ACE is a multidisciplinary research group which brings together researchers from engineering, science, mathematics, physics and medicine. The Centre combines an active undergraduate and postgraduate teaching programme with pure and applied research to provide an environment in which innovative theoretical developments can be rapidly turned into technologies that provide solutions to a range of real-world problems. The focus of the research is the development of intelligent information processing systems and their applications. The group is active in the areas of artificial neural networks, computer-assisted learning, control, digital signal processing, human-computer interaction, image processing, parallel and reconfigurable computing, robotics, software engineering, and spoken language systems.

The staff of the group include:

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**AUTOMOTIVE LAB**
(Prof. Thomas Bräunl)
The Automotive Lab was established in 2008 and is dedicated to research in alternative drive systems, such as plug-in electric vehicles, as well as active driving safety, such as driver-assistance systems. The Automotive Lab currently houses five vehicles, a BMW X5, a Hyundai Getz, a Lotus Elise S2 and two Formula SAE race cars.

A list of all projects is available at: [http://robotics.ee.uwa.edu.au/students/projects.html](http://robotics.ee.uwa.edu.au/students/projects.html)
Electric Cars - REV

REV (Renewable Energy Vehicle)
This is a Faculty-wide project and looks at finding alternatives to petrol-based cars. These projects are suitable for students in Mechanical, Mechatronics, Electrical, Computer Engineering and Computer Science.

REV is converting the following cars to electric drive:
- Economy car: Conversion of a 2008 Hyundai Getz to electric drive using DC technology
- Performance car: Conversion of a 2002 Lotus Elise S2 to electric drive using AC technology
- Formula SAE Electric (FSE) car: Conversion of 2001 UWA Motorsport car to pure plug-in electric car
- Formula SAE Electric Race Car (under construction)

Web: theREVproject.com

Drive-by-wire
The BMW X5 is being converted to steer-by-wire and brake-by wire while maintaining its normal drivability. The car is being used as a test vehicle for evaluating vision-based driver assistance systems.

Projects available:

1. **BATTERY/CONTROLLER management for Electric Performance Car**
   Design and implement circuitry for connecting the electric motor, batteries and controller box. Analyzing and experimenting with controller box, finding optimal drive parameters.

2. **ON-BOARD INSTRUMENTATION for Economy and Perfomance Car**
   Using a colour LCD touch-screen, develop a central car information centre that can display all relevant driving information and car status info.

3. **BLACK BOX for Electric Performance Car**
   Develop a black box for a car, similar to a flight recorder in a plane. This will comprise an embedded controller, sensors including GPS, Accelerometer, Analog inputs for current/voltage and a USB memory stick for data recording.
   The project also includes the requirement for a user interface both on the black-box side (start-stop recording) as well as on the PC side (graphical presentation of results, e.g. Excel)
4. **DRIVE-BY-WIRE for BMW X5**
Conduct a study and design all components for converting a performance car to drive-by-wire. This requires gas-by-wire, brake-by-wire, steering-by-wire.
Note: Our aim is to keep the car street-legal, so an essential part of this project is to make sure all legislative requirements are being met.

5. **GETZ AND LOTUS: Mechatronic: Performance analysis**
Compare and contrast operational efficiencies of these two electric vehicles under different driving conditions, and propose modifications which may improve their performance.

6. **FORMULA SAE ELECTRIC (FSE) - build Mechanical: Aluminium Spaceframe Chassis Design**
Using in-wheel motors will free up a lot of the space in the vehicle body, and calls for a unique chassis layout and design. Steel spaceframe chassis are commonly used for Formula SAE, but can aluminium offer superior strength to weight?

7. **FORMULA SAE ELECTRIC (FSE) - Mechanical: Carbon Fibre Spaceframe Chassis Design**
Using in-wheel motors will free up a lot of the space in the vehicle body and calls for a unique chassis layout and design. In recent years the UWA Motorsport team had used a carbon fibre bathtub chassis design for their Formula SAE vehicles, but can the structural advantages of spaceframe designs combined with the strength to weight of carbon fibre offer a superior solution?

8. **FORMULA SAE ELECTRIC (FSE) - Mechanical: Suspension design**
The 2012 will use in-wheel (hub) motors, which presents unique challenges for suspension design. This project requires familiarisation with suspension technology, and its application to our FSE vehicle with special attention to the consequences of increased unsprung mass.

9. **FORMULA SAE ELECTRIC (FSE) - Mechanical (Aerodynamics): Passive Ground Effect Devices**
Passive ground effect devices use aerodynamics beneath a vehicle to increase downforce through reducing under-body air pressure. Is this a viable proposition for Formula SAE?

10. **FORMULA SAE ELECTRIC (FSE) - Mechanical: (Aerodynamics) Dynamic Control Surfaces**
Electronically controlled dynamic control surfaces such as variable-angle wings can modify a vehicle's downforce and drag balance in realtime, offering more downforce during cornering without compromising drag coefficient during straightaways. Are they a viable option in Formula SAE?

11. **FORMULA SAE ELECTRIC (FSE) - Electrical (Power Electronics): Brushless DC Motor Controller**
Electric vehicles can use their motor(s) to slow the car down, reducing the load on mechanical brakes. However most commercial motor controllers have greatly reduced regenerative braking capabilities, which restricts the usefulness of regen braking. Design a BLDC motor controller which can provide as much regen current as drive current.

12. **FORMULA SAE ELECTRIC (FSE) - Electrical (Power Electronics): Electromechanical Brake Energy Storage**
Regenerative braking performed by motors in electric vehicles can offer powerful braking, but few batteries can accept a high enough rate of charge. Design an electronic device based around either ultracapacitors or shunt resistors which can accept high rates of current from a DC buss.
13. **FORMULA SAE ELECTRIC (FSE) - Mechatronic: Advanced Cabin Design for FSE Vehicles**

In an electric Formula SAE vehicle the driver will need to view various vehicle parameters such as battery state of charge, power flow, motor temperatures, and be able to quickly respond to any emergency conditions. Design an intuitive cabin layout for a FSE vehicle which complies with Formula SAE rules.

14. **FORMULA SAE ELECTRIC (FSE) - Computer Eng: Realtime FSE Telemetry Monitoring Software**

Our 2012 FSE vehicle will have a variety of onboard telemetry systems being transmitted in realtime back to a monitoring PC. Design some software to view and analyse this datastream.

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**ROBOTICS AND AUTOMATION LAB**

*(Professor Thomas Bräunl)*

The Robotics and Automation lab has been active since 1998 undertaking research on all types of autonomous mobile robots, including intelligent driving and walking robots, autonomous underwater vehicles, and unmanned aerial vehicles. We also work on the design of embedded controllers and embedded operating systems, as well as on simulation systems.

A list of all projects is available at: [http://robotics.ee.uwa.edu.au/students/projects.html](http://robotics.ee.uwa.edu.au/students/projects.html)

**Projects available:**

1. **Driver Assistance Systems**

We have developed a new version of the image processing rapid-prototyping tool "Improv". This tool is based on the library OpenCV and is to be used for implementing vision-based driver-assistance functions for automobiles.

1.1. **Lane Recognition in BMW X5:**

Using an embedded system and our image processing framework ImprovCV, implement a driver-assistance system that can automatically detect lane markings and warn the driver acoustically of a dangerous situation.

Note: We have existing software for lane recognition. This project will have to port this PC software to a small embedded System. Good C/C++ knowledge is required.
1.2. Vehicle detection and vehicle tracking with collision avoidance.
1.3. Automatic braking assistant for collision mitigation.
1.4. Porting and extending of standard OpenCV image processing functions to Improv.

2. **Automotive Simulation System**

We are building a comprehensive automotive simulation system as a group project. The simulation system will run either on a standard Windows PC or on a full mock-up with driver cabin and projectors. A public domain full 3D physics engine is used in this project to calculate realistic acceleration forces and motion vectors. The simulation system will later be used as a testbed for driver-assistance functions.

2.1. User Interface Implementation.
2.2. Design of car models (graphics and physics features).
2.3. Design of environment models (streets, traffic signs, buildings):
   We will use true map data and recreate subsets for the cities of: Perth (AUS), Los Angeles (US), München (GER). Inner-city scenes as well as highway scenes will have to be modelled.
2.4. Design of car API and virtual sensor interfaces and implementation.

3. **Autonomous Underwater Vehicle**

This group project is to build mechanics, electronics and software for an autonomous underwater vehicle. The goal is to participate in the new Australian AUV competition.


3.1. Echo-sounder based navigation and control
3.2. Vision-based detection tasks
4. **Autonomous Wheel-Chair**
We have built an electric wheel-chair platform that operates as an autonomous vehicle. The wheel-chair will be equipped with a number of sensors and on-board controllers. This is a joint project for several students working together.

4.1. **Driving along a corridor:**
The wheel-chair should be able to drive along a corridor without hitting the wall, obstacles or people.

4.2. **Autonomous door-way passing:**
The wheel chair should adjust itself and drive through a narrow door-way autonomously.

4.3. **Navigation:**
After entering a room number, the wheel-chair should autonomously find its way in the EE building and drive to the desired room.

5. **Second Life**
UWA has a [Second Life](https://secondlife.com) presence as of Oct. 2009. The goal of this project is to model interactive robots and possible electric cars developed in the Robotics and Automation lab and bring them into Second Life.

