UNIVERSITY OF LEEDS

CANDIDATE BRIEF

PhD Studentships in Computational Medicine, Schools of Computing & Mechanical Engineering, Faculty of Engineering

Salary: £15,009, p.a.

Reference: CISTIB PhD Studentship

Closing date:

Fixed-term 36 months

PhD Studentships in Computational Medicine, Schools of Computing and Mechanical Engineering, Faculty of Engineering

Do you enjoy finding innovative solutions to unmet clinical needs and translating these innovations to the clinic? Do you have a passion for conducting world-class research and pushing the boundaries of medical technology? Do you have a background in mathematics, engineering, computer science, or the like? Are you ready to think out-of-the-box, innovate, and find solutions to challenging problems?

The Centre for Computational Imaging and Simulation Technologies in Biomedicine (CISTIB), within the Faculties of Engineering and Medicine & Health, comprises various academics and their research groups. It focuses on algorithmic and applied research on computational imaging, and image-based computational physiology and simulation. Its members work in close cooperation with clinicians from various research centres from the University of Leeds and the academic hospitals of the Leeds Teaching Hospitals NHS Trust, the largest NHS Trust of the UK.

CISTIB members have contributed to and made substantive innovations in various clinical areas, most notably the cardiovascular, musculoskeletal, and neural systems domains, where they have developed diagnostic and prognostic quantitative image-based biomarkers and methods and systems for interventional planning and guidance. Oncology is emerging as a further significant area of growth for the Centre. CISTIB hosts academic members from the University of Leeds, and Research Fellows, Research Associates, PhD Students, and Scientific Software Developers, forming a cross-disciplinary team committed to clinical translation of their innovations.

We have funding for up to 7 top tier PhD candidates to tackle challenging, clinically-driven problems, covering various aspects of medical image computing, including: machine learning, deep learning, population imaging analysis, biophysical model based imaging, and model personalization using large scale imaging data sets. The projects have clear clinical motivations and designed to address specific challenges associated with image-guided radiotherapy, computer aided diagnosis for early detection of cancer, outcome prediction for patients receiving treatments, etc. Hence, you will be provided with opportunities to innovate useful applied tools and contribute to the state-of-the-art core methodologies. To proceed you will require innovative

thinking, excellent maths and programming skills, outstanding team work, and flexibility to work within a group of international researchers. You will also have the opportunity to work closely with more senior researchers under guidance of your direct supervisor.

Description of the projects

1. **Bayesian Deep Atlases for Cardiac Motion Abnormality Detection from Imaging and Metadata:** Cardiovascular Diseases (CVDs) cause more than 26% of all deaths in the UK, costing over £15 billion each year. There is good evidence that a large array of CVDs can be diagnosed by an assessment of heart motion abnormalities. The motion of the heart is acquired using a cine CMR imaging technique, generating a sequence of images across a cardiac cycle at various slices through the heart. In this project, we will propose a scalable probabilistic approach for holistic motion atlas modelling from a big population data (UK Biobank Cardiac Imaging) comprising >= 20k patients. The motion will be modelled as the spatiotemporal (3D+t) sequence of the heart shapes across a full cardiac cycle, extracted from cine CMR images. The atlas will be a recurrent deep model that, given a cine sequence, will predict a probabilistic distribution function (pdf) for the next status of the heart. More importantly, the pdf will be conditional on the patient metadata (genomics, age, gender, lifestyle, etc.). Thus, by measuring the spatial deviations from the expected shape at each phase, it will allow accurate and personalised quantification of functional abnormality map. (contact: Dr Ali Gooya, a.gooya@leeds.ac.uk)

2. Deep learning for outcome prediction after pelvic radiotherapy: Modern radiotherapy is highly optimized with respect to individual patient anatomy, utilising 3D anatomical imaging for treatment planning and guidance. This optimization is, however, fundamentally based on underlying assumptions about the relationships between the radiation dose delivered to specific anatomical structures (tumours and normal tissue) and tumour control and/or treatment toxicity – relationships which are still not well understood. Outcome modelling - relating radiation dose to early and long-term patient outcomes – is consequently an extremely active field of research. In this project, we use machine learning to predict toxicity and tumour control after pelvic radiotherapy in Cross-sectional data from a population of patients. We will construct a probabilistic statistical atlas describing the spatial patterns of radiosensitivity across the whole population. We will also create patient-specific sensitivity maps to feed into treatment plan optimisation. To alleviate the problem of missing outcome classification data, we will machine learning, e.g. semi-supervised models and cycle GANs. (contact: Dr Ali Gooya, a.gooya@leeds.ac.uk)



