Contents

**Associate Professor Sherman Cheung**
Fire Modelling for Performance-based and enhanced engineering solutions ..................4

**Associate Professor Xu Wang**
A study of regenerative electromagnetic shock absorber for improving energy efficiency ....5
A novel direct drive linear generator for ocean wave energy conversion ......................6
A study of vibration control of commercial vehicle seating system ............................7

**Associate Professor Yasuhiro Tachibana**
Development of Metal Halide Perovskite Solar Cells by Controlling Interfacial Charge Transfer Processes .................................................................8
Metal Oxide Nanomaterials for Solar Water Splitting ...............................................9
Development of Narrow Band Gap Semiconductor Quantum Dot Solar Cells .............10

**Dr Bahman Shabani**
Gad Diffusion Layer (GDL) Optimisation for PEM Fuel Cells, Electrolysers and URFCs ...11
Design and optimisation of active control strategies for operating conditions of PEM fuel cells ..........................................................12
Simultaneous Passive Thermal Management of PEM URFCs and Metal Hydride Storage Canisters Using Heat Pipes ......................................13

**Dr Cameron Stanley**
Multi-objective design optimisation of a high flux jet impingement heat sink ............14

**Dr Kate Fox**
Smart Implants: The Bionic Bone ..............................................................................15
Diamond Implants ..................................................................................................16
Model Led AM Orthopaedic Implants: Physical Characterization and Interfacial Testing .................................................................................17

**Dr Kiao Inthavong**
Next generation respiratory drug delivery devices ...............................................18

**Dr Mladenko Kajtaz**
A Biomimetic approach to Self-Repair of Long Fibre Reinforced Composites .............19
Innovative design of personal protective equipment utilizing 3D spacer technology ....20
Wearable Rehab ..................................................................................................21
Dr Stefania Castelletto

Functionalisation of silicon carbide material via direct laser writing for applications in magnetic sensing and nanophotonics devices.................................................................22

Professor Firoz Alam

Aerodynamics and Hydrodynamics in Sports.................................................................23

Professor Gary Rosengarten

Vessels-on-a-chip to study blood flow dependent thrombotic processes...............24
Ultra-high heat flux cooling using nanostructured surfaces,........................................25

Professor Jiyuan Tu

Numerical Investigation of Flow around Submerged Objects........................................26
A Multiscale Modelling Platform for Nanoparticle Inhalation Risk Assessment...........27
Air quality and transmission of airborne diseases in densely occupied passenger cabins.....28

Professor Peter Dabnichki

Ultra-low temperature testing for Underwater Vehicle Design....................................29
Physiologically Relevant Loading for Artificial Bone and Implant Testing.....................30
Ubiquitous computing system for monitoring effectiveness of treatment and rehabilitation programmes........................................................................................................31

Professor Pavel M. Trivailo

Development of the new morphing spacecraft, with controlled “flipping” capabilities, based on “Dzhanibekov’s Effect”.................................................................32
Optimal Design of Spacecraft Formation Systems for Australia...................................33
Celestial Bodies Sampling Using Rotating Tethered Systems......................................34
Long Range Smart System for Evacuation and/or Delivery of Personnel or Equipment Using Airborne Fixed Wing Aircraft/UAV, without the Need for Landing During the Pick-Up or Set-Down........................................................................................................35
Fire Modelling for Performance-based and enhanced engineering solutions
Mechanical & Automotive Discipline, Computational Fluid Dynamics Group, Bundoora East Campus

Project Description

Fire safety is a critical requirement for a wide range of industries. In civil construction, passive fire protection (fire retardant materials) and active fire protection (suppression devices) are crucial to the protection of buildings such as data centres and cultural heritage sites to preserve irreplaceable data and maintained world heritage sites for future generations. In the oil and gas and maritime industries, the use of highly effective fire protection systems (fire retardant materials as well as suppression devices) is paramount to safeguard workers on offshore platforms and passengers in marine vessels against the severity of fires at sea.

Numerous computational models at different levels of fidelity have been developed to predict the thermal degradation (pyrolysis) process of solid materials, propagation of fire, suppression of fire and human behavioural response for crowd movement [1]. Because of the complex chemical structure of lightweight materials such as of polymeric materials, the ability to extract the actual chemical composition of emitted volatiles in order to develop the combustion chemistry in the gas phase and modelling the solid pyrolysis process remains highly challenging [2]. Modelling the fire propagation requires the ability to predict the complex turbulent reacting flow interacting with the radiative participating media (by-products of combustion products) [3], which still requires further development. For predicting the suppression of fires due to the deluging of water droplets, numerous challenging aspects in the multiphase modelling of a two-phase gas-liquid flow persist [4]. Development of more sophisticated social-forces models is still required to better predict crowd movement. An integration by bringing together of all these models remains absent in performance-based assessments of fire safety. The ability to comprehensively evaluate the fire performance of new advanced lightweight materials in different settings and exposure to more realistic fires will be realised through high-fidelity computations of the integrated fire models. (No ethical concern is required for the project).

References:

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A study of regenerative electromagnetic shock absorber for improving energy efficiency
Mechanical and Automotive Discipline and Dynamic Research Group, Bundoora

Project Description

This project will develop linear regenerative electromagnetic shock absorber (LRESA) system with a double relative speed of the magnets with respect to the coils. The LRESA system will have a novel stacking pattern of the rare earth permanent magnets, three phase coils and separator disks/washers for maximizing the magnetic flux density and its change rate. Ferro-fluid bearings will be adopted for a frictionless LRESA system. Automatic control algorithms for the vibration energy conversion and conditioning will be developed for reduction of the circuit losses.

This project aims to investigate a regenerative shock absorber in a suspension system for improving vehicle energy efficiency and dynamic performance. Combination of a Halbach array of magnets, three phase coils, a rack and pinion into a shock absorber, integrated with intelligent control is the key innovation. Vibration energy conversion science will be established through the investigation for energy harvesting and storage, automatic control and self-powered active motion control. The outcome will meet the emerging demands of the nation for sustainable vehicle technologies which reduce fuel or energy consumption, emissions and cost, thus benefiting the Australia economy and environment.

Electricity-generating shock absorber system is a significant new value-adding technology for the global automotive market-place. This technology will not only enable a vibration energy conversion science, but also address an important problem of the Australian vehicle energy utilization efficiency for reduction of greenhouse emission and energy cost.

References:

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**A novel direct drive linear generator for ocean wave energy conversion**  
Mechanical and Automotive Discipline and Dynamic Research Group, Bundoora

**Project Description**

This project will develop a novel translator of a multiple degree of freedom non-linear oscillator system built with Halbach magnet ring arrays and ferro-fluid bearings.

Wave energy conversion science will be established through investigating a novel frictionless direct drive linear tube generator machine, its integration with a buoy structure under wave loadings and automatic control of power conversion and conditioning, to conduct dimensionless analysis for its wave energy conversion power and efficiency. The effects of spatially varying electromagnetic field of the linear electromagnetic tube generator on its wave energy conversion performance will be studied using simulation and experimental methods. The effects of the mechanical friction loss, non-linearity, the number of degree of freedom of the oscillators on the wave energy conversion performance will be investigated using analysis, simulation and experimental methods.