5.1. **Omni-Wheelchair**
5.2. **Biped Robots**
5.3. **EyeBot Robots**
5.4. **REV Eco+Racer**

6. **Augmented Reality**
The goal of this project is to develop an interactive application between real and simulated robots on one side and human operators on the other side. The set-up will include a ceiling-mounted projector that displays scenarios on a table and a ceiling-mounted camera that gives feedback about the interaction.

6.1. **Graphics generation**
6.2. **Implementation of virtual (simulated) robots**
7. Advanced Embedded Systems

We are developing a new RoBIOS-Version on top of Linux for the latest EyeBot M6 controller project. The hardware is an ARM9 together with a Xilinx FPGA and stereo cameras. The following projects concentrate on software development for this new hardware.

7.1. Development of image-preprocessing routines in VHDL for FPGA
7.2. Development of actuator and sensor routines (motor and sensor drivers) for controller
7.3. Porting of all RoBIOS functions
7.4. Development of Monitor program

8. EyeSim Simulation Systems

For the new high-performance embedded controller, we need an new version of the EyeSim simulator, which can also emulate the new controller features such as:

- widescreen, color LCD
- touch-screen
- dual (stereo) cameras
- updated RoBIOS functions

8.1. Modify EyeSim user interface
8.2. Update EyeSim-RoBIOS functions
These projects are in collaboration with the International Centre for Radio Astronomy Research (ICRAR). ICRAR is a joint venture between the University of Western Australia (UWA) and the Curtin University of Technology supported with funding from the Government of Western Australia. ICRAR aims to make a significant contribution to scientific and technical programs supporting the Australian SKA Pathfinder and SKA by participating in key science programs involving very large scale surveys, time-domain astronomy and data intensive research which pose a computational challenge for the computer programs used in analysis due to the sheer scale of the data involved.

NGAS is a highly scalable file object archiving and distribution system which supports globally distributed components. It is based on two main requirements: combining archive and data transfer; and co-locate processing and storage. It is being used at ESO since 2001 and at NRAO since 2008 and is currently being deployed for ALMA and the eVLA.

Projects Available:

1. **NGAS Buildout**

The core of the Next Generation Archive System (NGAS) has been implemented back in 2001 already using Python 1.6 in the beginning. Around that time there was no proper build and distribution process for big projects available and thus a proprietary system had been implemented. In the meantime there are a few very advanced build and distribution systems around and it now makes sense to move NGAS to use one of those. In particular for this project the zc.buildout should be evaluated in detail and at least the build part should also be implemented. If time permits the extended NGAS tests should also be migrated into the new system.

2. **NGAS Multi Process**

The Next Generation Archive System (NGAS) is implemented in 100% pure Python. One draw-back of the Python interpreter for efficient usage of modern multi-core processors is the so-called global interpreter lock. This lock prevents Python code of using more than one core in multi-threaded programs. In Python version 2.6 a new module is available which exposes individual processes in the same way as the Python threading library, thus making it possible to refactor multi-threaded programs into truly multi-process programs. The goal of this project is to first evaluate the impact of such a refactoring for NGAS and if the impact seems to be justified implement the usage of the multi-process module.

3. **NGAS Postgres Plugin**

The Next Generation Archive System (NGAS) already allows the usage of five different relational database systems as a backend. The database backend is encapsulated in a plugin system and thus implementing another database boils down to implementing a plugin for that database. The goal of this project is to implement a backend plugin for the Postgres database.
4. **OpenCL Fast Transient Detector**

Maximising the performance of the CRAFT GPU-based fast transient detector will allow it to search for a wider range of transient events. While the current GPU transient detector is CUDA-based, developing an OpenCL-based version will enable the use of a wider range of heterogeneous parallel accelerator architectures. The Open Computing Language (OpenCL) is an open industry standard framework for writing programs that can be executed across a range of such platforms.

In this project, the student will port the existing CUDA-based GPU fast transient detector to OpenCL and investigate the performance on NVIDIA and AMD ATI graphics processing units, as well as multicore CPUs. Testing will use Aricebo data, and there will be scope for improving the algorithm for improved peak detection and radio frequency interference. The student should be comfortable programming in C, and have some experience with a parallel heterogeneous programming framework such as CUDA or OpenCL.

**PROJECTS AVAILABLE:**

1. **Real time analysis of music to determine the chord progression:**
   The aim of the project is to sample music and determining the chord progression in real time. The project will be in two stages, first stage to break down the musical sound into the harmonics and determine the root frequency as well as the harmonics. The key will be known for this process. The second stage will be to sample the whole song and determine the key, then using this information in real time determine the chord progression.

2. **Railway Safety System**

   Develop methods of determining the state of the foundation of a rail formation in advance of a moving train. This project has real benefits to rail operators where the rail line may be intact but the supporting formation may be compromised. This will be part of an ongoing research project that we will be approaching industry for implementation. This first stage will require some interaction with geotechnical engineering. Chris Croft as co-supervisor will be able to provide that assistance as he is a civil engineer and has worked as a geotechnical engineer. The project has major economic benefits for major rail users world wide and would suit a student that may be interested in pursing this project past undergraduate level, either in postgraduate study or while in industry.
The Signals and Systems Engineering (SSE) has several research laboratories outlined below:

- **The Signals and Information Processing Laboratory** undertakes key research in the areas of speech processing and speech and speaker recognition leading to developments in voice-activated technologies, robust speech recognition in real environments and biometric security by speaker verification.

- **The Control Systems Research Laboratory** undertakes theoretical and applied research in the areas of mathematical modeling, state estimation, robust control and sliding mode control.

- **The Biomedical Engineering Laboratory** undertakes research into applying theoretical control techniques to biomedical systems such as blood glucose control in diabetics, closed-loop control of mechanical ventilation in critically ill and patient controlled analgesia.

- **The Signal Processing for Wireless Communications Laboratory** undertakes fundamental and applied research into broadband radio communications and underwater acoustic communications leading to applications in areas such as broadband wireless to the bush, oceanographic data collection, and offshore pipeline monitoring.

- **The Renewable Energy Laboratory** undertakes fundamental and applied research into renewable energy technologies.

**Key areas of expertise**

- Biomedical Systems
- Control Systems
- Power Electronics Applications
- Renewable Energy
- Signal Processing for Wireless Communication
- Speech and Image Processing and Recognition
- Underwater Acoustic Communications

**Facilities**

- Software: Matlab, PSIM, Pspice, Nuance SDK, NS/2, Mathematica, and LabView
- Hardware: Specialized hardware for control, communication, power electronics, renewable energy and signal processing,
Year 2012 Final-Year Projects in
SIGNALS AND INFORMATION PROCESSING SYSTEMS
_A/Prof. Roberto Togneri_

We are currently in the first century of the information age and the new era of information systems engineering. The Signals and Information Processing (SIP) Lab is offering exciting and challenging final-year projects to students who can demonstrate the required motivation and passion. If you are interested in any of the projects on offer please email <Roberto.Togneri@uwa.edu.au> or drop by Room 4.10 to discuss further, your thoughts and concerns, and to help you make the right choice. For reading material and resources please also have a look at the online version http://www.ee.uwa.edu.au/~roberto/research/projects2012.html.

1. **Enhancement of Noise and Reverberant Degraded Speech**
   Speech enhancement encompasses a range of approaches which attempt to take a speech signal which has been degraded by additive noise and reverberations and by use of clever spectral and temporal signal processing is able to make the speech more intelligible for both human listeners and voice response computer systems. In particular speech recognition is very sensitive to both additive and reverberant interference (we human listeners can copy better with the latter, unless the reverberations are perceived echoes then even we start to have problems too!). In this project you will investigate one or more spectral and temporal approaches that are designed to deal with either or both additive or reverberant speech. For example, classical speech enhancement (spectral subtraction, Wiener filtering, etc.) for additive noise and/or more novel solutions (spectral subtraction of late reverberations, inverse filtering, etc.) for reverberant speech. This can either be an experimental or system development project involving analysis, implementation and evaluation of relevant signal processing theory and algorithms. **Check it out:** Speech Enhancement Tutorial, Review of Speech Enhancement Paper, Roomsim software.

2. **Microphone Arrays for Speaker Localisation and Separation**
   Microphone arrays consist of multiple microphones geometrically arranged so as to capture the directional information of speech and interfering sources. In this way it is possible to separate different speakers and speakers from interfering noise based on their spatial location. In this project you will investigate the application of microphone array technology in the SIP Lab to the task of speech source separation. More than one project is possible covering several interdependent investigations: setup and configuration of the microphone array hardware, software and processing for microphone arrays, simple practical beamforming (BF) to separate two (or more?) actual speakers, sophisticated signal processing algorithms for the estimation of Direction of Arrival (DOA) of the desired speech source, or Blind Source Separation (BSS) of individual spatially diverse sources. Projects can be hands-on, experimental or highly mathematically theoretical. The student will be co-supervised by post-doc researchers and PhD students from the SIP Lab. Team projects also quite possible. **Check it out:** Iain McCowan's Home Page, Beamforming Tutorial, BSS_EVAL software.

