Proposals for thesis projects in the Bioengineering area at the University of Sydney

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1. RF ablation guarding circuits for EIT

Synopsis:

Intracardiac and endovascular ablation therapies are widespread in their use in the treatment of a variety of cardiac arrhythmias as well as renal artery denervation. Currently radiofrequency energy is used to form thermal lesions in the vast majority of such ablations, however cryoablation, laser, high intensity focused ultrasound and microwave are emerging as alternative energy sources. Currently, there is no direct way to monitor in real time the delivery of these energies to the myocardium or vascular wall to determine whether an adequate lesion has been formed or whether there is risk of collateral damage to adjacent structures.

In collaboration with Westmead Cardiology, we have developed a Thermochromic Endocardial Phantom for ablation catheter testing. In the next step of this research, we plan on using Electrical Impedance Tomography (EIT) for real time tissue damage monitoring during an ablation. In this research, it is imperative to have a guarding/filtering circuit at each EIT electrode to mitigate the effect of RF ablation as EIT works at 50 kHz while RF ablation is usually between 450 kHz to 500 kHz at 20-36W. Thus, the energy delivered by the RF ablation is detrimental to the electronics of the EIT system.

The student participating in this project will develop prototype for the guarding circuit and testing its efficacy with medical ablation generators and EIT systems.

Due to time constrains of our project, we would prefer a dedicated student who is adept in electronics with knowledge of medical equipment, experience in PCB design and would be willing to work over the summer. You will be working with a team of engineers and cardiologists with ample opportunities to learn more about medical electronics in a clinical setting.

2. **Simulation of an inside-out EIT system for temperature monitoring during an ablation**

Synopsis:

Intracardiac and endovascular ablation therapies are widespread in their use in the treatment of a variety of cardiac arrhythmias as well as renal artery denervation. Currently radiofrequency energy is used to form thermal lesions in the vast majority of such ablations, however cryoablation, laser, high intensity focused ultrasound and microwave are emerging as alternative energy sources. Currently, there is no direct way to monitor in real time the delivery of the these energies to the myocardium or vascular wall to determine whether an adequate lesion has been formed or whether there is risk of collateral damage to adjacent structures.

We would like to investigate possible use of Electrical Impedance Tomography (EIT) for real time monitoring of tissue damage during a cardiac ablation. Current technology of EIT has very low resolution. One possible way to increase the resolution is to bring the entire system closer to the site of interest. In this case, an EIT array can be inserted into the oesophagus to monitor changes in tissue during a cardiac ablation.

In the first instance, we would like to test the feasibility of this idea computationally. This project will first develop a Finite Element Model of the problem, perform simulations with various electrodes arrangements and current injections patterns, and report on the efficacy of such methods, i.e., answering the question of how much more sensitive an inside-out system is to a typical EIT arrangement (with electrodes on the body surface), how sensitive to heating, localisation of heated structures, etc.

This challenging project would suit a student with particular strong Matlab and computational skills. You will be working closely with a PhD student who will be available to help you start up with the project and help with code debugging. You will be working with a team of engineers and cardiologists with ample opportunities to learn more about medical electronics in a clinical setting.

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1. Machine Learning for Automatic Thyroid Eye Disease Classification

Thyroid Eye Disease (TED) affects many people in the world. TED is an extremely unpleasant, painful, cosmetically distressing, and occasionally sight threatening condition. Early diagnosis is particularly important for TED disease since early treatment could minimize the risk of losing sights for severe TED patients. Current TED diagnosis is usually made by summing the score listed in the clinical activity score system e.g., redness of eyelid. However, even for experienced physicians, diagnosis by human vision can be subjective, inaccurate and non-reproducible. This is primarily attributed to the complexity of eye features that is used to describe the disease.
Machine learning plays an essential role in medical imaging field such as computer-aided diagnosis (CAD), where researchers apply modern machine learning and pattern recognition techniques such as deep learning to solve medical related problems. For instance, CAD system can help physicians with the screen procedures, such as to aid the physicians by indicating locations of suspicious tumours. However, to our best knowledge, there is no such a system/method for automatic TED classification.
In this project, we aim to develop 'machine learning' algorithm with the state-of-the-arts techniques to automatically produce the TED diagnosis results. Eventually, the algorithm would help physicians to make accurate, objective and reproducible decisions.

2. Skin Lesion Analysis for Melanoma Detection

Melanoma is one of the most lethal forms of skin cancer. An automated decision support tools that can assist in triage, screening, and evaluation of skin lesion will become essential for early detection and diagnosis. Machine learning plays an essential role in medical imaging field and modern machine learning techniques such as deep learning has been using to solve medical related problems. For instance, state-of-the-art machine learning systems can help physicians with the screening procedures, such as to aid the physicians by indicating locations of suspicious tumours. However, due to the complexity of skin lesions, the existing methods for skin lesion analysis and melanoma detection are still not accurate for indication purpose.
In this project, we aim to develop an accurate automated skin lesion analysis tools toward melanoma detection. Eventually, the melanoma detection tool will improve patient awareness and provide a cost-effective solution.

3. **Robotic Surgical Video Processing**

Over the past year there has been significant interest in robotic surgery which provides the surgeon with small and precise instruments attached to robotic arms that capable of the full range of movements. The robotic arm is controlled by a surgeon using a computer console with real-time video feed of the surgery. The ability to process surgical videos can provide exceptional level of clinical decision support as well as to measure surgical competence (training). This research will leverage the state-of-the-art in natural video processing, and optimise its application to surgical video analysis.

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1. Developing conductive gels for tissue engineering.

Hydrogels are 3D polymer networks swollen with water. Because of their swollen and wet nature, mechanical properties of hydrogels resemble those of soft tissues. Conductive hydrogels are a class of hydrogels capable of conducting electricity (ionic or by electrons). Since they combine desirable mechanical properties of soft hydrogels with electrical conductivity, they hold promising prospects in the future of tissue engineering. However, the main issue of most proposed gels is to reach a balance between mechanical performance and electrical conductivity while maintaining a low cytotoxicity. In this project, a conductive hydrogel with tuneable superior mechanical properties and electrical conductivity will be fabricated. The main applications of the formed hydrogel will be in biosensors and tissue engineering such as treating cardiac wounds and neural interfaces. This project demands a full-time commitment of a six-month period. It is required that the applicants have some knowledge of chemistry. Knowledge of polymer physics is also help to understand the system much better. Interested and highly motivated applicants are encouraged to contact us. The candidate will work in a multidisciplinary research environment that includes more than six postdoctoral fellows, several academics and more than 20 PhD candidates, and several honours students.