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**Stage 2: Apply to the China Scholarship Council (CSC)**

After receiving the unconditional offer letter from the University of Dundee, candidates must also apply to CSC for funding by completing an application for funding. Please apply to The China Scholarship Council online.
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Project Title: AAC System with Co-constructed Dialogue

Project Description:

People who are non-speaking (from birth, or due to accident or medical conditions such as stroke) often rely on Augmentative and Alternative Communication (AAC) technology to assist interpersonal interaction. Despite advances such as letter, word and phrase prediction, such communication is slower (often under 10 words/min) than natural speakers (typically ~150 words/min) and also less effective, reducing the extent to which AAC users can express themselves through engaging in dialogue and complex social interactions, leading to social isolation.

Typical AAC systems are based on pre-stored information and phrases, which are often focussed on transactional dialogue (requests and simple responses) and offer limited ability to handle broader conversations or adapt to new situations or conversational topics. The AAC user has a limited capacity to control and guide the conversation, and to engage the storytelling and narrative which is central to social interaction. Hence significant difficulties remain for AAC users who wish to express themselves in the context of a spontaneous, active conversation.

In normal conversation, both partners contribute (roughly) equally and both can guide the conversation, with cues being picked up and responded to by each partner. This co-constructed and co-operative nature of dialogue is missing for AAC users, as responding to novel topics is more difficult and time consuming, leading to asymmetrical dialogue with the non-AAC user taking the lead.

An under-researched method for facilitating social dialogue between AAC users and their conversation partners is to allow the natural speaker to directly influence the AAC system. This would use aural cues, e.g. recognising key topic words spoken, to guide the conversation direction; speech recognition requires considerable computing power, and this is only now becoming feasible within a portable AAC system.

This project proposes to research and develop a communication system which will use speech recognition and other extra-ordinary inputs to enhance the contextual awareness of the system and utilise information from the user’s dialogue partner. This will allow the system to predict dialogue utterances which are far more relevant to the situation, and hence improve the effectiveness of the communication allowing the user to have greater control over the conversation.

The system will be tested and compared to conventional communication systems to demonstrate the efficacy of handling the additional input channel(s), using an existing pool of non-speaking users available to the proposers’ research group.

The primary aims of the proposed research would be to:

- conduct research into the state-of-the-art in AAC systems, including the use of extra-ordinary inputs including audio (primarily speech)
- implement an AAC system which utilises appropriate extra-ordinary inputs to enhance the quality and depth of interaction possible
- evaluate the AAC system against a baseline system (which has no input from the conversational partner)
- produce appropriate published outputs (research papers, software etc.)

Supervisors: Professor John Arnott and Dr Iain Murray
Project Title: Advanced Biomaterial for Preventing Catheter-Associated Infections

Project Description:

Urinary catheters are used as soon as a patient cannot control urine drain as a consequence of incontinence or urine retention. Catheter-associated urinary tract infections (CAUTIs) account for about one third of all hospital-acquired infections and more than 1 million CAUTIs occur annually in the United States and Europe. CAUTIs cost the UK NHS approximately £99 million per year and result in increased morbidity and mortality. Currently only a silver coated catheter and a PTFE-coated catheter are still widely used in hospitals. Unfortunately clinical studies have shown that the use of silver-coated or PTFE-coated urinary catheters has resulted in an insignificant reduction in infection. Our new idea is to combine the anti-bacterial property of silver and anti-adhesive property of PTFE in a single coating by incorporating PTFE nano-particles into a silver matrix using a cost-effective electroless deposition technique.

The aim of the proposed research is to develop the novel silver-PTFE nanocomposite coatings on full-length Foley catheters and to evaluate their anti-biofilm properties in a simulated in vivo environment mimicking human bladder and long-term catheterisation, using the facilities available at the Biomaterial Research Centre, University of Dundee (see Fig 1 and Fig 2). The research work is supported by UK EPSRC.

Supervisor: Professor Qi Zhao
Project Title: A Numerical Study of Planet Formation

Project Description:

The observations over the last >20 years have revealed nearly 3000 confirmed extrasolar planets, which show both similarities to and differences from planets in the Solar System. On one hand, current observations show that Earth-like terrestrial planets with orbital periods less than a year are found about 50% of Sun-like stars. They are often in closely-spaced multiple-planet systems, in a similar manner to terrestrial planets in the Solar System. On the other hand, only about 10% of Sun-like stars are observed to have a Jupiter-like giant planet with an orbital period shorter than a few years. Since there are not too many systems which have both terrestrial and giant planets, it is possible that a multiple-planet system like the Solar System is not very common.

Two key questions here are how these planetary systems were formed and what led to their differences. The leading planet formation model predicts that planets are formed gradually in a protoplanetary disc as particles collide and agglomerate, though the detailed mechanisms of different stages of formation are still actively studied. The difference among planetary systems are likely to be caused by the difference in the efficiency of planet formation and the degree of dynamical evolution. How efficiently planets could form depends on the initial disc properties such as mass and dust-to-gas ratio, while how significant the dynamical evolution is for a particular planetary system depends both on disc and planetary properties.

In this project, we study formation of planets in a statistical manner by using numerical simulations, with a particular focus on the role of giant planets. Planets are formed in dusty, gaseous protoplanetary discs around protostars. We will start with observationally motivated initial conditions of protoplanetary discs, simulate planet formation in such discs, and constrain the initial conditions that lead to different types of planetary systems. We will also study how formation of terrestrial planets is affected by the presence or absence of giant planets.

