PROJECT 1: Deep neural networks for omni-modality musculoskeletal (MSK) image analysis

Description:

The discovery of biomarkers requires accurate delineation of bone and tissues surrounding a MSK defect, but this is difficult because different types of images (x-ray, PET, CT, MRI) depict different characteristics. We will derive a computerised image segmentation algorithm to automatically delineate bones and musculature surrounding the defect, using state-of-the-art convolutional neural networks (CNNs) – a data-driven approach to identify the quantifiable image characteristics that are most relevant for a particular task – in this case, segmentation. The key challenge will be to train the CNNs across all image types (both functional and anatomical) to identify the correlations between them so that bones and muscles can be optimally delineated regardless of the image type. The outcomes will be techniques to improve diagnostic processes by allowing automated localisation and biomarker analysis of the anatomical defect sites.

Project eligibility:

Interest and experience in the area of image analysis algorithms.

Familiarity with image processing and/or biology would be beneficial.

For further information contact:

Associate Professor Jinman Kim in the School Information Technologies at: jinman.kim@sydney.edu.au, or by phone +61 2 9036 9804.

PROJECT 2: Advanced 3D visualisation of musculoskeletal (MSK) imaging

Description:

Clinicians and surgeons need to interpret imaging data for diagnosis and pre-surgical planning. However, viewing the images directly is not optimal because the defect has a non-trivial risk of being obscured by noise or being occluded by other structures. The project will involve research on 3D graphics optimisations to create an algorithm that exploits graphics processing hardware to enable 3D visualisation of the anatomical defect on a computer display. The outcome will be a new 3D visualisation algorithm that enables improved diagnosis and pre-surgical planning, by allowing clinicians to view the anatomical characteristics of the MSK defect without the noise and obstruction inherent in the medical images.

Project eligibility:

Interest and experience is in the area of image visualisation algorithms. Familiarity with 3D graphics programming (CUDA) or image processing would be beneficial.

For further information contact:

Associate Professor Jinman Kim in the School Information Technologies at: jinman.kim@sydney.edu.au, or by phone +61 2 9036 9804.

PROJECT 3: Novel 3D-printed scaffolds to promote spinal fusion

Description:

The current lack of appropriate bone substitute materials for spinal fusion applications is a major clinical problem. This project will develop a novel 3D-printed synthetic scaffold suitable for bone repair in spinal fusion, featuring both mechanical stability (for weight-bearing) and bioactivity (to regenerate the bone) – so far an extremely difficult combination to achieve. We have recently developed novel bioactive ceramics with exceptional mechanical properties and bioactivity, and suitable for use in bone repair. The aim is to produce 3D-printed bioactive ceramic scaffolds with optimised geometry, microstructure, and strength for use as bone substitutes in spinal fusion. The mechanical and biological properties of the scaffolds in spine fusion settings will be evaluated. Due to the unique characteristics of the material and ability to produce customised implants by 3D printing, the bone substitute will have potential to closely match individual patient needs and greatly improve long-term treatment efficacy.

Project eligibility:

Strong background in materials science, additive manufacturing and tissue engineering, with interest in medical product design and development.

Knowledge of 3D CAD system (preferably Solidworks and Mimic software), as well as the ability to conduct theoretical analysis and develop mechanical test protocols for different spinal implants.

Experience in spinal instrumentation product development is highly desirable but not mandatory.

For further information contact:

Professor Hala Zreiqat in the School of Aerospace, Mechanical and Mechatronic Engineering at: hala.zreiqat@sydney.edu.au, or by phone +61 2 93512392.

PROJECT 4: Quick-release, fail-safe connector between osseointegration implants and artificial limbs

Description:

Osseointegration implants have been developed over the past two decades as a new technology for mobilising patients with lower-limb amputations, offering improved function and quality of life over traditional socket prostheses. Currently, artificial limbs for osseointegration implants are connected through traditional mechanisms used in the socket prosthesis system, which involve rigid screws and bolts that limit the versatility of the implant. As osseointegration implants become more common, there is a pressing demand for an ideal connector system designed specifically to meet the requirements of individual patients. This project aims to develop a unique and cost-effective connector system between osseointegration implant and artificial limb to allow: (1) quick and easy release for the recipient to rapidly attach and remove the artificial limb as required, and (2) a fail-safe mechanism to prevent undesirable impact and strain passing through the implant site, and to protect residual bone from breakage in the event of a fall. This project will involve medical device design, biomechanics analysis, prototype construction and testing, with ample potential for translation of the developed product.

