School of Aerospace, Mechanical and Mechatronic Engineering

Thesis/Capstone project topics.

2018 BIOMEDICAL TOPICS

Supervisor: Dr Andre Kyme (AMME Biomedical Engineering)

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Project 1: Use of deep learning for uninterrupted head motion tracking in medical imaging

Topic area: Biomedical

Project Summary

We have developed some key technologies that enable the brain of a rodent to be imaged while the animal moves freely inside a positron emission tomography (PET) scanner. This technique has enormous potential to improve our understanding of how brain function and behavior relate to each other in mammals. A vital component of the technique is using motion tracking to accurately estimate the animal's head motion during a scan. The current method relies on optical markers attached to the animal, but this has a crucial line-of-sight limitation which results in intermittent drop-out of motion tracking. In this project you will investigate the feasibility of applying deep learning methods to a head phantom under highly controlled robotic motion to solve this problem and maintain consistent tracking.

Deep learning is a booming field impacting a diverse range of applications from internet searching to financial modelling to disease prediction. Skills in machine learning are highly sought after by many employers. This project will help you to develop valuable knowledge and experience in this important area.

Project 2: A fast and reproducible multi degree-of-freedom robot manipulator for use inside an MRI scanner

Topic area: Biomedical, mechatronics

Project summary

Robots are superb for performing highly controlled and reproducible motion. This is essential for testing and benchmarking new motion corrected imaging methods, developing quality control procedures for motion-adaptive radiotherapy techniques, and enabling MRI-guided surgeries. Currently there are no robots available which can perform rapid, highly reproducible motion in multiple rotational and translational degrees-of-freedom within the high magnetic field of a MRI scanner. The aim of this project is to investigate suitable actuation approaches and robotic designs for the manipulation of phantoms in a 3T field, and to begin prototyping such a system.

Project 3: Development of a scalable 3D modeling tool using a 6-axis robot and computer vision

Topic area: Biomedical, mechatronics

Project Summary

Building 3D models of objects is a vital step in many engineering and biological applications. Such models can be reconstructed from a large number of 2D silhouettes of the object. Using a 6-axis robot, cameras and computer vision principles, you will develop the hardware and software tools to build a versatile modelling platform suitable for generating 3D object models over a wide range of scale and resolution. This project suits students with an interest in robotics, computer vision and programming.

Atomic Molecular and Plasma Physics / Condensed Matter Physics

Title of Project: Deposition of robust functionalized coatings on pulse-biased substrates

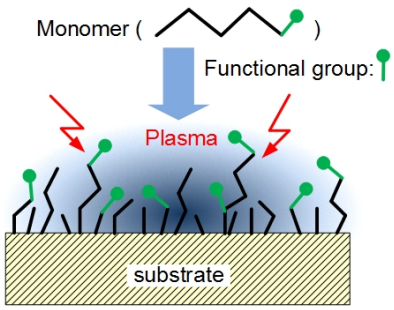
Supervisor: Dr Behnam Akhavan and Prof. Marcela Bilek

Co-supervisor:

Email Contact: behnam.akhavan@sydney.edu.au and marcela.bilek@sydney.edu.au

Brief Description of Project or Project Area:

Plasma polymerization is a versatile surface engineering process capable of depositing ultra-thin functionalized films for a range of applications such as biomaterials for cell attachment and immobilization of enzymes and proteins. In this technology, the desired monomer is initially converted into vapour under a low pressure, and it is subsequently excited into the plasma state using an electric field. The recombination of active species takes place on any surface exposed to the plasma, thus forming a thin layer of functionalized plasma polymer coating. Production of plasma polymer films that are high in functional group(s) yet stable in body fluids is, however, challenging. This research will be focused on the production of robust functionalized plasma polymer films through judicious choice of plasma deposition parameters. The student will obtain experience in laboratory experiments including both fabrication and characterization of novel engineered surfaces.



Plasma polymerization

Credit: Dr Behnam Akhavan

Title of Project: Development of plasma activated coatings on particulate surfaces

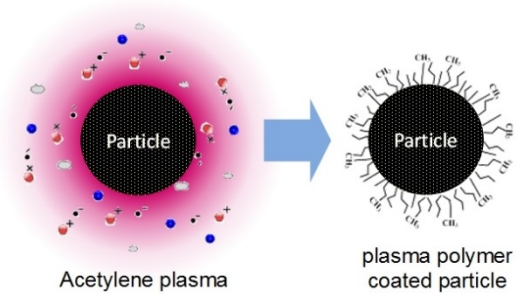
Supervisor: Dr Behnam Akhavan and Prof. Marcela Bilek

Co-supervisor:

Email Contact: behnam.akhavan@sydney.edu.au and marcela.bilek@sydney.edu.au

Brief Description of Project or Project Area:

A plasma activated coating (PAC) is deposited onto substrates via excitation of a precursor gas, e.g. acetylene, in a plasma deposition system consisting of an RF electrode and a pulsed voltage source. PAC facilitates the immobilization of bioactive molecules on the surface owing to highly reactive radicals generated in the coating. While we have successfully fabricated such surfaces onto 2-D substrates, there is great potential to further develop this knowledge for the coating of particulate materials. In comparison with 2-D substrates, plasma polymer-coated 3-D surfaces are of more interest in real-world applications such as protein adsorption/separation and removal of toxic matter from water. This project will involve designing an agitation system to retrofit an existing plasma deposition system followed by the deposition of plasma activated coatings onto model particulate substrates. The student will obtain experience in laboratory experiments including both fabrication and characterization of novel engineered surfaces.



Credit: Dr Behnam Akhavan

Title of Project: Fabrication of oxidized sulphur-containing films through a plasma-assisted approach

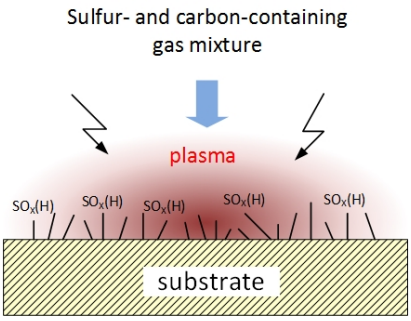
Supervisor: Dr Behnam Akhavan and Prof. Marcela Bilek

Co-supervisor:

Email Contact: behnam.akhavan@sydney.edu.au and marcela.bilek@sydney.edu.au

Brief Description of Project or Project Area:

Surfaces containing oxidized sulfur species [$-SO_x(H)$] are of great interest in a number of critical applications including biomaterials, fuel cells, and water purification. $SO_x(H)$-containing surfaces show remarkably high blood compatibility because of their decreased platelet adhesion and anti-inflammatory properties. These surfaces also exhibit enhanced ionic conductivity, which makes them excellent candidates for proton-exchange membranes. This project will look into the fabrication of such surfaces using a plasma deposition system consisting of an RF electrode and a pulsed voltage source for biasing the substrates. Precursor gas mixtures and deposition parameters will be tuned to achieve desirable sulphur-containing plasma polymer films for the above-mentioned applications. The student will obtain experience in laboratory experiments including fabrication and characterization of novel engineered surfaces.



Credit: Dr Behnam Akhavan

Title of Project: Plasma ion implantation treatment of porous polymeric materials

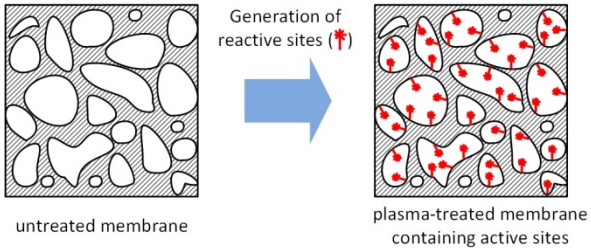
Supervisors: Prof. Marcela Bilek

Co-supervisors: Dr Elena Kosobrodova and Dr Behnam Akhavan

Email Contact: marcela.bilek@sydney.edu.au and behnam.akhavan@sydney.edu.au

Brief Description of Project or Project Area:

Plasma immersion ion implantation (PIII) results in the creation of highly reactive radicals on targeted polymeric materials. These reactive radicals are excellent sites for the immobilization of bioactive molecules. Membranes and porous materials treated via this technique will be of interest for a number of applications including cell culture, tissue engineering and protein adsorption/separation. For such applications, reactive sites should ideally be generated not only onto the surface of a membrane, but also onto the entire internal network of pores. The development of these membranes requires specific reactor designs and geometries that are already available in our laboratories. This project will involve PIII treatment of porous materials under optimized conditions followed by immobilization/separation of targeted biomolecules. The student will obtain experience in laboratory experiments including fabrication and characterization of novel engineered surfaces.



Credit: Dr Behnam Akhavan

Please email this document to Physics Student Services at physics.studentservices@sydney.edu.au

Applied and Plasma Physics / Biological, Biomedical and Medical physics

Title of Project: Bioactive interfaces for cardiovascular implants using plasma discharges

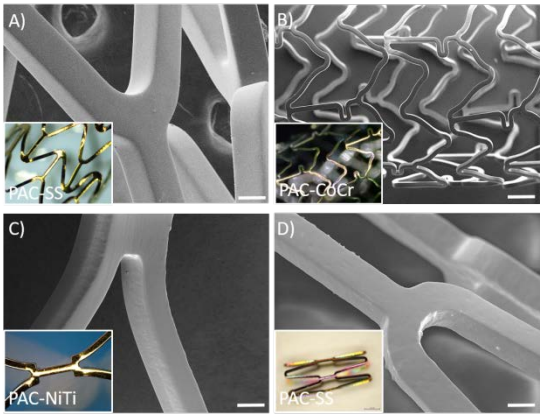
Supervisor: Professor Marcela Bilek

Co-supervisor: Dr Behnam Akhavan and Dr Steven Wise (Heart Research Institute)

Email Contact: marcela.bilek@sydney.edu.au

Brief Description of Project or Project Area (5 – 10 lines long):

In this project you will develop and characterise biocompatible plasma activated interfaces for medical implants using state-of-the-art plasma discharge technologies. The work will develop novel High Power Impulse Magnetron Sputtering (HiPIMS) and Plasma Immersion Ion Implantation processes, aiming to synthesise thin films for improving the compatibility of cardiovascular stents. Precursors for the films can be delivered as sputtered vapour or dip-coated natural materials such as Shellac. Electrical and optical diagnostics will be used to explore the most relevant plasma physics during the process. The physical and chemical characteristics of the thin-films will be studied using electron microscopy techniques (TEM, SEM, EDS and EELS), nano-indentation, X-Ray photoelectron spectroscopy (XPS), infrared spectroscopy (FTIR) and ellipsometry. The project is highly interdisciplinary and will involve a continuous collaboration with the Heart Research Institute, where the biocompatibility and mechanical stability of the plasma coated stents will be further studied using *in-vitro* and *in-vivo* techniques. You can learn more about our project at the following link: http://www.abc.net.au/catalyst/stories/4145875.htm



Plasma activated coatings on cardiovascular stents made from a range of materials including stainless steel (A and D) and CoCr (B) NiTi (C). All stents were subjected to plastic deformation carried out by crimping and balloon expansion. Scale bars are 100 µm (A), 60

Credit: Miguel Santos and Dr Steven Wise.

Title of Project: Plasma pen discharges to activate tissue engineering scaffolds during additive manufacturing

Supervisor: Professor Marcela Bilek

Co-supervisor: Dr Khadijeh Alavi and Professor David McKenzie

Email Contact: marcela.bilek@sydney.edu.au

Brief Description of Project or Project Area (5 – 10 lines long):

Additive manufacturing (commonly also known as 3D printing) holds great promise in medicine where it can be used to create arbitrarily complex scaffolds for tissue and organ repair/ replacement. The thermoplastic materials optimised for use with these manufacturing processes typically suffer from poor biocompatibility. Our group has developed a number of low-pressure plasma processes that can render such materials not only biocompatible but positively biologically active in that they stimulate and direct desirable cell proliferation. This project aims to develop and characterise localised discharges that can be used to render scaffolds and implantable devices biocompatible during their additive manufacture. The work builds on a prior honours project in which capillary discharges compatible with the additive manufacturing processes were created and their ability to activate polymeric surfaces to enable covalent attachment of biomolecules was demonstrated. In this project, the fundamental physics unpinning the biomolecule immobilisation will be explored. Experiments conducted in controlled atmospheres in which certain atmospheric gas constituents are absent and pretreatment with chemicals that inactivate radicals and other reactive species will be used to eliminate various hypotheses. The physical and chemical characteristics of the plasma-activated scaffolds will be studied using X-Ray photoelectron spectroscopy (XPS) and infrared spectroscopy (FTIR). The project is highly interdisciplinary and will involve a continuous collaboration with the Charles Perkins Centre, where the biocompatibility of the plasma-modified scaffolds will be studied using *in-vitro* and *in-vivo* techniques.

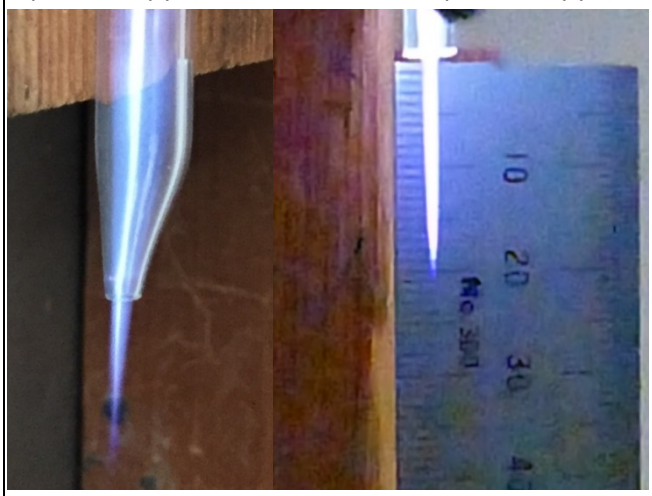


Figure: Two plasma pen designs operating in laboratory atmosphere using Argon and Helium respectively as feed gases.

Credit: Oliver Charles Lotz and Dr Khadijeh Alavi.

Title of Project: Next generation hybrid materials for biomedical applications

Supervisor: Professor Marcela Bilek

Co-supervisor: Dr Behnam Akhavan and Professor Fariba Dehghani (Faculty of Engineering)

Email Contact: marcela.bilek@sydney.edu.au

Brief Description of Project or Project Area (5 – 10 lines long):

Hydrogels are cross-linked fibrous materials that incorporate large amounts of water and provide environments for cells that mimic the native aqueous environments of cells in living tissues. Existing technologies allow the creation of a variety of hydrogels that incorporate biological signalling molecules but they lack the structural stability and mechanical strength required for many applications in biomedical implantable devices and sensing. This project will investigate the potential of using plasma surface activation to create hybrid hydrogel materials in which the hydrogel is robustly bonded to a stronger polymeric scaffold. Plasma parameters with a focus on gas flow dynamics and electric field distributions will be tuned to achieve uniform activation of complex scaffold structures. We have already demonstrated that such treatments are possible and that they make the polymer surfaces more hydrophilic and capable of direct covalent binding to hydrogels. The hydrophilic surfaces facilitate easy hydrogel incorporation and the embedded radicals facilitate covalent bonding of the hybrid structures. The physical and chemical characteristics of the plasma-activated scaffolds will be studied using X-Ray photoelectron spectroscopy (XPS) and infrared spectroscopy (FTIR). Together with our colleagues in Engineering, mechanical properties of the hybrid materials will be assessed for suitability for applications in implantable medical devices and microfluidic sensors.

Title of Project: Plasma immersion ion implantation for controlled drug release and biodegradation

Supervisor: Professor Marcela Bilek

Co-supervisor: Dr Behnam Akhavan and Dr Steven Wise (Heart Research Institute)

Email Contact: marcela.bilek@sydney.edu.au

Brief Description of Project or Project Area (5 – 10 lines long):

Local delivery of drugs and biological from coatings on biomedical implants to prevent infections, mitigate adverse immune responses and facilitate optimal tissue integrations suffers from high initial release rates leading to toxicity and lower than therapeutic release rates thereafter. Biocompatible coatings with tuneable degradation and release rates could solve these problems. Shellac, a fundamentally biocompatible resin secreted by the female lac bug, can be dissolved in ethanol, combined with drugs or biological agents and brushed or dip coated onto arbitrarily complex structures as used in biomedical devices. In this project, we plan to explore the use of ion implantation from a plasma to control the degradation rates of such coatings in aqueous environments and study the effects on drug release rates over time. Ions accelerated by high voltages in a plasma sheath deposit energy tens of nanometers below the coating surface breaking chemical bonds and forming new cross-links in polymeric materials. We have evidence that shows that release of agents loaded into the treated surface layers is inhibited, eliminating the initial toxic burst and that the cross-linking can slow the biodegradation leading to a sustained therapeutic delivery in the long term. An in-depth study of the changes in microstructure, cross-linking and degradation rates is required to allow the production of controlled drug release devices. The physical and chemical characteristics of the ion implanted coatings will be studied using contact angle goniometry, ellipsometry, X-Ray photoelectron spectroscopy (XPS) and infrared spectroscopy (FTIR). Elution assays will be used to study changes in drug elution rates and biodegradability. Biological testing will be carried out together with colleagues at the Heart Research Institute and colleagues in China.

Title of Project: Multi-functional nanocarriers for targeted therapeutics and imaging (a range of projects available)

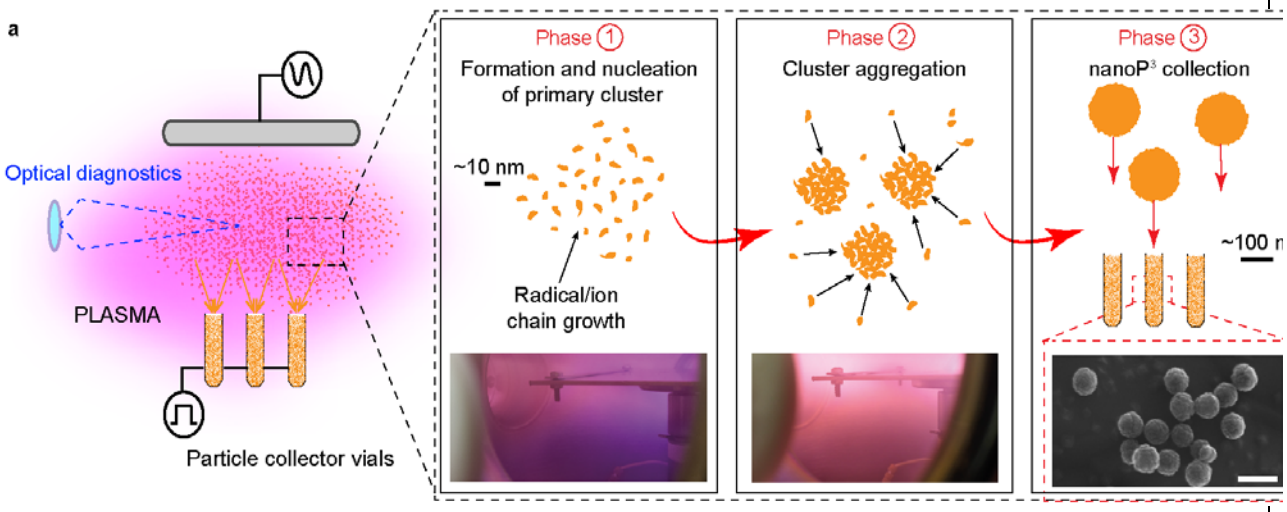
Supervisor: Professor Marcela Bilek

Co-supervisor: Dr Steven Wise and Miguel Santos (Heart Research Institute)

Email Contact: marcela.bilek@sydney.edu.au

Brief Description of Project or Project Area (5 – 10 lines long):

Nanoparticles hold great promise in medicine. In the size range 50-200 nm they can enter cells and deliver cargo including drugs, imaging and targeting agents. An optimum nanocarrier would be able to find a specific target (eg a malignant tumour), deliver a drug and be externally detectable with convenient medical imaging modalities to allow effective monitoring of the treatment. Although there has been a great deal of research on the development of nanoparticles globally, nanoparticles that can be easily functionalised with multiple agents are not available. In recent research, our group has developed and patented a new type of nanoparticle that contains reactive species that enable linking of a wide range of cargo molecules on contact. The attachment of the cargo is achieved through a spontaneous reaction with radicals embedded in the surface of the particle during its synthesis in plasma. We are in discussion with Thermofischer and Merck about the commercial translation of these particles and are conducting a number of engineering, biomedical and basic physics studies to gain a deeper understanding of the mechanisms unpinning their plasma synthesis, behaviour in aqueous solution when mixed with cargo to be attached, mechanisms of reaction, charge-charge interactions that can be used to orient immobilised bioactive molecules and their biological interactions in vitro and in vivo. This work enables many interesting honours projects and can be tailored to student interests.



