



Ph.D. position in applied mathematics

Background

We are looking for a Ph.D. student in applied mathematics on a project at the *intersection of computational and applied linear algebra and signal reconstruction for biomedical engineering applications*. The student would be situated in the School of Mathematics at Trinity College Dublin supervised by Professor Kirk M. Soodhalter. This project is in collaboration with a biomedical engineering team focusing on neurophysiology and neural signal analysis, based in the Academic Unit of Neurology, Trinity College Dublin (led by Dr. Bahman Nasserroleslami). The overarching project is multidisciplinary and focuses on the analysis of the brain activity and connectivity in health and disease, but this Ph.D. position is focused on the mathematical component and requires an applicant with a strong applied mathematical background, with the goal of earning a Ph.D. in mathematics.

The person obtaining this Ph.D. would be well-positioned, with a broad set of skills and knowledge, to pursue academic, research, and industrial jobs. This work involves applying hard mathematics to a project which will have eventual applications in diagnosis of neurological diseases, precision medicine, data analytics for drug development and next-generation medical devices.

Subject Description

The study of the brain, including cognitive function, sensory perception, motor and movement control relies considerably on the tools that can record or image the neural activity during functional tasks. The neuro- electrophysiological recordings provide a rather direct measurement of the neuronal activity and provide excellent temporal resolution, making them ideal measures for studying the normal function, as well as the impairment in neurological conditions for diagnosis, prognosis or as outcome measures of therapeutic interventions. The relationship between the activity of brain sources and the sensor (electrode) readings has been established by Boundary/Finite Element and Finite Element Modelling (BEM/FEM) of the electrical conduction differential equations in 3D brain models (found by MRI imaging). This leads to mapping from the source space to sensor space (e.g. a 10,000-to-128-dimensional mapping), described as a linear matrix equation.

These underlying mathematical problems arising here are examples of ill-posed inverse problems. The solution of inverse problems which are ill-posed is a core problem that often arises in a variety of computational sciences and engineering. These problems arise in diverse scientific applications, such as image reconstruction, astronomy, adaptive optics, tomography, medicine, and applied physics.

The application of state-of-the-art iterative methods (such as Krylov subspace methods) from numerical linear algebra has enabled the fast and efficient solution of a range of such problems from crucial real-world applications. Generally speaking, one starts with a complicated high-dimensional or even infinite dimensional mathematical model of some

scientific process. One may use such a model to simulate a scientific process or (as in this case) to describe the transformation from the unobservable information/signal/image to the measurements one is able to make using instruments. These problems are projected down onto some subspace and solved efficiently there, with this smaller solution being mapped back to the original problem space to serve as an approximation of the solution. Analysis of how this process is performed for the brain source mapping problem is crucial to understanding the effectiveness of current techniques as well as how they may be improved.

Duties

The Ph.D. student will work in collaboration to develop new mathematical foundations to exploit the structures in the neural time series (EEG) in order to develop efficient new iterative methods for realistic mapping of the sensor-space EEG activity to the underlying brain source.

The work involves the following tasks:

- Gain a full mathematical understanding of the existing (BEM/FEM) model of the electrical conduction differential equations in 3D brain models
- To use iterative solution techniques to access the activity of the brain sources that are typically less-accessible by the existing non-iterative methods.
- To find new regularisation methods using penalty functionals that are directly defined based on the brain's neuroelectric behaviour
- Develop techniques to apply an inverse mapping on the data which preserves important structural characteristics of the data
- Analyse potential new reconstruction techniques using analytic tools for regularization operators.
- Contribute to/produce peer-reviewed publications and open toolboxes for EEG/MEG source analysis

The PhD studies at Trinity College are conducted over a 3- to 4-year period, fulltime, and involve engagement with undergraduate tutorial delivery. Two years of funding are available for this position, generously supported by a Provosts PhD Project Award; PI Soodhalter and PhD student will apply for funding to support the remainder of the project. Both EU and non-EU fees can be covered for this position. This position is available to potential students worldwide.

Qualifications

Eligible candidates for the position must have a Masters or equivalent degree in mathematics. The candidate is expected to have a solid background in applied mathematics with experience in numerical analysis, numerical PDEs, integral equations, multivariate statistics/linear algebra, and inverse problems. Having done a Masters thesis, bachelors project, or other such work in inverse problems or a related field would be an asset, and strong consideration will be given to such candidates.

Remuneration

€25,000 per annum plus Trinity student fees: the position is open to EU and non-EU students alike.

Information

Entrance to position: Preferably September 2024

For more information please contact: Kirk M. Soodhalter, ksoodha@maths.tcd.ie.

Application

Application packages need to contain a CV, a letter of motivation, copies of degree certificates, and relevant course transcripts along with contact details of at least two academic referees. Mark your application with the reference number #TCDMathNeuro. The candidate must have, or soon receive, a degree that permits him/her to enter a Ph.D. program. This might be a Masters degree, a "Diplome", an Honours Bachelor or 4-year Bachelor, or equivalent. Candidates need to graduate before 1. September 2024. By the time of appointment, candidates will have shown evidence of English language proficiency (test certificate).

Deadline

Rolling: the position remains open until filled

Trinity College Dublin, The University of Dublin

Trinity is Ireland's premier university, with a proud tradition of excellence stretching back to its foundation in 1592. The oldest university in Ireland, and one of the oldest in Europe, today Trinity sits at the intersection of the past and the future, and is ideally positioned as a major university in the European Union. Our 47-acre campus is located in the heart of Dublin city centre and is home to historic buildings dating from the University's establishment, as well as some of the most cutting-edge teaching and research facilities in Ireland. The pursuit of excellence through research and scholarship is at the heart of a Trinity education, and our researchers have an outstanding publication record and strong record of grant success.

One of the most instantly recognised parts of Trinity's campus is the famous Old Library, home to the historic Book of Kells as well as other internationally significant holdings in manuscripts, maps, and early printed material. Trinity's Library is the largest research library in Ireland and is an invaluable resource to Trinity's students and research community. Built up over the four centuries of the University's existence, the Library's collections have benefitted from its status as a Legal Deposit library for the past 200 years, granting Trinity the right to claim a copy of every book published in Ireland and the UK. At present, the

Library's holdings span approximately 4.25 million books, 22,000 printed periodical titles, and access to 60,000 e-journals and 250,000 e-books.

Trinity's Ranking

- Trinity College Dublin is Ireland's No.1 University - QS World University Ranking 2023; Times Higher Education World University Rankings 2022
- Trinity is ranked 81 in the World by the QS World University Ranking 2024
- Trinity is ranked 134 in the World by the Times Higher Education World University Rankings 2024
- Trinity is ranked 43 in the world for international outlook - Times Higher Education 2022