: Direct Detection Dark Matter Experiments in the Lab**

Research Group: Frequency and Quantum Metrology

Supervisors: Dr. Stephen Parker and Prof. Michael Tobar

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 stephen.parker@uwa.edu.au for further information or to discuss any aspects of the projects.

**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 leas 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.

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# Professor Michael Wise

**Relative Codon Adaptation as a Marker of Horizontal Gene Transfer and its Use for Building Phylogenetic Trees**

In all species, when the DNA is being used to encode a protein, DNA triplets (or “codons”) are read off and translated into the corresponding amino acids, which are joined together to form proteins.

A great deal of redundancy is built into this translation process, e.g. the codons: CCA, CCC, CCG and CCT each encode the amino acid proline. This is perhaps not so surprising when you realise that the 43 possible codons encode only 20 amino acids. However, the level of redundancy is not uniform, with certain amino acids having just a single encoding (methionine, tryptophan) while others have six (leucine), presumably reflecting greater numbers of the corresponding anti-codons. Furthermore, different species have preferences about which encodings they prefer to use, so, for example, engineering the encoding of the polio virus capsid protein to use less favoured codons resulted in a significant attenuation of the virus (Mueller et al., J. Virol 2006). The Codon Adaptation Index (CAI) was developed some years ago to measure how optimally a gene is encoded (Sharp and Li, Nuc. Acids Res. 1987). Given the species specificity, researchers have tried to use CAI differences to identify genes that have arrived in a host genome through Horizontal Gene Transfer (HGT). Such attempts have so far proven to be unsuccessful; A number of studies in bacteria have found that low CAI is not necessarily an indicator of HGT and that differences in CAI between HGT genes and native genes can be minor (Koski et al., Mol Biol Evol 18: 404, 2001; Wang, Mol Evol 53: 244, 2001). Essentially, they found it difficult to distinguish between low CAI due to low expression and low CAI due to HGT. However, the CAI computation is based on the codon usage across a panel of highly expressed proteins (typically ribosomal proteins), and it can be shown that while CAI based on different (but overlapping) sets of highly expressed genes infers other highly expressed genes consistently, there is little consistency across the two CAI implementations for low CAI values. In other words, little can be inferred from low CAI values.

What is proposed for this project is that instead of using CAI values representing just the species of interest, codon usage tables have been computed for the same set of highly expressed genes across a range of species (in principle every species for which the data is available). The significance of using highly expressed genes is that they are like to be native to that species, rather than arising due to HGT (Park & Zhang, Genome Biol Evol 2012).

Your first task is to write a Python program that, given a query protein-coding nucleotide sequence (CDS) – i.e. the actual sequence of codons – and a set of codon usage tables, returns a list of species in order of descending CAI score. It is assumed that the species with the highest CAI score will be the most likely source as the encoding of the input sequence will be most consonant with that species' codon usage. Your main task will be to take the codon usage tables representing the different species and compute phylogenetic trees using the Neighbour-Joining algorithm (I can give you code for that) based on a distance metric were each table is viewed as a vector of length 59 (64 codons minus 3 Stop codons and methionine and tryptophan, which have only a single encoding).

Ability to program in Python is important for this project.

# Assoc/Prof Mikhail Kostylev

**Project 1:**

**Title: Ferromagnetic resonance studies of interface effects in magnetic films for applications in future magneto-electronic hydrogen gas sensors (experimental)**

One important direction of our group’s research is investigation of magnetic properties of Pd/Co bilayer films. These films possess strong perpendicular magnetic anisotropy (PMA) at the interface of the two layers. We have shown that PMA strength can be measured in a ferromagnetic resonance (FMR) experiment [1]. Pd is known to be able to absorb a lot of hydrogen gas (H2); in our recent experiment we demonstrated that absorption of H2 by Pd changes the PMA strength [2].