Supervisors: Dr Soko Matsumura
Project Title: A New Painless Micro-needle Thermocouple for Early Breast Cancer Detection

Project Description:

Malignant tumours tend to be warmer than benign tumours due to increased metabolism and more importantly due to vascular changes surrounding the tumour. Thermography has been extensively used as a cancer detection tool, but has not been accepted for routine application. One of the main reasons is that unlike mammogram, thermography only provides superficial abnormal thermograms. The best noninvasive thermography technology could map body temperature approximately 1 mm beneath the skin, but still unable to determine the temperature of tumors in deeper areas.

We measured 27 tumors that were 1 – 3 cm beneath the skin in the heads and necks of 27 patients with a needle thermocouple (single use). Our experimental results showed that the difference in temperature between the core area of the tumor and the surrounding skin (ΔT) could discriminate whether the tumor was malignant or not. We first found that for the benign tumors ΔT was < 0.40 °C, while for the malignant tumors ΔT was > 0.7 °C (p < 0.001). This finding suggests that ΔT could be an important criterion in the early detection and diagnosis of malignant tumors.

Through this PhD project we aims to develop a painless micro-needle thermocouple for early breast cancer detection, in the collaboration with clinical doctors and relevant companies. The temperature distributions will also be calculated using relevant models.

Supervisor: Professor Qi Zhao
Project Title: A Posteriori Error Control and Adaptivity for Nonlinear Schrödinger Equations

Project Description:

Today numerical methods for the simulation of Partial Differential Equations are ubiquitous. But how do we know that the numerical solution is a reasonable approximation of the exact solution? Traditionally, this question is answered through a priori error analysis: ideally, we have a Theorem stating that, if we use enough degrees of freedom (“points”) in our computation, the result should converge to the exact solution. Two things can go wrong: for demanding computations we may be barely able to compute a result with a few points, and we not be able to check whether numerical convergence has occurred; or we may not be able to prove such an a priori error bound at all.

These things do go wrong in some computations, and they provide the motivation for a posteriori error control: can I compute, along with my numerical solution, an upper bound for the error? Then I have a way to establish rigorously whether numerical convergence has been achieved even with relatively few points. Moreover, it turns out that we can have a posteriori error control even in problems that do not have a priori error bounds. That is, we can attack problems where convergence is not guaranteed a priori, not even in the limit of the number of points going to infinity, and sometimes our error estimator can indicate that the computed solution is correct. An example of such a problem can be found in [3]. A key feature of the estimator is that it can break down the error over regions of space and time, and thus guide adaptivity, i.e. add points in the regions / timesteps where they are most needed to produce a better solution.

This project is about the refinement and implementation of a posteriori error estimators for the nonlinear Schrödinger equation, related to work from [1,2].

References:

Supervisors: Dr Irene Kyza and Dr Agissilaos Athanassoulis
Project Title: Computational Studies of Haemodynamic Properties in Arteriovenous Fistulae and Peripheral Arteries

Project Description:

(I) Background to Project

It is important to understand the haemodynamic properties in renal dialysis venous access (DVA) in patients with kidney failure and renal replacement programmes. Such an understanding will help to improve the performance and longevity of renal DVA which underpins the life supporting haemodialysis techniques. There is evidence that arterial flow patterns and wall shear stresses are related to the site and severity of arterial disease and the performance of the AV graft. It is thus important to estimate haemodynamic properties such as flow patterns and wall shear stress distributions in the blood flow/arterial wall system.

(II) Aims of Project

The objectives of the project are: (i) to develop proper models and simulate the blood flow and its interaction with the hyperplasia of the intimal layer of the arterial wall associated with the aggressive formation of stenosis; (ii) to develop a most proper finite element method for the models with necessary analysis; (iii) to characterise the flow patterns, wall stresses and haemodynamic factors within fistulae or grafts and to assess their role in venous intimal hyperplasia (VIH); (iv) to identify whether or not observed different flow patterns are associated with VIH in central veins; (v) to develop better implantable medical and eventually influence strategies of improving patient outcomes.

(III) Methods and Protocol to be used in the Project

There are three main methodologies in the project: 1. Data acquisition. Elastic and geometric data of AV fistulae and arterial walls (including wall anatomy and wall thickening) will be obtained from images of Ultrasound, CT and MRI, through the collaboration with Cardiovascular Imaging Group, Ninewells Hospital, University of Dundee. Ultrasound is able to provide relatively accurate tissue movement so as to measure the distension of blood vessels and estimate wall elasticity. CT and MRI are of use clinically for identifying central venous stenosis. MRI can also provide 3D flow patterns in the changing central venous haemodynamic setting. All these will be used to validate blood flow-wall model and determine proper physical parameters for the next two steps. 2. Flow-wall Modelling. We will start with a Newtonian blood flow with the arterial wall geometry obtained from Step 1. Then we will develop more realistic model with the wall moving and interacting with the blood flow. The wall may be considered as a very viscous non-Newtonian fluid and thus the flow-wall interacting formulates a two-phase flow problem. It would be very interesting to develop a phase-field (diffuse-interface) model for this. 3. Computational Techniques. It is a challenge to simulate 3D blood flow models with a complex geometry and moving wall. Finite element methods, which we have extensive experience, will be specially designed for these models and programmed in its software development platform e.g. FreeFEM++, DUNE.

Supervisor: Professor Ping Lin (collaborator: Professor Graeme Houston NHS Tayside)
Project Title: Deep Learning for MR Brain Tumour Segmentation and Analysis

Project Description:

AIM OF PROJECT

The objectives are: 1) to develop deep learning methods for feature extraction to automatically quantify the edema/tumour appearance and textures based on the manual annotations; 2) to develop semi-automatic or automatic tumour segmentation algorithms; 3) to predict and mutation of patient with brain tumours.