This project aims to investigate a direct drive linear electromagnetic generator system for the maximum wave energy conversion and frequency bandwidth. The outcome will meet the emerging demands of the nation for wave energy conversion technologies which reduce power generation cost and emissions, thus benefiting the Australia economy and environment.

The direct drive linear tube generator, having no contact friction, wear and maintenance requirements, is a significant new value-adding technology for the global energy market-place. This technology will not only enable a related wave energy conversion science, but also address an important problem of the Australian wave energy utilization for reduction of greenhouse emission and energy cost.

**References:**


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A study of vibration control of commercial vehicle seating system
Mechanical and Automotive Discipline and Dynamic Research Group, Bundoora

Project Description

Long-term exposure to vibrations transferred from uneven road surfaces, vibrating tools, and vibrating machinery significantly influences driver comfort, fatigue, safety, and can also cause neck and shoulder pain, lower back injuries, and spinal injuries. This project will develop a novel tubular linear motor based hybrid passive/semi-active/active actuators, which have appropriate passive static stiffness and adjustable semi-active damping functions, and fast active force control capability. This project will implement a novel 6-DOF seating system using these actuators to effectively reduce vibration in three translational and three rotational directions. A multiple-DOF biodynamic linear lumped-mass parameter model will be developed for control system design. A nonlinear complex multi-body model will be developed for system analysis and performance evaluation of the seated driver’s body. A state estimation, vibration frequency preview, and motion-mode detection based human-in-the-loop control strategy will be developed for real-time vibration reduction of the developed seating system. This project will investigate and test the proposed seating system performance according and provide useful instructions for the further development of seating vibration control systems.

This project aims to develop an innovative 6-degree-of-freedom seating system for commercial vehicles, including heavy duty trucks and mobile machinery, to maximize the reduction of unwanted multiple directional vibrations to the driver’s body. The expected outcome of the project is a comfort and ergonomic seating system to be widely used in industry, agriculture, transportation, mining and construction vehicles, both in Australia and internationally.

This project provides new methods and technology platforms for the automotive industry in developing innovative seating systems. It has a direct impact on the occupational and safety related professional health management in mechanical, mining and transportation industries. This project also indirectly promotes population health and wellbeing through increased productivity of a healthier community and the delivery of novel scientific skills in economy.

References:

Contact Details
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Associate Supervisor - Professor Sabu John (sabu@rmit.edu.au)
Development of Metal Halide Perovskite Solar Cells by Controlling Interfacial Charge Transfer Processes
Nanomaterials & Solar Photovoltaics Group and Energy CARE Group

Project Description

Metal halide perovskite solar cells have been recognized as a newly emerging solar cell with the potential of achieving high efficiency with a low cost fabrication process. In particular, facile solution processed cell fabrication facilitated rapid development of optimum cell structure and composition. Over the last few years, the cell efficiency has rapidly been improved to 22%.[1]

A typical perovskite solar cell employs a perovskite layer sandwiched by p-type semiconductor (such as spiro-OMeTAD, PEDOT or NiO) and n-type semiconductor (such as TiO₂, ZnO or PCBM) layers. Intensive research has been conducted for developing perovskite films using different components to tune an optimum band gap and to improve functional stability.[2] Following light absorption, an electron and a hole are separated at the perovskite film interface, and are collected at the back electrodes. Based on this simple configuration, it is clear that the perovskite interface controls the cell performance and stability. We have actively been working in this area. For example we reported a role of a TiO₂ nanocrystalline film acting as an electron acceptor [3]. We also found that the electron injection rate (~10 ns) is relatively slow compared to QD sensitised films [3,4], however it is sufficiently fast compared to the excited state lifetime (~200 ns), confirming high charge transfer quantum yield.

This project aims at developing novel metal halide perovskite nanomaterials/films to be applied for solar cells by identifying parameters controlling charge separation and recombination dynamics at the perovskite interfaces employing a series of state-of-the-art transient absorption and emission spectroscopies we have in RMIT. Nanosecond transient emission spectroscopy (Vis-ns-TES) clarifies charge separation processes, while Vis-NIR submicrosecond-millisecond transient absorption spectroscopies (VisNIR-smm-TAS) identify charge separation efficiency and charge recombination rates. We will also assess electron and hole mobilities in perovskite films by employing a time resolved microwave conductivity (TRMC) system that will be constructed this year with supports from the awarded ARC LIEF fund (LE170100235). Our collaborator, Prof. Trevor Smith, the head of the Ultrafast Spectroscopy Group in Melbourne University, will also support the project by assessing excited state dynamics and ultrafast charge transfer dynamics employing Vis to Mid-infrared femtosecond transient absorption spectrometers.

References:
[1]. https://www.nrel.gov/pv/assets/images/efficiency-chart.png

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Metal Oxide Nanomaterials for Solar Water Splitting
Nanomaterials & Solar Photovoltaics Group and Chemical Engineering

Project Description
Solar water splitting is one of the most attractive processes to generate clean energy.[1] This process does not emit greenhouse gases, and the generated hydrogen can be stored and used when required. Although finding the optimum material combination is extremely challenging, extensive efforts have been focused on developing nanomaterials for such solar water splitting reactions at low cost. Identification of parameters controlling water splitting efficiency has also been extensively investigated, however research towards nanomaterial development in correlation with the reaction mechanism has rarely been conducted.[1]

Metal oxide nanomaterials such as TiO₂, Fe₂O₃ and WO₃ and their doped materials or combination with different nanomaterials have been intensively studied to improve efficiency of water oxidation reaction.[2] By optimizing the metal oxide nanomaterial structure and device configuration, the device has reached solar-to-chemical conversion efficiency of >3%.[3] However, despite this progress, the mechanism of the key reactions has rarely been understood. We are interested in elucidating mechanisms of photocatalytic water splitting reactions at semiconductor interfaces. We have studied interfacial charge transfer processes using TiO₂ nanocrystalline films,[4] and identified several key parameters that potentially control water splitting reactions.

This project aims at developing novel metal oxide semiconductor nanocrystal structures to be applied for solar water splitting devices. We will employ wet chemistry methods to control metal oxide nanocrystal structures, and employ a series of state-of-the-art transient absorption spectrosopies (visible to mid-infrared, nanosecond to millisecond time scale) we have in RMIT to monitor photo-induced electron and hole reaction dynamics, and reactions of water molecules for those nanomaterials. We will also assess electron and hole mobilities in metal oxide nanocrystalline films by employing a time resolved microwave conductivity (TRMC) system that will be constructed this year with supports from the awarded ARC LIEF fund (LE170100235). Our collaborators, Prof. Kanematsu and Prof. Nakamura, in the Ultrafast Spectroscopy Group in Osaka University will support the project by providing the access to and expertise on ultrafast water reaction dynamics employing mid-infrared femtosecond transient absorption spectrometers. Also, our collaborator (Prof. Ryu Abe) in Kyoto University will provide different types of metal oxide nanocrystals to fabricate and characterise water splitting devices.