Research into H2 sensors is a hot topic nowadays, because it is believed that the next generation of automobiles will have H2 powered engines. Because hydrogen gas is highly flammable, sensors of H2 are required in order to ensure safety of the future cars and gas fuelling stations. This need motivated our research.

In the framework of the proposed project the student will fabricate a number of Pd/Co, Pd/Fe and Pd/NiFe films using our magnetron sputtering machine and measure their FMR response. In contrast to our previous studies, the ferromagnetic layers (Co, Fe or NiFe) fabricated in this project will be thick – their thicknesses will be in the range between 30 and 60 nm. It is anticipated that for such thick ferromagnetic layers, the interface PMA will produce a very interesting effect of interface pinning of dynamic magnetisation [1]. The goals of the proposed experiment will be (1) extracting strength of the interface magnetisation pinning from the obtained FMR data and (2) understanding how the pinning is modified in the presence of H2.

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.

[1] I.S. Maksymov and M. Kostylev, Physica E 69, 253 (2015).

[2]. C. S. Chang, M. Kostylev, and E. Ivanov, Appl. Phys. Lett. 102, 142405 (2013).

**Project 2:**

**Title: Approximate model of a microwave stripline ferromagnetic resonance experiment (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, microwave nano-oscillators, microwave metamaterials and various sensors.

The ferromagnetic resonance (FMR) method [1] is a key experimental tool with which to study and characterise magnetic properties of these materials. It makes use of excitation and detection of microwave magnon dynamics in them. Recently our group found that microwave eddy currents are strongly exited in the conditions of the stripline FMR experiment [1-3]. We showed that they may potentially degrade performance of future spintronic devices [2]. On the other hand, their excitation in the conditions of the stripline FMR experiment may be beneficial, since it may deliver important information about material properties hardly accessible otherwise [1,2].

In the framework of this project the student will work on further improvement of a theory for the stripline broadband FMR experiment [3]. The drawback of the numerical code from [3] is that it is very slow. However, it should be possible to significantly accelerate numerical computations with the model by making a number of reasonable approximations in the employed equations.

Deriving the approximate equations will be the first step of the proposed project. Once the approximate equations have been obtained, the student will incorporate the equations into the existing numerical code and carry out numerical simulations to check the validity of the upgraded software.

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.

[1] I.S. Maksymov and M. Kostylev, Physica E, 69, 253 (2015).

[2] I. S. Maksymov, Z. Zhang (USTC student), C. Chang, and M. Kostylev, IEEE

Mag. Lett. 5, 3500104 (2014).

[3] Z. Lin (USTC student) and M. Kostylev, J. Appl. Phys. 117, 053908 (2015).

# Professor Mohammed Bennamoun

Ever expanding human activity coupled with climate change have severely damaged marine ecosystems, which play a key role in our planet’s ability to sustain life. Yet automated technology to monitor the health of our oceans still does not exist, with marine scientists still having today to process manually a massive amount of raw underwater imagery. During this UWA research training program, you will work closely with a research team involved in the development of advanced computer vision tools for rapid, large-scale, automatic identification of marine species. Such an automated technology would greatly benefit marine ecological studies in terms of speed, cost, accuracy of the spatial/ temporal sampling and thus in better quantifying the level of environmental change marine ecosystems can tolerate.

The background knowledge and skills that the student will need to undertake your proposed project include programming with Matlab. image processing, computer vision and/or artificial intelligence.

# Professor Paul Low

**See attached PDF for** [**Paul Low project**](Paul%20Low_Projects.pdf)

# Professor Reto Dorta

**See attached PDF for** [**Reto Dorta project**](Reto%20Dorta%20group%20_internships_Projects_2016.pdf)



# Professor Ryan Lowe

**Project 1:**

**Title: CFD modelling of turbulent flow through aquatic canopies**

Fluid flow close to the bed in coastal environments typically develop a logarithmic boundary layer structure. This structure is well defined over bare sediment beds but is less well understood when the bed contains large bottom roughness such as aquatic vegetation or coral communities. In this project, a computational fluid dynamics (CFD) model will be developed in OpenFOAM to investigate the turbulent flow structure over coral communities of different densities. The project will involve the setup and gridding of the model, running of simulations, and the analysis and interpretation of the results. The project will be supervised by Professor Ryan Lowe and Mr. Andrew Pomeroy.