BACKGROUND

The primary use of MRI-based medical image analysis for brain tumour studies is in diagnosis, treatment planning and follow-up monitoring etc. The segmentation has great potential for reliably monitoring tumour growth or shrinkage in patient during therapy and also could play an important role in surgical planning or radiotherapy planning, where not only the tumour has to be outlined but also the edema region are of interest. However, in current clinical practice, the manual segmentation of brain tumour is not widely used as it is time-consuming and tedious for the radiologists. Evaluating MRI brain images is either based on qualitative criteria only (e.g., the presence of characteristic hyper-intense tissue appearance in T1 contrast MRI) or by relying on rough quantitative measures as the largest diameter visible from axial images of the lesion. Therefore, providing machine intelligence to perform automatic segmentation is highly desirable and would be of enormous potential value for improved diagnosis, treatment planning and follow-up of individual patients.

In order to develop automatic or semi-automatic brain tumour segmentation tools, it is essential to develop algorithms that are capable of transferring the knowledge from the domain expert into machine intelligence. Ground truth annotation, which indicates the presence of region interest (e.g., a tumour or edema region) from clinician experts, is essential to achieve this transfer. Moreover, ground truth annotation allows a quantitative, statistical comparison between the results of programs and results from experts, indicating the robustness of the proposed algorithm. Therefore, in the view of machine learning, the success and usefulness of image analysis algorithms will largely depend on the level of availability and reliability of those annotations and generally more training data can generate better segmentation results. Though complete annotations and abundant training data are desirable for the algorithms development, they are expensive and burdensome to obtain. The proposed study of this project will serve as a steering point for developing segmentation algorithms to address this challenge.

Track Record and Preliminary Work

This project is a collaborative initiative between the Computing’s Computer Vision and Image Processing group (CVIP), the X-Ray department in Ninewells hospital, and The National Hospital for Neurology and Neurosurgery at UCL. CVIP has been developing analysis methods for medical images for years, including traditional histopathology images, OPT images, retinal images, and endoscopy images etc. Recent algorithms, developed by Zhang/Manuel’s team to won the MICCAI 2017 challenge on Brain White Matter Hyperintensities Segmentation Challenge in Canada. Relevant experience could be adapted for this PhD study. The team has developed an MRI brain tumour segmentation framework which achieves state of the art segmentation performance on public dataset [3], which could serve as the starting point of this study.
The team members have served as general/area chairs of BMVC2011, BMVC12-18, MICCAI2018, and will host ECCV2020 as general chair.

**METHODOLOGY:**

The objectives of this study will be addressed over a 48-month period consisting of four work packages (WP1-4):

**WP1: DATASET AND PILOT STUDY** – The main purpose of this task is to build up a dataset containing full and partial annotations of tumours on different MR modalities (including, T1, T1-C, T2-Flair, and MR perfusion maps). Two types of annotations will be explored: 1) full annotation delineating the edema region and the enhanced tumour region from the T1-C images along the axial plane; 2) partial annotation indicating the some information of the region (e.g., clicked based annotation, or diameters). Finally once the annotation protocol is set up, we will build up a dataset containing 60 3D MR images with full and partial annotations. In parallel, will be used an initial dataset as algorithm development purpose. The student will perform a literature review and pilot study on public datasets from Brats’13 and 15. The CVIP group already has several in-house feature extraction and learning methods which will give the student a firm grounding on which to base further ideas.

**WP2 -- 3D FEATURE EXTRACTION** – Annotated digital images will be analysed using feature learning method to identify quantifiable features that can distinguish the following regions: edema region, non-edema region, enhanced tumour region. Specifically, efforts will focus on developing hand crafted features and automatic feature learning methods including deep learning etc. Adaptive scales and contextual support will be taken into consideration in the development.

**WP3 – CONTEXTUAL SEGMENTATION and ANALYSIS** – Segmentation algorithms, which are capable of learning from partial annotations and full annotations will be developed using spatial context cues via probabilistic graph models including Conditional Random Field, and Markov Random Fields. We will investigate whether algorithms learned from partial annotations could achieve similar performance to the algorithms learned from full annotations, and whether the texture features extracted in the segmented brain tumour region could be used to predict the survival rate of the tumour patient.

**WP4 – VALIDATION and THESIS WRITEUP**. The student will conduct the significance analysis of the experimental results. Results will be validated by the manual annotations, and published in the mainstream of medical image analysis journal and conferences such as Journal of Medical Image analysis. IEEE TMI, ISBI or MICCAI. The student will benchmark the outcomes against state-of-the-art algorithms on public datasets (e.g. Brats) and private dataset in-house. The PhD thesis will be completed by the end of year four.

**SUPERVISORS:** Dr. Jianguo Zhang, Computing; Prof. Manuel Trucco, Computing and Prof. Sotirios Bisdas, National Hospital of Neurology and Neurosurgery, University Colleague London.
Project Title: Diagnosis of prostate cancer using viscoelasticity measurement of Optical Coherence Elastography

Project Description:

Prostate cancer is the most frequently diagnosed malignancy in men. Digital rectal examination (DRE) - a known clinical tool based on alteration in the mechanical properties of tissues due to cancer has traditionally been used for screening prostate cancer. Essentially, DRE estimates relative stiffness of cancerous and normal prostate tissue. Such as measurement provides insight into detection and progression of disease. Suspected men with abnormal DRE are offered further diagnostic test to confirm diagnosis. Current diagnostic approach using grey scale ultrasound guided biopsies has multiple limitations including inability to differentiate aggressive from indolent prostate cancers. This proposal addresses the challenge by evaluating the role of optical coherence elastography (OCE) in the detection and differentiation of aggressive from indolent cancers. OCE has several inherent advantages such as micron-scale resolution, millimetre-scale penetration depth and non-destructive imaging and has huge clinical potential. Current, the OCE system can differentiate normal and malignant tissue, however, it is difficult to differentiate degree of cancer.