3. **Time-Frequency Feature Extraction for Robust Speech Recognition**
   Commercial speech recognition applications use fairly simple front-end processing and concentrate on sophisticated acoustic and language modelling. Works great when you have a close-talk microphone (right next to your mouth), but can fail miserably when the microphone is no more than a couple of feet away from you, and most certainly if you have background noise and interference. One reason for this is that speech recognition degrades significantly in the presence of such mismatch. In this project you will investigate time-frequency domain processing of the speech signal and how to extract features which are robust to (i.e. insensitive to) the key types of environmental noise encountered. You will first become familiar with basic speech recognition: how to extract...
features, build models and recognise what is being said. Then you will investigate one or more robust feature extraction paradigms: time filtering, frequency filtering, normalisation, and speech enhancement, evaluated under different environmental conditions. This is an exciting project allowing you to explore the different spectral and temporal characteristics of speech and noise and innovative time-frequency filtering approaches. Check it out: Speech Recognition Tutorials, Resources for Noise-Robust Speech Processing, HMM ToolKit (HTK), Noisy Speech Recognition Paper, Time-Frequency Filtering Paper.

4. Robust End-Point Detection of Cockpit Voice Recordings
Forensic analysis is usually a pain-staking, tedious but important process in criminal and accident investigations. This is particularly true in airline crash investigations where all the available information (no matter how little) has to be thoroughly examined. One of the key elements of any such investigation is the so-called black box or cockpit voice recorder (CVR). Although retrieving it and salvaging the contents is crucial, facilitating and automating the analysis of the recordings for the human investigator is also important. A key part of this analysis is the robust endpoint detection of dialogue important for determining the cause of a crash. However CVR recordings contain a mixture of speech, alarms, silence and other sounds making it difficult to pinpoint the segments of interest. In this project you will examine robust Voice-Activity Detection (VAD) for endpoint detection of human speech from sample CVR recordings. You will research, implement and evaluate one or more VAD strategies based on statistical signal processing of the speech and noise characteristics of the CVR recordings and gain a good appreciation of fundamental digital signal processing. Check it out: CVR Recording Database, CVR VAD Paper (Simple), CVR VAD Paper (Challenging).

5. Advanced Topics: Compressive Sensing and Dynamic Bayesian Networks
For the student who wants a project which is mathematically challenging and explores novel and sophisticated computational statistical pattern recognition and signal processing paradigms look no further! Compressed sensing (CS) is a novel technique used to reconstruct a signal from few training examples, possibly below the Nyquist sampling rate. This has profound implications for source compression and signal acquisition. In this project the highly motivated student with a strong mathematics background and penchant for all things signal processing looking to be challenged by an emerging research (and technology) area, will be tasked to investigate CS and develop the theory, implement algorithms, and carry out simulations on speech and image signal representations and reconstructions. But if your interest is in more sophisticated machine learning paradigms then Dynamic Bayesian Networks (DBNs) is definitely for you. DBNs represent a general framework based on graphical models to represent complex stochastic processes. In this project you will investigate the theory, algorithms and software for DBNs and apply to the modelling of stochastic time-series signals (e.g. human speech). Check it out: CS: The Big Picture, Compressive Sensing Resources, Compressed Sensing for Audio Paper, DBN: The Theory, DBN GMTK Software, DBN BNT Software, DBNs for Speech Recognition Paper.

6. Build Your own Speech Recognition System
This is a systems engineering project where you will build and investigate the technology that underpins speech recognition system. Possible systems you may like to build include: limited vocabulary (e.g. financial transactions, control commands, etc.), English alphabet recognition (for dictation and spelling), recognition of complete phrases rather than just words, recognition in another language, recognition of connected speech (speaking a limited set of words with deliberate pauses), and real-time voice-activated applications (e.g. design of a reliable voice-activated TV remote). For a more challenging project you can investigate advanced issues like: keyword spotting, task independent phone models, continuous speech recognition, tone and syllable recognition (e.g.
spoken Mandarin), recognition of the confusable /e/ set of alphabets: "b", "d", "e", "g", "p", "t", and real-time implementation with minimum memory and computational requirements, etc. Team projects also quite possible. **Check it out**: Speech Recognition Resources, HMM ToolKit (HTK), CMU Sphinx ToolKit, FBDTW, WebASR.

7. Audio-Visual Speech and Speaker Recognition
In current speech recognition, only the audio information is used, and yet it is well known that visual lip reading also works for speech recognition, especially in noisy conditions maybe the only means to understand and for hearing impaired the only way to communicate. For biometric identification, speaker recognition usually implies audio information only, and yet face recognition is just as effective, so why not combine the two together? In this project you will investigate the fusion of audio-visual information for either speech or speaker recognition. With speech recognition the student interested in image processing/computer vision can investigate visual lip reading and the visual cues for the different sounds of the English language (especially confusable sounds like /bah/, /dah/ and /fah/ which are visually more distinct than aurally). Or for speaker recognition you can implement a basic audio-visual speaker recognition prototype using standard tools for face recognition and speaker recognition and investigate different fusion strategies. You can do this by direct capture of audio-visual features of friends and family, recordings of pertinent TV broadcasts (e.g. newreader broadcasts) or make use of available AV corpora. **Check it out**: Audio-Visual Speech Recognition Workshop Paper, Audio-Visual Speech Recognition Overview Paper, Audio-Visual Recognition Overview Paper, Audio-Visual Recognition Application Paper, VidTIMIT Corpus, AVOZES Corpus.

8. Biomedical ECG, EEG and EMG Signal Analysis and Modelling
Medical diagnostic analysis represents a wide range of procedures that help medical practitioners monitor and detect behaviours which may indicate conditions that may require treatment and intervention. Of the many such tools one of the most important is biomedical signal analysis of ECG (heart), EMG (muscle) and EEG (brain) neurological signals which can provide important clues as to the condition of important organs, especially ECGs for cardiac arrhythmias and EEGs for neurological conditions. In this project you will investigate statistical signal processing and pattern recognition algorithms (most notably ICA, GMM and HMMs) and apply these to the analysis, modelling and characterisation of key biomedical signals. An important outcome of this project is a better appreciation of the complexity of biomedical signals and the powerful tools from engineering signal analysis that can be applied. **Check it out**: ICA for Biomedical Signals Paper, GMMs for Biomedical Signals Paper, HMMs for Biomedical Signals Paper, EEGLAB, ICALAB, EMGLAB, PhysioNet Biomedical Resources.

There are many applications involving audio-only communication (e.g. computer or mobile telephony) and recordings (e.g. surveillance and court transcripts) for which the ability to verify a speaker is critical. This is a systems level project where you explore the latest technologies and research in audio-based speaker verification. Using established corpora (NIST 2002 SRE) and verification protocols (false acceptance, false rejection and equal error rate analysis) and applying key strategies for dealing with channel and session variability (e.g. Joint Factor Analysis (JFA) and Nuisance Attribute Projection (NAP)) you will implement a basic speaker verification system and compare and appreciate the need for the different strategies to deal with the noisy variabilities that arise in real speech recordings. You will also be exposed to the standard techniques and protocols that apply to all security authentication systems and fundamental algorithms and techniques which have been developed for audio speaker verification which are only now just being applied to other research areas in speech and image recognition. **Check it out**: Overview of Speaker Recognition Paper, A
10. Psychoacoustics and Speech Perception

The human auditory system allows us to listen to the subtest sounds and yet cope with the loudest noises. We can understand one another in the presence of other speakers and other noises. However when engineers attempt to get communications systems to code, transmit and recognise speech it becomes apparent from the difficulties involved there is a lot we don't understand about human audition. In this project you will explore different auditory and perception models (there are at least 4 different freeware modelling toolkits you can access) and implement one or more of these as a frontend feature extraction to a speech recognition system or for the perceptual enhancement of speech (e.g. in hearing aids or cochlear implants) and evaluate the performance under both quiet speech and noisy speech. This is an ideal project for the highly motivated student interested in biomedical processing with a solid background in signal processing, systems modelling and a keen interest in how human hearing works, and when it doesn't! Your investigation will contribute to the Australian research effort in speech and hearing through a better understanding of what aspects of human speech perception are important for speech recognition, especially under noisy conditions (our human hearing has plenty of "smarts" to improve the quality of noisy or degraded speech but how exactly does it do this?). Check it out: Auditory Toolbox, Development System for Auditory Modelling (DSAM), Auditory Image Model (AIM), HUTear ToolBox, Auditory Demo.
Projects on Control System Theory: The following projects involve theoretical analysis and Matlab simulations.

1. Model Reduction Techniques (2 projects)

Mathematical description of the dynamic characteristics of a system is called a mathematical model. The dynamic system may be a chemical process, multimachine electrical power system altitude control of a space craft, synchronous orbit satellite, etc. Deriving a reasonable mathematics model is the most important part of analysis and design of dynamic systems. In many practical situations, one can obtain a fairly complex and a very high order model for the system. This complexity often makes it difficult to obtain a good understanding of the behaviour of the system. The analysis and design of such systems can be accomplished with greater ease if a low-order model is derived which provides a good approximation. This problem is known as "model reduction problem". The objective of model reduction problem is to find a low-order model for a given high-order system such that the low-order model retains or closely approximates the input-output behaviour of the system.

In this project, we analyse and compare different model reduction techniques for various applications such as Circuit simulation, Nonlinear systems, Electromagnetics, etc.

