LONDON'S GLOBAL UNIVERSITY

Job Description

Research Fellow in Image-Based Cardiac, Pulmonary and Other Organ Computational Modelling

Grade: 7

Department: UCL Mechanical Engineering

Location: UCL Bloomsbury Campus

Reports to

Profs. Peter D. Lee and Ryo Torii

About the Project

Would you like to help generate, visualise, analyse, and model some of the world's newest and highest resolution bioimaging data of intact human organs and joints? A new Research Fellow position is available to join the team doing this, with your post having a focus on performing in situ image-based modelling using the world's highest resolution tomographic imaging of intact human organs (ex vivo). The images will be obtained using Hierarchical Phase-Contrast Tomography (HiP-CT, see https://mecheng.ucl.ac.uk/HiP-CT), providing 4D scans of intact organs, ex vivo, with near cellular (micron) resolution locally, and down to ca. 10 microns everywhere (bit.ly/HiP-CT-PW).

Not only imaging the anatomy at the highest resolution, HiP-CT offers a unique opportunity to biomechanically characterise the tissue within organs. This is achieved through quasi-static imaging across the length scales, enabling direct insights into physiological mechanisms such as the expansion and contraction of blood vessels and airways, and the effect of local tissue property change such as osteoarthritis (OA) on both soft and hard tissues in our joints.

The data set available – anatomical and biomechanical data across scales – is unprecedented and will facilitate modelling of fluid and solid mechanics, and interaction of them at different scales. The project is primarily aimed at developing novel computational methods/workflow to achieve that, and apply those in the context of key organ diseases, such as pulmonary and cardiac flows in health and disease. One typical example of disease where such interaction between flow and tissue mechanics play an important role is pulmonary hypertension. Computational modelling based on the unique data set from HiP-CT is expected to reveal the significance of interplay between flow and tissue, and between small and large vascular networks.

You will work with Research Fellows based at ESRF (the European Synchrotron) to perform stepped dynamic imaging to measure the properties of tissue and flow in situ. This will provide validation data, and hopefully new insights, into how the multi-scale anatomical and structural characteristics of heart muscle and vasculature affect the success of treatment, such as angioplasty.

The overall project is led by Peter D Lee, Claire Walsh, and Rebecca Shipley in the UCL Mechanical Engineering Department and Dr. Paul Tafforeau at ESRF (www.esrf.eu), together with an international set of collaborators. The overall HiP-CT project involves about twenty Postdocs and PhD students.

About the Location, UCL Mechanical Engineering at Bloomsbury Campus

At UCL Mechanical Engineering, we develop and apply core competencies to produce world-class research into a wider range of engineering challenges than most would imagine. UCL Mechanical Engineering has a strong track record in healthcare engineering, driven by almost a half of its academics associated with this field.

Located in central London, UCL has an ideal inter-disciplinary work environment with clinical partners in the key NHS hospitals such as UCL Hospitals and Great Ormond Street Hospital for Children. This is strongly supported by UCL-wide initiatives through the Institute of Healthcare Engineering (www.ucl.ac.uk/healthcare-engineering/) and NIHR Biomedical Research Centres (https://www.uclhospitals.brc.nihr.ac.uk/).

The project will be conducted also in close collaboration with ESRF that is the world's first 4th generation high-energy synchrotron, producing the world's brightest X-rays. It is a centre of excellence for fundamental and innovation-driven research in condensed and living matter science. Located in Grenoble, France, the ESRF

owes its success to the international cooperation of 22 partner nations. You will have opportunities to visit ESRF.

About the Collaborators

The project is an international interdisciplinary collaboration between scientists and mathematicians at UCL, ESRF and clinicians in Germany (Aachen, Mainz and Hannover), the UK and France, together with many other collaborators.

You will be working directly with Profs Peter D Lee, Ryo Torii, Rebecca Shipley, and colleagues in Mechanical Engineering on the image-based computational modelling of fluid, solid and their interactions. On the image segmentations, you will be working with Dr Claire Walsh and Prof. Danny Alexander and half a dozen RFs and PhD students developing Machine Learning Segmentation algorithms. You will also work with clinicians and medical experts, including Prof. Andrew Cook in the UCL Institute of Cardiovascular Science.

In addition to your core project, you will also be part of a Hub helping research groups worldwide learn and apply the HiP-CT technique to vast variety of physiological/pathophysiological challenges in the areas such as neurology (with the Harvard/MIT Martinos Centre), lung disease (with UCLH and Antwerp) and prostate cancer (with Aachen, Mainz and Hannover). You will help the continuous development of the Human Organ Atlas project (https://Human-Organ-Atlas.esrf.eu).