Pathological changes are usually correlated with changes in mechanical properties of soft tissues, such as Young’s modulus. Therefore, fully characterization of mechanical properties of soft tissue (elasticity and viscosity) would help to identify pathology regardless of observers and subject variations and further to differentiate degree of cancer. Aim of this project is to measure viscoelasticity of prostate biopsy from man suspected with Prostate cancer and identify the relationship between the viscosity, elasticity and tumor malignancy.

Supervisors: Dr Chunhui Li and Professor Ghulam Nabi
Project Title: Discovery of Composite Biomarkers and the Role of the Retina in Risk Prediction for Systemic Diseases Using Deep Learning

Project Description:

Aims and objectives.

The project will use deep learning (DL) techniques to discover combinations of phenotypic and genotypic features working as predictive risk scores for high-incidence conditions (e.g. cardiovascular, diabetic complications)

Experience and Environment

Doney’s group has extensive and internationally visible experience of research bioinformatics. Doney directs the development of the eClinical Phenome within the Health Informatics Centre which manages large bioresources in Tayside linked to electronic Medical Records (EMR). In addition to the EPSRC project above, Trucco was funded by the EU, MRC, the Royal Society, the Wellcome Trust, Toshiba, OPTOS and various charities. Trucco’s group (CVIP/VAMPIRE) has extensive experience of DL applied to medical image and data analysis, and runs its own GPU resources (~10 NVIDIA cards). The student will join the friendly and active CVIP/VAMPIRE laboratory and be attached to the NIHR student cohort for effective interdisciplinary integration.

Materials available

We shall rely on the GoDARTS bioresource comprising more than 9,000 diabetic patients and 8,000 controls (http://diabetesgenetics.dundee.ac.uk/) with numbers set to more than double in the next few years. In addition to genome-wide genotyping GoDARTS is linked to 30 years of comprehensive longitudinal electronic medical records. This is excellent ground for data mining with artificial intelligence techniques. All GoDARTS participants have provided consent for research of this kind and has been used by Doney and Trucco in collaborative projects for about 10 years.

Training and work plan

1. Initial induction: familiarization with interdisciplinary computing-medicine group; literature review (DL and drug response; related topics); training in machine / DL, clinical statistics, clinical context; short project (~2-3 months) leading to conference paper.
2. Identification, implementation, test of DL architectures for target problem; investigation on transfer learning and pre-trained large networks.
3. Definition of final specific problem expected after first year.

Supervisors: Prof. Emanuele Trucco, Computing and Dr Alex Doney, School of Medicine
Project Title: Energy Dissipation in Turbulent Space Plasmas

Project Description:

This project involves investigating energy dissipation in space plasmas, important for our understanding of phenomena in the Sun’s atmosphere, the Earth’s magnetosphere, and throughout the Universe. Plasmas make up over 99% of the matter in the Universe, and magnetic fields play a crucial role in the dynamics of these plasmas on all scales, from galaxies to the Sun, planetary magnetospheres, and laboratory fusion devices. Many dynamic, energetic phenomena in these plasmas involve rapid energy conversion mediated by plasma turbulence. One example is a solar flare, an explosive event that releases an enormous amount of stored magnetic energy (more energy than tens of millions of hydrogen bombs) into the Sun’s atmosphere on a timescale of a few minutes. Solar flares launch high-energy particles toward the Earth thousands of times a year, presenting a major hazard to satellites, global communications, and space exploration. However, our understanding of the details of the energy release process is so far rather limited, meaning that flare predictions are at present difficult. In this project we will investigate the triggering of this rapid energy release process, and the three-dimensional magnetic structures that are involved as it proceeds. The aim is to improve our understanding of when and where explosive energy release occurs.

This research project involves the development of computational and/or mathematical models of turbulent energy release in complex magnetic field geometries, and comparison of these models with observations from the Sun’s atmosphere and/or Earth’s magnetosphere. A student undertaking the project will gain skills and expertise in modelling, high-performance computing, and data analysis. The results will enhance our understanding of energetic events in plasmas on a range of scales throughout the universe. The results may have important implications for the rapidly expanding Space Weather industry. This project would suit a student with a background in Mathematics or Physics/Astrophysics.

Supervisor: Dr David Pontin
Project Title: Enhancing Photocatalytic Pollutant Degradation and Self-Cleaning of Building Surfaces Using Captive Radicals

Project Description:

Photocatalytic processes are currently used as a means of removing pollution from urban atmospheres, through the use of titanium dioxide coatings on surfaces in the built environment. This approach also has the added benefit of rendering the surfaces self-cleaning, since the photocatalytic process also breaks down dirt particles, which are then removed by rainwater.

The photocatalytic process involves the formation of OH and O$_2^-$ radicals when the TiO$_2$ surface is illuminated with UV radiation from sunlight. These radicals react with pollutants and compounds in dirt particles to give carbon dioxide and water. Whilst this is effective at removing pollutants, greater efficiency is still desirable, to make such surfaces as environmentally beneficial as possible.