3. **Deep learning for early detection of cancer recurrence in patients with glioblastoma through imaging:** Brain tumours are cancer of unmet need and are the most common cause of cancer death in under 40s. Glioblastoma is the most common primary adult brain tumour and carries one of the worst prognoses amongst human cancers, with a median survival time of about 15 months. The fundamental question to be answered in this project is: can deep learning be used for early detection and prediction of glioblastoma recurrence through imaging? To this end, we will extend the state-of-the-art using Bayesian recurrent variational auto-encoders (VAE) that will be conditioned on the patient meta-data. An LSTM-RNN will be trained to approximate the predictive distribution of the next set of MR images, given current images and patient meta-data. We will devise an end-to-end training mechanism that will jointly learn the encoding-decoding maps along with the predictions of the spatio-temporal maps. (contact: Dr Ali Gooya, a.gooya@leeds.ac.uk)

4. **Integrated biomechanical / AI-based motion models for adaptive radiotherapy:** A fundamental challenge for personalised radiotherapy (RT) is enabling regular in-treatment RT plan adaption to account for organ motions, e.g. due to respiration, peristalsis, and bladder/bowel filling. These motions diminish the accuracy of the RT delivery to target regions (tumours), meaning that significant treatment margins must be incorporated in the plans, with the certainty that normal tissues also will then receive elevated radiation exposure. This project's aim is to develop image-driven modelling approaches that can reliably predict tissue motion states from sparse, and in some cases low quality, images acquired during and between treatments. Such predictions could enable responsive adaption of RT plans, potentially allowing dose escalation in target regions, with simultaneous toxicity reduction in sensitive nearby tissues. We envisage a hybrid modelling approach for this purpose, that integrates biomechanical models of the relevant organs with AI techniques that can learn mappings between model configurations and corresponding images. This will ensure motion predictions are based on reliable physical and physiological principles, while enabling robust and efficient exploitation of information derived from images. The work will thus span computational biomechanics and machine learning / AI, while drawing heavily on medical image computing techniques, also. (contact: Dr Zeike Taylor, z.taylor@leeds.ac.uk)

5. **Accelerating computational fluid dynamics through deep learning:** Computational fluid dynamics (CFD) simulations have been proposed as a tool for the pre-operative evaluation and planning of cardio- and cerebrovascular diseases, such as brain aneurysms. By studying the changes in blood flow induced by pathological vascular defects and linking them to the biological response, we can attempt to predict the time course of the disease before and after treatment. However, CFD simulations are computationally expensive and clinical practitioners have neither



the training required nor access to the supercomputing resources needed to utilise such tools currently. In this project, we apply deep learning through convolutional neural networks to accelerate the fluid simulations by training the network to mimic the outputs of a traditional CFD solvers. Parametric virtual phantoms will be developed for various vascular diseases and the neutral network will learn dependency of the flow and related biological processes based on the parameters of the phantom geometry. Such models can then be translated into applications that provide real-time predictions of vascular flow and support clinical decision making. (contact: Dr Toni Lassila, t.lassila@leeds.ac.uk)

6. Novel cardiac phenotyping for population imaging and imaging genetics. Cardiovascular conditions like heart failure, coronary artery disease and structural heart disease manifest in alterations of the anatomy or deformation of the myocardium. Cardiovascular magnetic resonance (CMR) is increasingly recognised as the most accurate test for the non-invasive characterisation of the myocardium and provides a plethora of methods for detailed phenotyping. Many heart conditions have a genetic basis but their expression in cardiac functional phenotypes is highly variable. For example, family members of patients with inherited heart disease are often genotype positive but phenotype negative – when currently available testing methods and analyses are used. More sophisticated phenotyping methods will combine usefully with genetic testing. The aim of this study is to develop fully automatic cardiac image analysis methods providing detailed three-dimensional phenotyping of cardiac morphology and deformation, scaling up to hundreds and thousands of datasets in population imaging studies, and statistical methods that relate quantitative image phenotypes with genetics and omics data. The expected outcome is an improved understanding of their interplay and the development of more sensitive and specific patient stratification schemes and risk scores. This project will explore three main avenues: a) will undertake a detailed comparison of competing algorithms for CMR analysis applicable to population imaging studies and will use UK Biobank as testbed to carry out large-scale scalability tests; b) will develop new machine learning techniques for CMR analysis (e.g. methods exploiting available metadata and producing measures of uncertainty on their outputs); and c) will explore statistical methods for imaging genetics applied to CMR and accounting for uncertainty on the image-derived phenotypes. (Contact Prof A F Frangi, a.frangi@leeds.ac.uk)