2. Functional Observers (2 Projects)

State observers estimate all the states of a system and require a full order dynamical system for estimation. The functional observers on the other hand estimate linear functions of the states and the dynamical system that estimates can be of much lower order than the state observer. In this project it is required to investigate various design procedures reported for functional observer design and propose a new scheme.

3. Observers for Chaotic Systems (2 Projects)

Synchronization of chaotic systems is a challenging problem and finding a solution has been important because of its practical application related with secure data transmission. Observer based techniques have been utilised as a possible way of synchronizing chaotic systems. In this project, we analyse and compare different observer based techniques and consider the application of functional observers to solve synchronization problems of chaotic systems.
Projects on Control System Implementation:

Control System Design via Programmable Logic Controllers (4 Projects)

Programmable Logic Controllers (PLCs) are widely used in industry to automate many basic functions and are well known to be very versatile and durable. With the proper sensors, PLC’s can operate on most routine processes. The programming structure of PLC’s is called ladder logic and is very similar to circuit design in digital electronics. However, unlike a circuit, the logic can be easily changed to accommodate changes in what you want the robot or process to do. In this project PLCs are used to design controllers for the following applications:

1. Control of DC Motor Position System
2. Control of Two Tank Process
3. Control of Lifts
4. Control of Traffic lights at a junction
Final-year projects offered in SPWCL are focused on the implementation, simulation and analysis of various future generation communication systems.

1. **Underwater Acoustic Communications**

Acoustics is the primary means to achieve wireless communications in the oceans. Underwater acoustic communications could play a key role in many subsea applications such as oceanographic data collection, environmental monitoring, and offshore hydrocarbon exploration and production. In this project, you will investigate various signal processing techniques for underwater acoustic communications. Potentially, you can also build an acoustic modem (the key component in underwater acoustic communications) using a Digital Signal Processing (DSP) platform.

2. **Broadband Wireless to the Bush**

Wireless communications, due to its potentially low initial deployment cost, high scalability and flexibility, will play a key role in providing broadband communications to sparsely populated areas of Australia. This project focuses on promising technologies for future broadband wireless communications especially to rural areas:

- Multiple-Input and Multiple-Output (MIMO) Systems
- Orthogonal Frequency Division Multiplexing (OFDM) Systems
- Fountain Codes
- Multiple Access Techniques
- Low Density Parity Check Codes

3. **Build Your Own Radio Station Using USRP**

Can you imagine using a single gadget to produce and receive all the possible radio signals (e.g., digital radio, TV signal, CDMA signal, GSM signal, GPS signal, to mention a few)? The USRP (Universal Software Radio Peripheral), aided with a general purpose computer and the “software-defined radio” technology, can achieve this task. So using the USRP, you can easily build your own radio station. Potentially, you can also use the box to eavesdrop your mates’ mobile phone conversation, though we do not recommend you to do so.
Year 2012 Final-Year Projects in
RENEWABLE ENERGY LABORATORY

Prof. Victor Sreeram and Prof. Herbert Lu

1. Smart Grid (2 Projects)

Presently there is a global concern about the economic downturn and a green earth which in turn is related to a better and efficient method to generate and transmit electric power. With the advent of plug-in electric vehicles and renewable energy generators, a smarter more efficient and customer friendly power grid is essential. Governments around the world are investing in R&D strategies to construct a smart electric power transmission infrastructure which supports the decentralized approach of power generation, employs two-way intelligent communications for real-time monitoring, demand and fault management and utilizes latest security protocols to contribute towards a rigid and attack free electric power network. The aim of this project is to study the various methodologies proposed for Smart Grid and analyse the performance of power systems in terms of quality, efficiency and reliability.

2. RegenerativeBraking for Electric Cars (1 Project)

In a conventional braking, the kinetic energy of the car is wasted as heat in the brake pads due to friction, whereas in regenerative braking, much of this energy is converted to electricity which can be used to charge the car’s batteries. This setup will not only increase the range of the battery powered electric car, but also reduces the wear and tear of the brakes. Regenerative braking is currently only available in significantly more expensive AC motors. The objective of this project is to develop regenerative braking scheme in cost-effective DC motors in order to increase the range of the battery powered electric vehicles in which DC motors are utilized.

This project is funded by a grant from Australian Power Institute. The project involves working with dc machines and designing and building power electronic circuits.

3. Development of Memristor Based Chaotic Circuits (2 Projects)

The memristor was postulated as the fourth circuit element by L.O. Chua in 1971. In 2008, researchers in HP fabricated a solid state implementation of the memristor. Potential applications of such memristor span diverse fields ranging from nonvolatile memories on the nano-scale, to model neural networks. Recently, memristor based chaotic circuits have been constructed. In this project, we will develop and analyze the memristor based chaotic circuits. Also, we will study the chaos control algorithm in these circuits.

The project involves mathematical analysis, Matlab simulations, and hardware implementation of the actual circuits.
MICROELECTRONICS RESEARCH GROUP

The Microelectronics Research Group (MRG) is headed by Professor Laurie Faraone, and consists of 7 academic staff, 7 research staff, and 20 postgraduates. The MRG has built up to be one of Australia’s largest and most respected microelectronics research groups. This has led to collaboration with a wide range of international and Australian industry and research organisations. In 2008, the Microelectronics Research Group was awarded a prestigious Eureka Prize for Science in Support of Defence and Security for its world leading work.

The projects undertaken by the MRG cover:

- Microelectronics,
- Optoelectronics,
- Micro-electromechanical systems (MEMS),
- Nanotechnology, and
- VLSI

with applications in:

- Agriculture,
- Defence,
- Manufacturing,
- Medicine,
- Remote sensing and environmental monitoring,
- Spectroscopy,
- Surveillance, and much more

The work covers areas from semiconductor device modelling, fabrication, and fundamental material characterisation, through instrumentation and control electronics, to systems integration and analysis. The support for the research and engineering projects undertaken by the MRG comes from a mixture of Government and industrial funding.

The facilities available are among the best in Australia in the area of semiconductor material and device fabrication, characterisation and modelling. The group operates a nanofabrication facility for fabrication of semiconductor devices, and has a multitude of test and characterisation equipment, as well as commercial packages used for device and circuit simulations, modelling and layout. For many projects in this area students will use state-of-the-art equipment and techniques to measure a number of important semiconductor or device parameters. In some projects students will also undertake data analysis and help develop explanations of the observed semiconductor

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1 Some of the organisations with which the MRG has ongoing links include: Defence Science and Technology Organisation (DSTO, Australia), Tenix Defence Systems (Australia), CSIRO Division of Telecommunications and Industrial Physics (Australia), Australian Institute of Nuclear Science and Engineering (AINSE, Australia), Integrated Spectronics (Australia), Grain Research and Development Corporation (GRDC Australia), IMEC (Belgium), CEA-LETI (France), CNRS (France), University of Tabriz (Iran), Technion (Israel), Korean Advanced Institute of Science and Technology (KAIST, Korea), Vigo Systems (Poland), US Navy Space and Naval Warfare Center (SPAWAR, USA), Lakeshore Cryotronics (USA), University of California at Santa Barbara (UCSB, USA), University of Illinois at Chicago (UIC, USA), Naval Research Laboratories (NRL, USA), DRS Infrared Technologies (Dallas, USA), Defence Advanced Research Project Agency (DARPA, USA), Army Research Labs (ARL, USA), Night Vision Electronic Sensor Directorate (NVESD, Washington, USA), Raytheon Vision Systems (Santa Barbara, USA), University of New Mexico (Albuquerque), Charles University, Prague (Czech Republic), Parma University (Italy)
material/device behaviour, much of which will be new and never before reported. There is also scope to develop automated instrumentation control software in some areas.

All the final year projects offered by the MRG are self-contained but are related to, or support, larger ongoing projects (for more information about these visit the MRG web page at http://mrg.ee.uwa.edu.au/). The type of work involved varies from fundamental and theoretical research through to applied instrumentation control and development. Most projects include some mixture of experimental and theoretical work. Final year students will work alongside postgraduate students and research staff with all projects conducted in a collegiate atmosphere of collaboration between students and staff.

The following sections describe the general areas of research undertaken by the MRG. There are a number of projects available in each area. Most projects tend to be somewhat open-ended as would be expected with a research program. The exact limits and expected outcomes of your project depend to some extent on your interests, and will be defined in consultation with you. You will be part of a team of staff and postgraduate students, each working on different aspects of a larger project and who are interested and keen to see your project succeed. In return for this support, you will be expected to regularly report your results to the group and take a wider interest in the overall project. For more information about projects, please contact any of the members of the MRG. Particular experience and/or skills are advantageous to achieve the requirements of some of the projects described. However, the scope of projects is sufficient to allow the student to obtain these skills during the course of project.

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### The following postgraduate students are doing their research with the MRG:
- Jaber Hassan J. Al Yamani
- Azlan Baharin
- Ben Cheah
- Fei Jiang
- Hemendra Kala
- Ashok Kumar Kurapati
- Meifang Lai
- Wonjae Lee
- Hao Liu
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- Balaji Sankarshanan
- Rohid Sharda
- James Sharp
- Mohamad Susli
- Dhirendra Kumar Tripathi
- Yan Wang
- Danny Wee
- Yueqin (Jerome) Wu (UQ)
- Yimeng Yang
- Jing Zhang

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The following are international visitors to the MRG (2011/2012):

Prof. Asghar Asgari  
University of Tabriz, Iran

Prof Sorin Cristoloveanu  
IMEP - INP Grenoble MINATEC, France

Prof. Klaus Ploog  
Paul Drude Institute, Germany

Prof. Krishnamachar Prasad  
Auckland University of Technology, New Zealand

Prof. David L. Pulfrey  
University of British Columbia, Canada

A. MICROWAVE DEVICES AND OPTOELECTRONIC SENSORS

These projects fall into three main areas; gallium nitride-based devices; micro-machined sensors; infrared (IR) sensors and systems. Projects in the devices area involve a combination of experimental and theoretical work. Fabrication, characterisation and/or modelling of devices from all three of the sub-areas are undertaken by the MRG.