Recent preliminary research at the University of Dundee has found that the photocatalytic process can be enhanced by including compounds capable of forming other radicals in concrete surfaces treated with TiO$_2$. These radicals are ‘captive’: after taking part in pollution degradation they are re-incorporated into the concrete surface, thus allowing them to be recycled, potentially indefinitely.

This project will examine ways in which this process enhancement can be optimised. It will explore the different variables (cement composition, exposure to light, presence of catalysts) which are likely to influence the process through a series of laboratory experiments. The experiments will also examine the longevity of the captive radicals. Once optimal conditions have been identified, the research will develop prototype construction products suitable for general construction applications, and trial these in urban environments.

**Supervisors:** Dr Thomas Dyer and Professor Rod Jones
Project Title: Experimental Investigation of the Effect of Cavitation Erosion on Strength and Fatigue Performance of Fibre Reinforced Composites

Project Description:

Several methods for conversion of kinetic energy of tides generated in seas and oceans into electricity are currently under fast development. One of them is based on the use of horizontal axis tidal stream turbines with propeller-type blades. During turbine operation, passing water applies pressure on the blades. Pressure fluctuations induced by current turbulence, wind and tidal waves, changes in hydrostatic pressure due to the rotation of the blades in the rotor are associated with the fatigue limit state. Additionally, localised pressure drops on the blade surface can cause the seawater to cavitate. Depending on its extent and severity cavitation can damage the turbine blades through the erosion of the blade surface. If the damage has not been identified in time, it can affect the strength and fatigue performance of the blade shell. The proposed project will focus on the experimental investigation of the effect of cavitation-induced damage on the strength and fatigue resistance of fibre reinforced materials used for manufacturing of tidal turbine blades. A criterion describing the deterioration in strength and fatigue resistance depending on the level of cavitation damage will be established. The knowledge derived in this project will enrich the capabilities of practicing engineers in evaluation and prediction of blade performance in long-term deployment of marine turbines and contribute to proper planning of blade maintenance and repair procedures.

Supervisors: Dr Leon Chernin and Dr Tom Dyers
Project Title: Evaluation of Drug Effects Using 3D Tissue Engineering Corneal Models

Project Description:

The cornea is the outermost layer of a human eye. It has a transparent, dome-shaped surface that covers the front of the eye. The transparency of the corneal permits the light to enter the eye, and the cornea plays an essential role in focusing the vision. It is also a protective barrier against dirt, germs, and other potential damage that can harm the eye. Additionally, the cornea is also exposed to damages, such as injuries, scratches, laser surgery and chemical reagents. The cornea usually heals on its own after minor injuries, but deeper injuries can cause corneal scarring, which will result in a haze on the cornea that impairs vision.

Some anti-inflammatory drugs and antibiotics have been used to reduce the infection and regulate the immune system to promote the wound healing process. It is of significance to effectively evaluate the drug effects before releasing to the market. However, using in-vivo animal models seems difficult due to the ethic concern, the short of animal models, as well as the inherent differences between human and animal eye in the aspects of structure and physiology. Also, it is extremely difficult to collect human donors. Alternatively, a reconstructed human corneal model suits better for this task using tissue engineering techniques.

The tissues of the cornea are arranged in five different layers. Among them, the epithelium measures slightly less than 10% of the thickness of the overall cornea, and the stroma is approximately 90% of the thickness of the entire cornea. This project is intended to reconstruct the human cornea using 3D epithelium-stroma co-culture model, and mimic the eye injury by scratch assay and chemical lesion, as well as conduct the assessment of drug effects using different biotechnological and biomedical methods. During the period of this project, the student is expected to

1. design and plan the experiments using suitable materials and methods,
2. prepare a review of literature of current research activities related to this project,
3. develop tissue engineering skills to successfully build a 3D corneal model,
4. be skilled at operating associated biotechnological and biomedical instruments,
5. be capable to analyse the data using statistical software.

Supervisors: Dr Chunhui Li and Professor Zhihong Huang
Project Title: Lifetime Sensitive Lightsheet Microscopy (SPIM-FLIM)

Project Description:

Lightsheet microscopy, also known as selective plan illumination microscopy (SPIM) has advantages which include its low phototoxicity, high contrast, large field-of-view, and high 3D isotropic spatial resolution. This is only possible by using a camera to image complete sections within a sample. A thin sheet of light (hence lightsheet), usually less than 1 µm thick, is projected through the specimen producing fluorescence only from the illuminated region, thus capturing a deep tissue, sub-cellular resolution image in one go on a camera sensor (see Fig.1). To observe key dynamic events in the sample an exciting new camera technology is available [2]. Single photon counting avalanche diode (SPAD) cameras have the ultimate single photon sensitivity and temporal resolution (100 picoseconds). Recent developments in these detectors using CMOS design approaches have allowed more than 20,000 detectors to be mounted on a single device (~2 mm×2 mm in latest sensors), resulting in massively parallelised single photon detection and timing. The opportunity now is to exploit this powerful photon processing engine for volumetric fluorescence lifetime imaging (FLIM) in live samples, a feat not achieved so far.

In applying the newly developed SPIM-FLIM device we aim to study the spatio-temporal dynamics of cyclic adenosine monophosphate (cAMP) mediated cell-cell signalling during multicellular development of the social amoebae Dictyostelium discoideum [3]. cAMP is synthesized and secreted by starving cells in an oscillatory manner and through local synchronisation results in waves of cAMP propagating through the population of cells. cAMP is a key chemoattractant and these waves control the chemotactic cell movement of hundreds of thousands of cells. The Weijer lab has working FRET sensors for cAMP signalling want to use these to study the spatiotemporal dynamics of cell-cell communication in vivo using lifetime imaging based FRET techniques. Since this involves relatively fast biological processes, the lightsheet based lifetime imaging will be ideal.