References:

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Development of Narrow Band Gap Semiconductor Quantum Dot Solar Cells
Nanomaterials & Solar Photovoltaics Group and Energy CARE Group

Project Description

Semiconductor quantum dot (QD) is one of the most attractive nanomaterials employed for solar energy conversion devices. With their relatively large extinction coefficients and a wide light absorption range over visible to near infrared wavelengths, QDs can be effective light absorbers. Recently three dimensional arrangement structure of QDs, QD solid, has attracted considerable interest, since superior semiconductor performance is expected by forming extended states inside a QD solid.[1] Their highly conductive opto-electronic property can be employed to fabricate low cost opto-electronic devices such as photovoltaics.[2]

A solar cell can readily be fabricated with a facile solution processed method, and such cell efficiency has reached greater than 11%.[3] However, despite these attractive properties, when they are employed in solar cells, their function, particularly exciton states, charge separation and recombination dynamics has not been well understood. For example, the excited electron and hole can readily be trapped by the surface states, losing initial excited energy, however their relations to the solar cell function is still not clear. We have been actively working in this area. We have reported a novel method to synthesize high photoluminescence PbS QDs [4], and application of QDs to fabricate novel QD sensitised solar cells.[5]

This project aims at developing novel narrow band gap QDs to be applied for solar cells. We will employ high photoluminescence QDs to prepare QD solid films, and assess their charge transfer and transport performance by a series of state-of-the-art transient absorption and emission spectroscopies (visible to mid-infrared, nanosecond to millisecond time scale) we have in RMIT. We will also assess electron and hole mobilities in QD solid films by employing a time resolved microwave conductivity (TRMC) system that will be constructed this year with supports from the awarded ARC LIEF fund (LE170100235). Our collaborators, Prof. Kanematsu and Prof. Nakamura, Ultrafast Spectroscopy Group in Osaka University will support the project by assessing excited state dynamics and ultrafast charge transfer dynamics employing Vis to Mid-infrared femtosecond transient absorption spectrometers. Also, our collaborator (Prof. Teranishi) in Kyoto University will provide different types of QDs for us to fabricate solar cells.

References:
[3]. https://www.nrel.gov/pv/assets/images/efficiency-chart.png

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Project Description

Gas Diffusion Layer (GDL) has a critical role in determining the performance of Proton Exchange Membrane (PEM) fuel cells and electrolysers by facilitating uninterrupted and smooth gas and water transport to and from the active areas of these cells [1]. The design of GDLs has been evolved and modified significantly during recent years with the key aim of improving their performance for delivering their role. The main focus of these modifications was on water management and reactant delivery improvement as per defined for the role of GDLs. These modifications were mainly done by working on GDL hydrophobicity, GDL porosity, engineered perforated GDLs, and introducing a Microporous Layer (MPL) to the GDL [2]; they considered key design aspects such as MPL thickness, pore size, porosity, hydrophobicity and hydrophilicity, and the role of cracks in MPL structure [2, 3]. Despite a widespread research conducted to date on this topic, there are still clear research gaps to be addressed, some of which are as follows [1-4]:

- Limited works have been done on modification of GDLs for improving the performance of PEM electrolysers
- Design and optimisation of GDL for Unitised Regenerative Fuel Cells (URFCs), that needs to work in both fuel cell and electrolyser modes (i.e. considering the contradictory requirements of GDL of the oxygen side in these two modes of operation).
- Experimental study of GDL with gradient hydrophobicity for fuel cells and electrolysers
- The use of perforated metallic GDLs in URFCs with focus on proper Micro-Porous Layer (MPL) composition for URFCs and electrolysers considering the corrosive electrolysis environment.
- The water management effect in GDL has not been fully understood and the findings of different research groups were not found to be conclusive (i.e. sometimes contradictory)
- The effect of operating condition (e.g. temperature, humidity, etc.) on the design of GDL

References:

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Associate Supervisor - Professor John Andrews (john.andrews@rmit.edu.au)
Design and optimisation of active control strategies for operating conditions of PEM fuel cells
Mechanical and Automotive Engineering Discipline, Renewable Energy and Energy Storage Research Group, Bundoora Campus

Project Description
Proton Exchange Membrane (PEM) fuel cells performance (i.e. at different loads) are very sensitive to the operating conditions [1] such as air stoichiometry, inlet air pressure, inlet air temperature, inlet hydrogen relative humidity, inlet hydrogen pressure, operating temperature, hydrogen purging characteristics [2, 3], and etc.[4]. In commercially-available PEM fuel cells these conditions are preplanned by the manufacture (i.e. a passive control, usually set manually) for a wide range of operating points. However, controlling the operating conditions within such pre-planned ranges does not necessarily offer an optimum performance for a given operating point and condition (e.g. in terms of efficiency or lifetime). Considering this, active control of fuel cells operating condition, similar to what is commonly implemented in internal combustion engines (i.e. through their ECU systems) can help a fuel cell perform optimally at any operating point and conditions: i.e. through an active control that decides on customised input conditions at any operating points/conditions [1]. This also provides opportunities to increase the lifetime of fuel cell systems. Such a control system is expected to help determine the input operating conditions by getting feedbacks through a range of sensors such as exit air relative humidity, operating temperature, cell, resistance, rate of voltage drop, and etc. Despite the importance of developing active control strategies for optimum operation of PEM fuel cells, very little can be found in the literature covering this topic. The present research though focuses on finding multidimensional links between the performances of PEM fuel cells and their operational inputs such as purging characteristics, inlet air and hydrogen relative humidity, fuel cell temperature (i.e. adjusted by the cooling system), the pressure of reactants, and etc. This will then be used for developing optimum active control strategies for active control of the stacks operational inputs at any given operating point and conditions.

References:

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Simultaneous Passive Thermal Management of PEM URFCs and Metal Hydride Storage Canisters Using Heat Pipes
Mechanical and Automotive Engineering Discipline, Renewable Energy and Energy Storage Research Group, Bundoora Campus

Project Description

Although the efficiency of a PEM fuel cell in generating electricity is relatively high (i.e. up to ~55% based on the high heating value of hydrogen), still a substantial amount of heat is generated as by-product that needs to be effectively removed from the fuel cell in order to maintain its temperature at a desirable level (e.g. ~60-80 °C) [1]. At the same time the Metal Hydride (MH) hydrogen storage systems that are sometimes used to supply hydrogen to the fuel cells usually face the challenge of having low supply rate (i.e. fail to meet the demand of the fuel cell at its rated power) [2]. This challenge can be addressed by supplying heat to the MH storage canisters to speed up the release rate of hydrogen. On the other hand, the heat generated by the fuel cell can offer a perfect opportunity for thermal management of the MH canisters, while the canisters can also play the role of a thermal sink and contribute to thermal management of the fuel cell [3]. Heat pipes are passive devices that have been used before for thermal management of MH canisters and fuel cells separately. Considering this, the novel idea of using heat pipes for passive thermal bridging between the fuel cell and MH hydride has only been recently proposed and studied by RMIT hydrogen research team [4]. This idea can be expanded and implemented for thermal coupling of electrolysers used to charge MH hydrogen storage canisters. By heating up the electrolyser its performance can be enhanced; on the other hand the MH generates heat during charging mode and has to be constantly cooled down to maintain an acceptable level of hydrogen absorption rate. Combining these two modes of operation (i.e. fuel cell and electrolyser modes), this arrangement can be applied and optimised for a Unitised Regenerative Fuel Cell (URFC) connected to a MH hydrogen storage system. However, the idea is expected to face some practical challenges due to the contradictory requirements of the URFC and the MH in two modes of operation that demands for an optimisation task. Hence a whole system innovative design and optimisation approach is required; in particular this optimisation becomes more critical by considering the fact that passive heat pipes give minimum opportunities to apply a dynamic control strategy on their performance (i.e. in terms of their heat removal capacity/performance in different modes of URFC operation).