Many of the projects involve collaborative work with international researchers from University of California at Santa Barbara (UCSB), University of Illinois at Chicago (UIC), Lakeshore Cryotronics in the USA, Vigo Systems in Poland, Raytheon Vision Systems (USA), NVESD (USA), and DRS Infrared Technologies (Dallas).

GaN-BASED DEVICES

(BD Nener, G Parish, L Faraone, J Antoszewski, G Umana Membreno,)

This project aims to achieve reliable, manufacturable high performance III-nitride (GaN, AIN, InN and alloys) transistors for use in high power, high frequency applications such as radar and communication systems. The GaN-based FET technology offers significantly improved performance for applications in RF/microwave power amplifiers, high speed switching for power electronics, and operation in harsh electrically noise environments, such as the automotive industry, space applications, and switch mode power supplies. Despite rapid progress in performance, AlGaN/GaN-based transistors are hampered by a variety of impediments. Two particular thrusts of our research in this area are ion implantations and dielectrics. Ion implantation offers the potential to enable a reliable, commercially feasible fabrication technology for GaN-based electronic devices. Dielectric thin-film technologies are desired for gate-insulation and surface passivation layers to enhance the performance, and overcome present limitations, of GaN- and AlGaN/GaN-based microwave transistors for high power and high temperature applications. The third thrust is improvement in electronic properties of InN, which will enable even faster electronic devices due to the high mobility and peak velocity in InN compared to GaN.

Projects in this area include:

A.1 AlGaN/GaN Transistor Device Reliability

What are the key limitations to AlGaN/GaN device performance? This project will involve the study of degradation effects on critical device parameters such as channel properties in AlGaN/GaN field effect transistors. In particular, understanding charge distribution and behaviour at the AlGaN/GaN interface has been identified as a crucial issue by our partners at UCSB, in the path to commercialisation of microwave GaN-based transistors.

A.2 Magneto-Transport of GaN-Based Transistor Structures

Q: What makes a transistor a HEMT (high electron mobility transistor)? A: Excellent carrier transport properties. This project will involve measurement of carrier transport in FET devices, under the influence of an applied magnetic field. Current joint projects with UCSB include investigations into
the effect of passivation layers such as silicon nitride, and use of ion implantation for industrial scale processing. This project is closely related to A.1.

A.3  Modelling and Simulation of GaN Devices

The AlGaN material system exhibits many unique properties that must be carefully considered in modelling device behaviour. Furthermore, as a relatively new material system, there are many aspects and parameters that are unknown or as yet unconfirmed experimentally. This project will involve development of in-house modelling packages for GaN-based devices through adaptation of commercial packages such as Sentaurus. Models developed will be used to simulate device behaviour and compare with measured results.

A.4  Electronic Biological/Chemical Sensors

This project aims to develop a novel electronic biosensor. A bio-friendly, chemically inert and stable III-Nitride-transistor-based bio/chem-sensor will be developed to detect responses to various specific compounds/chemicals, particularly through cell receptors. 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, and chemical sensing applications. The primary aims are:

• Study biocompatibility between the semiconducting material used as the sensor and living cells.
• Develop and optimise electronic device structures to attach and confine the living cells to the semiconductor surface of the biosensor.
• Study the behaviour of the electronic bio/chem-sensor before and after exposure to chemicals/compounds. Identify the dominant physical mechanisms that influence the detection limit of the bio/chem-sensor.

MICRO ELECTRO-MECHANICAL SYSTEMS (MEMS)

(MJM Dell, J Antoszewski, L Faroone, A Keating, M Martyniuk)

Micro Electro-Mechanical Systems (MEMS) represent the integration of mechanical elements, sensors and actuators, with photonics and electronics on a single substrate. The application of microfabrication technology, developed for the manufacture of silicon very-large-scale-integrated (VLSI) circuits, to generate miniature three-dimensional structures such as motors, gears, accelerometers and pressure sensors on the same substrate as the associated drive and sensing electronics has dramatically changed and expanded the field of mechatronics. In addition to allowing mechanical manufacture on a micro-miniature scale, MEMS technology brings the low-cost, high-throughput techniques of VLSI technology to mechanical and sensor systems. Specific applications of MEMS include accelerometers for air-bag deployment and shock sensors, micropumps for drug delivery, pressure sensors for measuring tyre pressures. The Microelectronics Research Group is working on optical MEMS technology to make optical detectors which are only sensitive over a small, electrically tuneable wavelength range.

A.5  Investigation of Chemical Sensing Technologies Based on MEMS Devices

Small, inexpensive and robust chemical sensing is now a major business, with applications from security (detection of explosives at an airport for example), to global warming (determination of total carbon in soil is important for carbon sequestration and development of carbon-credit schemes), medicine, automotive engineering, ... This project will investigate the use of MEMS and some innovative properties of materials developed at UWA for applications in chemical sensing. The devices to be developed will be effectively electronic noses. This project will is quite open and could be a broad scoping study, or could investigate a particular type of device in detail. It will primarily be theoretical. Skills required for this project will be an interest in innovative technologies and the
ability to mathematically model a number of different physical phenomena including optical waveguides and mechanical resonances in small structures.

A.6 Lab-on-Chip Technologies

Lab-on-chip research within MRG focuses on techniques which can allow rapid analysis of ultra-small volumes of fluid. Particle separation within the fluid is a key step required in many chemical assays of biological fluids containing cells. One approach being considered is the use of acoustophoresis on-chip (ultrasonics) to setup a standing wave within the microchannel. The acoustic pressure pushes the particles (cells) to the standing-wave anti-nodes, which can be subsequently separated/routed to a specific microchannel outlet. Our contribution is the development of techniques to enable this approach to be applied in plastics and to biological fluids such as milk, which requires the heat generated on chip to be minimized.

A.7 Mapping Micro-photoelastic-induced Changes for Characterization of Biosensors

Microcantilever based biosensors are a novel next generation approach to building high sensitivity sensor arrays. The aim of this project is to create a computer controlled system which focuses a pulsed high power laser onto an absorbing thin film. The absorbed thermal pulse is expected to cause localized thermal expansion, resulting in a propagating acoustic wave. A laser Doppler vibrometer will be used to measure the induced vibrations. After programming of the XY-motion stage and laser to map the surface, the process will be characterized to determine the magnitude of the induced thermal expansions. Using simple structures such as micro-cantilevers, the project will investigate optimal locations where the photo-induced thermal expansion can be applied.

INFRARED SENSORS
(J Antoszewski, JM Dell, L Faraone, BD Nener)

The ability of IR detectors to directly sense the thermal output of an object has found wide application in thermal imaging for medical diagnostics, bushfire detection, satellite remote sensing, search and rescue, thermal loss budget estimation, as well as the more traditional defence and aerospace applications. In addition, emerging applications of IR detectors are found in spectroscopic systems for mineral exploration, pipeline monitoring, pollution detection and identification, and gas monitoring systems. Specific examples include; detection of tumours and tissue damage, detecting illegal waste disposal by ships in harbours, preventative maintenance in electrical switchgear such as high voltage transformers. For the fabrication of sensitive IR detectors, the highest performance is achieved in devices using the semiconductor material mercury cadmium telluride (HgCdTe or MCT). There are a number of unique properties which give MCT an advantage over competing technologies, with the main advantage being the ability to bandgap engineer the material, for specific applications. The MRG has recently developed new detector structures that are at the leading edge of IR sensor technology. A large amount of research is being carried out to characterise and test the performance of new devices. Projects in this area will include:

A.8 Characterisation and Modelling of HgCdTe Photovoltaic Detectors

This project will undertake theoretical modelling and performance measurements of infrared photodiodes fabricated in the MRG laboratory. The junctions are formed using an in-house developed process, and are expected to deliver state-of-the-art performance. These detectors are employed in large two-dimensional arrays that are used for infrared imaging for applications such as night vision, surveillance, medical imaging and environmental applications. A commercial modelling package, Sentaurus Device, will be used to perform two-dimensional modelling of devices.
A.9 **Characterisation of HgCdTe Heterojunction Photodiodes**

This work will investigate the performance of HgCdTe photodiodes based on bandgap engineered structures. This will involve both measurements and theoretical calculations. Bandgap engineering is one of the latest methods used to improve device performance and functionality, and involves the control of material thickness down to the atomic layer level.

A.10 **Noise in HgCdTe Based Photodetectors**

The signal-to-noise ratio in photodetectors is a key performance parameter. The measurement of noise and the identification of noise mechanisms is a fundamental requirement in the improvement of performance. This project will look at theoretical noise models and measurement of noise. The project will use devices known as gated-photodiodes to measure and identify noise mechanisms.