Supervisors: Dr Mike MacDonald (Physics), Dr Nikola Krstajic (Bioengineering) and Professor Kees Weijer (Life Sciences)


Project Title: Lightsheet Imaging of Developing Chick Embryos

Project Description: One of the most active areas of current microscopy research is Lightsheet Fluorescence Microscopy (LSFM). We built the UK’s first LSFM system here in Dundee and continue to develop new methods for live widefield imaging of tissues. This project is aimed at developing higher spatio-temporal resolution with increased depth penetration in chicken embryos.

Live imaging of the dynamics of complex cell behaviours is an essential and rapidly developing methodology required in order to tackle key questions in the life and medical sciences. LSFM is the emerging technique of choice for live imaging of complex samples [1]. We are developing state-of-the-art multiview lightsheet microscopes [2] that allow us to image complex cell and tissue dynamics in developing amniote embryos (see fig. 1).

A particular challenge for imaging tissues in situ is the loss of contrast due to scattering of both the excitation and emission light. To overcome this challenge the student will use advanced beamshaping and adaptive optics techniques to improve imaging of critical cell behaviours such as division and movement and cell-cell signalling in deeper regions of the gastrulation stage chick embryo.

The project will particularly suit a student with a Physics background, but will develop skills from optics and life sciences and include advanced data processing and image analysis techniques to analyse the hundreds of terrabyte data that these experiments can produce.


Supervisors: Dr Mike MacDonald (Physics) and Professor Kees Weijer (Life Sciences)
Project Title: Low Carbon Concrete

Project Description:

Portland cement (PC) is a key material for society but its production is energy intensive with correspondingly large CO₂ emissions. Demand reduction and/or replacement of PC are not realistic given current trends in economic growth and increasing urbanisation. Global production of PC is currently of the order of 3 billion tonnes and is expected to increase by 0.5 billion tonnes by 2030. China is by an order of magnitude the largest global producer and consumer at around 2.4 billion metric tons in 2017.

The globally leading cement companies gathered in 1999 to create the Cement Sustainability Initiative (CSI), under the auspices of the World Business Council for Sustainable Development (WBCSD) and issued a ‘shared statement of ambition’, by which CO₂ emissions should be reduced by 20-25% by 2030. The Mineral Products Association, which represents the UK sector, has expanded on this, and aims to reduce greenhouse gases by 81% by 2050 (cf 1990). This maps onto the UK Government roadmap. There is, therefore, a critical urgency to develop practical and economic solutions that the concrete supply industries can adopt.

There has already been significant research in development of non-Portland cements that are considered, although often unproven, to embody less energy and emit less CO₂ during manufacture. There is no agreed definition for what constitutes a ‘low energy/low carbon’ cement but some examples are MgO, belite-aluminate, sulfoaluminates, geopolymers, and calcined clays. A major problem with many of these materials is that the volume of raw materials is not available at the scale needed to replace PC. The potential of carbon capture and storage (CCS) is established but for the foreseeable future is too costly to implement. Modelling initiatives at various scales are underway but their practical application to concrete manufacturing has been very limited. Therefore, the only viable and scalable solution in the medium term (10-30 years) for the reduction of carbon emissions in the concrete industry is through innovative microstructural engineering using materials available in large volumes and using the ‘core’ PC clinker more efficiently.

This project approach will be to integrate the application of advanced instrumentation with both fundamental engineering science and practical concrete technology to manufacture a wide range of low carbon concretes, suitable for deployment in China and the UK. Optimised low carbon mixes will be validated with durability, strength and performance tests. One highly novel feature is to enable outcomes to be made available in open source using Building Information Modelling (BIM) technology to provide comprehensive data for industry and researchers.

Supervisors: Professor Rod Jones and Dr Moray Newlands
Project Title: Response Analysis of a Novel Floating Offshore Wind Turbine

Project Description:

In recent years, significant attention has been given to the development of marine renewable energy. The offshore wind energy, in particular, has experienced remarkable growth and continues to expand worldwide. Fixed offshore turbines are limited to shallow waters near shores. Floating turbines in deep water, however, offer some distinct advantages over fixed structures, including (i) access to more powerful wind resources farther offshore, (ii) elimination of visual impact, (iii) further flexibility in site selection, (iv) a versatile, integrated hull design solution that can be applied at different sites, and (v) easier installation procedure. Design, control and analysis of Floating Offshore Wind Turbines, however, is a complex process and involves a number of challenging, coupled problems.

This project will focus on the use of existing engineering solutions, and on the development of a state-of-the-art model to analyze the response of offshore floating wind turbines to waves, current and wind. In particular, a novel design of floating wind turbine will be considered. The floating structure is designed to support multiple wind turbines and it rotates in response to the environmental loads. A rendered view of the floating wind turbine is shown in the below Figure. The environmental loads on the structure include the water wave load, current load, the wind load on the topside, and the mooring loads.

![A rendered view of the novel floating offshore wind turbine](image)

Figure: A rendered view of the novel floating offshore wind turbine (Courtesy of: Wang, C. (2015), EWEA Offshore Conference, Copenhagen, Denmark, pp. 1-10).