References:

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**Multi-objective design optimisation of a high flux jet impingement heat sink**

Laboratory for Innovation Fluid Thermal Systems, City Campus

**Project Description**

Overheating in electronic devices is becoming a serious concern as the processing power requirements increase, and physical sizes decrease. There are a number of applications such as high performance computer chips, power electronics and concentrating solar devices which require very high flux heat removal. Some devices generate heat fluxes beyond 100W/cm², with localised “hot spots” reaching fluxes up to 1200W/cm² [1]. Meeting these demands, and allowing for increasing computational performance in the future, demands advanced cooling technologies.

Jet impingement heat exchangers have demonstrated a capability of achieving very high heat transfer rates and excellent temperature uniformity [2]. However, the penalty for these is the requirement for relatively high pumping powers. Recent advances in manufacturing techniques, such as additive manufacturing, have provided improved methods for fabricating complex fluid galleries otherwise impossible with traditional manufacturing techniques [3]. The advantages of this includes the ability to create enclosed volumes without the need for joinery or fluid sealing, incorporating internal radii on part features to reduce frictional pressure drop, and rapid prototyping.

This research aims to investigate the characteristics of jet impingement heat sinks comprising an array of submerged liquid jets striking a heated surface using numerical simulations and gain physical insight into key design factors and the underlying mechanism. Computational analysis will be performed for a range of jet configurations represented by design parameters (e.g., nozzle diameter, jet velocity, and nozzle spacing) in order to simultaneously achieve two primary objectives, i.e., maximum heat transfer and minimum pressure drop. The design space will be explored by applying the state-of-the-art multi-objective optimisation (MOO) capability using a hybrid approach, coupling evolutionary algorithms and local search methods with surrogate modelling. Additive manufacturing will be used to manufacture and test a range of prototype heat sinks and provide experimental measurements to support the computational analysis.

**References:**


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**Smart Implants: The Bionic Bone**
Project between Mechanical and Automotive Engineering Discipline and School of Science, City

*Project Description*

RMIT is at the forefront of optimising 3D printing technology for medical prototyping.[1] As a result of the great advances in additive manufacturing, scope exists to implement smarter implants combining not only implant itself but also embedded electronics and sensors.[2,3] In this project, the student will develop new smart orthopaedic implants capable of both electrically stimulating and recording at the bone-implant interface but to also act to treat a series of bone disorders. The student will design the implant, the embedded smart system and generate a prototype device. As a result, the project combines high impact fundamental research with commercial application. It is expected that the new implant will provide an improved 3D scaffold capable of improving the implant-bone interface and mapping implant activity in vivo.

Skills: Understanding of surface science, materials, electrical circuits, in vivo wireless sensing. Willingness to work on a collaborative interdisciplinary project. Some animal work may be required.

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Associate Supervisor - Dr Nhiem Tran (nhiem.tran@rmit.edu.au)
Diamond Implants

Project between Mechanical and Automotive Engineering Discipline and School of Science (aligned with the Center for Nanoscale Biophotonics), City

Project Description

It is essential that new materials can be generated for improved implant technologies. The industry standard, titanium, although bioinert, has a natural surface oxide which prevents integration between metal and surrounding bone. Diamond is known to possess biocompatibility and biostability.[1,2] Here, we will investigate the development of diamond implants for dental applications. Diamond is an ideal material for implants as its piezorestivity can be used to detect changes in strain. In this project, the student will develop prototypes of a smart diamond implant capable of measuring strain in vivo. RMIT is at the forefront of optimising 3D printing technology for medical prototyping. It is expected that the new implant will provide an improved 3D scaffold capable of improving the biomaterial-bone interface and mapping in vivo strains within the healing phase of a dental implant.

Skills: Understanding of surface science, materials, physics, electronics. Willingness to work on a collaborative interdisciplinary project. Some animal work may be required.

References:

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Senior Supervisor - Dr Kate Fox (kate.fox@rmit.edu.au)
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Model Led AM Orthopaedic Implants: Physical Characterization and Interfacial Testing
Mechanical and Automotive Engineering Discipline, Location: City/Bundoora East

Project Description

RMIT is at the forefront of optimising 3D printing technology for medical prototyping.[1] Current implants are subject to failure predominantly due to implant loosening due to stress shielding, wear debris and micromotion. It is imperative that there is a mechanism to detect failure before failure. Additive Manufacturing (AM) is a perfect method for creating patient-specific implants, that are crucially to be utilised on permanent basis by the patients. AM also offers a new method to tailor bone growth within its structure. However, understanding of the nature of bone loading as part of its interaction with the muscle groups under external physical and subsequent bone response needs more in-depth understanding. Specifically the aspects related to ageing and reduction of the rigour in the muscle action. The problem is multi-scale and multidisciplinary in nature and in-depth understanding could only be achieved through a synergy of mathematical and high fidelity physical models. In this project, the student will work to develop and optimise physiologically-led models to develop and characterise physical prototypes of orthopaedic implants.

Skills: Understanding of surface science, additive manufacturing, modelling, in vivo assessment. Willingness to work on a collaborative interdisciplinary project. Some animal work may be required.

References:

Contact Details
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Joint Associate Supervisor - Professor Milan Brandt (milan.brandt@rmit.edu.au)
Next generation respiratory drug delivery devices
Mechanical and Automotive Engineering, Bundoora East

Project Description

Pulmonary drug delivery has emerged as a critical method for treating respiratory diseases. Nebulizers, Dry Powder Inhalers (DPIs) and Pressurized Metered Dose Inhalers (pMDIs) are common devices that generate fine drug particles through atomization, and are inhaled orally targeting deep lung deposition [1, 2]. Among these devices, the pMDI is the preferred choice by patients for treatment of asthma and COPD [3]. Despite its popularity, drug delivery efficiency on average reaches only 5%-20%.

The nasal spray devices also provides respiratory drug delivery where drugs depositing on the mucus walls can provide direct transfer into the blood, bypassing gastric breakdown. Furthermore Nose-to-brain drug administration along the olfactory and trigeminal nerve pathways offers an alternative route for the treatment of central nervous system (CNS) disorders. The characterization of particle deposition remains difficult to achieve in experiments. Alternative numerical approach is applied to identify suitable aerosol particle size with maximized inhaled doses.

This research focused primarily on developing useful and economically viable CFD approaches aimed at providing practical solutions in order to improving drug delivery efficiency of inhalation therapy devices. Drug delivery efficiency in a realistic human nasal cavity for a variety of aerosol drug administration systems targeting the olfactory region will be investigated. Outcomes of this work will lead to new innovative delivery device designs for effective respiratory treatment.