A.11 **Small Infrared detector arrays - applications**

Small infrared detector arrays are used in a wide range of commercial applications. One of them is contactless, real time, temperature measurement. In this case the detector array hybridized with another array of micro Fabry-Perot filters represents a spectrometer with a number of preselected infrared bands. Such a spectrometer can be used for the analysis of black body like radiation and in consequence calculation of the objects temperature. In this project the task will be to fully characterise the hybridized detector/filter array, collection of black body characteristics versus temperature and develop a software for fast algorithm converting signals measured from detector array to temperature. This project requires a person interested in both, the research in the field of infrared detectors and solid opto-electronic systems engineering.

B. **SEMICONDUCTOR MATERIAL PROCESSES AND CHARACTERISATION**

(J Antoszewski, JM Dell, L Faraone, G.Parish, BD Nener, G Umana Membreno, M Martyniuk, G. Tsen)

The MRG has some of Australia’s best facilities for undertaking materials characterisation for a wide range of semiconductors, and has developed techniques that are now licensed by large semiconductor facilities around the world. A number of projects are available in this area, working on the development of new techniques, as well as using techniques we have already established to measure the properties of semiconductor layers.

The data obtained from these measurements give information about the electrical, optical and structural properties of the semiconductor layers. This information will be used to design new growth processes and develop new electronic and sensor devices.

Students will gain experience in high technology instrumentation, low-level signal measurement techniques, and low-noise system layout. These skills are applicable in a wide range of communications and electronics areas, as well as in the mainstream semiconductor industry.

B.1 **Sensitivity of Quantitative Mobility Spectrum Analysis (QMSA) Technique**

QMSA is a state-of-the-art analysis technique developed at UWA, and currently licensed to a US scientific equipment supplier, for characterising multiple hole and/or electron carrier species that often exist in modern semiconductor materials and devices. This project seeks to investigate theoretically the influence of sample’s non-uniformities (such as material composition, doping level, thickness) on the transport parameters extracted by QMSA.

B.2 **Characterisation of Silicon-on-Insulator (SOI) Materials**

In the present bulk-Si nanoelectronics technology, where individual transistors are already approaching the size comparable with silicon layer thickness (tens of nanometres), the size/thickness
related issues lead to fundamental problems in the process of scaling devices. It is generally believed that further miniaturisation will be achieved through Silicon On Insulator (SOI) technology, which, in contrast to its predecessor, is based on silicon layers with thickness approaching less than ten nanometers, allowing further scaling without compromising the size/thickness ratio. This project involves characterisation of electrical transport properties of state of the art SOI wafers, supplied by overseas vendors, using Hall Effect and Magnetoresistance techniques.

**MERCURY CADMIUM TELLURIDE**

The MRG has an established Molecular Beam Epitaxy (MBE) growth facility for mercury cadmium telluride (HgCdTe) semiconductor structures for high-performance infrared detectors. MBE, a state of the art technology for semiconductor crystal growth, allows growth of layers of different semiconductors, from as thin as a single atomic layer, to layers tens of microns thick. MBE technology is very important for fabrication and design of ultra-high performance electronics and optoelectronics devices using bandgap engineering. The Defence Science and Technology Organisation (DSTO) selected the Microelectronics Research Group to establish a university based MBE facility for the growth of mercury cadmium telluride (MCT) semiconductors, using equipment worth ~$3.5 million donated by DSTO.

**B.3 How to Make Stable Semiconductor Materials**

While mercury cadmium telluride is the best material to make infrared detectors, it also has many difficulties. One of these is that the surface of the semiconductor is very sensitive. To fix this problem, the surface is coated using another material (cadmium telluride). While this works, it is unclear why it works and if this is the optimum way of fixing the problem. This project will investigate the interface between the two materials to try and understand what is happening. This will be done using very simple semiconductor devices – capacitors and photoconductors. The capacitor (a metal-insulator-semiconductor or MIS capacitor) allows extraction of data related to charges trapped at the interface and how they are trapped. A photoconductor is a light sensitive resistor that can be used to measure rate at which electrons and holes are trapped at the surface. HgCdTe material used in this work is either grown in-house (using Molecular Beam Epitaxy) or purchased externally. In either case, to prove the device quality of the material photoconductors are an ideal test device.

**B.4 How to Make Nano-scale pn Junctions in Mercury Cadmium Telluride**

Making a pn junction diode in mercury cadmium telluride is the basis of the most sensitive infrared detector structures. The size of the pn junction directly relates to how sensitive the detector is (may be surprisingly, the smaller the size of the diode, the more sensitive the detector can be). We have developed a very simple technique that should allow us to make pn junctions diodes with areas less than 1μm×1μm (that is less than 10-6mm2, or less than around one hundredth the diameter of a hair). The problem is then, how to you characterise such small diodes or even make contact to them. In this project you will use a scanning laser microscope (SLM) to do this. The SLM can be used for a number of techniques including: transient lifetime, laser beam induced current (LBIC) spatial photoresponse.

- **Transient lifetime** measurements are used to measure the lifetime of carriers in a semiconductor. Carrier lifetime is one of the most important semiconductor parameters and has a significant effect on the performance of devices fabricated from semiconductors. Transient lifetime is measured by illuminating the semiconductor with a pulsed focussed laser, and measuring the decay time of the resulting electrical signal.

- The **LBIC** technique is being investigated as a non-destructive in-process testing tool for the characterisation of IR arrays. Ideally the LBIC tests will give information about individual
photodiode performance, and the overall uniformity of the arrays. Projects in this area will investigate the correlation between LBIC signature and device performance.

- **Spatial photoresponse** uses a focused laser to stimulate carriers in a photodetector device, enabling the local response of the material to be measured. By scanning the laser in a 2-dimensional space, the uniformity of the detector active area can be quantitatively assessed.

These projects involve use of lasers, low-noise amplifiers, and the measurement of extremely low signals. Once measurements are obtained, various data analysis techniques are then employed to determine device and material performance.

**B.5 Characterisation of MBE Grown Material**

Molecular Beam Epitaxy is the required semiconductor growth method for fabrication of complex multilayered device structures. The MRG runs an MBE growth facility that can grow HgCdTe. This project will look at the analysis of the grown semiconductor layers using a number of material characterisation techniques including Secondary Ion Mass Spectrometry (SIMS), LBIC, and Hall measurements and transient lifetime.

**B.5.1. Characterisation of MBE grown MCT by x-ray diffraction**

The X-ray diffraction facility at LaTrobe University in Melbourne has recently gone 'on-line'. Be the first to use this 'telepresence' system to make measurements on the sub-nanometer scale of the crystal structure of MCT samples grown at UWA. The results will be analysed to give information about strain and defect formation in the semiconductor layers.

**B.5.2. Measurement of molecular fluxes in molecular beam epitaxy using cavity ring-down spectroscopy**

This project is the start of a much larger project which aims to measure very low concentrations of gases in a semiconductor crystal growth chamber using optical absorption techniques. Cavity ring-down spectroscopy is a new ultra-sensitive laser absorption spectroscopy technique that can be used to detect gas concentrations to much less than one part per billion. The student will be involved in predicting the sensitivity of various cavity ring-down experiments and constructing models of the optical absorption spectra expected during crystal growth.

**B.5.3. High precision multi-channel voltmeter/data acquisition system**

High performance analogue to digital conversion (ADC) chips are now readily available at low cost, offering the possibility of constructing a high precision / low data rate voltmeter with computer interface at a lower cost than commercial systems. This project aims to create a multi-channel data acquisition system for monitoring several process variables during semiconductor crystal growth. The system will require a PC user interface (written in LabVIEW) to communicate with a microcontroller/ADC board and low-noise input electronics.

**B.6 Characterisation of Plasma Processed HgCdTe**

Plasma processing via reactive ion etching (RIE) is the technique used by the MRG to convert p-type HgCdTe to n-type and thus form an n-p junction. This project will undertake characterisation of this converted region. The methods that will be used include Hall measurements and Secondary Ion Mass Spectrometry (SIMS).

**III NITRIDE**

III nitride (GaN, AlN, InN and alloys) semiconductor technology is relatively immature, with significant progress in this material system only having been achieved in the last 15 years or so. Despite the many inherent advantages of nitride-based materials, significant challenges still exist in
the growth and fabrication of devices. Therefore there is much to be learned regarding both the fundamental material properties of and defects within the material. Such studies are critical in enabling nitride-based technology to reach its true potential.

The majority of the III nitride materials studied in the MRG are obtained as part of a long standing collaborative arrangement with the University of California at Santa Barbara. The MRG undertakes the detailed materials characterisation needed in the development of new device structures.

B.7 **Optical Measurements of GaN Minority Carrier Properties**

Measure an important but elusive property in nitride material. GaN material quality is directly related to its ability to emit light, which in turn is related to minority carrier lifetime. This project will use novel techniques that utilise photocurrent and photo-induced luminescence to investigate minority carrier properties in GaN material, and consequently use this information for improved materials and device performance.

B.8 **Device Processing of GaN**

Help develop state-of-the-art gallium nitride processing capabilities. GaN is a desirable material partly because of its high temperature stability and chemical inertness. However, these properties also make device fabrication difficult. This topic includes investigations into etched wafers and fabricated metal contacts, both challenging but vital processing steps.