7. Blue sky methods in machine and deep learning for medical image analysis at scale. This project is targeted to PhD student applicants with a strong technical background in computer science and mathematics who are interested to develop new blue sky methods in machine learning and deep learning in an inspiring environment. Unlike other projects with a stronger translational focus, this project has no a priori application domain but is challenge driven. We seek candidates with interest and background to tackle the following challenges: a) new machine learning techniques for medical image segmentation and registration at scale; b) new machine learning



approaches to handle uncertainty in inputs and outputs in regression and classification problems; and c) new approaches to manifold learning of spatio-temporal trajectories (Contact Prof A F Frangi, a.frangi@leeds.ac.uk).

Candidate Requirements. Successful candidates will have an excellent first degree in engineering, mathematics, computer science, or a related discipline. A solid mathematical background is essential, as are strong programming skills (in C++/Python/Matlab), and a keen interest in high-impact research work. The applicant's academic transcript and/or GPA will witness these. Previous experience in a research environment and a corresponding track record of publishing results in excellent journals and conferences are not essential but would be valued. The foregoing is in addition to standard entry requirements for University of Leeds postgraduate research programmes, that must always be satisfied (upper 2nd degree or higher, English competency, etc.)

What does the role entail?

As a PhD candidate, your main duties will include:

- Generating and pursuing independent and original research ideas in your subject area;
- Developing research objectives and, with supervisors, setting the direction of your research project;
- Where appropriate, helping to prepare proposals for funding, in collaboration with colleagues;
- Evaluating methods and techniques used and results obtained by other researchers and relating such evaluations appropriately to your own work;
- Preparing papers for publication in leading international journals and disseminating research results through other recognised forms of output;
- Working both independently and as part of a larger team of researchers, engaging in knowledge-transfer activities where appropriate and feasible;
- Maintaining your own continuing professional development and acting as a mentor to less experienced colleagues as appropriate;
- Contributing to the training of undergraduate and postgraduate (Masters) students, including assisting with the supervision of projects in areas relevant to your project;
- Comply with PhD studies processes and regulations at the University of Leeds;



- Set own goals, time-manage and proactive drive your PhD project, engaging with supervisors as and when needed;
- Proactively contributing to the life of the Centre, for example by engaging with, and where appropriate, helping to organise initiatives like scientific retreats, seminar series, public outreach events, and other activities that promote a collegial work environment and/or help to raise the Centre’s external profile

These duties provide a framework for the role and should not be regarded as a definitive list.

How to apply

Formal applications for research degree study should be made online through the university's website. Please state clearly in the research information section that the PhD you wish to be considered for.

Additional information

Faculty and School Information
Further information is available on the research and teaching activities of the Faculty of Engineering and the Schools of Computing and Mechanical Engineering.

A diverse workforce
The Faculty of Engineering is proud to have been awarded the Athena Swan Silver Award from the Equality Challenge Unit, the national body that promotes equality in the higher education sector. Our equality and inclusion webpage provides more information.

Working at Leeds
Find out more about the benefits of working at the University and what it is like to live and work in the Leeds area on our Working at Leeds information page.

Candidates with disabilities
Information for candidates with disabilities, impairments or health conditions, including requesting alternative formats, can be found on our Accessibility information page or by getting in touch with us at disclosure@leeds.ac.uk.

Criminal record information



Rehabilitation of Offenders Act 1974

A criminal record check is not required for this position. However, all applicants will be required to declare if they have any ‘unspent’ criminal offences, including those pending.

Any offer of appointment will be in accordance with our Criminal Records policy. You can find out more about required checks and declarations in our Criminal Records information page.