References

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A Biomimetic approach to Self-Repair of Long Fibre Reinforced Composites
Mechanical and Automotive Engineering Discipline

Project Description

For more than 40 years, high tensile and high strength fibres have been used as reinforcement for thermoset materials such like epoxy, bakelite and 2k component resin. Fibre such as carbon HT, glass-E S R and kevlar are available with long fibre bundles for structural materials as one of the primary solutions for a lightweight design. The long fibre reinforcement follows the biomimetic principle of load path optimisation and lightweighting by orienting fibres in the required direction, which offers substantial weight reduction and new possibilities for integral parts. Further to the fibre reinforcement, in the past 15 years, the development of the second generation of the composites has been observed, which incorporates Structural Health Monitoring (SHM) principles.

The abovementioned first and second generation approaches to the fibre composites almost complete the full biomimetic idea and the principle. The missing link is Self-Repair Action (SRA), which would lead to the third generation of long fibre reinforced material usage that would complete the circle of life of a composite part according to biomimetic way of thinking (i.e. Function – Monitoring – Self-repair).

This project will consider innovative solutions to the problem with the application in load-bearing structures.

Contact Details
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Innovative design of personal protective equipment utilizing 3D spacer technology
Centre for Additive Manufacturing, City and Bundoora

Project Description
In this modern era, ballistic body armour has been a crucial part of survival for all personnel in law enforcement and the military. Existing solutions in the protection bracket up to level 3A (NIJ), employ multiple layers of high performance fibres which fail to completely reduce post impact injuries. These layers of material are also impermeable which inhibits heat transfer and thus leads to thermal stress. To combat these, innovative structures have been designed which incorporate bioinspired concepts and will be created with the utilization of 3D spacer technology.

Backface deformation and remaining impact energy in current armour can result in different associated injuries from blunt force trauma (Prat et al. 2012). Injuries are directly relatable to the pressure waves caused by the projectile which damages the skin (Prat et al. 2012), (Lee, Kosko & Ander 2005). The occurrence of the aforementioned injuries are a result of poorly designed NIJ compliant structures (NIJ 2008), however, even with this compliance, damage to the torso often occurs. In this project, the objective will be to explore 3D spacer fabrics as a potential technological enabler to mimic energy absorbers occurring in nature, such as wood peckers, and adaptations of such structures are to be the basis of concept generation. These are in hopes of increasing the impact resistance and energy absorption in order to address the issues with post impact injuries.

In addition to improving energy absorption capability, this project intends to provide an innovative solution to the reduction in thermal stress experienced by the wearer as the existing solutions typically do not consider the thermal stress in their design, meaning that the wearers comfort significantly diminishes (Mahbub et al. 2014). Skin temperature sensations can rise 5°C locally which is equivalent to a 10°C increase in ambient temperature (Wang and Gao, 2014) and hospitalisation of the members of law enforcement as a result of thermal stress are not uncommon (Brianna, 2011).

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Wearable Rehab
Centre for Additive Manufacturing, City and Bundoora

Project Description

Rehabilitation of limb injuries and the joint injuries, in particular, is expensive, very resource-demanding and often extremely long. Furthermore, an injury is deemed to be successfully rehabilitated if the capacity is restored to at least 20% of the capacity before the injury. All this costs money, happiness, affects the quality of life and sometimes causes major socio-economical changes in the person’s life.

This project aims to greatly improve the rehabilitation process in terms of time, care, and quality by providing an advanced exoskeleton as a technological assistance and enabler to increase mobility and load-carrying capacity of injured limbs and joints. This exoskeleton (the external skeleton as opposed to the human internal (endo-) skeleton) design is to utilise the latest additive manufacturing techniques (the 3D printing in particular) available at RMIT University, to enable full personalisation to the individual bodies and integration of necessary sensors and actuators into the exoskeleton.

The novelty to the existing exoskeleton market is to be facilitated by innovative solutions to measurements (sensing) of specific limb forces (muscles, ligaments, etc) and angles; gait changes recognition and pain recognition through self-learning systems. The novelty is also to be facilitated by advancements of the actuators with new and advanced capabilities to artificially stimulate muscles to adjust the load on the ligaments, and provide “smart” and variable force-resistance curves.

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Functionalisation of silicon carbide material via direct laser writing for applications in magnetic sensing and nanophotonics devices
Mechanical and Automotive Engineering Discipline, MicroNano Research Facility, City

Project Description

This project aims to develop new a sensing platform for photonics and spintronics devices. This will be achieved by the deterministic and on-demand in situ creation of fluorescent silicon carbide (SiC) colour centres, whose emission is sensitive to magnetic field, mechanical strain and temperature. These active sources can to be integrated within SiC standard semiconductor nano-fabrication, photonics technology and SiC CMOS compatible-technology.

Currently these color centres formation in the material in not fully controlled and this is limiting the engineering of devices with integrated color centres.
This project will focus on direct laser writing of colour centres in SiC bulk, nanostructures and devices. We will leverage from our recent progress and discoveries in the engineering and isolation of deep optical defects in bulk and nanoscale SiC, in their integration in p-i-n junctions and photonics micro-cavity. The aim is to create these color centres “on-demand” and in arrays or periodic structures for their integration in SiC photonics devices and in SiC nanomaterials for spin/magnetic sensing within biological samples.

The focus of the project will be in the following tasks:
1. Colour Centre Formation: Colour centres in SiC are naturally randomly distributed, impeding scalability. We will generate precisely positioned colour centres within SiC materials or devices, by femtosecond laser writing until colour centres are formed from nearby impurities and vacancies. By detecting in situ the formation of colour centres, we will improve the yield of colour centres formation and control their concentration.

2. Characterization of the as such formed color centres from the optical and magnetic sensing point of view

3. Direct laser writing in SiC nanocrystals and applications in biological imaging of magnetic molecules.

Training on the use of femtosecond laser and imaging systems will be required via attending the Laser Safety Course and by the Supervisor.

References:

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Aerodynamics and Hydrodynamics in Sports
Mechanical and Automotive Engineering, Sports Aerodynamics Research Group, Bundoora Campus

Project Description

Today performance enhancement is paramount in competitive and recreational sports. Sports balls (tennis, cricket, baseball, golf, soccer, rugby, AFL, NFL), cycling, swimming, ski jumping, running, ice skating, alpine skiing, sports gear (including sports garments, helmets), and sailboats—all need to overcome aerodynamic or hydrodynamic resistance (drag force). The minimisation of aero/hydrodynamic drag is vital in competitive sports. This is why sports aerodynamics area is niche and emerging research area. For example: the flight behaviour of cricket ball, baseball and golf ball is still not fully understood. With high speed bowling, imparting spin and continuous aging due to the impact and bowling actions, an asymmetric boundary conditions and flow separation generates sideways swing hence unpredictable flight behaviour.

The orientation of seam, hairy fuzz and imparting spin create complex and unpredictable flight behaviour of tennis ball. The behaviour becomes more unpredictable with aging as the hairy fuzz gradually breaks down. The centre piece of soccer game is the spherical ball. Technological advancements have progressively been introduced in soccer ball development since 2000 by Adidas and other manufacturers. The traditional 32-panel ball now becomes 6 panels in 2014. The complex seam, seam width, length and the surface structure as well as imparting spin makes the ball’s flight trajectory unpredictable.