B.9 **Hall/QMSA of III-nitride Materials**

Good transport properties (carrier concentration and mobility) of III-nitride materials are of vital importance for application of these materials into state-of-the-art devices. These projects will involve transport measurements using the powerful 12T magnet and then analysis of results using QMSA. Particular materials of interest include ion-implanted GaN, and InN.

**POROUS SILICON**

Porous silicon is a novel nano-material with the capability to perform as a mirror, waveguide, light emitting diode, photodetector, and sensor. Porous silicon is formed by the anodisation of crystalline silicon, and can be produced with a wide range of refractive indices, varying surface area, variable energy bandgap. Furthermore a variety of materials can be infiltrated into the nanopores, including polymers, biological species, and liquid crystals. Aside from optoelectronics, other applications include: photonic bandgap structures in micro-optics, solar cells for energy conversion, gas sensing for environmental monitoring, high etch selectivity for wafer technology, highly controllable etching parameters for micromachining, biosensors, and enzyme immobilization in biotechnology.

B.10 **Development of Porous Silicon-based Devices for Optoelectronic Applications**

This area of research is relatively new within the group and hence work in this area will concentrate on the development of a process for the fabrication of porous silicon and characterisation of the material. The ultimate aim is to produce devices for optoelectronics applications. Some key parameters of porous silicon are: porosity, porous silicon depth, optical properties, homogeneity. These parameters are to be measured as a function of the formation process parameters. This project will involve the investigation of techniques to produce uniform layers of porous silicon for optoelectronic device applications.

Porous silicon-based devices that are currently being developed within the group are: distributed Bragg reflectors (mirrors) for optical filters, and anti-reflection coatings for micro lenses.
B.11  **Build a Sensor Based on Porous Silicon**

Porous silicon is an advanced material which can be used for biological and gas sensing applications. This project explores the possibility to make a low cost optical sensor based on porous silicon. An array of light emitting diodes, each with a different wavelength will be reflected from the porous silicon surface and measured over time. The change is reflected signal level will provide an indication of the analyte being sensed. This project is perfect for mechatronics engineers. The project includes electronic and mechanical design. Skills to be developed include mechanical design, optical sensing, an understanding of porous silicon, and understanding of sensing technologies, signal processing, data collection and analysis.

B.12  **Study of Stability of Porous Silicon**

One ongoing issue with porous silicon is that the material is not stable when exposed to atmosphere, which leads to device characteristics changing over time. This project aims to implement a series of tests to determine if various treatments will render the material stable. Approaches for stabilising porous silicon include annealing and functionalisation of the surface. Accelerated aging tests will be performed on the material and tools such as reflectance measurements and FTIR will be used to assess the stability.

B.13  **Measurement of Thermally-induced Stress and Its Effect on the Optical Properties of Porous Silicon**

The thermal and optical properties of silicon are well known. However, when forming pSi, a significant portion of the silicon matrix is replaced with air (pores). If these pores are filled with different material (oxides or nitrides) the optical and mechanical properties of the films change. Since these films are used for the creation of optical (bio) sensors and micro-electro-mechanical devices, and understanding of these properties is extremely important. As part of this work, students will have access to and learn about a range of advance metrology tools such as Fourier Transform Infrared (FTIR) spectrometers, optical profilometers and optical characterization systems.

B.14  **Direct Laser Writing of Structures into Porous Silicon**

PSi is extremely important for forming optical (bio) sensors and micro-electro-mechanical devices, however optical photolithography (used extensively in microelectronics) cannot be used on these films as the films are incompatible with the chemical used. Recently, we have developed a technique to make these films robust (passivating) in the presence of these chemical, but requires heating films rapidly to 600°C in a nitrogen atmosphere. This project aims at using a focused laser beam onto the surface of the pSi to achieve the temperatures required in a very localised region, selectively passivating areas of the film. Subsequent exposure to a weak-base should remove all regions which were not exposed to the laser. Using a computer controlled XY stage, we intent to directly write features into the porous film.

C.  **ELECTRONIC/OPTIC SYSTEMS**

(JM Dell, A Keating)

The projects in this area involve the design and production of electronic and optics systems that assist in characterising MRG devices or demonstrating the capabilities of MRG work.

C.1  **Design of Automated Soil Analysis Instrumentation for Agriculture.**

In agriculture, the cost of inputs to production (seed, water, fertilizers, insecticides, herbicides, etc) is rapidly increasing, and returns are increasingly tied to crop quality. The ability to be able to monitor soils and target where fertilizers, herbicides etc need to be applied, and where the highest quality produce is likely to be harvested is now essential information for farmers, but is so expensive
to obtain that it can only be used on a limited scale. Projects in this area are examining the
instrumentation required to be able to measure key soil parameters in real time using optical
techniques including infrared analysis and laser light scatter, and electrical probe measurements.
Specific projects include design of optical systems to measure infrared signatures of soil,
implementation of laser scattering measurements to determine particle size, use of electronic and
RF probing techniques to determine moisture content, and analysis of infrared signatures to extract
soil properties. Applications include wheat, rice and other grain farming, and analysis of soils for
vineyard production monitoring. These projects will be undertaken in cooperation with the School
of Earth and Geographical Sciences and the School of Plant Biology.

C.2 Infrared Analysis of Breast Milk

Breast milk is recognised as the optimum nutritional source for new born infants. However, for
premature babies, it is often essential to supplement breast milk in order that essential nutrients are
included in the baby’s food. To determine if such supplements are needed, the mother’s breast milk
must be analysed, requiring often significant sample volumes, which are then not available to the
baby. This project, undertaken in collaboration with Biochemistry and Molecular Biology at UWA, is
examining ways in which infrared spectroscopy, microfluidics and signal processing can be combined
to obtain real time measurement of key nutrients in breast milk using very small sample volumes.

C.3 Design of a Sub-picofarad Capacitance Measurement System

To accurately control displacement in many MEMS devices, the capacitance between two parallel
plates is measured. Because of the size of the devices, this capacitance is very small. This project
will look at capacitance measurement techniques that can be implemented in analogue field
programmable gate arrays. The initial designs will use a technique that called a “balanced-bridge,”
but other techniques are possible. The skills required for this project are an interest in electronics
design, an interest in implementation of a system, and some budgetary skills (the project will have a
budget which is reasonably large but not infinite).

C.4 Design of a Position Control System for MEMS Tuneable Detectors

This project will look at implementation of a control system to accurately and precisely set the
wavelength of a tuneable detector. It is an electronics design project, which will be implemented in
a combination of analogue and digital field programmable gate arrays. The control system is
notionally simple, generating a voltage that controls the separation between two plates. The
capacitance between the plates will be used to sense the separation between the plates (it is this
separation that controls the wavelength of the tuneable detector). The skills required for this project
are an interest in electronics design, an interest in implementation of a system, and some budgetary skills (the project will have a budget which is reasonably large but not infinite).

C.5 An Automated Computer-controlled Gantry for Improving Porous Silicon Fabrication

The aim of this project is to design and build an automated computer controlled gantry for a multi-
bath porous silicon growth system. Background: Porous silicon is a novel material for many opto-
electronics applications. The Microelectronics Research Group is currently investigating growing
porous silicon using a multibath method. To be able to do this safely and in an automated fashion a
mechatronic gantry to move the porous-silicon growth cell between the baths is needed. The gantry
will need to be approximately 600-800 mm wide and 400-600 mm tall. It will have a crane on the top
rail controlled by stepper motors which can accurately move the porous-silicon growth cell between
up to four baths. The baths themselves are 120x180mm and will be located on a raised platform.
The system will be controlled using a computer through a PIC micro-controller and an RS232
interface. The student undertaking this project will gain basic knowledge of the porous silicon
growth process and how the system is aiming to improve on current limitations. The project will
involve skills in mechanical and electronic design, and as such will ideally suit a mechatronics engineer although mechanical and electrical engineers are encouraged to consider this project.

C.6 Build an Ellipsometer to Measure Scattering in Porous Silicon

To understand the characteristics of porous silicon, an advanced material used for sensors, detailed optical characterization if required. Current methods used are inadequate to accurately determine the porosities of the film and the roughness of the porous silicon/silicon interface. This project is perfect for mechatronics engineers. The student will gain an understanding of porous silicon and its applications, design, build, test and analyse an ellipsometer to characterize porous silicon. The ellipsometer requires high precision 2-axis rotational control of an optical beam and the sample. Skills in signal processing, mechanical design and control will be developed as part of the project.

C.7 Build a Micro-gram Scale for Gravimetric Measurements of Porosity in Porous Silicon

To find the porosity (density of holes) in porous silicon it is required to measure the weight of the silicon before and after forming pores (porosification). However, the expected change in weight is in the order of 10^-4 grams, requiring a scale with an accuracy of at least 10-times less than this value. Commercial scales often compromise between range of measurement and accuracy. However, the largest weight we expect to measure is the bare silicon, which comes to around 1.4 grams, requiring a dynamic range of only 10^5. This project aims to build, characterize and calibrate a highly accurate scale for porous silicon. The student will subsequently form porous silicon samples and determine the porosity verse anodization current. This project is perfect for mechatronics engineers. The student will gain an understanding of porous silicon and its applications, design, build, test and analyse a highly accurate scale and address the issues associated with the scale accuracy including drift due to temperature, humidity and air movements. Skills in signal processing, mechanical design and control will be developed as part of the project.