Nanoparticle production in plasma. Credit Miguel Santos.

Title of Project: Plasma surface engineering of high surface area to volume scaffolds for stem cell expansion and protein/blood purification

Supervisor: Professor Marcela Bilek

Co-supervisor: Dr Elena Kosobrodova, Dr Ali Abbas (Chemical Engineering) and Dr Giselle Yeo and Dr Anna Waterhouse (Charles Perkins Centre)

Email Contact: marcela.bilek@sydney.edu.au

Brief Description of Project or Project Area (5 – 10 lines long):

Stem cells, found in the bone marrow, are cells that can differentiate into a wide variety of cells and hence they can be used to repair and regenerate tissues all over the body. As such they have great potential in medicine. Despite stunning results that have already been demonstrated in therapies employing stem cells, their introduction in standard treatment modalities is limited by the difficulties and expense arising from the expansion of these cells in vitro (outside the patient). Reactors in which small populations of cells can be used to cost-effectively generate populations 100s of times larger are required. Effective reactors need to have very high surface area to volume ratios as the cells need to adhere to a surface to proliferate and the volume needs to be continuously refilled with costly media, containing nutrients to keep the cells alive. The surfaces need to have physical and chemical properties that facilitate cell adhesion and promote their growth. This project (suitable for more than one student) will develop and employ novel plasma treatments to create optimal cell microenvironments in a variety of inexpensive 3D porous materials and structures including cuttlefish bone and organic polymers. The physical and chemical characteristics of the plasma-activated scaffolds will be studied using X-Ray photoelectron spectroscopy (XPS) and infrared spectroscopy (FTIR) to develop an in depth understanding of how conditions in the plasma regulate the surface properties. In prior work, we have shown that treatments involving energetic ions generate radicals below the surface that can be used to attach biologically active molecules. The radical densities will be quantified using electron spin resonance (ESR) and selected bioactive molecules will be immobilised on the modified surfaces to optimise microenvironments for the growing cells. Incorporation of the structures into bioreactor designs will be done together with Dr Ali Abbas of the School of Chemical and Biomolecular Engineering. Opportunities to utilise the same materials functionalised with antibodies for blood or protein purification devices will be explored together with colleagues at the Charles Perkins Centre.

Title of Project: Microfluidic devices for analysis of blood materials interactions

Supervisor: Professor Marcela Bilek

Co-supervisor: Dr Elena Kosobrodova and Dr Anna Waterhouse (Charles Perkins Centre and Heart Research Institute)

Email Contact: marcela.bilek@sydney.edu.au

Brief Description of Project or Project Area (5 – 10 lines long):

Blood clots present major and often fatal problems for virtually all implantable blood contacting devices, such as cardiovascular stents, as well as imposing limitations on the processing of blood products from donors. Materials that can make contact with flowing blood without initiating clotting or thrombosis are needed but an understanding of how blood flow in contact with the surfaces of synthetic materials causes clotting or thrombosis is currently lacking. This project aims to create microfluidic devices that can be used to study the clotting behaviour of blood in contact with various materials under a range of flow conditions. Lithographic processing will be used to make microfluidic structures that will be tested with blood in the Charles Perkins Centre together with thrombosis expert, Dr Anna Waterhouse. The surfaces of these devices will be modified using a variety of plasma treatments ranging from low pressure to atmospheric and the effects on thrombosis quantified. The physical and chemical characteristics of the plasma-modified surfaces will be studied using contact angle goniometry, ellipsometry, X-Ray photoelectron spectroscopy (XPS) and infrared spectroscopy (FTIR) to reveal new understanding of the effects of various surface properties on the formation of blood clots.

Title of Project: Bio-functionalization of capsules to maintain insulin secretion, enhance angiogensis and inhibit fibrosis

Supervisor: Professor Marcela Bilek

Co-supervisor: Dr Elena Kosobrodova, Dr Steven Wise (Heart Research Institute) and Prof Peter Thorn (Charles Perkins Centre)

Email Contact: marcela.bilek@sydney.edu.au

Brief Description of Project or Project Area (5 – 10 lines long):

Diabetes is an increasingly prevalent autoimmune disease that is difficult to manage and predisposes suffers to many life-threatening and debilitating secondary conditions. Since the underlying cause is that the body's own immune system destroys insulin secreting beta cells, the only cure currently available is to implant beta cells in a capsule that keeps the immune cells out. Such treatments have been successful but they are typically short lived due to difficulties in maintaining effective insulin secreting cell populations within the capsules. In this project, we will explore the use of polymeric hollow fibres of no more than a few hundred nanometres in diameter with pores below 50 nm in size as capsules for beta cells. Plasma treatments recently developed in our group will be used to render both the inner and outer surfaces of the fibres hydrophilic and activated so that functional biological molecules can be covalently tethered. The physical and chemical characteristics of the plasma-activated fibres will be studied using X-Ray photoelectron spectroscopy (XPS) and infrared spectroscopy (FTIR) and correlated to biological outcomes. Biomolecules for functionalising the inner regions of the capsules will be chosen to promote healthy beta cell function whilst those on the outside will be selected to promote angiogenesis (the creation of blood vessels) for effective transfer of insulin into the circulation through the pores in the fibre walls. This project is part of a multidisciplinary research program funded by the US based JDRF. Beta cell studies to evaluate the efficacy of the fibres will be carried out by the team of Professor Peter Thorn in the Charles Perkins Centre and in-vivo assessments of angiogenesis performance will be carried out by the team of Dr Steven Wise at the Heart Research Institute.

Anatomy of a fibre capsule.

Title of Project: Early detection bio-sensors for Alzheimer's disease

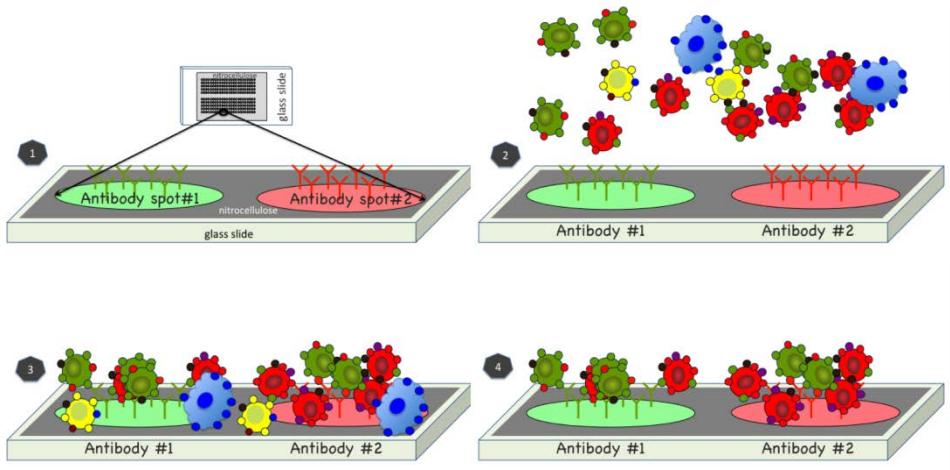
Supervisor: Professor Marcela Bilek

Co-supervisor: Dr Elena Kosobrodova

Email Contact: marcela.bilek@sydney.edu.au

Brief Description of Project or Project Area (5 – 10 lines long):

As our populations are living longer the incidence of Alzheimer's disease and other neurodegenerative conditions is increasing. As recent clinical trials failed to show positive effects of promising trial treatments, interest is shifting to early detection combined with measures that can delay the on-set of these conditions. Our research group has teamed up with an Australian spin-off company, AusBiologics Pty Ltd, to develop early detection bio-sensors for neurodegenerative disease. AusDiagnostics has developed proprietary antibodies that interact strongly and specifically with oligomers that appear in a patient's blood and spinal fluid many decades prior to the on-set of symptoms. The aim of this project is to investigate a number of biosensor concepts that can be employed to detect these oligomers at low concentrations in patient samples. AusBiologics' antibodies will be immobilised on plasma treated polymer slides and used to capture oligomers from solution. A focus will be on developing protocols using electric fields to maximise the surface density and optimise the orientation of the immobilised antibodies to provide the lowest possible detection limit. Orientation will be studied using time-of-flight secondary ion mass spectroscopy (tof-SIMS). Detection based on optical and infra-red sensing will be explored in parallel using spectroscopic ellipsometry and Fourier transform infra-red microscopy respectively.



Sensor in the form of an antibody microarray

Credit: Dr Elena Kosobrodova

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2018 THESIS TOPICS

Effect of Cutting tool on Impalement Events

Cutting tools cause considerable vibration. Most studies have concentrated on the user, but in impaled situation the effect of vibration on the impaled patient needs to be considered. Fire brigade has different tools at their disposal, whereby not just vibration must be considered, but also heat and sound and how these can affect the patient.

This project aims to study all these effect on vibration on the human body when an impaled situation has arisen. Some experiments might be carried out to analyse the vibration / heat / noise of cutting tools and correlate. Finite element models will be used to simulate the response of the human body. This research is in conjunction with the Fire Brigade, Care Flight and the medical faculty. The results will be used directly by the fire brigade and used in future situation.

Thrombosis Group @ HRI

HEART RESEARCH INSTITUTE

THE UNIVERSITY OF SYDNEY

Charles Perkins Centre

Project objective

Our long-term goal is focussed on developing a clinically useful, rapid and high throughput profiling microdevice for disorders in haemostasis and thrombosis. This multidisciplinary project between haematology, microfluidics, biorheology and imaging aims to develop a prototype microfluidic device that can detect exaggerated blood clot formation associated with diabetes, obesity and the metabolic syndrome.

Microfluidic analysis for biomechanical thrombosis: A future point-of-care diagnostics for clotting problems.

[Internal Supervisors - Prof Hala Zreiqat and Dr Young No]

Tissue Engineering and Biomaterials Research Unit and Australian Research Council Training for Musculoskeletal Biomedical Technologies

Email: hala.zreiqat@sydney.edu.au

young.no@sydney.edu.au

[External Supervisors - Prof Shaun Jackson and Dr Arnold Ju]

Excessive clotting (thrombosis) leads to the cardiovascular diseases such as heart attack and stroke— the No.1 world-wide killer, killing one Australian every 12 minutes. It has long been recognized that platelets play a central role in thrombosis and are unique in their ability to form stable adhesive interactions under conditions of rapid blood flow. We have recently discovered a new 'biomechanical' prothrombotic mechanism that highlights the remarkable platelet sensitivity to the shear stress gradients of blood flow disturbance. Importantly, we found that the current anti-platelet agents have limited effect against this biomechanical thrombosis. Notably, at the Charles Perkins Centre and Heart Research Institute, we have developed humanized biomechanical thrombosis models – a novel microfluidic device that recapitulates shear stress gradients, capable of inducing platelet aggregation. In this project, we will characterize several versions of microfluidics that mimics different levels of flow disturbances typically caused by atherosclerotic narrowing of the vasculature, capable of inducing platelet aggregation. These devices will then be

used to profile the prothrombotic phenotypes of patients with high cardiovascular disease risk factors such as diabetes, obesity and metabolic syndromes.

The main tools, used in this project are microfluidics, fluorescence microscopy and AutoCAD engineering designs. In addition, we can offer a profound training in haematology, biorheology and cell biology. Please send through your CV for application at arnold.ju@sydney.edu.au

HEART RESEARCH INSTITUTE

THE UNIVERSITY OF SYDNEY

Charles Perkins Centre

Project details

Microfluidic analysis for biomechanical thrombosis: A future point-of-care diagnostics for clotting problems.

Platelets play a central role in the development of atherothrombosis by initiating and propagating plaque development, as well as promoting thrombus formation on the surface of disrupted plaques [1]. It has long been recognized that blood biomechanics plays a key role in regulating platelet behaviours and thrombus development. In our recent landmark study published in *Nature Medicine*, we have defined a novel concept that under rapid and disturbed blood flow conditions, which are typically caused by a partial luminal obstruction (a developing thrombus, an atherosclerotic plaque or an intravascular device), a change in vessel geometry (extrinsic constriction of blood vessels, vascular bifurcation or aneurysm) or sudden flow changes (vessel hypoperfusion due to shunting or upstream obstruction), the platelet thrombus are mechanically initiated by the shear stress gradients [2]. This not only challenges the classic view that platelet thrombus development is driven by agonist diffusion (e.g. ADP, TxA2 and thrombin), but also provides important insights on drug resistance of atherothrombosis to commonly used antithrombotic agents, including aspirin, clopidogrel and warfarin [3].

Notably, to investigate such novel mechanism in human with a humanized biomechanical thrombosis models, we have developed a microfluidic device that recapitulates flow disturbances typically caused by atherosclerotic narrowing of the vasculature, capable of inducing platelet aggregation (Fig. 1A) [4, 5]. This device incorporates a symmetric, micron-scaled stenosis designed to subject platelets to a defined amount of haemodynamic shear (Fig. 1A). This process results in the biomechanical activation of platelets, which generates measurable platelet aggregation (Fig. 1B). Remarkably, this platform allows us to visualize real-time thrombus formation, propagation and embolization. As a long-term goal, this microfluidic study will lead to a novel point-of-care diagnostics to profile the prothrombotic phenotypes of patients with high cardiovascular disease risk factors such as diabetes, obesity and metabolic syndromes.

As a multidisciplinary project between cell biology, hematology and biomechanics, you will learn about blood rheology, microfluidics and platelet biological functions. You will also learn about applying biomechanical tests to patient samples and profile the diseased phenotypes.

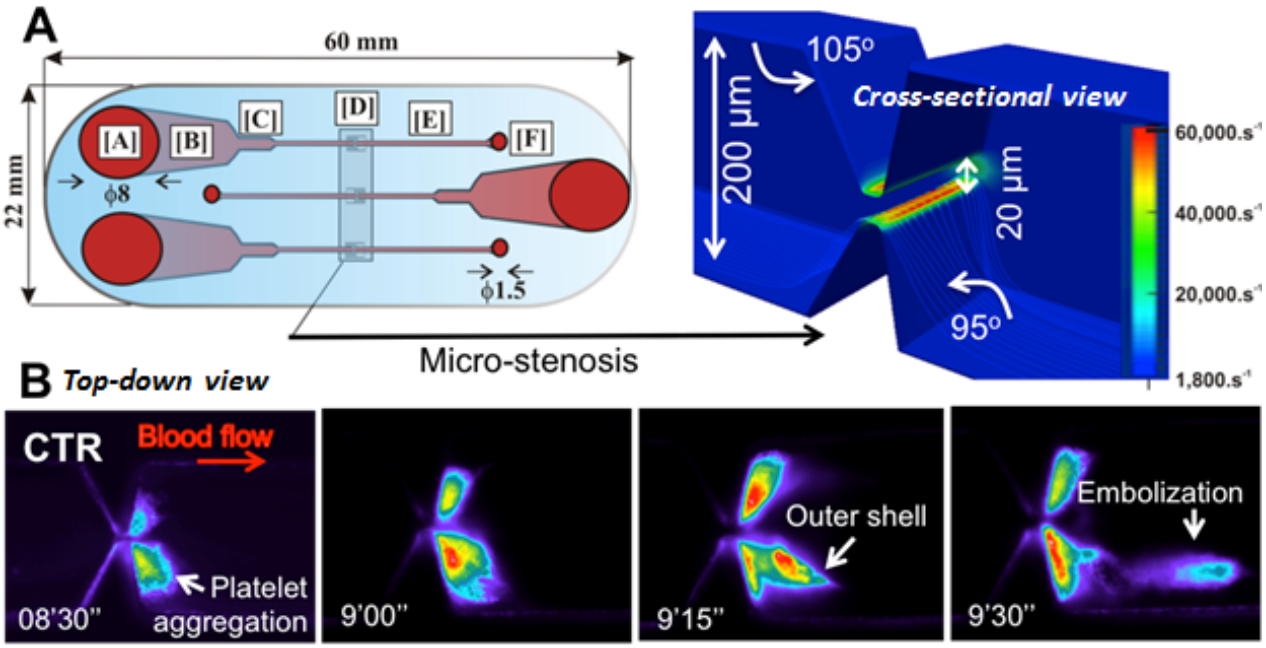

FIG.1 **High-throughput *de novo* microfluidic device for biomechanical platelet aggregation.** ***A.*** Schematics of the microfluidic chip. ***B.*** Epifluorescence image showing fluorescently labelled whole blood platelet aggregation under the flow conditions imposed by the device.

Associated publications from our group:

1. Jackson, S.P., *Arterial thrombosis--insidious, unpredictable and deadly.* Nat Med, 2011. **17**(11): p. 1423-1436.
2. Nesbitt, W., et al., *A shear gradient–dependent platelet aggregation mechanism drives thrombus formation.* Nat Med, 2009. **15**(6): p. 665-673.
3. Jackson, S.P., W.S. Nesbitt, and E. Westein, *Dynamics of platelet thrombus formation.* J Thromb Haemost, 2009. **7**(Suppl. 1): p. 17-20.
4. Tovar-Lopez, F.J., et al., *A microfluidics device to monitor platelet aggregation dynamics in response to strain rate micro-gradients in flowing blood.* Lab Chip, 2010. **10**(3): p. 291-302.
5. Tovar-Lopez, F.J., et al., *An investigation on platelet transport during thrombus formation at micro-scale stenosis.* PLoS ONE, 2013. **8**(10): p. e74123.

Thrombosis Group @ HRI

HEART RESEARCH INSTITUTE

THE UNIVERSITY OF SYDNEY

Charles Perkins Centre

Project objective

Our long-term goal is focussed on determining the mechanisms underlying clot formation in human individuals; utilising this knowledge to better understand the mechanisms leading to platelet hyperactivity and pathological blood clot formation; and ultimately development of safer and more effective therapies to treat cardiovascular diseases including heart attack, stroke, diabetes and the metabolic syndrome.