**Background knowledge:** knowledge in fluid dynamics

**Requirements:** skills in numerical methods / scientific programming

***Desirable but not essential:****knowledge of the CFD models such as OpenFOAM*

**Project 2:**

**Title: Investigation of the effects of nearshore vegetation on waves and dune erosion**

Over the past decades many researchers have focused on the effect of nearshore vegetation (e.g. seagrass, mangroves, kelp) on coastal hydrodynamics. Vegetation is found to attenuate wave energy and limit wave runup, generally leading to increased coastal safety against flooding. Despite the growing knowledge on the interaction between vegetation and waves and currents, there are still numerous knowledge gaps. For instance, the effect of the presence of vegetation on sediment transport and morphological development of sandy coasts is largely unknown. The objective of this project is to better understand the effect of vegetation on wave impacts and dune erosion. To obtain this understanding, a process-based numerical model for dune erosion (XBeach), which was recently extended with a vegetation module (Van Rooijen et al., 2015), will be validated using the data and applied on a number of scenarios. For this project, previous experience with MATLAB/PYTHON and numerical modelling is preferred. The project will be supervised by Professor Ryan Lowe and Mr. Arnold van Rooijen (UWA).

**Background knowledge:** knowledge in fluid dynamics and/or coastal engineering

**Requirements:** skills in numerical methods and data analysis

***Desirable but not essential:****knowledge of numerical wave models*

**Project 3:**

**Title: Assessing the directional spectral evolution of wind waves with phase resolving wave models**

The intermediate water depths (10-50 m) of inner continental shelves represents a region of considerable wave transformation through both linear (e.g. shoaling and refraction) and nonlinear mechanisms (spectral energy transfers, changes in wave shape). The project will assess the ability of a phase resolving wave model such as SWASH to accurately simulate the spectral evolution of directionally spread waves using various field datasets along the coast of Western Australia. The project will be supervised by Professor Ryan Lowe and Dr. Jeff Hansen.

**Background knowledge:** knowledge in ocean wave dynamics and/or coastal engineering

**Requirements:** skills in numerical methods / scientific programming and time-series data analysis

***Desirable but not essential:****knowledge of numerical wave models*

# Professor Swaminathan Iyer K. L - BioNano Group

**Project 1:**

**Title: Magnetically guided migration of stem cells in-vivo**

Supervisors: Prof. Swaminatha-Iyer, Prof. Fiona Wood, Prof. Tim St. Pierre, Dr. Rob Woodward and Dr. Mark Fear

Despite recent therapeutic advances, the mortality and morbidity from major burns remains high.

Consequently, there is a pressing need to develop economical, efficient and widely-available therapeutic approaches to enhance the rate of wound re-epithelialization and restoration of the protective epithelial barrier. Skin, the largest organ of the human body, provides an essential protective barrier and serves several homeostatic/sensory functions vital to health and its functional recovery post burn injury remains the ultimate goal of wound healing research. The ultimate goal of the treatment of acute burns and wounds is to restore the damaged skin both structurally and functionally to its original state. Recent research advances have shown the great potential of stem cells in improving the rate and quality of wound healing and regenerating the skin and its appendages. Using magnetically activated mesenchymal stem cells (MSCs), the project will explore the possibility of magnetic field guided migration of the cells to the injury sites. We will monitor migratory patterns of the cells in animals following administration in the presence and absence of a magnetic field, developing critical knowledge to advance stem cell based therapy in tissue engineering.