With the increase of venting, the thermal comfort increases but it also increases aerodynamic drag. It is highly desirable to develop an optimal helmet that can provide excellent thermal comfort with higher aerodynamic efficiency.

The flight trajectory of the oval shape balls such as Rugby, Australian Rules football and American football is extremely complex and unpredictable. Additionally, the ball can spin around the longitudinal and lateral axes making the flight behaviour chaotic. Till to date, the accuracy of goal scoring kicks is less than 50% by even top level elite players. Research on any of above mentioned topics can be undertaken at RMIT University. All relevant facilities and equipment are available.

References:

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**Vessels-on-a-chip to study blood flow dependent thrombotic processes**
Laboratory for Innovative Thermal Fluid Systems, Mechanical and Automotive Engineering
ECP: Advanced Manufacturing, and Biomedical and Heath Innovation, City

**Project Description**

Fluid flow underpins almost all biomedical systems; from the transport of oxygen to our blood, to the mechanism of wound repair.

This project focuses on the processes that modulate arterial thrombosis (clotting), with an emphasis on the contribution of blood flow dynamics. We have previously demonstrated that thrombi themselves create flow conditions that promote further thrombus growth. Also, the presence of atherosclerotic plaques that have grown in arteries and veins promote thrombosis (pro-thrombotic) due to their geometries. A key player in the pro-thrombotic state of the blood in areas of altered flow dynamics is the blood-borne protein von Willebrand Factor (vWF). This multimeric plasma protein is critical in platelet aggregation under arterial blood flow conditions and becomes “activated” at sites of severe vessel narrowing where blood flow velocities are greatly increased. Aortic valve stenosis, is such, a medical condition where the aortic valve is calcified, leading to a reduced flow area during systolic blood flow. The aim of this project is to delineate the effects of extreme blood flow conditions on vWF. The student will develop a range of microfluidic vessels, or vessels-on-a-chip, to study the effects of blood flow on the overall thrombotic process. Furthermore, in collaboration with Drs. Erik Westein and Christoph Hagemeyer they will use specifically made single chain antibodies against VWF which are capable of inhibiting the VWF-platelet interaction specifically under these prothrombotic shear conditions. This diverse project will combine microfluidic technology, platelet biology, and fluorescence microscopy to adequately address the research questions.

This is a collaborative project with Drs Westein and Hagemeyer at the Australian Centre for Blood Disorders.

**References:**


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Associate Supervisor - Dr Christoph Hagemeyer ([christoph.hagemeyer@monash.edu](mailto:christoph.hagemeyer@monash.edu))
Ultra-high heat flux cooling using nanostructured surfaces
Laboratory for Innovative Thermal Fluid Systems, Mechanical and Automotive
City Campus

Project Description

The transfer of heat and the flow of fluids are fundamental to our society. From simply pumping water to complex operations like electricity generation, these processes are both ubiquitous and vital. By bringing together two fields of research which are generally disparate – nanofabrication and fluid mechanics – it is possible to overcome long-standing limitations in heat transfer and fluid flow [1]. Through investigating the central phenomena of how micro/nanostructured surfaces interact with fluids, our initial work indicates that it is possible to significantly increase the efficiency of devices involving the transport and storage of heat. Therefore we propose that by using a combination of theory, experiments and simulations, we can develop optimal combinations of surface structures and heat transfer fluids, for enhanced convective heat transfer rates, with reduced fluid friction (and thus pumping power).

Particular applications that involve very high heat fluxes are power electronics and concentrating solar collectors. In fact some power electronic devices have been shown to have heat fluxes commensurate with the surface of the sun! These need to be cooled efficiently to function. In this project the student will conduct experiments, and use theory to analyse the effective heat transfer performance of spray cooling with variously fabricated nano/microstructured surfaces from hydrophilic to superhydrophobic. The ultimate aim is to develop novel heat exchangers capable of removing ultra-high heat fluxes to keep up with the requirements of industrial applications.

This project will involve collaboration with one of the best Universities in Mechanical Engineering in Germany, the Technical University of Darmstadt.

References:

Contact Details
Senior Supervisor - Professor Gary Rosengarten (gary.rosengarten@rmit.edu.au)
Associate Supervisor - Dr Cameron Stanley (cameron.stanley@rmit.edu.au)
Numerical Investigation of Flow around Submerged Objects
Mechanical and Automotive Engineering, Bundoora East

Project Description

The interaction of bubbles with flow boundaries has been traditionally of high interest for marine engineering because it plays an important role in reducing drag for underwater vehicles and the survivability of Navy platforms. For example, when a conventional submarine is snorting, a large quantity of exhaust gas will be discharged into water which results in a highly turbulent bubbly plume. This plume will generate acoustic and visual signatures, and the strong interaction with the boundary layer will lead to the formation of a bubbly wake, which may comprise the survivability of the submarine. To be able to develop the best mitigation strategy, a deep understanding of the associated physics is required. There exist few articles published in open literature addressing this two-phase fluid system.

In gas-liquid bubbly flows, the local hydrodynamic variables (e.g. bubble size distribution, void fraction, bubble coalescence and breakage rate and interfacial area concentration) can dynamically evolve and this can make the flow structure very complex. To be able to develop the best mitigation strategy, a thorough understanding of the associated physics is necessary. Capturing bubble evolution may also be important for understanding other associated phenomena (e.g. flow noise, cavitation inception). Most of the studies in the literature deal with a single-phase flow. For example, the David Taylor Research Center has performed a thorough experimental investigation of turbulent single-phase flows around different submarines, including DARPA SUBOFF [1-3]. However, there is no numerical or experimental data in open literatures for a two-phase fluid flow around a submerged complex body.

The aim of this project is to investigate and identify the best available numerical methods and algorithms to predict the bubble size distribution around submerged objects. The outcome will enhance the design of such geometries. The candidate will also be educated to share the research outcomes by publishing in prestigious international journals and presenting in national and international conferences. She/he will also benefit from national and international collaborations to enhance professional network and develop future career.

References:

Contact Details
Senior Supervisor - Professor Jiyuan Tu (jiyuan.tu@rmit.edu.au)
Associate Supervisor - Dr Sara Vahaji (sara.vahaji@rmit.edu.au)
A Multiscale Modelling Platform for Nanoparticle Inhalation Risk Assessment

Mechanical and Automotive Engineering, Bundoora

Project Description

The exponential growth in nanomaterial production for many consumer products (e.g. office printers, disinfectant sprays, textiles) has led to increased exposure to toxic airborne nanoparticles. An understanding of nanosafety is vital to ensure public health risks are mitigated as we continue to take up nano-based products. This is a challenging problem because toxicology studies involving human subjects are an unviable option. Instead modelling approaches can be used to describe nanoparticle behaviour and predict its health effect on the human body.

However these models lack detail regarding multiscales involving the large indoor air environment during exposure, through the respiratory airways during inhalation, and down to nanoparticle penetration in the respiratory tissue cells. While developments have been made in independent studies at the different scale levels, the cause-and effect identification of potential health problems from nanoparticle exposure cannot be connected – a gap this project will aim to fill.

