PROJECTS FOR PhD, Masters and BSC Honors Program 2018

The following are examples of project concepts for research programs (click on the Link to View USQ Handbook):

- **Doctor of Philosophy** PhD
- **Doctor of Applied Science** DASC
- **Master of Science Research** MSCR
- **Master of Science** MSCN (Research Project I and II): via MSC8001 & MSC8002
- **Bachelor of Science Honors** (BSc Hon)

**Note:** The depth of project will vary according to the length of program. Email: ravinesh.deo@usq.edu.au, or see existing students in my research group. https://eportfolio.usq.edu.au/user/u1007881/research-higher-degree-rhd-supervision-1?new=1

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Modelling and Simulation of Environmental Systems

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**Project Title:**  
Artificial Intelligence Modelling of Harmful Solar Ultraviolet Index for Health-risk Mitigation

**Abstract:** Australians (particularly Queenslanders), New Zealanders and Europeans facing significant damage from solar ultraviolet radiation effects on the human body. Implementing sun-protection to mitigate health risk of erythemally-effective solar radiation is a strategic initiative of the WHO Global Solar UV index (UVI). Exposure to UV contributes to malignant keratinocyte cancers. Smart forecasting models embedded in an outdoor decision-support system to simulate solar index (UVI) can predict UVI and help mitigate the risk of skin cancers. Such predictive models can inform the real-time sun-protection behaviour and act as a useful tool for public health advocacy.

In project, the student will learn new modelling skills, develop and apply artificial intelligence models to design high-performance systems to simulate solar ultraviolet index. Students will learn to integrate innovative mathematical tools, such as wavelets, Bayesian Average Models and Artificial Neural Network to generate artificial intelligence based predictive models. The models will utilise satellite-based data including ground measured products and reanalysis, yielding high performance in scientific models applied for mitigation of health-risk (e.g. skin cancer).

The purpose of this project is:

- Develop neural network tools (e.g., artificial neural networks, extreme learning machine or support vector machines) and statistical models (ARIMA) for forecasting solar radiation at risky locations in Australia.
- Apply statistical techniques to investigate uncertainties in UV predictive models, particularly from the viewpoint of designing a real-time decision support system for health-risk mitigation.
- Evaluate model preciseness with statistical score metrics (and implement modern-day multi-resolution analysis techniques e.g. wavelet transformation and empirical mode decomposition).

The project will empower students to enhance the science in respect to forecasting capabilities of models related to measured conditions that provide real-time advice for public to mitigate the potential for solar UV-exposure-related disease. It suits students with a background in public health, engineering, solar radiation science, computing, climatology, meteorology, mathematics, statistics, environmental and atmospheric physics.

Student will learn MATLAB as an intensive data analysis and artificial intelligent modelling tool. The project is scalable for further research, such as to a Masters or a PhD program to advance research careers, acquire programming skills and model design with strong publication opportunity within Environmental Modelling and Simulation Research Group.

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Modelling and Optimisation of Wind Power with High-precision Models using Geophysical, Statistical and Evolutionary Modelling Approaches

Abstract: Clean wind power is a promising renewable energy, whose interest is driven by a crisis of fossil reserve depletion and environmental concerns of its usage. Wind power industry is the fastest growing renewable resource and is expected to continue to grow over 2030s although the production of real energy will rely on accurate simulation models of wind speed over hourly, daily and monthly periods. Wind prediction models can enable short-term (real-time) and long-term wind energy feasibility studies and future wind power investments.

Australia has excellent wind resources. Although research in onshore and offshore wind farms must be performed, reliable wind prediction models are lacking. Wind energy resources for potential wind farm sites require integrated high quality monitoring with a micro-scale model of wind flow incorporating the effects of topography and terrain. However, advanced forecast models that provide reliable information on wind power sustainability, and address stochastic behaviour of wind regimes for more accurate predictions, can assist in economically-viable future investments, to solve wind energy utilization challenges.

In this project, the students will learn about the design of farms and optimisation of power using high-precision forecasting tools and geophysical, statistical and evolutionary models. It will consider uncertainty and power-failure risk, effect of wakes with power production, atmospheric stability on performance and loading characteristics throughout a typical daily cycle, power production in extreme event and optimum placement of wind system. Students will apply machine learning (i.e., artificial intelligence) to predict wind speed at topographical and geographic locations. Machine learning is unique as a fast and efficient data transformative tool, yet the application in renewable energy remain very limited.

The project is scalable for further research, such as to a Masters or a PhD program to advance research careers, acquire programming skills and model design. It integrate knowledge of data science, atmospheric and climate sciences, mathematics/statistics to develop models for wind energy.

The project will suit students in renewable energy, engineering, computing, climate, meteorology, mathematics, statistics, environmental science and atmospheric physics. Students have opportunity to engage constructively with supervisor to publish and further research within Environmental Modelling and Simulation Research Group.