D. ATMOSPHERIC PROPAGATION

(N Fowkes, BD Nener)

The ultimate performance of an EO System is determined by the atmosphere. The atmosphere can degrade the signal through scattering and absorption by aerosols, background radiation, scintillation and refraction. Projects in this area are both theoretical and/or involve experimental work. The experimental work is at sites like Rottnest measuring atmospheric parameters important to EO propagation and involves the design and installation of the instruments, and the analysis and modelling of atmospheric data and effects. The theoretical work involves mathematical and numerical modelling of atmospheric effects relevant to EO systems, particularly refraction and scintillation.

Current work is funded by the Australian Department of Defence and Tenix Defence Systems Ltd (an Australian owned defence contractor). The effort is in collaboration with the UWA Department of Mathematics and Statistics; the Remote Sensing and Satellite Research Group (RSSRG) of the Physics Department of the Curtin University of Technology; CIMSS, Space Science and Engineering Center, University of Wisconsin, Madison, Wisconsin, USA, and the US Navy Space and Naval Warfare Center (SPAWAR), San Diego, USA.

D.1 Refractive Index Change in Atmosphere

Modelling of the effects on light and microwave propagation of refractive index changes due to temperature gradients in the atmosphere over the ocean; modelling of mirages and other image distortions of objects seen at large distances; scintillation.
E. **INTEGRATED CIRCUIT DESIGN**  (Associate Professor Farid Boussaid)

E.1 **Camera-on-chip**

The current trend in Digital Imaging Technology is towards building camera-on-a-chip imaging systems, i.e., CMOS imagers. The fully integrated product results in significant manufacturing cost savings, reduced system size, but also in lower power consumption. The unique concept of CMOS imagers offers the opportunity to integrate photo-sensing array and signal processing circuitry on a single silicon chip, enabling the development of a new generation of smart mobile imaging systems. Half the size of a small postage stamp, a CMOS imager chip can even be swallowed (pill-camera) to transmit images from inside the body. Besides biomedical, CMOS imagers have numerous commercial applications in cell phones, PC notebooks or any application for which a “micro-camera” can be requested.

Proposed final year projects will involve building such a camera, and optimize its performance in terms of dynamic range, resolution and/or power consumption. During the project, you will further develop your analog/digital electronic design skills.

E.2 **Electronic nose**

Sniffing-dogs are able to detect thousands of chemicals with high sensitivity and selectivity using only biological components. These nasal powerhouses have been successfully used to search for pipeline leaks, drugs, or explosives. You will develop a biologically inspired Electronic Nose (or ENose for short), that mimics the organization and neural processing of the olfactory bulb. The Enose will comprise a chemical sensor array and a gas recognition engine, integrated on a single chip. Projects offer an opportunity to discover and apply neuroscience principles into made-made engineering systems. Projects will be tailored around your interests, whether neuroscience and/or integrated circuit design.
E.3 UWA Unmanned Aerial Vehicle (UAV)

We seek to develop, design and manufacture a UWA-made UAV (Unmanned Aerial Vehicle). UAVs are man-made flying vehicles capable of operating without a person on board. UAVs come in a large variety of sizes and shapes and applications. This project will focus on the ‘miniature’ UAV category, which is defined as having a maximum take-off weight of 30Kg, maximum flight time of 2 hours and a maximum altitude of 300 meters. This category represents a good trade-off between size, complexity and cost when compared to larger UAVs. Mini-UAVs are large enough to carry useful payloads such as digital cameras, sensors and other equipment. They are also small enough that they can be built relatively cheaply and do not come with the strict regulation requirements for operating and testing larger aircrafts.

The core components of a UAV are: the airframe, the propulsion system, the avionics, the radio data link, the base-station and the payload. Given that the UAV project has just started, help is sought at all levels and disciplines.
Optical + Biomedical Engineering Laboratory

**Staff:** Professor David Sampson, Dr Robert McLaughlin, Dr Brendan Kennedy, Dr Dirk Lorenser, Mr Andrea Curatolo, Mr Bryden Quirk, Mr Rodney Kirk.

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**Webpage:** [http://obel.ee.uwa.edu.au](http://obel.ee.uwa.edu.au)

If you are interested in instrumentation, optoelectronics, lasers, optical engineering or computer vision, and their applications in medicine and biology, then OBEL could be for you. Projects in OBEL will help to develop your practical skills in these areas as well as in systems integration, interfacing, numerical modelling, or programming. These skills are sought in a wide range of industries in the instrumentation, telecommunications, biomedical engineering, and biotechnology sectors.

OBEL develops new medical and biological imaging techniques based on optics. Although our research is strongly motivated by these biomedical applications and based on the use of light, YOU DO NOT NEED PRIOR KNOWLEDGE OF BIOMEDICINE OR OPTICS.

OBEL’s final year projects fall into one or more of the following categories:

- Systems integration, interfacing and software design and development;
- Optical engineering – design and realization of optical systems;
- Mechanical systems – design and realization of mechanics for endoscopic and portable hand-held devices;
- Image processing, 3D reconstruction and visualization;
- Numerical modelling; and
- Microscopy of biological cell and tissue samples.

Your project will form a part of the group’s research and will be strongly collaborative and team based. OBEL’s staff and postgraduate students will be interested in your project, and will be eager to help you succeed.

All project areas can accommodate two or more students. From the project descriptions alone, it may not be completely clear to you what you would actually do – come and talk to us so that we can define a project around your skills. Contact details are on our webpage.
1. Medical imaging with optical coherence tomography

Optical coherence tomography (OCT) is an ultra-high resolution medical imaging modality. Conceptually, it is similar to ultrasound imaging, except that reflections of light are detected rather than sound. This enables a much finer scale of image than is possible with ultrasound. OCT is providing images of unprecedented clarity of living biological entities and is providing new information on a variety of diseases and conditions, including cancer and muscular dystrophy.

OCT research at OBEL aims at understanding and improving the technique and in designing and building instruments for various applications, including breast cancer (with surgeons at Sir Charles Gairdner Hospital), skin (scar assessment with the Laboratory for Genetic Epidemiology, WAIMR), and animal muscle tissue (for muscular dystrophy research with Miranda Grounds at Anatomy & Human Biology).

Examples of possible projects:

i) **Instrumentation Design:** Design and construct a compact OCT system for clinical use. The focus is on miniaturization of the current optical fibre-based system and involves the design and construction of portable/compact electronic and optical modules. The portability and reliability of the system will be tested under clinical conditions;

ii) **Muscle imaging:** Early work suggests OCT may be able to differentiate between dystrophic and non-dystrophic mice, which could reduce the need for subjects and improve the statistics and accuracy of many experiments. You will continue investigating what OCT can provide.

iii) **Image Processing for Breast Cancer:** OBEL is currently exploring the use of OCT to detect breast cancer in lymph nodes. You will develop image processing algorithms to improve these images and help clinicians to identify cancerous regions. This is a software-based project and will require knowledge of either Matlab or C++.

(left): Optical coherence tomography scan of a human breast lymph node. (right) Matching H&E histology image of the lymph node.

(right) OCT image of muscle for muscular dystrophy research.
2. OCT needle probes for breast cancer

We have developed a number of prototype needle probes, where the miniaturised optics of the OCT system are encased in a medical hypodermic needle. These probes will enable surgeons to more accurately detect cancer during surgery, through assessment of lymph nodes and testing tumour margins.

We are actively exploring new probe designs, and possible projects will focus on the optics and mechanical design of the probe itself. These are hardware-based projects that will involve researching a new probe design, fabrication of the optics and assessment of the probe.

3. High resolution elastography

Elastography is a new imaging technique which creates an image of what tissue ‘feels’ like. It can be used to differentiate between healthy and diseased tissue by measuring the elastic properties of the tissue. We have combined this technique with optical coherence tomography to achieve extremely high resolution images. Examples of possible projects are:

i) **Construct an ‘artificial’ phantom tissue**: Design and develop a set of validation objects, which have the same elastic and optical properties as human tissue. Such objects are made from biological substances such as fibrinogen, thrombin and collagen. They are critical to allow calibration of an elastography scanner before it can be used clinically, and also allow researchers to test new imaging methods.

ii) **Mechanical modelling of tissue**: Create a numerical model of how forces are transmitted through different layers of tissue. This will allow elastography measurements to be converted into absolute quantities, allowing reliable differentiation of features such as cancerous and healthy tissue.
4. Investigation of optical properties of biological samples

One goal in OCT is to measure the optical properties of different tissue samples. This includes measuring how rapidly light attenuates and the directionality of optical scattering. It is important to benchmark optical property measurements in OCT using independent techniques. A possible project would involve building optical setups using components such as lasers, optical fibres, goniometers and integrating spheres to allow this benchmarking to be performed. Another possible project would involve characterisation of nanocrystals for use in optical spectroscopy.

5. Visualisation and rendering

A large component of our research involves efficient handling of large 3D datasets. Possible project in this area are related to visualisation, feature extraction or GPGPU (General Purpose Graphics Processing Unit) development. This could involve real-time 3D rendering for our optical imaging systems.

6. Improving OCT image quality

OCT images are subject to a granular or mottled appearance, similar to ultrasound, due to speckle. We are interested in developing techniques to reduce speckle and improve image quality, whilst maintaining high resolution. A possible project would involve developing new techniques and comparing existing techniques to achieve this.