**Project 2:**

**Title: Designing polymeric nanoparticles and evaluating its transport across the Blood**

**Brain Barrier for treating Neurotrauma**

Supervisors: Prof. Swaminatha-Iyer, Dr. Nicole Smith and Prof. Sarah Dunlop

Neurotrauma, such as traumatic brain or spinal cord injury, encompasses both acute damage induced by the primary injury and chronic progressive secondary degeneration of intact, but highly vulnerable, tissue, results in a drastic change in the cellular signalling pathways. Reactive oxygen and nitrogen species (ROS and RNS) are implicated to play a vital role in this, as their production is reported to exceed a cell’s antioxidant capacity following injury. Drug based intervention currently is limited following trauma. The central nervous system, one of the most delicate microenvironments of the body, is protected by the blood-brain barrier (BBB) regulating its homeostasis. BBB is a highly complex structure that tightly regulates the movement of ions of a limited number of small molecules and of an even more restricted number of macromolecules from the blood to the brain, protecting it from injuries and diseases. However, the BBB also significantly precludes the delivery of drugs to the brain, thus, preventing the therapy of a number of neurological disorders. As a consequence, several strategies are currently being sought after to enhance the delivery of drugs across the BBB. Using partial optic nerve injury model, we will evaluate polymeric formulations to deliver drugs across the BBB over time.

**Project 3:**

**Title: Developing a nanoscale therapy to alleviate oxidative stress in placental-related diseases of pregnancy**

Supervisors: Prof. Swaminatha-Iyer, Prof. Jeff Keelan and Prof. Brendan Waddell.

Pregnancy is a state of oxidative stress arising from increased placental mitochondrial activity and production of reactive oxygen species (ROS), mainly superoxide anion. The placenta also produces other ROS including nitric oxide, carbon monoxide, and peroxynitrite which have pronounced effects on placental function including trophoblast proliferation and differentiation and vascular reactivity. Excessive production of ROS may occur at certain windows in placental development and in pathologic pregnancies, overpowering antioxidant defences with deleterious outcome. For example: miscarriage and pre-eclampsia are the most common disorders of human pregnancy. There is mounting evidence that oxidative stress or an imbalance in the oxidant/antioxidant activity in utero–placental tissues plays a pivotal role in the development of placental-related diseases. This project explores the application of magnetic nanoparticles as

antixodant delivery agents in placenta via a systematic approach.

**Project 4:**

**Title: Manipulating the shape of iron oxide nanoparticles as high performance magnetic resonance imaging contrast agents**

Supervisors: Prof. Swaminatha-Iyer, Prof. Tim St. Pierre, Dr. Mike House, Dr. Rob Woodward and Prof. Martin Saunders.

Spherical superparamagnetic iron oxide nanoparticles have been developed as T2-negative contrast agents for magnetic resonance imaging in clinical use because of their biocompatibility and ease of synthesis; however, they exhibit relatively low transverse relaxivity. Till date most of the literature has looked into size dependent effect of iron oxide nanoparticles in MRI contrast.

In this project we will explore the ability to manipulate the shape of iron oxide nanoparticles and its effect as contrast agents for magnetic resonance imaging. The project will involve High-Res

Transmission Electron Microscopy, Magnetic Resonance Relaxometry and in-vitro analysis as contrast agents in PC12 cells.

# Professor Thomas Braunl

**Project 1 (with Marcus Pham):**

**Title: Realtime Image Processing on Embedded System for Mobile Robots**

Required skills: Excellent C / C++ programming skills, Linux experience

Desirable: Mobile Robotics experience, experience in image processing e.g. OpenCV