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Project Title:
Optimizing Biofuel as Renewable Energy by Modelling Photosynthetic Active Radiation with Artificial Intelligence

Abstract: Biofuels, as a renewable energy is clean and environmentally friendly. Global advocacy for climate change mitigation aims to minimize fossils fuel usage to support cleaner energy. While alternative energies (e.g., biofuels) extracted from feedstock (e.g., micro-algae), represent a promising role, their production requires reliably modelled Photosynthetically-Active Radiation (PAR). PAR models predict energy parameters (e.g. algal carbon fixation) to aid in decision-making at PAR sites

Critical to the biosphere is the PAR (400 ≤ PAR ≤ 700) nm utilised by microcellular organisms to develop chemical constituents that are the building blocks of marine and terrestrial food webs that in
turn, regulate and sustain biomass production systems. Subsequently, the availability of PAR affects crop yield, biodiversity and ecosystems and CO$_2$, water and energy control in plant-atmospheric systems through the carbon cycle. PAR predictions are important in biofuel-based renewable energy systems.

Biofuels provide 46 EJ of bioenergy globally, and drive a source of food, fodder and fibre, and hydrocarbons used for heat, electricity, liquid fuels and chemicals. Future knowledge of PAR is crucial to support increasing demand for sustainable energy, supporting agriculture, biological functions of plants and other bio-physical applications.

In this project, the students will utilise models to predict photosynthetically active radiation where ground based measured and satellite datasets are used. Artificial intelligence algorithms will be applied to simulate PAR and the predictive models will be improved by application of several, mathematical and statistical tools.

The project is suitable for students interested in renewable energy, engineering, biology, agriculture, atmospheric science, mathematics, physics and data science. The project is scalable for further research, such as to a Masters or a PhD program to advance research careers, acquire programming skills and modelling. The project present opportunity to develop new modelling & computational skills and research-publications within the Environmental Modelling and Simulation Research Group.

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Project Title:  

Heatwave and Drought Modelling with Nature-Inspired Machine Learning

Abstract: Drought and heatwaves are challenging events that are catastrophic and cause significant harm to crops, human health, ecosystem and economy. Advanced modelling of drought and heatwaves is challenging, so new models that are smart enough to accurately represent their behaviour is very important. Such models can be used in decision systems by farmers, resource managers, water quality management and government.

In this project, the students will model big data (of environmental origin such as rainfall, temperature and streamflow) for drought and heatwave prediction. Often, the agricultural industry fails to utilise relevant input features from atmospheric and hydrological data when developing a drought or a heatwave model. In this project students will use machine learning that offers advanced solutions for high-precision modelling, as an emerging technology to discover the patterns in natural (geographic & hydro-physical) data to design prototypical models for prediction of heatwaves and drought.

The nature-inspired models will analyse patterns in hydro-meteorological variables to model drought and heat indices over daily and seasonal scales. Local-scale models are useful for real applications, yet challenging since they require large (atmospheric & ground) inputs from physical and statistical sources. This project will develop models for feature selection to find optimal features in inputs, reduce model complexity and improve its efficiency. Students will apply bio-inspired algorithms to predict heatwaves or drought and will learn about their application in agriculture, climate risk management and environment.

The project will suit students with background in environmental science, agriculture, mathematics, computing and climate/atmospheric physics. The project is scalable for further research, such as to a Masters or a PhD program to advance research careers, acquire programming skills and modelling. Students will learn artificial neural network models, machine learning in agriculture, expert system development with smart predictive tools and evaluation of such models in real-time forecasting of drought or heatwaves.
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### Project Title:  
**Precision Agriculture with Machine Learning: Influence of Soil Fertility on Coffee Yield**

**Abstract:** Coffee is the second most important traded commodity in African, American and Asian countries. Yield is significantly dependent on environmental, climatic and soil fertility conditions, and especially the soil fertility constituents whose correct proportions can impact the productivity. As it is not known what soil fertility conditions are the best for optimum yield, this remains a challenging task for agricultural modellers.

Biophysical models require a knowledge of the processes in soil-plant-atmosphere continuum that affects optimal crop yield. Owing to the complexity and parameterisation of best fertility properties for crop simulation models, statistical analytics built in an intelligent model can provide a new a predictive approach for yield optimisation through carefully selected soil fertility properties. The soil organic matter containing most of the soil’s reserve of nitrogen and large portions of phosphorus and sulphur plays a vital role for nutrient availability and absorption by plants but when the process of selecting and reducing variables is automated, predictors chosen might not highlight the biological assumptions.

The purpose of this project is to investigate robust data-intelligent methods [i.e., extreme machine learning (ELM) and random forest (RF)] to model the relationships between soil fertility parameters and coffee yield for smallholder farms. The project will determine the best performing model and relevant organic matter, available potassium and sulphur, etc as the predictors of coffee yield. The project is scalable for further research, such as to a Masters or a PhD program to advance research careers, acquire programming skills and modelling.