Solving a sticky clotting problem in Diabetes with single-molecule biomechanics

[Internal Supervisors - Prof Hala Zreiqat and Dr Yogambha Ramaswamy]

Tissue Engineering and Biomaterials Research Unit and Australian Research Council Training for Musculoskeletal Biomedical Technologies

Email: hala.zreiqat@sydney.edu.au

yogambha.ramaswamy@sydney.edu.au

[External supervisors - Prof Shaun Jackson and Dr Arnold Ju]

The leading cause of death in diabetes is cardiovascular disease, with up to 70% of deaths relating to the development of blood clots supplying the heart (heart attack) or brain (ischemic stroke). Diabetic individuals are more prone to develop blood clots, and these clots are more resistant to standard anticlotting therapies. We have recently discovered a new 'biomechanical' clotting mechanism severely affected by diabetes that is resistant to the beneficial effects of commonly used antithrombotic agents, including aspirin, clopidogrel and warfarin. Studies currently ongoing aim to identify how high blood sugar levels (hyperglycaemia) can enhance this new clotting mechanism. To achieve this, we are using Biomembrane force probe ('BFP') technology recently established at the Charles Perkins Centre (CPC), University of Sydney. This platform is the first of its kind in Australia, and allows us to study how a single platelet senses mechanical cues at the molecular scale.

The main tools, used in this project are biomembrane force probe, micropipette fabrication and kinetics analysis. In addition, we can offer a profound training in haematology, biophysics and cell biology. Please send through your CV for application at arnold.ju@sydney.edu.au

HEART RESEARCH INSTITUTE

THE UNIVERSITY OF SYDNEY

Charles Perkins Centre

Project details

Solving a sticky clotting problem in Diabetes with single-molecule biomechanics

Investigating the biomechanical integrin activation in diabetes

Diabetes has become one of the major healthcare challenges of the 21st century and a leading cause of cardiovascular disease worldwide. Up to 70% of all diabetes-related deaths are due to cardiovascular disease, primarily related to atherothrombosis. Diabetes enhances the atherosclerotic process in large arteries, increasing the risk of acute myocardial infarction (heart attack), cerebral infarction (ischemic stroke) and peripheral vascular disease. In addition to developing more extensive atherosclerosis, diabetic individuals also exhibit a prothrombotic phenotype that manifests as an exaggerated accumulation of platelets at sites of plaque disruption [1]. However, the mechanisms by which diabetes causes platelet hyperactivity and a prothrombotic phenotype remain incompletely understood. We have recently defined a new mechanism promoting arterial thrombus formation that involves biomechanical (rheology-dependent) platelet activation [2] that leads to the aggregation of discoid platelets (**FIG.1**). Here we provide evidence that this aggregation mechanism is dysregulated in diabetes, leading to excessive discoid platelet aggregation and thrombus formation in vivo. We have identified that chronic oxidative stress in diabetes plays a key role in amplifying discoid platelet aggregation by altering the shear-sensitivity of the major platelet adhesion receptor integrin $\alpha_{IIb}\beta_3$ (commonly referred to as GPIIb-IIIa). We ***hypothesise that this biomechanical prothrombotic mechanism is associated with alterations in redox-sensitive signal pathways linked to GPIIb-IIIa***. Importantly, exaggerated platelet aggregation is not inhibited by conventional antiplatelet agents such as aspirin and clopidogrel, which may partly explain reduced efficacy of antithrombotic therapy in individuals with diabetes.

Studies currently ongoing in our laboratory aim to identify how high blood sugar levels (hyperglycaemia) can enhance this new clotting mechanism. To achieve this, we are using Biomembrane force probe ('BFP') technology [3, 4] recently established at the Charles Perkins Centre (CPC), University of Sydney [5, 6]. This platform is the first of its kind in Australia, and allows us to study how a single platelet senses mechanical cues at the molecular scale.

During this project, you will learn about *biomechanical* platelet activation, as well as the current understanding of what is known about the effects of diabetes and hyperglycaemia on platelet function. You will also learn about BFP technology first-hand, by working alongside postdoctoral scientists currently using this technology to examine diabetic platelet function.

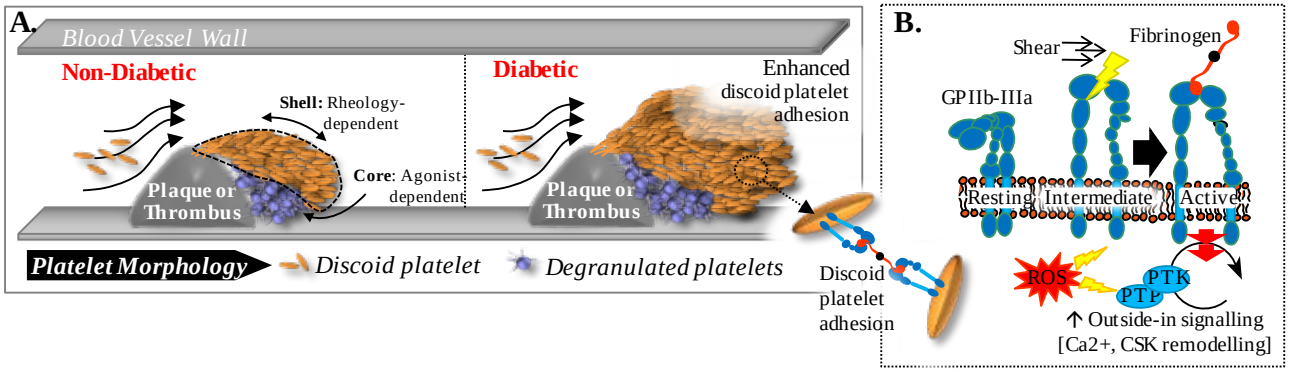

FIG.1 Biomechanical adhesive function of GPIIb-IIIa regulates discoid platelet adhesion. A. *Thrombi consist of a stable 'core' of fully activated platelets, driven by soluble agonists. The outer 'shell' of the propagating thrombus is composed of discoid platelets that are tightly regulated by shear forces. The process facilitating discoid platelet adhesion is exaggerated in diabetes.* ***B.*** *Our hypothesis is that chronic oxidative stress in combination with shear induces a GPIIb-IIIa 'intermediate' activation state that mediates discoid platelet aggregation (**inset**). We hypothesise that this occurs through alterations in GPIIb-IIIa mechanotransduction, involving redox-sensitive signalling pathways (ROS) linked to various kinases (PTK) and phosphatases (PTP).*

Associated publications from our group:

1. Jackson, S.P., Arterial thrombosis--insidious, unpredictable and deadly. Nat Med, 2011. 17(11): p. 1423-1436.

2. Nesbitt, W., et al., A shear gradient–dependent platelet aggregation mechanism drives thrombus formation. Nat Med, 2009. 15(6): p. 665-673.

3. Ju, L., et al., The N-terminal flanking region of the A1 domain regulates the force-dependent binding of von Willebrand factor to platelet glycoprotein Ibα. J Biol Chem, 2013. 288(45): p. 32289-32301.

4. Fiore, V.F., et al., Dynamic catch of a Thy-1–α5β1+syndecan-4 trimolecular complex. Nat Commun, 2014. 5: p. 4886.

5. Ju, L., et al., Cooperative unfolding of distinctive mechanoreceptor domains transduces force into signals. Elife, 2016. 5.

6. Ju, L., et al., Two-Dimensional Analysis of Cross-Junctional Molecular Interaction by Force Probes. Methods Mol Biol, 2017. 1584: p. 231-258.

Internal Supervisor: **Professor Hala Zreiqat**, Tissue Engineering and Biomaterials Research Unit and Australian Research Council Training for Musculoskeletal Biomedical Technologies

Email: hala.zreiqat@sydney.edu.au

External Supervisor: Dr Anna Waterhouse, Cardiovascular Medical Devices Group

Charles Perkins Centre, Central Clinical School

Heart Research Institute

Email: anna.waterhouse@sydney.edu.au

Project 1:

Creating micro-systems to study medical devices and their failure mechanisms

The diagnosis and treatment of many diseases involves the use of medical devices, for example, vascular stents, heart valves, pacemakers, dialysis machines and cardiopulmonary bypass circuits. However, these are all made with artificial metals and plastics which cause many side effects such as thrombosis (blood clots) and pathogen adhesion (biofouling). These processes are difficult to study in the lab because the devices are large and complex. Advances in micro and nanotechnology have revolutionised bioengineering, allowing high precision manipulation of materials for modelling medical devices in the lab.

In order to better understand these processes and develop improved materials for medical devices, we are creating micro-systems to study medical device materials in the laboratory. Utilizing the new facilities at Australian Institute of Nanoscale Science and Technology (AINST) at the University of Sydney, this project aims to created micro-systems that mimic aspects of medical device materials and geometries. Using these micro-systems, we will study how variations in material properties and blood flow dynamics govern the initiation of biomaterial-induced thrombosis (Fig 1). This knowledge can ultimately be used to improve or generate new materials for use in medical devices to improve their function and patient outcomes.

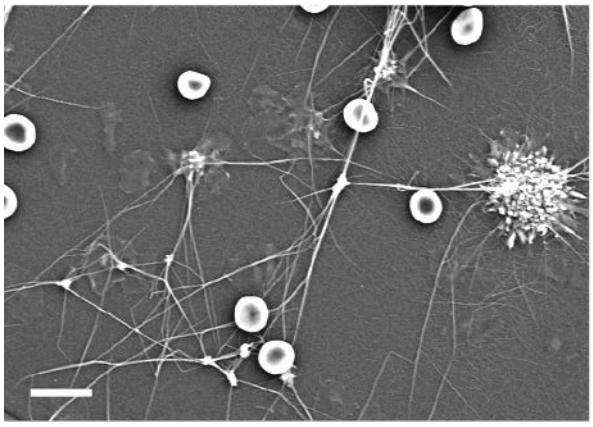

Figure 1. Material Thrombosis.

Scanning electron micrograph showing initiation of material induced thrombosis after 30 minutes of whole, partially heparinised blood incubated with a polysulfone sample. Fibrin fibrils adhere to the surface as well as to platelets, which are also activated and spread on the polysulfone surface.

Internal Supervisor: **Professor Hala Zreiqat**, Tissue Engineering and Biomaterials Research Unit and Australian Research Council Training for Musculoskeletal Biomedical Technologies

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External Supervisor: Dr Anna Waterhouse, Cardiovascular Medical Devices Group

Charles Perkins Centre, Central Clinical School

Heart Research Institute

Email: anna.waterhouse@sydney.edu.au

Project 2:

Slippery surface coatings to prevent thrombosis and pathogenic biofouling of medical devices

Medical devices such as artificial hearts, vascular stents, vascular grafts, heart valves, pacemakers, catheters and cardiopulmonary bypass circuits, can fail due to side effects from the interaction of the patients' proteins and cells with the device materials. This can cause blood clots (thrombosis) and microbe adhesion (biofouling), meaning that patients require additional blood thinning or antibiotic medication, increasing their risk for additional complications. Dr Anna Waterhouse and her team are using micro- and nano-bioengineering strategies to design systems to test materials in the laboratory and understand these failure mechanisms, and design new materials and devices that are more compatible with the body.

Newly developed, super slippery, liquid-repellent surface coatings have great potential to revolutionize medical devices, imparting anti-adhesive properties to materials. Given that surface adhesion of proteins and cells is the driving factor in medical device fouling in processes such as thrombosis and pathogen adhesion in biofilm formation, this repellent surface coating is being investigated to prevent thrombosis of materials due to its ability to repel blood (Figure 1). As part of the Australian Centre for Microscopy and Microanalysis (ACMM) at the University of Sydney, the Charles Perkins Centre houses a suite of microscopes with high resolution capabilities to visualize biomolecule-surface interactions. In this project, we aim to elucidate the mechanism by which these liquid-surfaces are anti-adhesive to proteins, mammalian cells and bacteria, with the goal of translating this to medical devices in the clinic to prevent their failure.

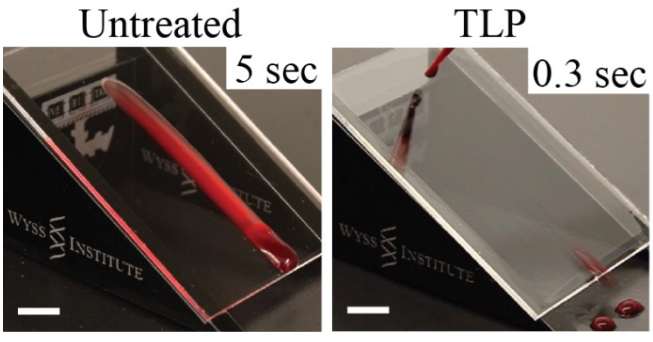


Figure 1. TLP repulsion of blood. Photographs taken from a video of whole, citrated, blood interacted with tilted acrylic slides. Blood adheres to the untreated surface but is repelled and slides off the TLP treated surface immediately.

Honours Thesis Project

Project Title: Optimising the fabrication of ceramic scaffolds for bone tissue engineering using stereolithography

Supervisor: Professor Hala Zreiqat

Auxiliary Supervisors: Dr Young No and Ms Christina Viray

Description:

Additive manufacturing (AM), also known as 3D printing, is a method increasingly being used in the field of bone tissue engineering to produce bespoke scaffolds for patients with bone defects. AM is advantageous in that designed porous ceramic scaffolds can be reproducibly fabricated with defined shapes, geometries, and chemical compositions.

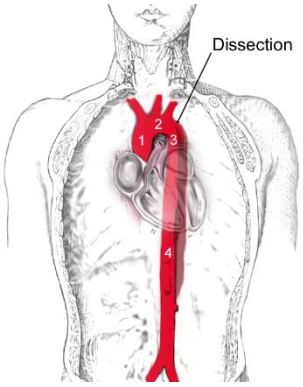
Stereolithography (SLA) is an AM technique that involves using a laser to photopolymerise a liquid solution to form a 3D solid layer by layer. SLA produces higher resolution struts in comparison to extrusion-based AM techniques, offering increased biomimetic capabilities to recapitulate the architecture found in native bone.

This project aims to optimise the stereolithographic fabrication of ceramic scaffolds using bioactive ceramics previously developed by the Tissue Engineering and Biomaterials Research Unit known as Sr-HT-Gahnite and Baghdadite. The project will involve optimising and characterising the ceramic slurry in terms of the binder and ceramic powder, particle homogeneity, and rheological properties. Ceramic scaffolds will then be made using different architectural patterns, and mechanical properties characterised post-sintering. Cells will be cultured on these scaffolds to assess in vitro biocompatibility and viability on SLA-produced scaffolds.

Stents for aortic Dissection (continuation)

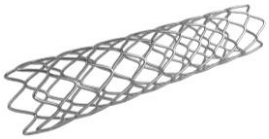
Supervisor: K Srinivas*,
(karksri@gmail.com, karkenahalli.srinivas@sydney.edu.au)
Co-supervisor: Itsu Sen**

(* AMME, University of Sydney, ** Advanced School of Medicine, Macquarie University)

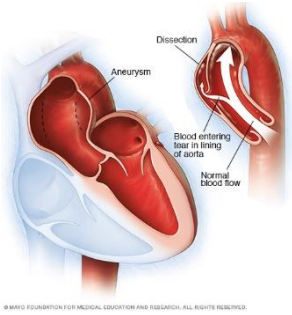


Aortic Dissection is the condition where the inner layer of the aorta tears and the blood flows through the space in between the layers, which are then forced apart. Though not very common, the consequences of this can be disastrous on the patient. Of the many treatments possible, deployment of stents is one. The challenge is to optimise the design of such a stent. It may be pointed out that these are used for curing stenosis and for regulating flow in an aneurysm.

The project proceeds in stages. The first is to compute the blood flow through a dissected vessel and then to work out the objective functions. Then these will be used to carry out the actual design utilising modern techniques of optimisation. We may start with a two-dimensional computation to be followed by a three-dimensional one. In the advanced stages of the project we will consider patient specific cases.



A stent



A basic knowledge of Fluid Mechanics and ability to run software such as ANSYS is highly desirable. There is potential for extension to a Master's project and then to a doctoral work.

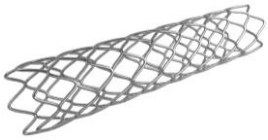
It is also possible to two or three students take up this work, each focussing on a specific issue.

Note: We have given only a broad description of the project. It is possible to tailor it suit the interests and capability of the interested student.

Multi-Disciplinary Design Optimisation of Stents

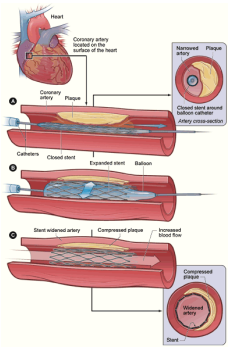
Karkenahalli Srinivas
AMME, University of Sydney
(karksri@gmail.com, karkenahalli.srinivas@sydney.edu.au)

Stents have been a very efficient non-invasive device to cure stenosis in coronary flows. They have also been used to cure aneurysms in cerebral flows and are called *Flow Diverters*. An effective design of them should involve various disciplines such as haemodynamics, structures, materials, compliance and others. Some work has been carried out on their optimisation based on fluid flow in the school. Now it remains to incorporate inputs from other disciplines. The challenge is



A stent

1. To formulate appropriate objective functions from different disciplines.
2. To refine the *Explore the Design Space* technique used for optimisation.
3. To develop better data mining techniques such as *Kriging* and develop appropriate software.

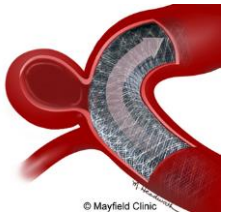


Coronary Application

The work needs a group of students for its execution. Most of the trials will be on idealised two-dimensional models, to be extended to three-dimensional and patient specific models. You can be involved in any one or more aspects of it. Please met me to discuss the possibilities. There is ample food for thought.

Knowledge of Fluid Mechanics, ANSYS and STRAND software is desirable.

Note: I have given only a broad description of the project. It is possible to tailor it suit the interests and capability of the interested student.

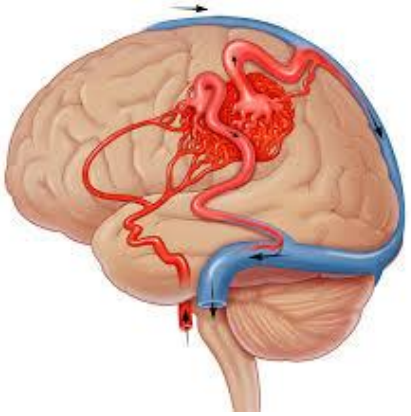


Flow Diverter

Arteriovenous Malformation, a Computational Study (Continuation)

Supervisor: K Srinivas*,
(karksri@gmail.com, karkenahalli.srinivas@sydney.edu.au)
Co-supervisors: Qing Lee*, Itsu Sen**, and Casikar Vidyasagar***

(*, AMME, University of Sydney, ** Advanced School of Medicine, Macquarie University, *** Neurosurgeon, formerly at the Nepean Hospital, Sydney)



AVM in the brain

Arteriovenous Malfunction denotes a tangle in the blood vessels where the blood from the arteries is bypassed to the veins. This can happen in the brain leading to what are called Brain AVMs. The consequences of AVM could be intracranial haemorrhage, seizures, headache and difficulty with movement, speech and vision. There is also a 25% chance of brain damage and stroke.