**Project 2 (with Franco Hidalgo):**

**Title: Autonomous Submarine Programming**

Required skills: Excellent C / C++ programming skills

Desirable: Mobile Robotics experience

# Associate Professor Vincent Wallace (post-doc Shuting Fan)

**Project 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.

# Dr. Weiguang Cui

With the fast developing of the super computer and numerical simulation techniques, numerical simulations are fundamental to give an accurate interpretation of the astrophysical processes observed, like the formation of galaxies, galaxy clusters and large scale structure of the Universe. However, do the different simulation programs give the same answer? if not, how well do they agree with each other? This questions lead to the nIFTy galaxy cluster comparison project, which uses 13 different simulation codes with different techniques to simulate the same galaxy cluster. There are already 4 papers: Sembolini et al. 2015a (Paper I), 2015b (Paper II), Elahi et al. 2015(Paper III) and Cui et al. 2015(Paper IV), which have been submitted under this project. The continuing work, which is also the main aim of this research training program, is to compare these simulation results in another point of view — the density probability distribution function (PDF). From this PDF, we can know the distribution of the dark matter, as well as the normal matter. It can also reveal the difference between these simulations in great detail, which cannot be seen from the halo density profiles.

**The required *background knowledge and skills:***

This needs basic knowledge of astronomy, numerical simulation and statistical methods.

The main required skills are the computer language (such as C, python, but others will also be OK)

# Group: Optical+Biomedical Engineering Laboratory

**Project 1:**

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

Group: [Optical+Biomedical Engineering Laboratory](http://obel.ee.uwa.edu.au)

Supervisor: [Prof David Sampson](http://obel.ee.uwa.edu.au/people/head-and-adjunct-staff-members/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.

Our group is the pioneer of a [Microscope-in-a-Needle](http://obel.ee.uwa.edu.au/research/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: Project: Modelling contrast in polarisation-sensitive optical coherence tomography**

Group: [Optical+Biomedical Engineering Laboratory](http://obel.ee.uwa.edu.au)

Supervisor: [Prof David Sampson](http://obel.ee.uwa.edu.au/people/head-and-adjunct-staff-members/david-sampson) and Dr Lixin Chin

Area: Biophotonics, Biomedical Optics, Biomedical Engineering

Skills: This project will largely involve modelling and theory and so will suit physicists or electrical engineers who can conceptualise and implement in models.

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 of tissue that reflects the order and geometry of its sub-resolution microstructure. We have recently demonstrated such an approach in the [Microscope-in-a-Needle](http://obel.ee.uwa.edu.au/research/microscope-in-a-needle), and shown we can tell cancer from non-cancer in dense breast tissue for the first time. There are some basic unresolved problems in how the alignment of the optical beam interacts with the optic axis of the birefringence. This project will seek to model this scenario with a view to understanding the limits on different scanning geometries and possibly to design strategy to measure birefringence in three dimensions. These projects will contribute towards the realisation of this goal.

**Project 3:**

**Title: Project: Optical elastography – New methods of imaging stiffness in cells and tissues**

Group: [Optical+Biomedical Engineering Laboratory](http://obel.ee.uwa.edu.au)

Supervisor: Brendan Kennedy

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, through to biological studies on engineering cells and tissues and clinical studies on breast cancer.

**Project 4:**

**Title: Computer vision and machine learning in biomedical imaging**

Group: [Optical+Biomedical Engineering Laboratory](http://obel.ee.uwa.edu.au)

Supervisor: [Prof David Sampson](http://obel.ee.uwa.edu.au/people/head-and-adjunct-staff-members/david-sampson) and [Philip](http://obel.ee.uwa.edu.au/people/staff/dr-brendan-kennedy) Wijesinghe

Area: Computer Vision, Biomedical Engineering

Skills: This project will largely involve software development, so it is most suited to software engineers.

This project will develop supervised machine learning algorithms for the identification and classification of features in three-dimensional images of cells and tissues. The classification images will be used to develop models of tissue structure, and potentially, to quantify tissue diseases. Further, these models will feed into simulations of image formation in optical coherence tomography, which will let us better understand the interaction of light with cellular constituents. The students will start by implementing support vector machines to recognise textures and patterns in images, and depending on their aptitude, they may develop more complex or more efficient algorithms. Students are required to be familiar, or have interest in either Matlab, C++ or Java, and also statistics and statistical methods.

*- End -*