The project suits students with a background in agriculture, environmental science, mathematics, computing and climate/atmospheric physics. Students will learn about neural network models, machine learning in agriculture, expert systems with smart tools and evaluation of models in real-time forecasting crop yield.

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### Project Title:  
**Real-time Flood Early Warning for Floods: Copula-Statistical Joint Models and Machine Learning System Design**

**Abstract:** Australia suffers from extreme and catastrophic floods. Flood monitoring is undertaken in conjunction with forecasts to provide advanced warning and heightened chance of a flood by estimation of river heights, streamflow, time of rainfall occurrence, and peak flow rates at a specified point in time resulting from changes in rainfall. Bureau of Meteorology, in partnership with agencies at state and local government, provides water level forecasts in rivers. Despite their effectiveness, the methods can be time-consuming, expensive and complex to implement in geographically diverse locations.
In this exciting project, students will learn about copula-statistical joint models and machine learning to predict hourly and daily flood events. Such forecasts are used in flood mitigation design. A new flood index based on daily effective precipitation for flood monitoring will be used. This method will consider a weighted sum of current and antecedent rainfall, and a time-dependent reduction formula applied on the recent (vs. older) rainfall to account for water accumulation due to hydrological factors. Hourly & daily data will be used to develop flood model considering rainfall accumulation redistributed by an objective formula factored via a time-dependent function, and applying machine learning models to predict flood events in advance.

The project will suit students with background in engineering hydrology, mathematics, computing, climate, water management and environment. Students will also explore deep learning to enhance the performance accuracy of flood prediction system. The project is scalable for further research, such as to a Masters or a PhD program to advance research careers, acquire programming skills and modelling.

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**Project Title:**

**Future Climate Projection: Downscaling Global Climate Model with Artificial Intelligence for Agriculture and Renewable Energy**

**Abstract:** In agriculture and renewable energy models the future projected solar radiation, rainfall, streamflow, temperature and wind speeds is essential. Warming scenarios are considered when projecting such variables with different CO₂ through global climate models (GCM), but the coarse resolution of GCM (in order of 100 km) makes it difficult to interpret and apply projected information at local (e.g. farm or city) level.

In this exciting project, the students will address the challenge by designing artificial intelligence models for future climate projections and downscaling global climate model variables (e.g. drought, heatwave, solar radiation). The project will use machine learning approach, a relatively new, yet a powerful tool to accurately downscale GCM data at high resolution local scales.

This will be done by a two-step process (i) the development of statistical relationships between local climate variables (e.g., air temperature and precipitation) and large-scale predictors (e.g., pressure fields), and (ii) the application of such relationships to the output of global climate model experiments to simulate local climate characteristics in the future. Students will learn advanced statistical skills, extract and model Intergovernmental Panel of Climate Change (IPCC) approved CMIP-5 (coupled model inter-comparison phase 5) datasets.

Students will apply downscaled models in perspective of renewable energy modelling, water resource prediction, streamflow simulation and agricultural applications (e.g. rainfall prediction). Smart level machine learning models such as extreme learning machines, deep learning neural networks, wavelet transformations, empirical mode decomposition and several other learning algorithms will be used.

The project will suit students with background in engineering, mathematics, computing, climate, hydrology, water management, renewable energy and environment. Students will explore deep learning to enhance the performance accuracy of downscaled models. The project is scalable for further research, such as to a Masters or a PhD program to advance research careers, acquire programming skills and modelling.
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**Project Title:**

**Energy Demand and Price Forecasting with Data Intelligent Models for Consumer Energy Predictability**

**Abstract:** Models for electricity energy demand are critical in engineering and science applications as they can assist renewable and conventional energy engineers, electricity providers, end-users, and government entities in addressing energy sustainability challenges for National Electricity Market (NEM). Demand knowledge also assists in the expansion of distribution networks, energy pricing, and energy policy development.

In this project, the students will design intelligent models to forecast energy loads and price over minute-scale, hourly, daily and seasonal scales. Students will apply Autoregressive Integrated Moving Average (ARIMA), Artificial Neural Network (ANN), Support Vector Regression (SVR), genetic algorithms, fuzzy logic, knowledge-based expert systems, and Multivariate Adaptive Regression Splines (MARS) among several popular forecasting tools used by energy researchers. As a major contribution to energy research, students will develop models based on other significant predictors, particularly in geographically diverse locations where climatic factors affect the electricity load. The study will therefore use climatic factors (e.g. temperature) in the prediction of electrical energy demand and energy pricing.

The project will suit students with background in electrical engineering, mathematics, computing and renewable energy. Students will explore and apply deep learning models for improved design of data-intelligent models. The project is scalable for further research, such as to a Masters or a PhD program to advance research careers, acquire programming skills, modelling and publication.