Context

Funded by the Chan Zuckerberg Initiative, you will be part of an International Collaboration to continue developing and applying Hierarchical Phase-Contrast Tomography (HiP-CT), a new imaging modality using the world's first 4th generation X-ray source located at the ESRF. The technique is capable of imaging whole, intact human organs at ca. 10 µm, zooming down to single cells at ~1µm, without physically sectioning the tissue. There are a number of scientific projects running concurrently, focusing on various human organs, and this project is to make the best out of those, primarily focusing on the heart. At the same time, this computational modelling project will be synergistic with the imaging projects and should also contribute to the development and application HiP-CT in the wider context, with Dr Paul Tafforeau, the ESRF lead of the overall project.

Main purpose of the job

This is an exciting opportunity to develop HiP-CT image-based computational models of physiological systems, especially blood and respiratory flow in interaction with the surrounding soft tissue. You will help segment images, working with ML RFs and PhD students. You will then develop and apply image-based models of blood and air flow, and tissue mechanics. You will use both 0D lumped parameter network and finite element/volume codes, simulating key dynamic physiological phenomena. You will validate these models via in situ digital volume correlation); using the 3D (and 4D) imaging data collected from HiP-CT at the ESRF.

The role will require close co-working with researchers from a range of backgrounds and disciplines, in a collaborative team.

HiP-CT is already proving to be a promising technique for understanding changes in angiogenesis in COVID-19 victims (see bit.ly/HiP-CT-paper05), helping demonstrate how angiogenesis can be altered. In cardiac applications, its helping interpret life-threatening heart arrhythmias and could further transform our understanding of dynamic changes in heart and lung microstructure. Your role will be to expand the applications, through experiment, image analysis and modelling.

Duties and responsibilities

- To develop and apply HiP-CT image-based models to simulate both tissue biomechanics and flow and interaction of them in multi-scaled vascular networks.
- To perform image segmentation using machine learning (ML) tools working with a team of ML/AI PDRAs and PhD students.
- To liaise and collaborate with a team of biologists, engineers, clinicians and imagers to develop biologically well-grounded models.
- To help perform in situ experiments with HiP-CT on large biological samples, with cardiovascular and musculoskeletal applications.
- To validate the models by applying imaging analysis techniques, including DVC.
- To develop systematic approaches for parameterisation and validation of computational models.
- To work with groups worldwide in the HiP-CT hub, training them to perform analysis of scans.
- To liaise and collaborate with biologists, clinicians to analyse and interpret the results.
- To maintain an awareness of research literature that is pertinent to the project.
- To disseminate the results in appropriate peer-reviewed journals, meetings, and conferences
- To prepare progress reports on research for funding bodies as required.
- To contribute to engagement activities, including both public and patient engagement, working with the broader research team.
- To help supervise MSc and PhD students.
- To contribute to the overall activities of the research team and Department as required.
- To contribute to engagement activities, including both public and patient engagement, working with the broader research team.

Person Specification

Criteria	Essential or Desirable	Assessment method (Application/Interview)
Qualifications, experience and knowledge		
• PhD in a relevant discipline (e.g. bio-mechanical or other engineering, computational biology, mathematics, biophysics)	Essential	Application
• Experience in the use of image-based modelling, ideally both 3D (finite element/volume) and 0D lumped parameter network models	Essential	Application, Interview
• Understanding of computational solid and fluid mechanics, and their application in biomedical context	Essential	Application, Interview
• Experience in large data handling	Desirable	Application, Interview
• Experience in x-ray imaging, ideally synchrotron tomography experiments with biological systems	Desirable	Application, Interview
Skills and abilities		
• Ability to segment and mesh 3D imaging data, ideally biomedical	Essential	Application, Interview
• Ability to perform computational simulations that are biologically motivated and useful	Essential	Application, Interview
• Ability to programme enhancements to image analysis, segmentation and modelling codes	Essential	Application, Interview
• Ability to perform, understand and interpret statistical analysis techniques	Essential	Application, Interview
• Effective written and verbal communication skills, which can be adapted to a range of audiences	Essential	Application, Interview
Personal attributes		
• Willingness to work collaboratively, within a team	Essential	Interview
• Commitment to high-quality, interdisciplinary research	Essential	Application, Interview
• Commitment to UCL's policy of equal opportunity and the ability to work harmoniously with colleagues and students of all cultures and backgrounds	Essential	Interview