The flow of blood from arteries to veins, bypassing the intervening capillary network, occurs because of the fistulous connections established. Though the medical community is trying to gain an understanding of the AVMs many fundamental questions remain unanswered. One of these is - when does a clinically silent lesion declare its presence? Is it by haemorrhage? Or is it by a neurological manifestation suggestive of deprivation of blood to normal areas of brain (called Steal Phenomenon)?

It is observed that the consequences of AVM cannot be explained adequately in terms of pressures and flow rates alone. Sizes of fistulas seem to have considerable influence, which are not easily determined.

It is proposed to search for answers to these questions using the computational techniques. Available software ANSYS will be employed for the purpose. Participating student will be using this software extensively.

The challenge exists in the generation of a suitable mesh for real patient geometries. Some modifications and simplifications of the geometry may have to be made. Application of the software then will generate vast amounts of data which are to be analysed.

The project will be an ideal one for any enterprising student who wishes to expand his learning experience into biomedical engineering.

Note: We have given only a broad description of the project. It is possible to tailor it suit the interests and capability of the interested student.

Thesis Project

Faculty of Engineering and Information Technologies
The University of Sydney

Project Title:

Radio Telemetry for a Bionic Eye

Summary:

Active, implantable medical devices such as cochlear implants and bionic eyes require a source of power and means of sending data to/from the implant. In order to avoid potentially life-threatening infections, it is important to avoid percutaneous (through the skin) wires. Induction is a proven method of energy and data transfer that is widely utilised in cochlear implants. In this project, we seek to realise a robust method of energy and data transfer for a bionic eye that takes into account the necessary requirements of a specific device (the Phoenix^{99} bionic eye system).

Description:

This project will build upon existing circuitry and aim to reduce its complexity by focusing on the specifics of an inductively-coupled link that passes energy and data across tissue to an implanted device. A Raspberry Pi microcomputer will be utilised as a driving platform for an inductive transmitter. Load-shift-keying (LSK) will be used to acquire reverse telemetry data. A suitable means of detection of the LSK signals, and a functional circuit for the transmission of 5 MHz inductive energy are key objectives (deliverables) of this project.

Supervisor(s):

Professor Gregg Jørgen Suaning- Biomedical Engineering

Student background:

The student will have a working knowledge of basic electronics and resonant circuitry, competency in C programming language and a willingness to learn CAD layout software for printed circuit board design.

What problem is this project expected to solve?

Successful completion of this project will produce a means of ‘talking to’ an implanted device within the body, to instruct the implanted device’s behaviour, to determine when stimulation is being delivered, and to instruct the device to telemeter information relating to the electrode-tissue interface on an implanted electrode array.

Where will the project primarily be undertaken?

Implantable Bionics and Electroceuticals Laboratory, The University of Sydney

Brief description of how the project will be run:

Students will be expected to be physically present within the laboratory for an agreed part of their weekly schedule. Weekly group meetings will be scheduled with individual meetings arranged as and when required. The laboratory operates under the principles of ISO 13485 and it is an expectation that, following appropriate briefing, students will adhere to all laboratory norms. It is a primary priority to ensure that staff and students remain safe in every aspect of their work. Accordingly, agreement to comply with the University's Workplace Health and Safety policies is a condition of entry into the laboratory.

Thesis Project

Faculty of Engineering and Information Technologies
The University of Sydney

Project Title:

Nanoparticle printing for implantable bionics

Summary:

Implantable bionics in the context of this project include neuromodulation implants that serve as sensory and motor therapies. As an illustrative example, visual neuroprostheses or 'bionic eyes' offer hope to sufferers of degenerative disorders of the retina that ultimately lead to blindness. Recent advances in nanoparticle printing technologies have opened remarkable possibilities in nanofabrication and new means of producing customised implantable devices for use in healthcare. In this study program, nanoparticles of various types will be explored for their use in the fabrication of implantable bionic devices for both stimulation and acquisition in rehabilitation and healthcare monitoring respectively. Heavy utilisation on 3D printing of nanoparticles, low-temperature sintering, and composite material interaction will be key attributes of this work.

Supervisor(s):

Dr. Lilach Bareket - Biomedical Engineering
Professor Gregg Jørgen Suaning- Biomedical Engineering

What problem is this project expected to solve?

To overcome limitations in the fabrication of small, implantable devices by applying recent 3D printing principles to nanoparticles and their processing.

Where will the project primarily be undertaken?

Implantable Bionics and Electroceuticals Laboratory, The University of Sydney

Brief description of how the project will be run:

Students will be expected to be physically present within the laboratory for an agreed part of their weekly schedule. Weekly group meetings will be scheduled with individual meetings arranged as and when required. The laboratory operates under the principles of ISO 13485 and it is an expectation that, following appropriate briefing, students will adhere to all laboratory norms. It is a primary priority to ensure that staff and students remain safe in every aspect of their work. Accordingly, agreement to comply with the University's Workplace Health and Safety policies is a condition of entry into the laboratory.

Thesis Project

Faculty of Engineering and Information Technologies
The University of Sydney

Project Title:

Implantable Device for Chronic Health Monitoring

Summary:

Maintaining human well being is the foremost objective in biomedical engineering. As our population ages and our collective knowledge on how best to care for ourselves improves, there is an unmet need for a source of data that may be used to assess trends and changes in our well being that may be indicators of disease so that interventions can occur. For instance, temperature is a key indicator of not only status of our immune system, but also may be used to determine cyclical changes such as ovulation. Other examples of well being assessment include accelerometers that can provide data on our body position, gait, and sleep patterns. In this study, we will explore the benefits of constructing an implantable device that measures and telemeters out a range of physical parameters as indicators of well being. The objective is to construct a circuit, initially using off the shelf components and a custom circuit board to explore what can be achieved without constructing an application-specific integrated circuit (ASIC) to miniaturise the system, and to better understand the requirements of that ASIC so that it may be designed in the future.

Description:

This project will begin with a survey of the state of the art of wearable devices and will progress to produce a functional prototype of a device that is capable of monitoring and reporting a variety of parameters such as temperature, position, heart rate, etc. The objective is to realise a circuit design that could conceivably be miniaturised in the future using very large scale integration (VLSI) and micro electro mechanical systems (MEMS).

Supervisor(s):

Professor Gregg Jørgen Suaning- Biomedical Engineering
Dr. Jeff Armitstead - Resmed

Student background:

The student will have a working knowledge of basic electronics and be willing to learn how to use software for the creation of schematics and design of printed circuit boards.

What problem is this project expected to solve?

Successful completion of this project will produce a first-generation circuit that can ultimately become an implantable (e.g. injectable) device for chronic health monitoring.

Where will the project primarily be undertaken?

Implantable Bionics and Electroceuticals Laboratory, The University of Sydney

Brief description of how the project will be run:

Students will be expected to be physically present within the laboratory for an agreed part of their weekly schedule. Weekly group meetings will be scheduled with individual meetings arranged as and when required. The laboratory operates under the principles of ISO 13485 and it is an expectation that, following appropriate briefing, students will adhere to all laboratory norms. It is a primary priority to ensure that staff and students remain safe in every aspect of their work. Accordingly, agreement to comply with the University's Workplace Health and Safety policies is a condition of entry into the laboratory.

Thesis Project

Faculty of Engineering and Information Technologies
The University of Sydney

Project Title:

Wearable image capture system for a bionic eye

Summary:

Visual neuroprostheses or 'bionic eyes' offer hope to sufferers of degenerative disorders of the retina that ultimately lead to blindness. Bionic eye technology requires a means of replacing lost photoreceptor cells within the retina with a sensor such as a camera or array of photodiodes. This project melds artistic design with technology to realise an aesthetically-pleasing and inconspicuous means of capturing real-time video images of the visual scene for use in image processing and subsequent delivery to the wearer in the form of electrical impulses from an array of electrodes implanted behind the retina.

Description:

Blind people typically seek normality - that is, they do not wish to stand out in public and instead wish to carry out their activities of daily living independently and without drawing significant attention to themselves. An important factor in the deployment of a bionic eye is the capacity to acquire images of the visual scene. Currently, bionic eye technologies employ awkward or unimaginative solutions to this important 'user interface'. This is as a result of the early-stage of this technology as well as inappropriate design choices. Some examples of existing solutions can be found in the following links:
http://www.abc.net.au/radionational/image/4570884-16x9-700x394.jpg
http://www.australasianscience.com.au/sites/default/files/bioniceye.jpg
http://www.smh.com.au/content/dam/images/z/r/2/4/v/image.related.articleLeadwide.620x349.zr1zh.png/1399001724201.jpg
Success in this project is defined as the implementation of an aesthetically-pleasing and inconspicuous solution that facilitate the capture of images. The images to be captured are to not only contain a two-dimensional depiction of the visual scene, but also information relating to the distance from the sensor and objects ahead.

Supervisor(s):

Professor Gregg Jørgen Suaning- Biomedical Engineering

Student background:

There are multiple components of this work and sufficient complexity to warrant two to three students working in collaboration on the project.

Student 1 will coordinate the overall design but in particular focus on the sensor and its implementation. A student with a mechatronics, mechanical, or industrial design student would be most suitable for this role. Prerequisites: A student at any point within their studies with an appropriate skill-set may apply.

Student 2 will manage the electronics of the sensor or sensors used in order to capture the visual scene. Prerequisites: A student at any point within their studies with an appropriate skill-set may apply.

Student 3 will use a Raspberry Pi or other suitable ‘single board computer’ to acquire the images from the visual scene, process them in real-time to extract depth, contrast and other pertinent features of the scene and produce an array of stimulation instructions to be sent to the implant. Prerequisites: A student at any point within their studies with an appropriate skill-set may apply.

Alternative combinations of the foregoing are also possible and can be arranged in negotiation with the supervisor(s).

What problem is this project expected to solve?

Delivering the outcomes of this project overcome significant challenges in the the clinical and patient acceptance of a bionic eye by addressing the unmet need for an aesthetically acceptable method of image acquisition that produces a real-time image containing contrast and depth data for use in the next generation of image processing algorithms in visual prosthesis research.

Where will the project primarily be undertaken?

Implantable Bionics and Electroceuticals Laboratory, The University of Sydney

Brief description of how the project will be run:

Students will be expected to be physically present within the laboratory for an agreed part of their weekly schedule. Weekly group meetings will be scheduled with individual meetings arranged as and when required. The laboratory operates under the principles of ISO 13485 and it is an expectation that, following appropriate briefing, students will adhere to all laboratory norms. It is a primary priority to ensure that staff and students remain safe in every aspect of their work. Accordingly, agreement to comply with the University’s Workplace Health and Safety policies is a condition of entry into the laboratory.

Thesis Project

Faculty of Engineering and Information Technologies
The University of Sydney

Project Title:

High density hermetic feedthroughs for implantable bionics

Summary:

Any active medical implant - that is, one that contains electronics - must be able to withstand exposure to ionic body fluids in order that it may deliver the required longevity. At the same time, in order to provide a therapy, electrical signals must pass through the wall of the implant. This is typically achieved by way of introducing a "feedthrough" which contains an electrical conductor surrounded by an insulating material. In medical implants, these materials must be body-compatible, and possess a longevity that may need coincide with the lifetime of the implant recipient. In this project, we aim to push the boundaries of what can be achieved using both high- and low-temperature co-fired ceramic (HTCC and LTCC) in the fabrication of multi-channel hermetic feedthroughs using laser micromachining.

Description:

Implantable bionics such as cardiac pacemakers, cochlear implants and deep brain stimulators have become mainstream therapies to treat various medical disorders. Visual neuroprostheses or 'bionic eyes' offer hope to sufferers of degenerative disorders of the retina that ultimately lead to blindness. Behind the achievement of these outcomes is a technology that lasts for the required duration within the harsh environment of the human body. This is achievable by means of a hermetic feedthrough - that is, one or more electrical conductors within the wall of the implant that allows for the passage of electrons but not fluids, ions or molecules that may reduce the longevity of the device through corrosion or electrical shorting. In this study, the student will explore two types of ceramic 'tape' - low temperature co-fired ceramic (LTCC) and high temperature co-fired ceramic (HTCC). LTCC is particularly interesting to medical implant designers as it allows for some electrical components (resistors, capacitors, inductors, etc.) to be incorporated into the design. The work will include techniques for fabrication of high-density hermetic feedthroughs that include the aforementioned components to advance the field of implantable bionics through the development of new feedthrough technologies.

Supervisor(s):

Professor Gregg Jørgen Suaning- Biomedical Engineering
Dr. Lilach Bareket - Biomedical Engineering

Student background:

A student with a mechatronics, mechanical, or electrical engineering background and appropriate hands-on capabilities will be an ideal candidate for this work.

What problem is this project expected to solve?

High reliability and high density feedthroughs are often viewed as mutually-exclusive goals. By introducing means of realising both, new advancements in implantable bionics may be achieved.

Where will the project primarily be undertaken?

Implantable Bionics and Electroceuticals Laboratory, The University of Sydney

Brief description of how the project will be run:

Students will be expected to be physically present within the laboratory for an agreed part of their weekly schedule. Weekly group meetings will be scheduled with individual meetings arranged as and when required. The laboratory operates under the principles of ISO 13485 and it is an expectation that, following appropriate briefing, students will adhere to all laboratory norms. It is a primary priority to ensure that staff and students remain safe in every aspect of their work. Accordingly, agreement to comply with the University's Workplace Health and Safety policies is a condition of entry into the laboratory.

Thesis Project

Faculty of Engineering and Information Technologies
The University of Sydney

Project Title:

Helix winding apparatus for implantable bionics

Summary:

Implantable bionics in the context of this project include neuromodulation implants that serve as sensory and motor therapies. As an illustrative example, visual neuroprostheses or 'bionic eyes' offer hope to sufferers of degenerative disorders of the retina that ultimately lead to blindness. Because of the limited space for electronics within the orbit of the eye, it is necessary to implant a 'split system' device comprising two parts - a telemetry implant behind the ear that manages data and power, and a single-chip visual stimulator placed within the orbit to deliver electric impulses to the surviving cells of the retina via an electrode array placed behind the retina. Communication between the two implants is achieved by a multi-conductor cable. This cable must be soft, flexible and extraordinarily robust. This project seeks an automated solution to the fabrication of helical cables for use in bionic eyes and other implantable devices.

Description:

Carrying electrical signals from one location within the body to another may seem straightforward. However, there are several factors that exacerbate this otherwise simple objective. For instance, surgical implantation can present significant distortion of the cable; body movement can expose metallic wires to millions of cycles that can induce fatigue; growth and other sources of distortion can stretch and ultimately fracture the wires; impact can crush or otherwise damage the wires or its insulation, the latter potentially exposing the implant recipient to potentially hazardous electrical currents. This project involves research and design that will yield a robust cable that is fabricated in a way that produces the identical outcome each and every time. The solution may include, but is not necessarily limited to a machine that winds the helical component and provides means of protecting it within a silicone elastomer sheath prior to back-filling the assembly such that it cannot harbour bacteria or pathogens.

Supervisor(s):

Professor Gregg Jørgen Suaning- Biomedical Engineering

Student background:

There are multiple components of this work and sufficient complexity to warrant up to two

students working in collaboration on the project. However, a sufficiently-skilled student could readily undertake the entire project.

Student 1 will coordinate the overall design with an emphasis on the the mechanical apparatus for the formation of multi-stranded, helical coils. Prerequisites: A student at any point within their studies with an appropriate skill-set may apply.

Student 2 will manage the electronics of the automation as well as the ‘user interface’ that is needed to ensure that each time the apparatus is used, the same outcome is achieved. Prerequisites: A student at any point within their studies with an appropriate skill-set may apply.

Alternative combinations of the foregoing are also possible and can be arranged in negotiation with the supervisor(s).

What problem is this project expected to solve?

Successful hand winding of a helical cable is reliant upon skill and dexterity. Given the crucial nature of this component of implantable bionics, it is essential that the helical cables produced are identical each and every time. This project addresses the unmet need for a highly-repeatable apparatus for the fabrication of helical cables.

Where will the project primarily be undertaken?

Implantable Bionics and Electroceuticals Laboratory, The University of Sydney

Brief description of how the project will be run:

Students will be expected to be physically present within the laboratory for an agreed part of their weekly schedule. Weekly group meetings will be scheduled with individual meetings arranged as and when required. The laboratory operates under the principles of ISO 13485 and it is an expectation that, following appropriate briefing, students will adhere to all laboratory norms. It is a primary priority to ensure that staff and students remain safe in every aspect of their work. Accordingly, agreement to comply with the University’s Workplace Health and Safety policies is a condition of entry into the laboratory.

Thesis Topics-Biomedical

Dr. Agisilaos Kourmatzis (agisilaos.kourmatzis@sydney.edu.au)

http://sydney.edu.au/engineering/people/agisilaos.kourmatzis.php

DRY POWDER INHALER FLUID DYNAMICS (max 2 projects)

Primary Supervisor: Dr. Agisilaos Kourmatzis

External Collaborators: Prof. Hak-Kim Chan (Faculty of Pharmacy), Dr. Shaokoon Cheng (Macquarie University)

Industry Link: DFE Pharma (Dr. Gerald Hebbink)

Our current understanding of the fluid mechanics of many inhaler systems remains very poor. This is particularly true of dry powder inhalers which have traditionally been designed on the basis of a trial and error approach using outdated engineering processes. This project aims to improve our fundamental understanding of how oral dry powder delivery systems work by applying state-of-the-art laser and optical diagnostic methods to enable us to design the next generation of inhaler devices. Key issues/tasks:

- What are the fundamental processes that drive the fragmentation of inhaled powders?
- Can we use this knowledge to improve drug delivery?
- Can we design a patient-specific inhaler?

Eligibility: Students from the biomedical stream must have completed AMME2261 or CHNG2803. You will be involved in either designing a new inhaler device or a new rig capable of replicating realistic human inhalation profiles through typical inhaler geometries. You should be interested in biomedical fluid dynamics and have some abilities in CAD drawing/modelling.

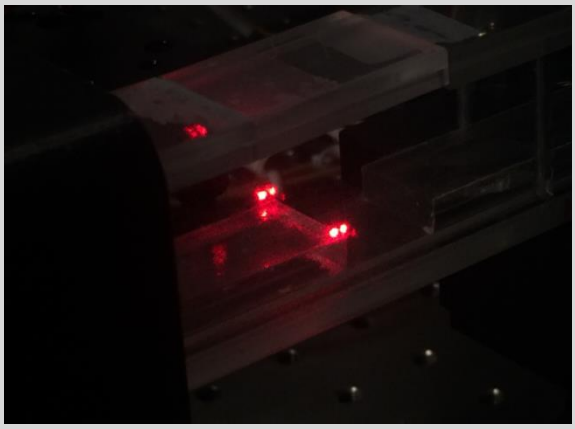


Figure from ongoing research: Dual Laser Extinction examining drug excipient evacuation rates at time resolution of 200,000 samples/second, spatially line integrated.