Supervisors: Dr Masoud Hayatdavoodi, Civil Engineering and Professor Ping Lin, Mathematics
Project Title: Statistical Prediction of Rogue Waves

Project Description:

In 1980, MV Derbyshire was lost with all crew south of Japan. At 91,655 gross register tons, she was the largest British ship ever to have been lost at sea. The wreck was found in June 1994, and the Woods Hole Oceanographic Institution took 135,774 pictures of it during two expeditions. A comprehensive analysis by Douglas Faulkner, Professor of Marine Architecture and Ocean Engineering at the University of Glasgow, was published in 2001, linking the loss of the MV Derbyshire with what he called the emerging body of scientific evidence regarding the mechanics of Rogue Waves [3]. Professor Faulkner concluded that, almost certainly, the MV Derbyshire had encountered a single wave of sufficient size to destroy her, something thought impossible at the time.

Subsequent research on irregular wavefields has established that random localisations of energy, induced by the linear dispersive mixing of different harmonics, can grow significantly due to nonlinear effects [3,4]. However, quantitative modelling and prediction of the emergence of Rogue Waves has been elusive until recently. In [1] a statistical model of noisy wavefields was proposed and analysed by the first supervisor in collaboration with a world leading team of ocean engineers, leading to the formulation of a stability condition. When this condition is violated, rapid concentrations of energy, possibly leading to rogue waves are likely. In [2] the bifurcation between stable and unstable sea states is further studied. It is further found that typical measurements are in the stable regime, up until the boundary of instability. This means that unstable sea states are uncommon but possible, further supporting this instability as a credible explanation for rogue waves.

This project will extend the results of [1,2] with emphasis in the simulation of unstable problems, and the inclusion of wind and wave-breaking effects.

Supervisors: Dr Agissilaos Athanassoulis and Dr Irene Kyza

References:
Project Title: Stratifying Patients by Drug Response in a Large Diabetic Cohort Using Deep Learning

Project Description:

Aims and objectives.
The project aims to stratify diabetic patients by their response to drugs using artificial intelligence (DL) techniques.

Experience and Environment

Pearson’s group has extensive and internationally visible experience of diabetes research and response to drugs. Pearson leads the €46M IMI-DIRECT project on stratification in Type 2 diabetes and is Strand 2 lead on the £2.7M MRC funded MASTERMIND project. In addition to the EPSRC project above, Trucco was funded by the EU, MRC, the Royal Society, the Wellcome Trust, Toshiba, OPTOS and various charities. Trucco’s group (CVIP/VAMPIRE) has extensive experience of DL applied to medical image and data analysis, and runs its own GPU resources (~10 NVIDIA cards). GoDARTS, used by Trucco in various projects already, has comprehensive consent for research. The student will join the friendly and active CVIP/VAMPIRE laboratory and be attached to the NIHR student cohort for effective interdisciplinary integration.

Materials available

We shall rely on GoDARTS, a large, cross-linked bioresource grown in the medical school including more than 9,000 diabetic patients and 8,000 controls (http://diabetesgenetics.dundee.ac.uk/). In addition to a variety of personal, lifestyle and clinical measurements and information, GoDARTS includes treatment history (which drugs, when prescribed, patient progress), outcomes, and full genetic profiles. This is excellent ground for data mining with artificial intelligence techniques.

Training and work plan

1. Initial induction: familiarization with interdisciplinary computing-medicine group; literature review (DL and drug response; related topics); training in machine / DL, clinical statistics, clinical context; short project (~2-3 months) leading to conference paper.
2. Identification, implementation, test of DL architectures for target problem; investigation on transfer learning and pre-trained large networks.
3. Definition of final specific problem expected after first year.

Supervisors: Prof. Emanuele Trucco, Computing and Prof. Ewan Pearson, School of Medicine
Project Title: The Use of Optical Methods for in vivo Analysis of Oscillatory Components of Microvascular and Metabolic Signals in Cardiovascular Disease

Project Description:

Monitoring of patient health, such as heart rate and blood oxygenation are now commonplace but spectroscopic measurements of tissue properties can also be used to look for indications of disease long before the onset of symptoms. This project will use a range of spectroscopic techniques to look for oxidative stress, as a potential marker for cardiovascular disease, paving the way to early diagnosis and treatment.

Oxidative stress is an imbalance between the increased cell production of reactive oxygen species (ROS) and the ability of the cells to detoxify their harmful effects[1]. Increased oxidative stress can cause microvascular dysfunction, a pivotal phenomenon in the development and progression of cardiovascular disease (CVD) [2]. During oxidative stress there is an increase in the intracellular amount of NADH [1], an auto-fluorescent coenzyme, and it is possible to take advantage of this molecular property by using NADH as a natural biomarker for in vivo non-invasive real time monitoring of oxidative stress [1]. Measuring NADH auto-fluorescence from the skin (LFS), in combination with skin microvascular function evaluated by Laser Doppler (LD) imaging and tissue oxygenation, could prove to be a powerful diagnostic tool for the pre-clinical evaluation of cardio-vascular disease risk [2-4] (see fig. 1).

In this project we will use novel photon transport modelling techniques to better understand how probe light samples the tissue, in turn giving a better understanding of the limitations and capabilities of this approach. In combination with this modelling, the student will investigate the use of a range of different temporal components in the collected data to probe NADH oscillations, which may be related to glucose metabolism in conditions such as diabetes. In addition, the integration of NADH oscillations with the analysis of microvascular LDI oscillations may provide additional information on microvascular function, and help find novel cardiovascular risk markers.