Project eligibility:

Strong background in computer-assisted design, finite element modelling, and biomechanics, with interest in medical device design and development.

For further information contact:

Professor Hala Zreiqat in the School of Aerospace, Mechanical and Mechatronic Engineering at: hala.zreiqat@sydney.edu.au, or by phone +61 2 93512392.

PROJECT 5: Optimisation of bone scaffolds by design of pore geometry to modulate permeability and diffusivity

Description:

An inherent problem for bone scaffolds is the limited ability to induce tissue ingrowth and angiogenesis at the centre. Permeability and diffusivity are the main design factors which can address these limitations, in addition to conventional parameters such as pore size, porosity, and interconnectivity. Permeability quantifies the ability of a porous scaffold to transmit fluid through its interconnected pores, while diffusivity indicates the spatial gradient of oxygen concentration within a scaffold. The effect of varying permeability and diffusivity on scaffold behaviour is little explored, and their role in modulating cell behaviour is unclear. We propose a unique method to design and fabricate bone scaffolds with optimised diffusivity and permeability, by altering strut and pore geometry through the combination of computational modelling and 3D printing. Designed scaffolds will be mechanically tested and their biological performance will be evaluated using bone-related cells.

Project eligibility:

Strong background in computational modelling and design, biomechanics, solid/fluid mechanics, and additive manufacturing.

For further information contact:

Professor Hala Zreiqat in the School of Aerospace, Mechanical and Mechatronic Engineering at: hala.zreiqat@sydney.edu.au, or by phone +61 2 93512392.

PROJECT 6: Implantable biosensors to monitor and stimulate tissue regeneration

Description:

Loss of bone density, reduced vascularisation, and muscle atrophy are limitations associated with osseointegration on large limbs in amputees. Recovery from surgery is slowed for want of a method to stimulate and monitor the regeneration of these tissues, and mechanical loading of the limb needs to be cautious due to the unknown bone porosity recovery status. This project will create new functionalised electrodes to detect changes in pH, leached materials, electrical signals, and biomechanical strain. These measurements will indicate factors that influence the healing process such as osteoporosis, implant fatigue, wear, and mechanical stimulation.

Project eligibility:

Strong background in biosensors and bioelectronics.

Familiarity with orthopaedic devices would be beneficial.

For further information contact:

Professor Alistair McEwan in the School Electrical and Information Engineering at: alistair.mcewan@sydney.edu.au, or by phone +61 2 93517256.

PROJECT 7: Smart dressings to diagnose, stimulate and monitor musculoskeletal tissue

Description:

Current bioinstrumentation for monitoring electrical properties of tissue is bulky and requires the use of gel electrodes that cannot be worn in the long term. This project involves designing an interface between smart dressings with conductive fibres and electrical devices. This project will involve simulation and development of electrical medical devices and interfaces using electrical impedance models and 3D-printed anatomically realistic phantom model with full electrical properties.

Project eligibility:

Strong background in biosensors and bioelectronics.

Familiarity with additive manufacturing would be beneficial.

For further information:

Professor Alistair McEwan in the School Electrical and Information Engineering at: alistair.mcewan@sydney.edu.au, or by phone +61 2 93517256.

PROJECT 8: Computational modelling and biomechanics for implant design

Description:

Additive biomanufacturing has enabled implantation in a true patient-specific basis, which has been seeing rapid growth in research and development and could potentially change prosthetic clinic in the near future. Additive biomanufacturing brings together a range of cutting-edge technologies, including medical imaging, biomaterials, biomechanics, advanced design and fabrication through computational modelling in a digitalised form. This project will work closely with clinicians and implant developers by developing novel computational modelling approaches to integrating these multidisciplinary areas for deliverable patient-specific prosthetic implants. Students will have the chance to explore high performance computing, 3D printing and bio-printing and clinical implantology.

Project eligibility:

Background and experience in some of the following areas: solid/fluid mechanics, biomechanics, biomaterials, computational methods, additive manufacturing, scientific programming and imaging processing.

For further information contact:

Professor Qing Li in the School of Aerospace, Mechanical and Mechatronic Engineering at: qing.li@sydney.edu.au, or by phone +61 2 9351 8607.