HUMAN UPPER AIRWAY DYNAMICS (max 3 projects)

Primary Supervisor: Dr. Agisilaos Kourmatzis

External Collaborators: Prof. Hak-Kim Chan (Faculty of Pharmacy), Dr. Shaokoon Cheng (Macquarie University)

The human upper airway is a complex dynamic structure. Recent work has shown us that neuromuscular activation of the upper airway muscles (particularly the genioglossus muscle of the tongue) causes airway dimensions to change from breath-to-breath and this varies according to an individual's physiology. We know virtually nothing about the fluid dynamics of this process despite how critical it is towards design new drug delivery devices. Key issues/tasks:

- How does dynamic movement of a physiologically representative airway wall affect general features of the flow?
- How does this dynamic movement influence the deposition of inhaled drug particles?
- Are there drug delivery device interventions that we can suggest to maximize deep lung deposition based on features of dynamic upper airway movement?

Eligibility: Students from the biomedical stream must have completed AMME2261 or CHNG2803. You will be involved in designing a new rig capable of replicating realistic human inhalation profiles and analysing physiologically realistic airflow profiles. You should have some abilities in CAD drawing/modelling, or have experience in computational fluid dynamics (CFD). This project may require some off-site work with collaborators at Macquarie University.

Figure from ongoing research: Inverse Casted Upper Airway Model Sample (from 3D Printed Mold). Reconstructed from axial MRI images, includes mouth, oro and laryngopharynx, epiglottis up to upstream of first airway bifurcation

FLUID DYNAMICS OF INTRANASAL DRUG DELIVERY FOR BRAIN TREATMENT (max 1 project)

External Collaborators: Prof. Hak-Kim Chan (Faculty of Pharmacy), Dr. Shaokoon Cheng (Macquarie University)

Drug Delivery to the brain is extremely challenging due to the presence of the blood-brain-barrier and due to hepatic metabolism. This generally makes standard intravenous delivery of drugs very ineffective for treatment of brain disorders. Intranasal drug delivery shows great promise in this area and has been applied under certain settings but it remains a non-established technology, due to our poor understanding of the mechanisms of drug particle transport in the nasal cavity. Key issues/tasks

- What is the influence of transient nasal flow on drug particle transport?
- What is the influence of nasal cavity geometry on particle deposition?

Eligibility: Students from the biomedical stream must have completed AMME2261 or CHNG2803. You will be involved in analysing transient fluid flow and drug deposition in a physiologically realistic model replica of a nasal cavity. You should have some abilities in CAD drawing/modelling, or have experience in computational fluid dynamics. This project may require some off-site work with collaborators at Macquarie University.

OPTICAL COHERENCE TOMOGRAPHY FOR MEASUREMENT OF ANATOMICAL STRUCTURES (max 1 project)

External Collaborators: Dr. Shaokoon Cheng (Macquarie University), Dr. Jason Amatoury (American University of Beirut)

Optical coherence tomography (OCT) is a medical imaging method broadly relying on laser interferometry to reconstruct spatial information related to a particular anatomical structure or feature. It has been used in the past to provide geometrical information on sarcomas, the eye, and the human airway amongst other features. In this project you will work on developing a new type of OCT system relevant to measurements in humans (Provision Patent Filed). This project will require some degree of off-site work (Macquarie University).

Eligibility: You should have some abilities in CAD drawing/modelling, or instrumentation & sensors, and have some knowledge of medical imaging. Proficiency in MATLAB would be highly beneficial.

Supervisor: Prof J Cairney

julie.cairney@sydney.edu.au

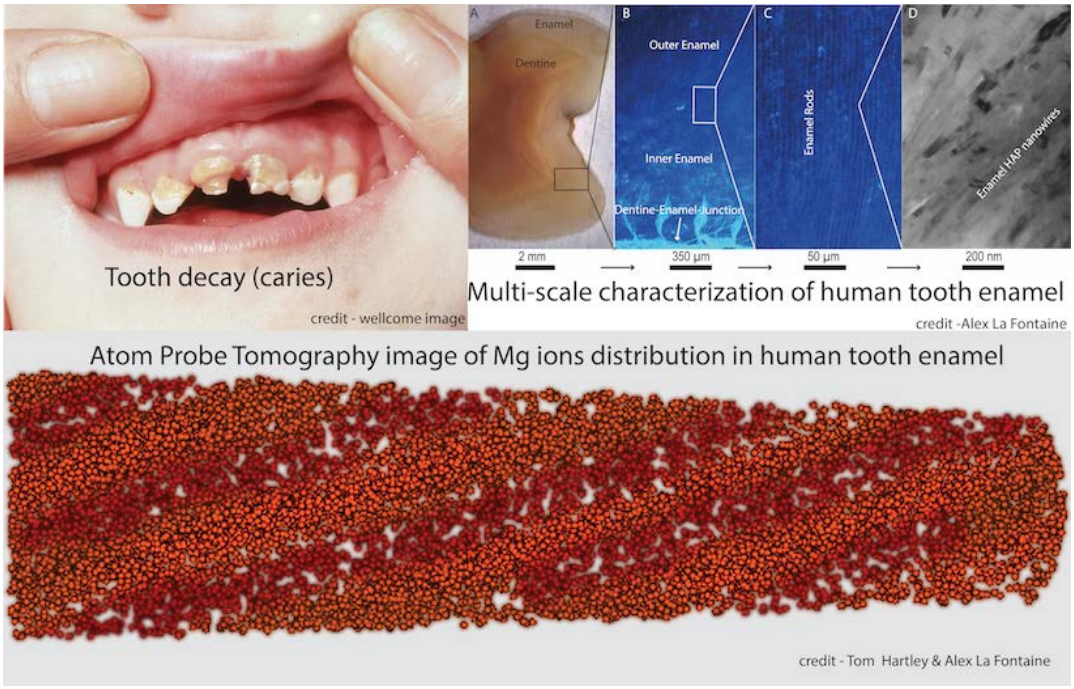
Understanding the dissolution of human tooth enamel at the atomic scale

According to the World health organization, 60-90% of children and nearly 100% of adults worldwide suffer from dental decay (caries), which occurs via the progressive dissolution of dental enamel. The development of effective treatments requires a basic understanding of the structure of enamel and the processes by which it forms and dissolves.

We recently examined human dental enamel using atom probe tomography (APT), which provides the position and identity of atoms in three-dimension within matter. In our results published this September in *Science Advances* [1], we find Mg-rich ACP nanolayers between the HAP nanowires that make up the enamel, and this work has drawn substantial attention rom the media [2]. Being more susceptible to acid dissolution than the HAP nanowires, this ACP phase is thought to be responsible for tooth decay. More importantly it can also accommodate a substantial amount of foreign ions (such as fluoride or iron) that could change the ACP phase chemistry making it less soluble in acidic environment.

The aim of this project is first to understand the role of Mg-rich ACP nanolayers in the dissolution of human dental enamel during acid attack (i.e. caries) and secondly to investigate the effect of fluoride and iron ions in the solubility of the ACP nanolayers in acidic condition. We will achieve this through a detailed study of the fine-scale structure of healthy and carious enamel using advanced microscopy techniques such as MicroCT, atom probe and electron microscopy. The long-term objective of this study is to enable new treatments to avoid or limit tooth decay by changing the ACP phase chemistry and make it more stable in acidic condition.

This project is suitable for Honours Thesis A/B and will be supervised by Alexandre La Fontaine, under the guidance of Prof. Julie Cairney



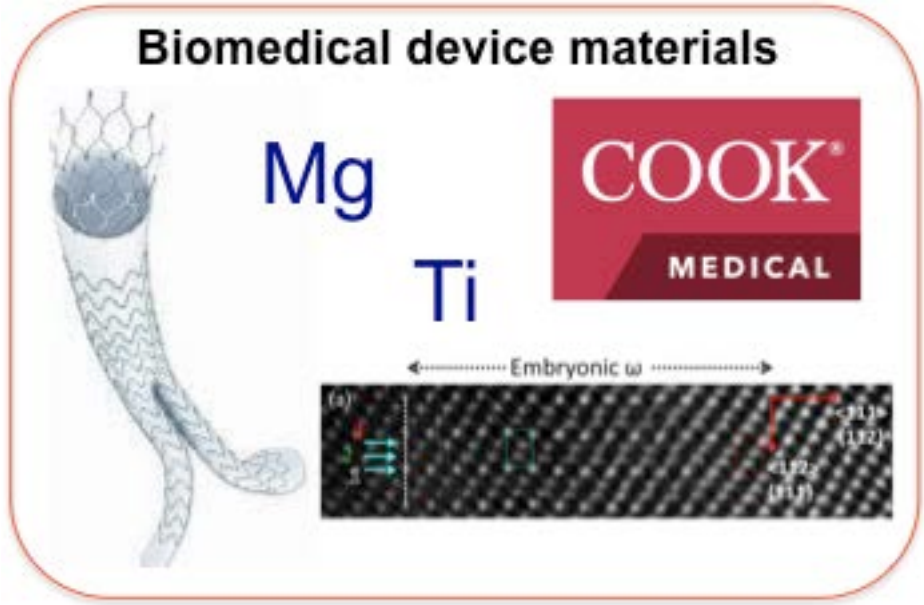
[1] A. La Fontaine, A. Zavgorodniy, H. Liu, R. Zheng, M. Swain and **J.M. Cairney**, "The atomic structure of human dental enamel", in press, *Science Advances.*

[2] http://www.forbes.com/sites/carmendrahl/2016/09/07/nanoscale-view-of-enamel-might-help-us-treat-tooth-decay/#3cc6f116d504

Alloys for biomedical devices

Project/Overview:

This project involves the development of new alloys for biomedical devices, including biodegradable Mg alloys, for various applications, including global endovascular aneurysm repair (EVAR) devices (stents). The project is supported by supported by the Australian Research Council (ARC) through both an ARC linkage project and an Industrial Transformation Research Hub. (the ARC Research Hub for Advanced Manufacturing of Personalised Medical Devices). The project will be conducted in collaboration with an industry partner, Cook Medical, and will involve characterization of alloys via atom probe tomography, transmission electron microscopy, electron backscatter diffraction, transmission Kikuchi diffraction and scanning electron microscopy.



Colin Dunstan
Honours thesis topics:

Developing a strain testing chamber for a mouse calvaria (skull bones)

This study is to develop the concept and the prototype of a chamber that will allow applying strain to a calvaria of a mouse with a glass window for microscope visualization and an system for perfusion with growth media under varying pressures.

Email: colin.dunstan@sydney.edu.au
Tel: 9351 7127

Cancer therapies (1-2 possible in this area)

Email: colin.dunstan@sydney.usyd.edu.au
Tel: 9351 7127

Cancer cells in cell culture or in mice implanted with cancer cells will be treated with novel anti-cancer agents. Isolated cells from the cultures or tissues of these mice containing breast and prostate cancer tumours will be assessed by micro-computerized tomography and histological methods to determine the amount of bone destruction and new bone formation, and the growth rates and invasiveness of the tumours cells. Results will be analysed to determine the possible benefit of these compounds in reducing cancer metastasis to bone. And on the the incidence and progression rates of breast and prostate cancers.

The student will be trained in some of the following techniques: tissue culture, molecular biology methods, immunohistochemistry the measurement of bone lesions using microCT, and histological techniques including hard tissue histology, histomorphometry, immunostaining and TUNEL staining for assessing cancer cell apoptosis (programmed cell death).

Other Topics

Email: colin.dunstan@sydney.usyd.edu.au

I also have a number of external collaborators who may be able to provide topics such as developing new treatments for multiple myeloma. Come and see me to investigate opportunities

Design and Additive Manufacturing (3D Printing) for Scaffold Tissue Engineering

Supervisor: Professor Qing Li (AMME)

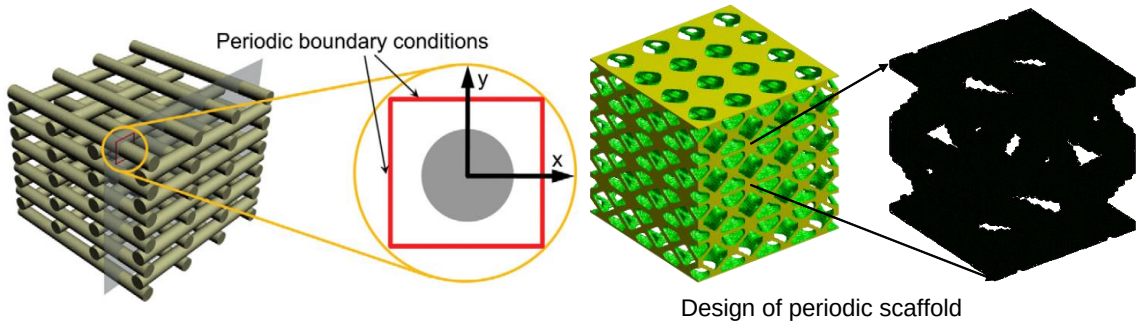
Rm S509, Bldg J07 Mechanical Engineering, ph: 9352 8607

Qing.Li@sydney.edu.au

Each year an estimated millions of patients suffer from bone fracture, while hundreds of thousands of patients have conditions where large segments of bone are destroyed or must be removed. As such new clinical treatment schemes are necessary to augment the body's natural healing process. As a fast emerging interdisciplinary technology, tissue engineering provides alternative therapeutic strategies for repair of damaged tissue and organs, which shows enormous potential to generate host-grown tissue in sufficient quantity and quality.

A milestone in the load-bearing tissue (e.g. bone/cartilage) engineering has been the development of 3D scaffold technique that guides cells to generate desirable functional tissue under appropriate mechanical and biological conditions. The success of tissue regeneration lies heavily on the architecture design of the scaffold and its bio-reaction with the seeding cells. Permeability has been recognised as one critical criterion for scaffold design in ensuring cell migration and nutrient delivery. This project aims to (1) characterise the effective permeability of different scaffold architecture; (2) develop finite element based homogenisation technique for permeable problem; (3) design optimisation for tailored effective permeability. The student is expected to closely work with the Research Fellow in the group and redevelop Matlab code for finite element analysis and homogenisation for the permeable problem. The results will be prototyped in commercial free-form solid fabrication facility.

Opportunity: Masters or Honours theses (biomedical and mechanical engineering students)



Design of periodic scaffold

Reference

Chen YH, Schellekens M, Zhou SW, Cadman J, Li W, Appleyard R, Li Q (2011) Design of Tissue Scaffolds Using Wall Shear Stress Criterion for Flow Induced Erosion, ASME Journal of Biomechanical Engineering - Transactions of the ASME, 133(8):081008.

Chen YH, Zhou SW, Li Q (2011) Microstructure Design of Biodegradable Scaffold and Its Effect on Tissue Regeneration, Biomaterials 32: 5003-5014.

Chen YH, Zhou SW, Li Q (2011). Mathematical modeling of degradation for bulk-erosive polymers: Applications in tissue engineering scaffolds and drug delivery systems. Acta Biomaterialia 7:1140–1149。

Chen YH, Zhou SW, Cadman J, Li Q (2010) Design of Cellular Porous Biomaterials for Wall Shear Stress Criterion, Biotechnology & Bioengineering 107(4):737-746.

Sturm S, Zhou SW, Mai YW, Li Q (2010) "On Stiffness of Scaffolds for Bone Tissue Engineering – A Numerical Study". Journal of Biomechanics 43:1738–1744.

Design of Safety Systems for Crashworthiness Criteria

Supervisors: Professor Qing Li (AMME) and Dr Guangyong Sun (AMME)

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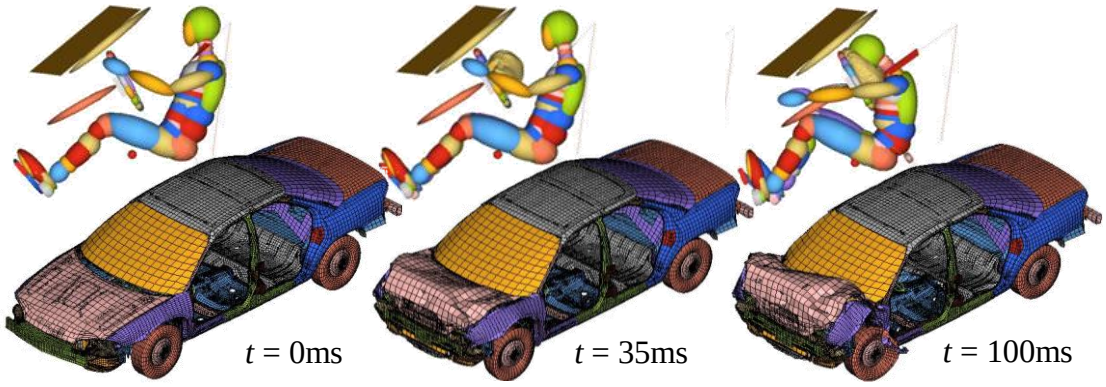
Crashworthiness is one of the most important criteria in vehicle design, which often requires large-scale design analysis for a full vehicle model consisting of many structural parts and special safety elements. This project develops a two-stage procedure to cope with crashworthiness design of structural frame and occupant restraint system.

In the first stage, a multiobjective optimization is carried out for structural parameters in the frontal parts without considering the details of the occupant restraint device. The foam filled thin-walled tube will be used as new energy absorber and a design optimisation will also be performed in this stage.

In the second stage, the parameters of the occupant restraint system are optimized based on an optimized structural system. Human dummy and restraint system will be modelled and optimised in details.

In these two stages, explicit finite element program (Dyna3D) and multi-body dynamics methods will be employed to respectively construct response surface and Kriging model with various design of experiment (DOE) techniques. A full-scale vehicle model will be developed to demonstrate the capability of the present two-stage design method.

Opportunity: Masters or Honours theses



References

Liao X, Li Q, Zhang W, Yang X. (2008) Multiobjective Optimization for Crash Safety Design of Vehicle Using Stepwise Regression Model. Structural and Multidisciplinary Optimization 35:561–569.

Liao XT, Li Q, Yang XJ, Li W, Zhang WG (2008) Two-Stage Multiobjective Optimization of Vehicle Crashworthiness under Frontal Impact. International Journal of Crashworthiness 13:279-288.

Sun GY, Li GY, Zhou SW, Li HZ, Hou SJ, Li Q (2011) Crashworthiness Design of Vehicle by Using Multiobjective Robust Optimization. Structural and Multidisciplinary Optimization 44:99–110.

Design Optimisation for Road Safety System

Supervisors: Professor Qing Li (AMME) and Dr Guangyong Sun (AMME)

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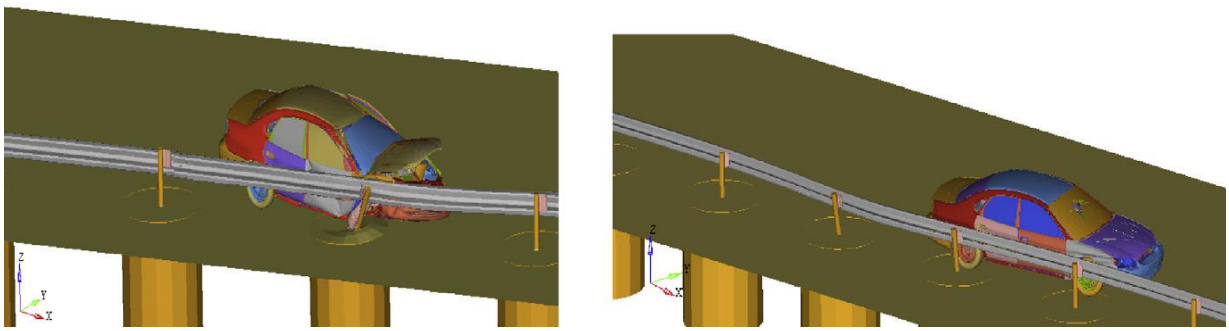
As the main safety facility on the highway, a guardrail system is essential for the vehicle safety. In this study, the 3D Finite Element (FE) models of the vehicle and the corrugated beam guardrail system will be created. Two types of widely used corrugated beam semi-rigid guardrails will be considered, which are the W-beam guardrail and the Thrie-beam guardrail. The collision between the corrugated beam guardrail systems and the vehicle body will be analyzed. In the collision process, the snagging effect of the post to the vehicle body is also taken into account. The multiobjective optimization problem will be used to determine dimensional sizes of guardrails. Response surface method (RSM) is applied to construct the surrogate models for the objective and constraint functions. The Pareto set and the optimal solution will be obtained.