The aim of this project is to explore the fundamental nanoparticle transport behaviour through the respiratory system, and gain a deeper understanding of the health effects caused by inhalation exposure using a novel multiscale modelling approach. This will allow a new predictive tool for health risk assessment of human exposure to nanoparticles to be developed.

The research objectives of this project are to:

- derive a set of constitutive equations to describe nanoparticle transport behaviour through the respiratory mucus, tissue and cell;
- test and refine these models using experimental measurements, computational fluid-structure interaction modelling, and fluid-particle dynamics simulations, and;
- Develop a complete multiscale human inhalation exposure toxicology risk assessment platform that connects the surrounding environment, human body, and the internal respiratory system.

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Air quality and transmission of airborne diseases in densely occupied passenger cabins
Mechanical and Automotive Engineering Discipline
Bundoora East

Project Description

The prosperous economy and globalization in recent decades has significantly stimulated the demands on interstate and international travels. Airliners and high-speed-rail (HSR) trains have been the most popular long-distance travelling approaches owing to their high efficiency and bulk transportation capacity. The world witnessed 3.5 billion people travelling by air and additional 2.0 billion people travelling by HSR in 2016. The numbers are predicted to be more than doubled in 20 years ahead. Airliner and HSR cabins are enclosed airtight spaces with a high density of passengers. The thermal environment and air quality in the cabins is of great importance to the ride comfort and public health. Particularly, the global outbreaks of severe acute respiratory syndrome (SARS) in 2003 and swine (H1N1) flu in 2009 and a number of Tuberculosis (TB) infections have been largely attributed to air and rail travel. A strengthened understanding of the air distribution and transmission dynamics of airborne diseases in densely occupied spaces is critical to the optimized design of ventilation schemes in order to improve the air quality and minimize the infection risks in airliner and HSR cabins [1].

We have conducted fruitful research in this area [2, 3] through collaboration with many academic and industrial partners. The group has been awarded a number of research grants by many domestic and international funding bodies, including the Australian Research Council (ARC), Rail Manufacturing Cooperative Research Centre (RMCRC), Chinese Ministry of Science and Technology (CMST) and the Boeing Company, etc.

The PhD student will participate in the exciting research project through team work with other researchers in the group. His/her PhD project aims to thoroughly understand the transport dynamics of pathogen-carrying respiratory droplets and their interactions with the airflow and human bodies [4]. The expected outcome of the PhD project is an integrated predictive model of airborne infections in densely occupied cabins. The PhD student will also have excellent opportunities of international collaborations and career development.

References:

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Associate Supervisor - Dr Xiangdong Li (xiangdong.li@rmit.edu.au)
Ultra-low temperature testing for Underwater Vehicle Design
Mechanical and Automotive Engineering Discipline
City/Bundoora East

Project Description

Biomimetic designs have been actively sought in a variety of advanced technology developments.[1] A specific area of interest is underwater vehicle building and design for reduced drag that could also be utilised to achieve reduced visibility and detection as a variety of species have successfully implemented such strategies. However, there are still outstanding gaps in our understanding of underwater motion of highly efficient biological species and their mode of locomotion. They are mainly due to difficulty involved in testing large scale models as such facilities are scarce but they also do not allow for studying the unsteady fluid effects that are critical in water based propulsion. Further to this the traditional facilities do not allow for simultaneous study of surface modification on propulsion and resistive drag. However, very recent development in low temperature physics suggest that substantially scaled-down models could be tested in liquid helium at around 4°K and they produce reliable and accurate reflection of larger scale test in normal temperature fluid. Such tests will be conducted by our colleagues while we will produce the SD printed prototypes and will utilise the data for large scale computer simulation. The work is likely to have defence involvement and the low temperature experiments are funded by European funding agencies.

Skills: Advanced knowledge of CFD and CAD; understanding of other advanced methods such immersed boundary elements and panel method. Understanding of surface characterisation and its effect on the immersed body drag.

References:
[1]. M La Mantia, P Dabnichki Added mass effect on flapping foil. Engineering Analysis with Boundary Elements, 36 (4), 579-590

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Joint Associate Supervisor - Dr Marco La Mantia (External)
Physiologically Relevant Loading for Artificial Bone and Implant Testing
Mechanical and Automotive Engineering Discipline

Project Description

RMIT is a world leading institution in using additive manufacturing for personalized implants that have been successfully used in complex orthopaedic procedures.[1] However, there are still outstanding issues related to implant failure specifically on the interface with bone. This is partially due to lack of sufficient knowledge muscle loads applied to the bone during variety of locomotion patterns not just planar gait but different daily locomotion patterns and the fact that most studies report data on young subjects (predominantly student age) rather than middle age and elderly where surgical intervention is usually required and specifically for amputees where the gait pattern changes substantially.[2] In collaboration with partners from the UK health service and academia our group has accumulated a large data base of daily routine activities of advanced age volunteers that is to be used for input in a muscle simulation model in order to obtain the physiological loads exerted by the muscles. The so obtained inputs are to be used to develop a test rig that will be used to test implants and implant/bone interfaces produced by the means of Advanced Manufacturing (AM). The test outcome will be the utilised in collaboration with experts from the AM precinct and medical specialists to optimise both the implant shape and interface with bone. It is anticipated that a parametric FE model will be developed to allow for personalised adjustments of the design and supplementary virtual testing.

Skills: Knowledge of biomechanics of human motion, muscle biomechanics and physiology, bone biomechanics, finite element modelling for biomedical applications. Willingness to work on a collaborative interdisciplinary project. Small extent work with volunteers for motion data acquisition may be required.

References:

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Ubiquitous computing system for monitoring effectiveness of treatment and rehabilitation programmes
Mechanical and Automotive Engineering Discipline

Project Description

Ubiquitous or as otherwise known pervasive computing has been well established in sport and leisure activities, as well as for medical trials of new drugs.[1] We further developed systems for clinical testing of neurological patients for in house testing. However, despite of multitude of mobile phone based applications there is still no proper systemic approach to monitor patients post-operative and/or post-stroke recovery especially in advanced age and the cross-influence of these factors on their overall activity, cognitive decline and other effects. Furthermore there are substantial problem in implementation of effective rehabilitation programmes due to declining cognitive and physical abilities of patients. We have a co-tutelle agreement with the university of Vienna and are currently running a number of project one of them assesses the effectiveness of interventions tackling foot deformities and the associated gait modifications.

This project will build on our earlier works with amputees [2] and the on-going gait modification one and will broaden the assessment of motion adjustment post critical events. In addition to gait pattern monitoring a broad activity index and vital signs will be added. The system will utilise comprehensive cognitive assessment tools and broad balance and coordination assessment to monitor potential side effects, secondary conditions and/or potential complications to alert medical and care personnel. The framework for the system was developed in the University of Vienna for monitoring child activity and growth. Further research will be focused on cross-testing and the development of recovery/deterioration index for indicative assessment of patient’s response to the rehabilitation programme. There is a strong possibility to work with MS and PD patients to monitor their treatment effectiveness at a later stage of the project. The project is partially funded by European resources.

Skills: Advanced programming skills, electronic device integration, statistical modelling, advanced signal processing, data processing and analysis; desire to work with volunteers on test trials of the system.