Supervisors: Dr Mike MacDonald (Physics) and Professor Faisel Khan (Medicine)

Project Title: Transport and Fate of Microplastics in Coastal Sediments

Project Description:

Although marine litter and microplastics (MPs) (particles and fibres <5mm) have received considerable media attention recently, surprisingly little is known about their transport pathways and fate in estuarine and coastal sedimentary environments. Addressing these current knowledge gaps requires new physical insight into:

i. **fluid-MP interactions** at micro- and macro-scales that control the dynamic behaviour of different types of MPs (i.e. compositions, densities, shapes, etc.) under prevalent hydrodynamic forcing conditions encountered in estuaries and coastal marine waters (i.e. tidal currents and waves), and

ii. **MP-sediment interactions** that control the physical behaviour of MPs within, and their incorporation into, natural sedimentary systems within these aquatic environments.

In this context, precise details of these fluid-MP interactions, and the specific role they play in the settling, deposition, intrusion, partitioning and resuspension processes for MPs have not yet been explored to any real extent. The project therefore aims to address these knowledge gaps by combining:

a. **scaled, parametric laboratory experiments** in an existing oscillatory flow system and grid-stirred settling column facility (both Dundee) that permit a wide range of environmentally-realistic hydrodynamic and sedimentary conditions to be tested in a systematic manner, and

b. **laboratory analysis** of sediment cores from selected coastal monitoring sites throughout Scotland (e.g. Firth of Forth; Orkney; Eden estuary, Fife).

The benchmark laboratory studies will combine development of a new high-resolution visualisation technique with existing probe measurements to resolve the turbulent flow and concentration fields generated within both test facilities, thus providing detailed new physical insight into key fluid-MP-sediment interactions and their role(s) in determining the ultimate fate of the MPs. As such, the intrusion and partitioning behaviour of MPs in sediment bed deposits will also be quantified, for the first time, via 3D X-ray tomography.

The laboratory analysis of field sediment samples will be run in conjunction with researchers at Heriot Watt University, who are conducting ongoing research to ascertain the prevalence and composition of MPs found at different coastal sites. As well as informing the laboratory tests on environmentally-realistic MP concentrations, the collected field samples will be analysed to determine MP distributions in natural sediment deposits (e.g. intrusion depths and partitioning characteristics), again via 3D X-ray tomography for direct comparison with the laboratory experiments. The new physical understanding of fluid-MP-sediment interactions to be gained from the project will improve existing frameworks utilised to assess the risks posed by now-widespread MPs in coastal marine sedimentary environments.

**Supervisors:** Dr Alan Cuthbertson and Dr Yong Sung Park (Dundee), [Dr Mark Hartl and Prof Teresa Fernandes (Heriot Watt)]
Project Title: Use of Machine Learning and Computer Vision to detect Cerebral Microbleeds in SWI MRI

Project Description:

Small areas of bleeding in the brain, known as cerebral microbleeds (CMB), are emerging as important features of an aging brain. Not only are they a marker for unhealthy blood vessels associated with development of dementia, but they also indicate an increased risk of major bleeding in the brain. This is particularly a concern in the common situation where doctors need to use medicines that stop clots from forming, and therefore increase risk of bleeding, to prevent heart attacks and ischaemic strokes. Although CMB are common they are not checked for routinely in conventional commonly used brain scan techniques and can only be detected with a specialised modality of Magnetic Resonance Imaging (MRI) of the brain known as Susceptibility Weighted Imaging (SWI).

In this project we would like to develop automated image processing techniques to count the number and location of CMB's in the brain from MRI SWI images. This project is part of a larger programme of ground-breaking work being conducted in a partnership between the Computer Vision and Image Processing Group and clinicians at Ninewells Hospital exploiting advanced image processing techniques to improve risk assessment, the diagnosis and stratification of dementias. Existing work on this topic includes the use of mixtures of Gaussians [2], deep learning [3], and other machine learning classifiers [1]. One starting point would be to investigate the use of a 3D 'blob' detector [4] to automatically generate candidate CMB regions, followed by a machine learning classifier to detect the true positives.

Datasets and annotations are already in place. This is an excellent chance for a PhD candidate to develop AI algorithms for automated microbleed detection.

Skills the student will develop

- Deep learning skills and inter-disciplinary working experience highly desirable by industry
- Programming Skills with Matlab/Python
- Image processing skills
- Empirical analysis and interpretation skills
- Writing and presentation

Supervisors: Dr Jianguo Zhang, Computing), Prof. Stephen McKenna Computing and Alex Doney, School of Medicine

References:


Project Title: Wave Carpet: Protecting Coastal Zones against Sea-level Rise Impact, While Generating Clean Energy

Project Description:

A submerged carpet is a deformable plate, or elastic mat, that can be used to extract the wave energy, and for mitigation of large waves in coastal areas. A schematic view of the submerged wave carpet is shown in the below Figure. The principle concept of a wave carpet energy device is similar to that of propagation of waves over a muddy seafloor, where significant amount of wave energy attenuates due to the strong interaction with the mud banks. Similarly, a wave carpet is a mud-resembling deformable plate that can potentially extract the entire wave energy. The plate deformation can be transferred into electricity generation by a direct-drive power take-off system connected to the plate. The goal of this project is to solve the problem of interaction of nonlinear long-waves with the elastic submerged plate by use of the nonlinear Level I GN equations, and by use of an open source Computational Fluid Dynamics (CFD) software, namely OpenFOAM. Results will be compared with laboratory measurements that are currently performed at the University of California in Berkeley. The computational model will then be used for some specific sites to determine the potential energy output of the device, and to assess its efficiency in mitigating the severity of large waves.

![Figure: A schematic view of a wave carpet device.](image)

**Supervisors:** Dr Masoud Hayatdavoodi, Civil Engineering and Professor Ping Lin, Mathematics