The student is expected to have background in finite element method and will be trained for highly nonlinear finite element analysis in LS-Dyna. Surrogate models based design will be applied for seeking multiobjective optimisation.

Opportunity: Masters or Honours theses



Reference

S Hou, W Tan, Y Zheng, X Han, Q Li (2014) Optimization design of corrugated beam guardrail based on RBF-MQ surrogate model and collision safety consideration, Advances in Engineering Software 78, 28-40.

FEA of Sheet Metal Forming and Design Optimisation

Supervisors: Professor Qing Li (AMME) and Dr Guangyong Sun (AMME)

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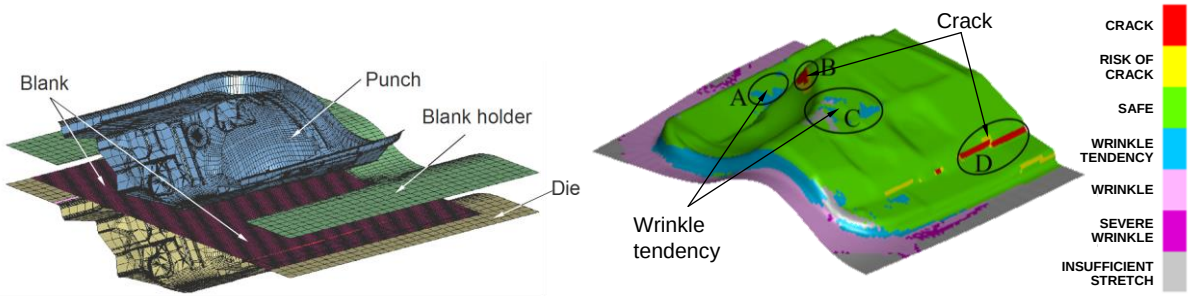
Sheet metal forming is one of the most widely used manufacturing processes in the automotive industry. Traditional process design has been largely based upon empirical and/or trial-and-error approach. Thus the production of a new tooling die often requires numerous prototype tests, leading to a long design cycle and excessive cost. Fortunately, with the rapid development of advanced computational technology, sheet metal forming simulation has become a well-established tool to precisely predict the formability of stamped parts and detect such defects as wrinkling and fracture in a design stage, which has made a significant cost and time reduction in design and a noteworthy improvement in the quality and the performance of parts. However, to achieve a good forming quality, the finite element analysis (FEA) needs to be performed many times by changing forming parameters manually in line with engineers' experience, whereas this by no means guarantees a global optimum. In this sense, how to transform FEA from a passive verification tool to a more active design tool is of considerable theoretical interest and practical value.

Fracture and wrinkling have been identified to be two major defects in sheet metal forming and should be eliminated via an appropriate drawbead design. This project aims to use a multiobjective optimization algorithm (e.g. multiobjective particle swarm optimization (MOPSO) to optimize the drawbeads. This multiobjective optimization to be developed here will differ from traditional multiobjective optimization with construction of a single cost function using weight functions. In this study, nonlinear finite element analysis (Ansys LS-Dyna) will be used for generating the metal forming responses in terms of fracture and wrinkling criteria. The surrogate modelling technique (e.g. response surface method - RSM) will be constructed for formulating the objective and constraint functions. Finally, the Pareto optimisation will be generated for optimising the fracture and wrinkling criteria.



Opportunity: Masters or Honours theses

References

G Sun, G Li, Z Gong, G He, Q Li (2011) Radial basis functional model for multi-objective sheet metal forming optimization. Engineering Optimization 43 (12), 1351-1366.

Multi-fidelity optimization for sheet metal forming process

G Sun, G Li, S Zhou, W Xu, X Yang, Q Li (2011) Multi-fidelity optimization for sheet metal forming process. Structural and Multidisciplinary Optimization 44 (1), 111-124

Topology Optimisation for Connection Design with Crashworthiness Criteria

Supervisors: Professor Qing Li (AMME) and Dr Guangyong Sun (AMME)

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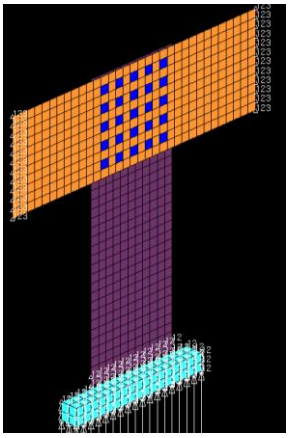
Crashworthiness is one of the most important criteria in vehicle design, which often requires large-scale design analysis for a full vehicle model consisting of many structural parts and special safety elements. The major challenge facing to engineering community is how to design multicomponent system for a range of crashworthiness criteria. Previous researches had found that different connection patterns will have different crashworthiness performances during the crush.

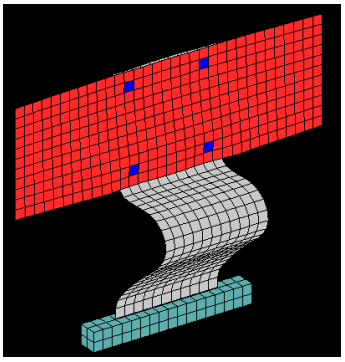
In the past, evolutionary structural optimization (ESO) had been applied to find out the locations with the highest stress concentration at the overlap area of connection and therefore to determine the proper locations for placing the connection elements. However, it has not proven that applying the connections on the highest stress concentration area will give the best performance on energy absorption under crashing scenarios and the connection patterns where connections are not in stress concentration area are not being concerned.

The genetic algorithm (GA) will be used in this study for determining optimal pattern of connection elements so that the highest energy absorption capacity can be obtained. This thesis study will tackle topology optimization problems for connection pattern in multicomponent system. The nonlinear FEA will be used as a solution engine for modelling, data collection, and optimisation.

The student is expected to have background in finite element method and will be trained for highly nonlinear finite element analysis in LS-Dyna. Surrogate models based design will be applied for seeking multiobjective optimisation.



Initial design at initial stage



Optimised design at the final stage

Opportunity: Masters or Honours theses

References

Q Li, GP Steven, YM Xie (2001) Evolutionary structural optimization for connection topology design of multi-component systems. Engineering Computations 18, 460-479.

Sydney Concord Hospital

Design Analysis and Optimization for Novel Arterial Stents

Supervisors: Professors Qing Li (AMME)

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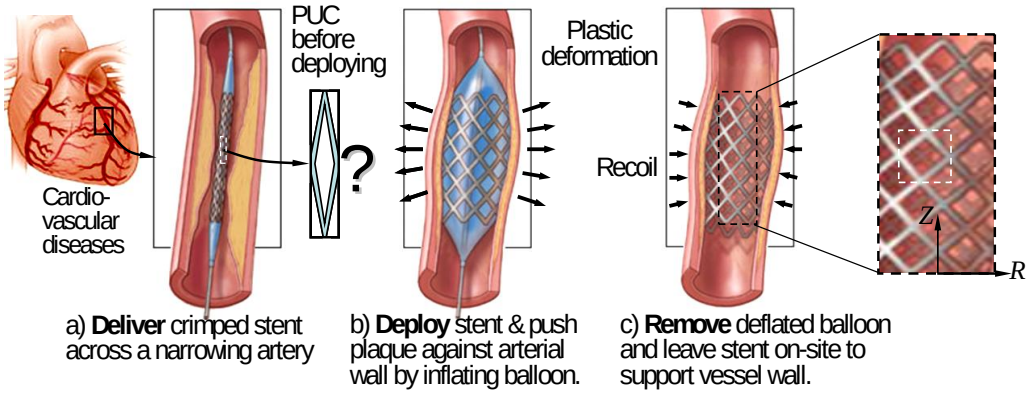
Cardiovascular diseases (CVD) are one of the leading causes of death in western countries due to lifestyle and an increasingly ageing population. In Australia, more than 176,000 patients are hospitalised and 180,000 cardiovascular procedures are performed each year. Open-heart bypass surgery is one of the most widely used procedures for CVD, and carries with it the major problem of long waiting lists due to the large number of hospitalised patient-days (> 1.64 million totally in 2004–05) in the country. As a fast emerging interdisciplinary technology in interventional cardiology, stenting treatment provides an alternative therapeutic strategy, which uses a mechanical device (called a stent) to compress the plaque against the artery wall opening the lumen of the obstructed artery for restoring blood flow. This technology demonstrates the enormous potential to minimise surgical invasion/risk and shorten the hospital days.

This research aims at developing a computational framework for stent design analysis and optimization. In this study, a newly designed cardiovascular stent with adapting the aorta stent geometry will be modelled and evaluated by three-dimensional finite element analysis. Compared with the existing conventional stents in the market, a series of novel designs will be assessed to characterise the stiffness, damage to the arterial wall, fatigue life, and other biomechanical behaviours. The geometry sharpness and increase the manufacturability.



Opportunity: Masters or Honours theses

Sydney Dental Hospital

Finite Element Modelling of Orthodontic Tooth Movement

Supervisors: Professor Qing Li (AMME) and Professor A. Darendeliler (Sydney Dental Hospital and Faculty of Dentistry)

Work Experience: Sydney Dental Hospital

Rm S509, Bldg J07 Mechanical Engineering, ph: 9352 8607

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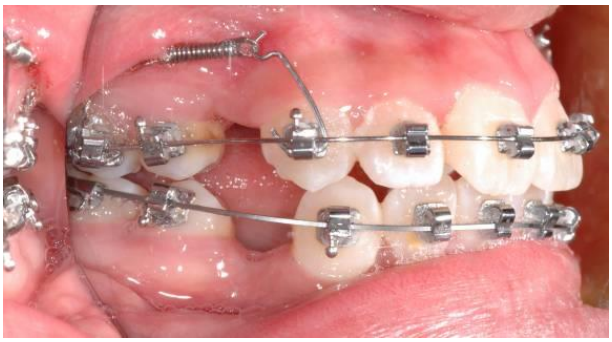
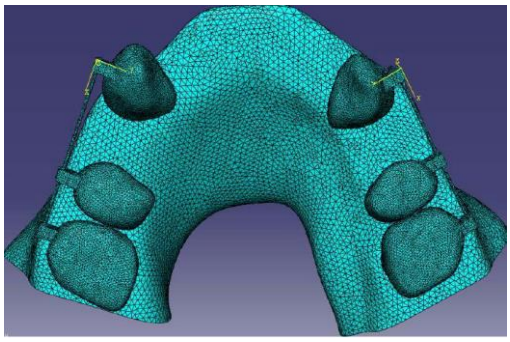
The ratio of patients who request orthodontic therapy to the total population is surprisingly high. Unofficial data reports that every year 60% of all adolescents in Australia undergo orthodontic treatment to improve their healthy start to life. Orthodontic tooth movement (OTM) within the dentoalveolar bone is based on the ability of surrounding bone and periodontal ligament (PDL) to react to a mechanical stimulus (e.g. stress/damage/strain energy) with remodelling processes. Orthodontic forces generate a complex set of mechanical stimuli triggering biological reactions in dentoalveolar and PDL, thereby causing teeth to move to ideal positions in the jaw. Although it is recognised that the change in biomechanical environment leads to OTM, it is unclear which of the mechanical signals are dominating the initiation of the bone remodelling and how to quantify a dynamic tooth movement process in response to the orthodontic force.

This project aims to (1) develop a precise model of the orthodontic treatment based on CT images (NewTom – Sydney Dental Hospital in USyd Faculty of Dentistry), which may involve uses of Rhinoceros/ScanFE – Solidworks – Ansys or Strand7); (2) quantify the biomechanical responses in several different stages of OTM; (3) correlate the mechanical stimuli to the OTM rate measured in clinic. In this project, the student will use his/her CAD/FEA skills to an interdisciplinary topic, and he/she is expected to closely work with USyd dental specialists (Prof Darendeliler) at Department of Orthodontics.





References

Field C, Ichim I, Swain MV, Chan E, Darendeliler MA, Li W, Li Q (2009) "Mechanical Responses to Orthodontic Loading: A Three-Dimensional Finite Element Multi-Tooth Model". American Journal of Orthodontics and Dentofacial Orthopedics 135:174-181.

Chen JN, Li W, Swain MV, Darendeliler MA, Li Q (2014) A Periodontal Ligament Driven Bone Remodeling Algorithm for Orthodontic Tooth Movement, Journal of Biomechanics 47:1689–1695.

Sydney Dental Hospital

Biomechanical Investigation into Orthodontic Root Resorption

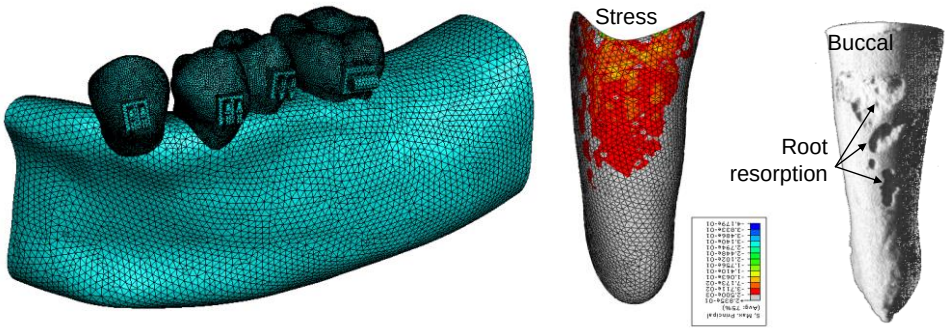
Supervisors: Professor Qing Li (AMME) and Professor A. Darendeliler (Sydney Dental Hospital and Faculty of Dentistry)

Rm S509, Bldg J07 Mechanical Engineering, ph: 9352 8607

Qing.Li@sydney.edu.au

Orthodontic root resorption (ORR) is described as the loss of hard tissue especially of cementum and dentine of tooth tissue which can be an irreversible sequel of orthodontic treatment. It has been documented that the phenomenon of root resorption is a very common disorder, affecting up to 100% of all treated cases, and after treatment, 41% of adult patients had increased root resorption of over 2.5mm in one or more teeth. Under severe circumstances root resorption may potentially jeopardise the longevity and functional capacity of the treated teeth; and may result in ending the treatment and greatly compromising the outcome of a successful orthodontic therapy.

This project aims to (1) elucidate the biomechanical pattern of orthodontic force distribution along the tooth root and its surrounding tissues by creating 3D finite element model and to develop a numerical prediction of ORR (by using micro-CT scanner SkyScan 1172 at Electronic Microscopic Unit and uses of Rhinoceros/ScanFE – Solidworks – Ansys or Strand7); (2) correlate the root stress/strain to the change in cementum properties; (3) To validate the numerical prediction through a clinical trial where the occurrence of orthodontic root resorption (ORR) is predicted and therefore may be prevented. In this project, the student will is expected to closely work with USyd dental specialists (Prof Darendeliler) at Department of Orthodontics.



Opportunity: Masters or Honours theses

Westmead Dental Hospital

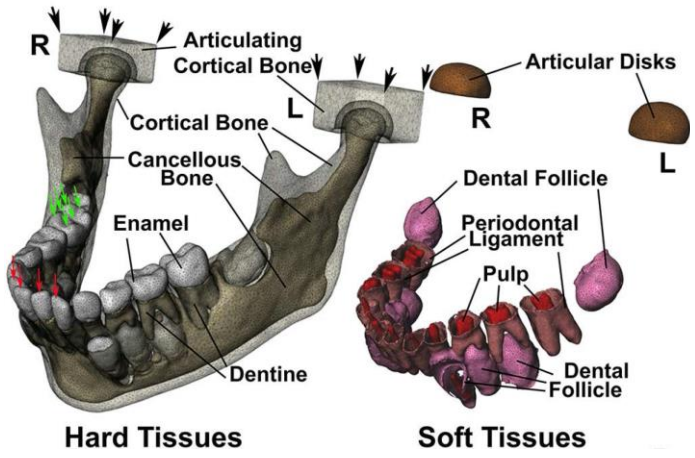
Biomechanics of Tooth Eruption Induced by Bone Remodelling

Supervisors: Professor Qing Li (AMME) Rm S509, Bldg J07 Mechanical Engineering, ph: 9352 8607 Qing.Li@sydney.edu.au

Dr Babak Sarrafpour, Email: babak.sarrafpour@sydney.edu.au (Westmead Dental Hospital and Faculty of Dentistry)

Developing teeth are surrounded by soft tissue, namely dental follicle, encased in a bony crypt. Although the bony anchorage of teeth provides a firm basis for biting, this does necessitate the development and subsequent eruption of teeth through bone, and we seek to understand the mechanisms controlling the necessary bony remodelling. As outlined in Figure 1, teeth form through complex interactions between epithelium and the underlying connective tissues, and before eruption are surrounded by a soft tissue dental follicle which is further encased by a bony crypt of dense cortical bone. As the tooth erupts, this bony crypt eventually becomes confluent with the jaw's cortical bone to form the 'lamina dura'. The periodontal ligament differentiates from that part of the soft tissue dental follicle that overlies the developing tooth, and anchors the root to the lamina dura.

An eruptive force is widely invoked as driving teeth out of the jaw bones into eventual occlusion with teeth from the opposing jaw, though the origin of such an eruptive force remains unclear. Separately, forces from the oro-facial musculature also play a major role in precisely positioning teeth within the jaws, as evidenced by the gross outward or inward displacement of teeth upon loss or gain of facial or tongue tissues, respectively. This study will adopt the CT imaging data for 3D finite element method to model the development process. Through which it is expected to gain new understanding how the jaw and tooth eruption take place in a proper way.



Opportunity: Masters or Honours theses

References

B Sarrafpour, M Swain, Q Li, H Zoellner. Tooth eruption results from bone remodelling driven by bite forces sensed by soft tissue dental follicles: a finite element analysis. PLoS One 8 (3), e58803

Westmead Dental Hospital

Modelling of Cracking in Dental Ceramic Restorations.