References:

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Joint Associate Supervisor – Professor Arnold Baca (External)
Development of the new morphing spacecraft, with controlled “flipping” capabilities, based on “Dzhanibekov’s Effect”
Mechanical Engineering/Sir Lawrence Wackett Centre
Bundoora East Campus

Project Description

A proposed research is prompted by the discovery in space made in 1985 by A.Dzhanibekov, who during unpacking of the payload observed periodic unstable motion of the rigid body, which after its apparent stable and undisturbed flight, suddenly changed its axial orientation by 180 degrees, simultaneously changing its direction of rotating to opposite in the body-axis coordinate system and continued its flight backwards. Due to its apparent significance, this phenomenon (known as “Dzhanibekov’s Effect”) was classified by authorities for 10 years, however after becoming available to the engineering community, became a favourite experiment on board of the International Space Station. For example, it has been run by JAXA Japanese astronaut Koichi Wakata on-board of the ISS in 2014 (Expedition #38).

In the most recent works by P.M.Trivailo and H.Kojima, the “Dzhanibekov’s Effect” phenomenon has not only been explained mathematically, numerically and with geometric interpretations, but a method of switching ON and OFF of this unstable motion has been proposed. It has been demonstrated that using this effect, the attitude of the spacecraft can be changed without using the control moment gyroscopic systems. The new method is based on the inertial “morphing” of the systems and is easy in its implementation. The key objective of the proposed research is to develop micro-satellite with morphing capabilities and explore new experiments in parabolic flights and in space for possible new space missions.

The plan of the research includes the following:
(1) Extensive systematic simulations and optimisation of the morphing systems, to propose “candidates” for the applications and experiments in space;
(2) Development of the specification for the possible demonstration experiment in space, involving a newly proposed “morphing of the spacecraft”;
(3) Development of the parabolic test on-board of the aircraft;
(4) Design and manufacture of the morphing systems with electronic control components for the parabolic test experiments and possible experiments in space;

References:

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**Optimal Design of Spacecraft Formation Systems for Australia**
Mechanical Engineering/Sir Lawrence Wackett Centre
Bundoora East Campus

**Project Description**

Over recent years there has been a growing interest in satellite formation flight technology as it is expected to offer improvements in cost, performance and resilience. However satellite formations often require precise relative geometry to realize these benefits. A key application considered in this study is the formation design of missions that would benefit Australia. New possible Australian spacecraft use-cases will be identified and optimal control or zero fuel formations will be designed for these cases.

In our previous published research, we developed Optimal Parameter Estimation of Dynamical Systems using Direct Transcription Methods [1] and software, which was the key success factor behind deployment of the longest ever launched tethered system of 32 kms, registered in the Guinness Book of the World records (YES-2 space mission designed by Delta-Utec and launched by ESA in 2008). We used this method and software to determine minimum fuel deployment of various spacecraft formations and reconfiguration of the satellites [2]. Furthermore, we developed high fidelity model for formation design, identification of important orbits for Australia and the design of viable formations within these orbits. The synthetic aperture radar system represents a possible investment in Earth observation that could be realised within a short period of time. This system would provide data to assist Australia in many of the challenges it faces, while reducing our dependence on foreign good-will. Daily coverage could be realised by using satellite formation flight. The geosynchronous application uses a novel orbit which offers spacecraft significant time overhead Australian cities [3].

With the proposed research we aim detailed development of satellite formation flight missions in compliance with specification of DSTG, featuring deployment, reconfiguration (if needed) and autonomous performance.

**References:**


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Celestial Bodies Sampling Using Rotating Tethered Systems
Mechanical Engineering/Sir Lawrence Wackett Centre
Bundoora East Campus

Project Description

There is a strong wish to establish whether, or not, life has originated elsewhere in our Solar System. Such alternative-origin life may be limited to primitive microbes, but its discovery would still be of profound philosophical importance [1]. Liquid water is strongly associated with life on Earth. Consequently, it is not unreasonable to expect that any large extra-terrestrial water mass (in excess of, say, the mass of Arctic Ocean, ~1019 kg) that has existed for a sufficiently long timescale could potentially permit the genesis of life. Several icy bodies are now thought to contain subsurface saltwater oceans that could feasibly provide suitable habitats for chemosynthetic life-forms (Appendix A). Enceladus [1] is of particular interest since continuous water plumes emanate from the so-called “tiger stripes” in the southern hemisphere. There is also evidence for transient water plumes emanating from Europa and Ceres. One or more of these icy bodies (or so-called “ocean worlds”) might feasibly contain microbes that are swept upwards by these plumes, possibly locked inside ice grains. After some orbit and trajectory considerations [1], a new idea is presented on the possible use of tethers to allow particulate collectors to enter plumes at reduced encounter velocities at relatively low altitudes.

A seemingly attractive opportunity is therefore presented: instead of employing landers, it may be possible to employ an orbiting or flyby spacecraft to collect microbial samples. This architecture would have a significant delta-V advantage (over those assuming landers) resulting in realistic near-term mission costs [2-5].

This proposed project will aim development of the feasible space tethered missions to undertake remote sampling from the mother spacecraft, without its landing. The main challenges would involve non-linear modelling of the complex tethered systems, their navigation and control. Optima control methodology may also enhance the feasibility of the developed missions, as would enable their planning within the very limited resources.

References:

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Long Range Smart System for Evacuation and/or Delivery of Personnel or Equipment Using Airborne Fixed Wing Aircraft/UAV, without the Need for Landing During the Pick-Up or Set-Down
Mechanical Engineering/Sir Lawrence Wackett Centre
Bundoora East Campus

Project Description

The aim is to design, develop and demonstrate a set of innovative systems that will allow any suitable light/large aircraft, after modification, to rescue personnel and/or collect payloads (and deliver them) to remote sites without the need to land. This technology acts via precise deployment and stabilisation of the tips of the towed cables, where precise navigation of the tip of the cable is ensured with the “smart” real-time integrated measurement/simulation/control system. This revolutionary new concept for the vertical pick-up (and deployment) of personnel and payloads has distinct new features, as compared with the existing systems: gentle handling (low accelerations at the pick-up stage), long range, fast access, low cost, reliability, ability to operate in the hostile environments and low visibility. The gentle handling, long range (operating radii) and fast access to the rescue locations, low cost and reliability of the system is ensured with the use of the fixed wing aircraft. The feasibility of operation in the hostile environments and low visibility is ensured with the long towed cable.

Previous research at RMIT University, has produced detailed studies using radio-controlled, UAV and light passenger circling aircraft towing long tether cables. It has been demonstrated that, by employing the combined effect of air resistance, gravity, cable elasticity and damping, it is possible to navigate and stabilise the free tip of the towed cable and to use it to pick up and/or drop off a payload from the ground/sea while the aircraft remains airborne. (These experiments have been described in the New Scientist Magazine [1]). Recent effort has studied ways of enhancing the near-stationary motion of the tether cable tip; dynamics of the cable during aircraft transition maneuvers; periodic solutions of a single-towed cable system for vertical aircraft oscillations, elliptic orbits, and cross-winds; periodic optimal solutions including cable winch control in cross-winds, using direct transcription methods, etc. [2-8].

References:

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