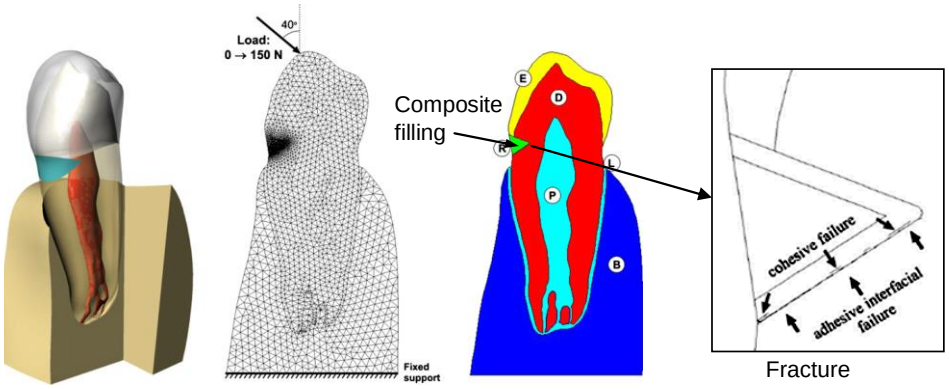
Supervisors: Professor Qing Li (AMME) and Prof Michael Swain (Sydney Dental Hospital and Faculty of Dentistry)

Rm S509, Bldg J07 Mechanical Engineering, ph: 9352 8607 Qing.Li@sydney.edu.au

Ceramics become more and more popular as dental restorative materials. However sintering and curing of such materials induces considerable residual stress of layered structure, resulting in tensile stresses at the margin that may induce fracture. The aim of this project is to utilise ABAQUS software to quantify the residual stresses and predict the conditions for the onset of failure and follow the extent of fracture.

The student is expected to (1) create 3D FE model of a tooth with caries and in-lay ceramic filling; (2) model shrinkage of materials in different temperature; (3) simulate the crack initiation and propagation around the filling region; and (4) optimise the filling shape to minimize potential fracture failure. The student is also expected to work with PhD students in dental clinical and experimental studies.

Opportunity: Masters or Honours theses



References:

1. Ichim I, Li Q, Li W, Kieser J, Swain M (2007) "Modelling of Fracture Behaviour in Biomaterials, A Leading Opinion Article". Biomaterials, 28:1317-1326.
2. Ichim I, Li Q, Loughran JG, Kieser J and Swain MV (2007) "Restoration of Non-Carious Cervical Lesions: Part I - Modelling of Restorative Fracture". Dental Materials 23 (12): 1562-1569.
3. Ichim I, Schmidlin PR, Li Q, Swain MV, Kieser J (2007) "Restoration of Non-Carious Cervical Lesions: Part II - Restorative Material Selection to Minimise Fracture". Dental Materials 23 (12): 1553-1561.
4. Zhang ZP, Guazzato M, Sornsuwan T, Scherrer SS, Rungsiyakull C, Li W, Swain MV, Li Q (2013) Thermally induced fracture for core-veneered dental ceramic structures, Acta Biomaterialia 9 (2013) 8394-8402.

School of Advanced Medicine, Macquarie University

Modelling of Femoral Fracture after Hip Replacement Surgery

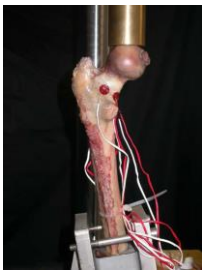
Supervisors: Professors Qing Li (AMME) and Richard Appleyard (School of Advanced Medicine, Macquarie University)

Rm S509, Bldg J07 Mechanical Engineering, ph: 9352 8607

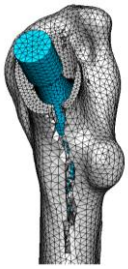
Qing.Li@sydney.edu.au

Hip replacement surgery enables patients who once suffered from osteoarthritis to walk pain-free. However, there is a high incidence of failure due to bone fracture, resulting in huge additional public and private health costs, and a reduced quality of life for ageing Australians. This project aims to develop the science for a computer-based technology that will enable surgeons to optimise the match between a patient's individual needs and a standard implant device.

The student is expected to work closely with the group in Murray Maxwell Biomechanics Lab at Sydney Royal North Shore Hospital on both FEA modelling and experimental studies. S/he will be trained to use Simpleware and ABAQUS for 3D modelling and fracture analysis in the following steps: (1) CT/MRI scanning of femur and hip replacement implants, segmentation of the images and modelling in Simpleware; (2) FE modelling of 3D femur and implants immediately after surgery; (3) modelling of the osseointegration process; (4) fracture modeling of the system in different time steps.



Experimental studies



FE modelling of femur fracture

Reference

Brad Miles, Elizabeth Kolos, William L. Walter, Richard Appleyard, Angela Shi, Qing Li, Andrew J. Ruys (2015) Subject specific finite element modeling of periprosthetic femoral fracture using element deactivation to simulate bone failure. Medical Engineering & Physics 37(6): 567–573.

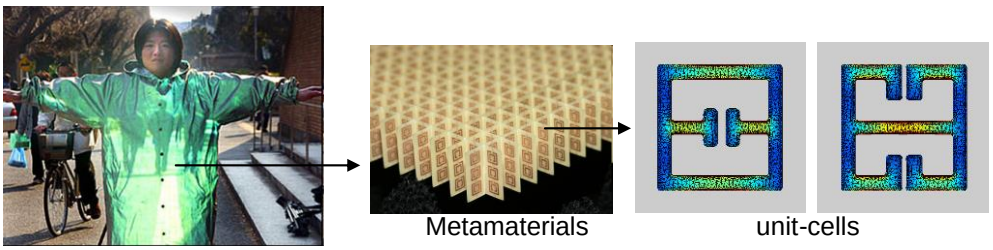
Design Optimisation for Metamaterials

Supervisor: Professor Qing Li (AMME)

Rm S509, Bldg J07 Mechanical Engineering, ph: 9352 8607, Qing.Li@sydney.edu.au

Metamaterials signify a new class of periodic materials and directly gain unusual properties from their special wavelength-scale microstructures. These properties have great potential to many electromagnetic applications and technological innovations such as super-lens and invisible cloaks. This project aims to develop a systematic method by formulating microstructural design in the topology optimisation framework. The evolutionary structural optimisation will be used to determine the novel configurations of unit cells for desirable physical properties.

The student is expected to conduct (1) modelling of unit-cell of periodic metamaterials; (2) sensitivity analysis; (3) design optimisation for unit-cell configuration. S/he will closely work with the research fellow in the AMME School and School of Physics.



Invisible cloak cloth

References

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Zhou SW, Li W, Li Q (2010) Level-Set Based Topology Optimization for Electromagnetic Dipole Antenna Design, Journal of Computational Physics 229 (2010) 6915–6930.

Zhou SW, Li W, Chen YH, Sun GY, Li Q (2011) Topology Optimization for Negative Permeability Metamaterials Using Level Set Algorithm, Acta Materialia 59:2624–2636.

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Sydney Westmead Dental Hospital

Oral Biomechanics – Building Right Mouth via 3D Modelling and 3D Printing

External supervisors: Professor Chris Peck: dentistry.dean@sydney.edu.au

Internal supervisor: Qing Li: Qing.Li@sydney.edu.au Rm S509, Bldg J07 Mechanical Engineering, ph: 9352 8607

Work Experience: Internship can be offered in Sydney Westmead Dental Hospital

Background: The relationship of the upper and lower jaws is critically important in just about every part of clinical dentistry. It is important to determine the optimal jaw relationships when placing a dental filling, inserting crowns or bridges or removable dentures.

Unfortunately the determination of clinical jaw positions is often an art rather than based on science. Dentists will debate fiercely the correct jaw positions and the way to obtain it.

One common method to determine the jaw position is to electrically stimulate the jaw closing muscles to determine the "neuromuscular jaw position"

Proponents of this method suggest it produces a "functional jaw position" because it is determined by activation, albeit external stimulation, of the jaw muscles.

Opponents to this method suggest it does not produce the optimal jaw position because the electrical stimulation is directed at the outer part of the jaw closing muscles, and not entire muscle. These outer fibres, when activated, produce an anteriorly and superiorly directed force vector which would consequently position the lower jaw in a position anterior to where it should be.

Aim: In this study, you will aim to better understand the difference in jaw positions created by normal jaw closing (asking the subject to bring the teeth together) and neuromuscular jaw closing.

The hypothesis is that the neuromuscular jaw position is anterior to the normal/habitual jaw position.

Methods: The jaw positions of 200 human subjects have been recorded in position (1) the normal jaw closing position and in position (2) the neuromuscular position. For each subject, these positions have been digitised. Using position (1) as the global reference, you will determine the relative displacement of position (2). You will need to develop a way to describe the rotational and translational difference to dentists and others who are not familiar with transformation matrices, vectors or other descriptors of displacement.

Opportunity: Masters or Honours theses

Cochlear Pty Ltd

Mechanical Finite Element Modelling of Intracochlear Electrode Arrays

Cochlear Project 1: XFEM modelling of brazing process induced cracking

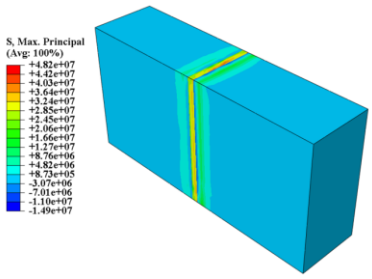
External Supervisors: Dr Anthony Powell (APowell@cochlear.com) (Cochlear Pty Ltd).
Internal Supervisor: Professor Qing Li (AMME) Rm S509, Bldg J07 Mechanical Engineering, ph: 9351 8607 Qing.Li@Sydney.edu.au

Background

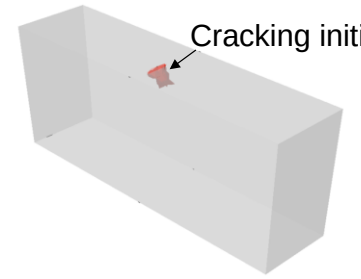
Like many biomedical devices, cochlear implant comprises a number of different materials through different manufacturing methods to bond different components and materials together. One of the methods used is brazing. Since different materials have different mechanical properties and the mismatch may cause considerable residual stress during the manufacturing process. High residual stress together with external mechanical loading may possibly lead to cracking and even failure of the device. This project aims to simulate cracking inside cochlear implant system.

Aims

To develop finite element model of bi-material system for simulating crack initiation and propagation under both thermal residual stress induced by the brazing process and additional mechanical loading during application.



Thermal residual stresses



Cracking under “thermal + mechanical” loading

Methods

The project would involve

- Development of a XFEM model of the bi-material system with realistic mechanical properties and thermal and mechanical loading used in-vitro tests.
- Some level of validation of the model by correlating cracking initiation site and length of visual/invisible cracks
- Simulation of various cooling processes and the effect on cracking process.

Requirement: Hons thesis project

Cochlear Pty Ltd

Mechanical Finite Element Modelling of Intracochlear Electrode Arrays

Cochlear Project 2: Modelling of intracochlear electrode arrays to predict insertion and removal dynamics

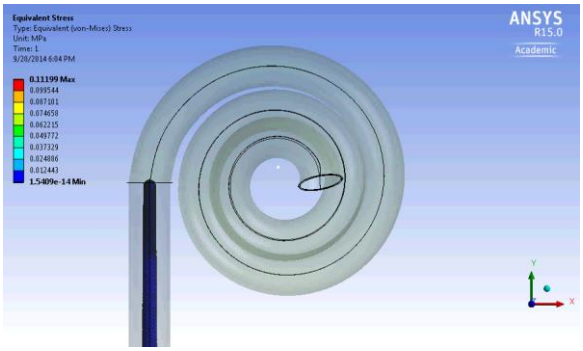
External Supervisors: Dr Anthony Powell (APowell@cochlear.com) (Cochlear Pty Ltd). Dr Nick Pawsey (NPawsey@cochlear.com) (Cochlear Pty Ltd).
Internal Supervisor: Professor Qing Li (AMME) Rm S509, Bldg J07 Mechanical Engineering, ph: 9351 8607 Qing.Li@Sydney.edu.au

Background

Cochlear implants provide the sensation of hearing to moderate to profoundly deaf recipients with sensorineural hearing loss. An array of electrodes is inserted into the scala tympani of the cochlea in order to provide electrical stimulation to auditory neurons. Electrode arrays must be designed to facilitate reliable insertion into the desired position in the cochlea, minimising the risk of complications such as tip foldover or buckling. In addition, arrays need to be flexible to minimise contact forces with cochlea structures to prevent damage that may degrade hearing performance.
Arrays may be straight, or pre-curved to match the spiral of the cochlea. Different designs have different insertion methods and risks. All must accommodate a range of cochlea sizes.

Aims

To develop a finite element model of electrode arrays, in order to simulate insertion into the cochlea and predict contact pressures between the electrode and the cochlea, both during the insertion and in the electrode's final position.



Methods

The project would involve

- Continuing the development of an existing finite element model to achieve successful simulation of electrode insertion and prediction of contact pressures.
- Preliminary experimental validation of the model against insertion force measurements.
- If above is completed, begin on a sensitivity study of effect of cochlea duct geometry on contact pressure on basilar membrane.

Requirement: Hons thesis project

Cochlear Pty Ltd

Mechanical Finite Element Modelling of Intracochlear Electrode Arrays

Cochlear Project 3: Modelling of intracochlear electrode arrays to predict mechanical properties and robustness

External Supervisors: Dr Nick Pawsey (NPawsey@cochlear.com) (Cochlear Pty Ltd). Dr Anthony Powell (APowell@cochlear.com) (Cochlear Pty Ltd).
Internal Supervisor: Professor Qing Li (AMME) Rm S509, Bldg J07 Mechanical Engineering, ph: 9351 8607 Qing.Li@Sydney.edu.au

Background

Cochlear implants provide the sensation of hearing to moderate to profoundly deaf recipients with sensorineural hearing loss. An array of electrodes is inserted into the scala tympani of the cochlea in order to provide electrical stimulation to auditory neurons. Arrays need to be flexible to conform to the spiral shape of the cochlea, accommodate a range of individual cochlea sizes, and to minimise contact forces with cochlea structures to prevent damage that may degrade hearing performance. The fine wires within the array need to accommodate large deformations during the insertion or removal. The mechanical properties, dimensions and position of the wires within the silicone carrier are critical to the robustness and flexibility of the array.

Aims

To develop a mechanical finite element model of an intracochlear electrode array, in order to predict overall flexibility of the array, as well as the stresses experienced by its components. This model could be used to investigate the sensitivity of these to various design parameters, such as wire sizes, mechanical properties, wire placement and silicone grades.

Methods

The project would involve

- Development of a detailed 3D CAD model of an electrode array
- Use of a commercial FEA software package to develop a model of the electrode using realistic material properties
- Recommendations for design guidelines for electrode flexibility and reliability

Requirement: Hons thesis project

http://www.optimizedortho.com/

Work experience: will be offered in Optimized Ortho Company
Supervision team:
Internal supervisor: Prof Qing Li (AMME), email: Qing.Li@Sydney.edu.au
External supervisor: Dr Jim Pierrepont (brad@kneesystems.com), Michael Topham (michael@optimizedortho.com)

1. Development of an Automated 3D Implant Positioning Tool for Total Hip Replacement Planning
The student will use Simpleware ScanIP +CAD to develop an automatic method of positioning hip implants within the femur and acetabulum using patient-specific landmarks. This topic will require the student to learn programming languages, in particular Python and MS VBA.

2. Validation of a Patient-Specific Neck Osteotomy Guide for the Direct Anterior and Anterolateral Approaches
A patient-specific neck osteotomy guide has been developed by Optimized Ortho for posterior approaches in Total Hip Arthroplasty. The guide is designed to assist the surgeon intra-operatively and increase the likelihood of achieving a desirable leg length and offset for each patient. The student will use Materalise Mimics Research software suite to validate the osteotomy level of Optimized Ortho's direct anterior and anterolateral femoral cutting guides.

3. Development and Validation of an Analytical Model for Determining Optimal Combined Alignment
The effect of combined alignment of the femoral and acetabular components in Total Hip Arthroplasty on the Range of Motion of the patient is not well understood. The student will be tasked with developing an existing analytical model created by Hisatome (2011). in Matlab. The final model will predictively measure the impingement and therefore Range of Motion of a patient by demonstrating the maximum functional movements a patient can perform before prosthetic impingement occurs. The analytical model will be validated in Solidwork. The student should be experienced in programming, no particular language is preferred.

4. Development and Validation of a 2D Registration Technique for Intra-Operative Femoral Stem Anteversion Using a Smartphone Camera
Stem anteversion is an important clinical factor when considering impingement within a hip prosthesis. A 2D registration technique will allow for intra-operative feedback on the stem anteversion to the surgeon. The student will develop a technique to capture a 2D image of the stem/femur during the operation and register the image to a virtual pre-operative plan.

5. Determining the Patient-Specific Changes in Functional Combined Anteversion
The combined orientation of both femoral and acetabular components in Total Hip
Replacements is not well understood. Throughout functional movements patients experience a

change in orientation of both these components, affecting their Range of Motion and chance of dislocation. The student would be tasked with exploring the effects of combined acetabular and femoral anteversion of patient outcome.

6. Use of Predictive Analytics to Determine Postoperative Changes in Functional Pelvic Tilt

Following Total Hip Arthroplasty, the pelvic tilt of a patient frequently changes, resulting in a varied functional orientation of the acetabular and femoral components. The student will investigate the differences between pre- and post-operative pelvic tilts to create a predictive model.

7. Can a Patient-Specific Guide be used to Control Femoral Stem Anteversion

Stem anteversion is an important clinical factor when considering impingement within a hip prosthesis. Controlling stem anteversion using a patient-specific guide will be crucial in the long term outcome of the patient's prosthesis. The student will need a good knowledge of solidworks in order to develop the model to be 3D printed/manufactured.

360 Knee Systems Pty Ltd

https://www.linkedin.com/company/360-knee-systems?trk=top_nav_home

Work experience: will be offered in 360 Knee Systems Pty Ltd
Supervision team:
External supervisor: Dr Brad Miles (brad@kneesystems.com), Willy Theodore (willy@kneesystems.com).
Internal supervisor: Prof Qing Li (AMME), email: Qing.Li@Sydney.edu.au

1. Investigation of post-operative kinematics with tibia component rotation variation

There are numerous references used to define tibia component rotation and there is yet a consensus which definition showed the strongest relationship with clinical assessment. This topic will require the student to understand various definitions of tibia rotation as well as run simulations to compare kinematics observed with various tibia component rotation placement.

2. Investigation the relationship of patella component placement achieved to post-operative Patient Reported Outcome Measures (PROMS)

Total Knee Arthroplasty (TKA) is considered to be one of the most successful arthroplasty surgery. However, there are still debate whether resurfaced patella can achieve better post-operative outcomes than non-resurfaced patella. Additionally, there is no consistent anatomical references used in placing patella button in a resurfaced patella. The student will process post-operative CT scans and developed an analytical relationship between the measured patella button positions relative to various anatomical references and post-operative PROMS.

3. Development and validation of a 2D-3D registration technique for pre-operative knee X-ray in functional positions

Understanding the pre-operative state of a Total Knee Arthroplasty (TKA) patient is important for surgical planning. One method to assess it is through pre-operative X-ray in functional positions. The X-ray need to be objectively assessed, i.e. measure the limits of the knee in the positions when the X-ray is taken. This topic will require the student to develop a 2D-3D registration technique (using 3D geometry of the patient and register it against a 2D image, e.g. X-ray) to measure the position of the distal femur relative to the tibia and develop a process to validate the registration technique.

Sydney Eye Hospital

Novel Design and Fabrication of Eye Drop Delivery Devices

Supervisors: Prof Qing Li (AMME), Dr Kenneth Ooi kgjooi@yahoo.com.au, and Professor Stephanie Watson (stephanie.watson@sydney.edu.au) Sydney Eye Hospital, University of Sydney,

Rm S509, Bldg J07 Mechanical Engineering, ph: 9352 8607 Qing.Li@Sydney.edu.au

Introduction:

Dry eye, the most common eye disorder, is frequently accompanied by blepharitis (eyelid inflammation) which has an overall prevalence of nearly 40%. Patients with dry eye and blepharitis have their daily activities disrupted and work productivity lowered due to recurrent blurred vision and ocular discomfort. Moderate dry eye damages the ocular surface and can lead to blindness following infection. The consequences of these common conditions occur despite maximal use of lubricating drops and ointments which address only the symptoms and not the underlying cause. We have developed the first patented statin-based eye drop that safely and successfully treats the causes and symptoms of dry eye and blepharitis.

Aims:

We aim to develop new intellectual property by developing a novel delivery device that will combine both statin eye drop and gel or ointment administration to increase patient convenience of use. Medicine that is problematic to administer leads to poor compliance. Currently, different forms of ocular medications (i.e. eye drops, gels, ointments) come in separate delivery devices. Patients typically carry more than one form of medication at a time. This is because eye drops do not tend to blur the vision and may be preferred if the patient is reading or driving, whereas gels and ointments last longer, providing greater lubrication, but blur the vision. Current ocular therapeutics in drop/gel/ointment forms are in separate delivery devices, which is inconvenient. Further, current delivery mechanisms can be difficult to use, particularly for elderly patients with arthritis. At least 50% of patients have reported difficulty with self-administration, frequently saying they have trouble squeezing the bottle. The goal of this work is to manufacture a combination topical Atorvastatin eye drop and gel/ointment device that allows tailored drop and gel/ointment use according to vision, cosmetic, and duration of action needs.

Methods:

Delivery device prototypes have already been conceptualised and will be designed according to viscous and surface tension properties of the topical Atorvastatin formulations which will determine optimal tip length and opening(s), dose dispensing time, size and weight to reduce overflow, drainage and incidence of any systemic side effects. Force requirements will be factored according to known force generating capacities of the 3 most-used handgrips and applicator plastic rigidity. Computer-simulated models will be run according to the above, and also account for dispensing angles. 3-D printed prototypes will then be built according to established protocols.

Expected outcomes:

A more convenient and novel combination topical Atorvastatin delivery system. Incorporating modern ergonomics, it will be easier to use than existing delivery devices and with improved aesthetics it will assist with product marketing.

Sydney Eye Hospital

Design of Biomedical Device for Topical Ophthalmic Use

Supervisors:
Dr. Kenneth Ooi, Ophthalmologist and Clinical Senior Lecturer, Save Sight Institute
Dr. Aleksey Valyaev, Commercial Development Officer, CDIP
Prof. Stephanie Watson, Clinical Professor of Ophthalmology, Save Sight Institute
Prof. Qing Li, Professor of Biomechanical Engineering, School of Aerospace, Mechanical and Mechatronic Engineering

Expressions of interest are sought for the continued development of a novel topical ophthalmic delivery device. A working prototype has already been manufactured and the student would be involved in the refinement of the design. The student is expected to be of interest and strengths in design analysis and fabrication with 3D printing. S/he is also expected to be self-motivated in driving the project and communicating effectively with the supervision team effectively. The project is biomedical industry based and there is the opportunity for an industrial placement at the Sydney Eye Hospital. Further details will be provided under a confidentiality disclosure agreement to interested candidates.

Inquiries can be made to Prof Qing Li +61 93518607, Email: Qing.Li@Sydney.edu.au

Opportunity: Masters or Honours theses

Sydney Eye Hospital

Biomechatronic Development of Novel Topical Ophthalmic Devices

Supervisors:
Dr. Kenneth Ooi, Ophthalmologist and Clinical Senior Lecturer, Save Sight Institute
Dr. Aleksey Valyaev, Commercial Development Officer, CDIP
Prof. Stephanie Watson, Clinical Professor of Ophthalmology, Save Sight Institute
Prof. Qing Li, Professor of Biomechanical Engineering, School of Aerospace, Mechanical and Mechatronic Engineering

Expressions of interest are sought for the development of a novel topical ophthalmic delivery device. A working prototype has already been manufactured and the student would be involved in the refinement of the design towards a new application. The candidate is expected from a mechatronic background with interests in biomedical engineering applications. S/he should have some knowledge and skills in circuit board and mechanism design for bioMEMS. The candidate is also expected to be self-motivated in driving the project and communicating with the supervision team effectively. The project is based on biomedical industry and there is an opportunity for an industrial placement at the Sydney Eye Hospital. Further details will be provided under a confidentiality disclosure agreement to interested candidates.

Inquiries can be made to Prof Qing Li +61 93518607, Email: Qing.Li@Sydney.edu.au

Opportunity: Masters or Honours theses

Sydney Orthopaedic Research Institute

Sydney Orthopaedic Research Institute is a not-for-profit organisation dedicated to the study and research of orthopaedic disorders, in particular those associated with the knee joint. The Institute uses high quality research methods to investigate the causes and development of common knee disorders, as well as treatments and rehabilitative procedures employed for these disorders. In addition, the Institute also conducts research on arthritis, cartilage pathologies, ligament injuries, knee trauma, and methods for clinical assessment of these conditions.

External Supervisor's Details

Director:
Professor David Parker
Email: dparker@sydneyortho.com.au

02 9904 7182
Suite 12, Level 1, 445 Victoria Avenue, Chatswood, 2067

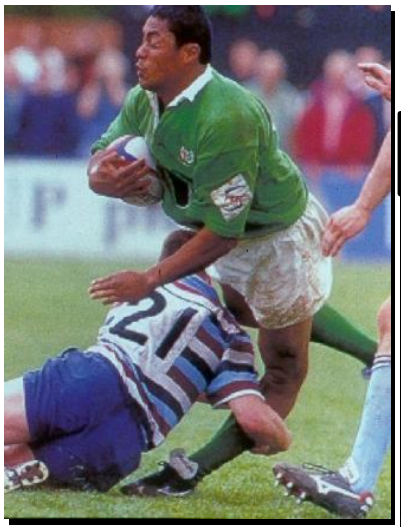
Prerequisites

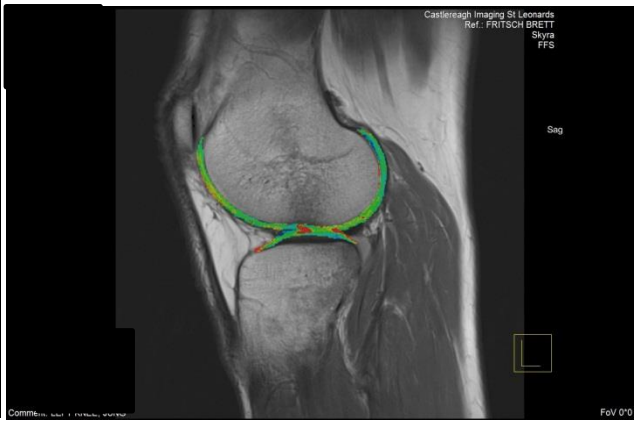
- Open to all disciplines
- Curiosity in how the human body works
- Interest in patient-centred research
- Pride and confidence in their work
- Willingness to learn new concepts and skills
- Modelling, Matlab or general computer programming skills an advantage

- **Sydney Orthopaedic Research Institute**

Quantitative imaging of knee structures following multiple-ligament knee reconstruction

Internal Supervisor: Prof Qing Li Rm S509, Bldg J07 Mechanical Engineering, ph: 9352 8607 Qing.Li@Sydney.edu.au
External Supervisors Professor David Parker, Email: dparker@sydneyortho.com.au





Background - Multiple ligament knee injuries are serious and complex injuries. They are highly variable, and will nearly always require surgical reconstruction to restore the joint. However, the high prevalence of joint degeneration and osteoarthritis in these patients suggests that current surgical techniques do not fully restore knee structure and function. The emergence of magnetic resonance imaging (MRI) and quantitative image analysis technology has begun to generate considerable information on the key structures of the knee. A number of specific analyses are available now to examine the status of a participant's knee which differs from the standard clinical MRI. To-date, the status of the articular cartilage, menisci and reconstructed ligaments in multiple-ligament reconstructed knees remains relatively unknown.

Goal – This project will perform quantitative analysis on a sample of reconstructed knees using the latest MRI techniques and associate these findings to clinical patient outcomes.

Suitable for: Thesis/Project

Sydney Orthopaedic Research Institute

Functional correlates of patient outcome during level walking following multiple-ligament knee reconstruction

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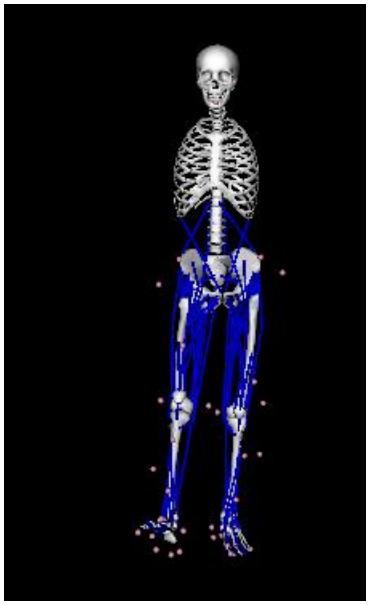

Background - The relationship between joint disease, joint forces and muscle control is well illustrated. Abnormal forces acting in one part of the knee are related to degeneration of key structures and the severity of symptoms, such as pain and stiffness. This can be caused by traumatic injuries which cause a rupture of one or more knee ligaments. Patients alter muscle control, at the affected joint and across the body, to relieve pain during functional activities such as walking. However, functional recovery after surgery is dependent on the pattern of muscle activity used by the patient during movement. The timing and magnitude of muscle forces regulates the forces acting on the knee and an optimal balance of forces is crucial to maintain long-term joint health.

Goal – This project will use the latest techniques in biomechanics to analyse joint function in a clinical population to identify at-risk individuals for future knee degeneration.

Suitable for: Thesis/Project

Sydney Orthopaedic Research Institute

FE analysis of the tibiofemoral joint following multiple-ligament knee reconstruction during locomotion

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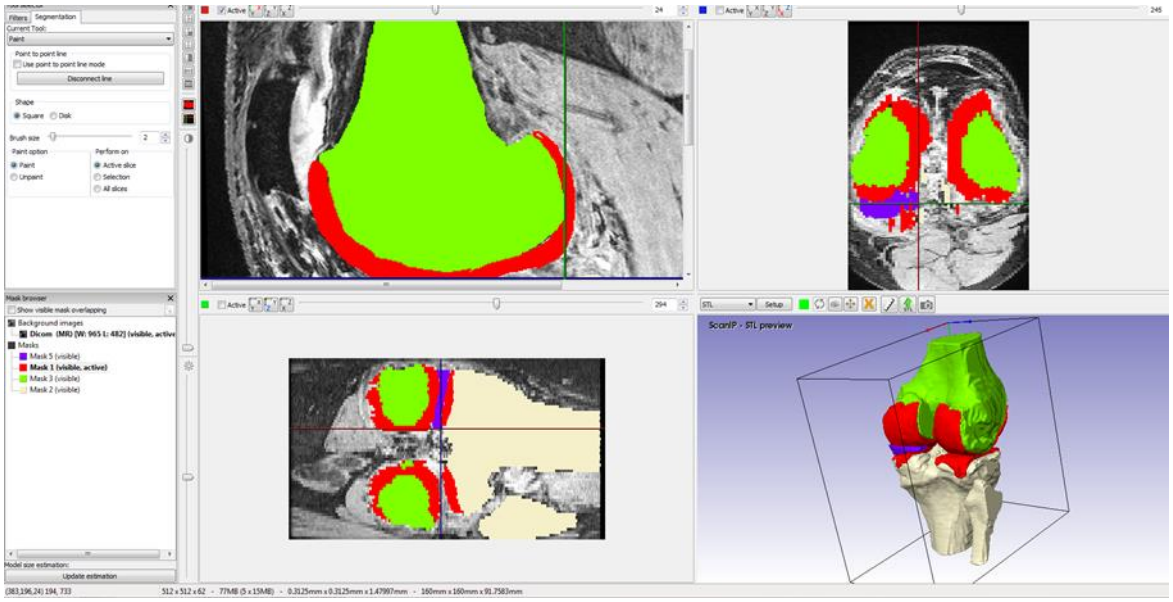

Background - The relationship between joint disease, joint forces and muscle control is well illustrated. Importantly, the pattern of loading is known to vary within and between individuals. This is particularly apparent in patients suffering multiple-ligament knee injuries. However, it remains unclear if reconstruction is able to restore normal loading, with emphasis on the articular cartilage and menisci. These structures are vulnerable to overload during locomotion and their dysfunction is thought to initiate joint degeneration leading osteoarthritis. FEA has provided considerable insight into other clinical problems such as joint replacement, but also has the potential to determine the efficacy of current surgical reconstruction techniques in this context.

Goal – This project will use the latest techniques in FEA to analyse articular cartilage and menisci loading in knee reconstructions to develop a method of identifying individuals at risk of future knee degeneration.

Suitable for: Thesis/Project

Sydney Orthopaedic Research Institute

Three-dimensional reconstruction of menisci during weight-bearing knee flexion

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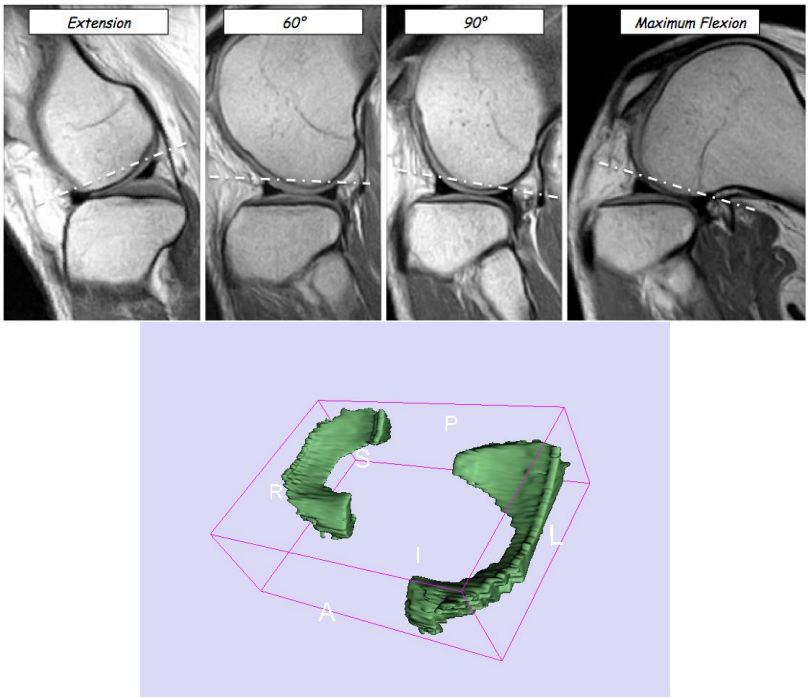

Background - Menisci are important cartilaginous structures within the knee that absorb load, guide joint kinematics and stabilise the joint. Due to their function, the menisci are vulnerable to traumatic tears and degeneration. Innovations in surgical repair have increased the ability of surgeons to preserve the structure despite considerable damage, which previously would have required removal to restore overall joint function. However, there is a lack of objective evidence linking meniscal repair with reduced incidence of osteoarthritis. Furthermore, there remains a lack of information regarding the ability of repaired menisci to replicate the function of uninjured structures. This project will use the latest modelling techniques to compare the loading response of uninjured and surgically repaired menisci.

Goal – This project will utilise Matlab and other image-processing platforms to generate 3-dimensional surface models of the menisci and track their deformation and translation during knee flexion.

Suitable for: Thesis/Project

Sydney Orthopaedic Research Institute

The effect of acute knee injury and surgical reconstruction on tibiofemoral kinematics during locomotion

Internal Supervisor: Prof Qing Li Rm S509, Bldg J07 Mechanical Engineering, ph: 9352 8607 Qing.Li@Sydney.edu.au
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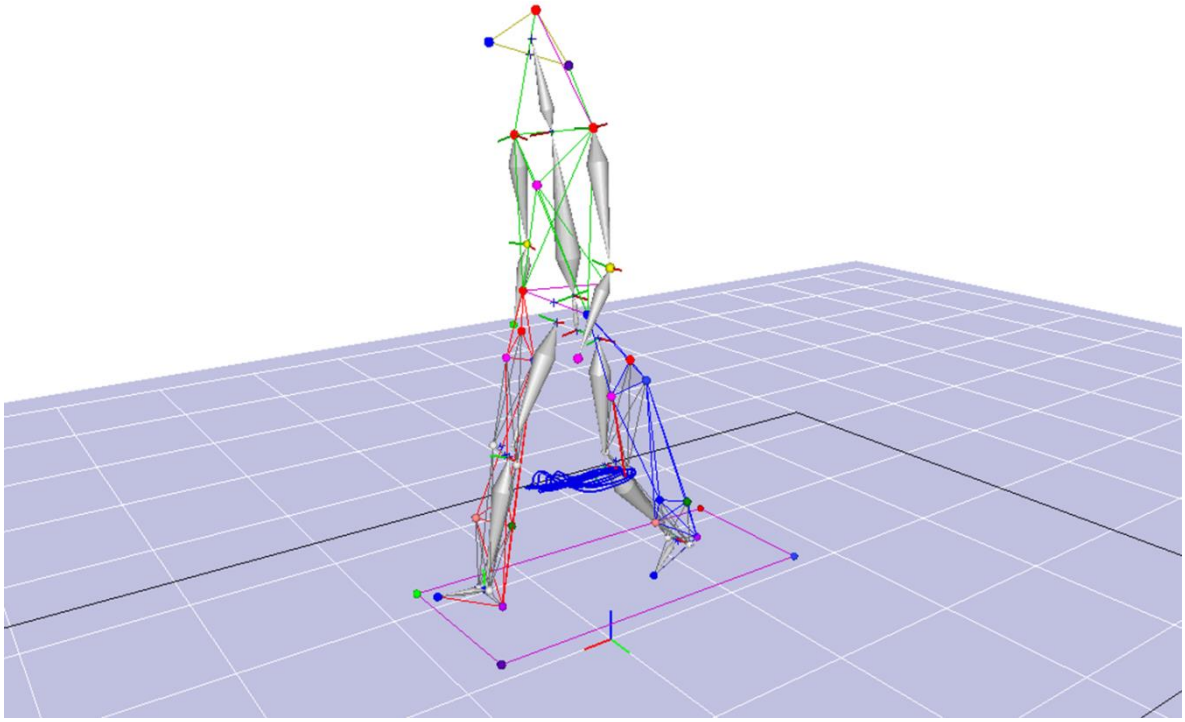

Background – Rupture of the anterior cruciate ligament is a common knee injury, which has considerable impact on joint function. A key role of the ACL is to provide sensory information such as limb position and movement velocity as well providing mechanical restraint. However, there is limited information in the literature regarding the sensory mechanisms that are affected by ACL rupture and whether individuals are able to compensate following injury. Importantly, it is not known whether surgical reconstruction helps to restore some sensory input during functional movements such as locomotion. Biomechanical analysis of the knee during locomotion has revealed some information in this regard; however there remains considerable potential for further research to examine this issue using emerging analytical techniques.

Goal – This project will examine the effects of locomotion speed after ACL reconstruction surgery on knee motion using the latest analytical techniques.

Suitable for: Hons Thesis and Master Capstone Project