

PhD Project Description

Project Title: Neural Physics for Inverse Modelling of Surface Electromyography

Supervisors

Lead Supervisor: Claire Heaney

Co-supervisor(s): Christopher Pain

Research Group – Applied Modelling and Computation Group (AMCG)

The PhD student will be based in **AMCG**, an interdisciplinary research group focused on the development and application of innovative computational and mathematical modelling techniques across earth, nuclear, environmental and biomedical engineering and science. The group provides a broad interdisciplinary environment spanning mathematical modelling, numerical computation, scientific machine learning, high-performance computing, parameter estimation, data assimilation and optimisation.

A recent focus of AMCG has been the integration of physics-based numerical methods within machine learning frameworks. The group has pioneered **Neural Physics**, a novel differentiable and platform-agnostic PDE solver that solves discretised systems exactly. Neural Physics exploits the mathematical correspondence between certain numerical discretisations and convolutional operations, enabling, for example, multigrid solvers to be recast as U-Net architectures whose weights are determined analytically

Project Summary

Surface electromyography (sEMG) provides a non-invasive way of measuring the electrical activity of muscles using electrodes placed on the skin. However, interpreting these measurements to determine the underlying properties of tissues such as muscle, fat, bone and skin is a challenging inverse problem. Developing reliable computational methods for recovering tissue properties from sEMG measurements could provide useful information about muscle health without the need for invasive procedures.

This project will develop a computational framework for estimating tissue conductivity and geometry from surface electrical measurements. The research will use the **Neural Physics** approach to provide a differentiable solver for the underlying electrical conduction problem, allowing gradients to be propagated through the numerical solution and used to iteratively optimise unknown tissue parameters. The initial work will generate synthetic sEMG measurements from prescribed tissue properties and then investigate how accurately the underlying parameters can be recovered from noisy surface measurements.

Research Context and Objectives

Surface electromyography provides a non-invasive means of measuring electrical activity generated by muscle fibres. The measurements obtained at electrodes on the skin, however, depend on the electrical properties and geometry of the tissues through which the electrical signal propagates. Recovering these underlying properties from surface measurements is therefore an inverse problem. The forward problem can be described using a quasi-static approximation to Maxwell's equations, resulting in a Poisson partial differential equation for

the electrical potential, with tissue conductivity entering the governing equation as a spatially varying parameter.

The **Neural Physics** framework provides a way of making this inverse problem computationally tractable. The numerical discretisation of the governing PDE is expressed using differentiable operations, allowing gradients to be propagated through the solver. This means that derivatives of a measurement misfit with respect to the unknown tissue parameters can be calculated directly and used within an optimisation procedure. In the proposed workflow, a multigrid solver provides the forward solution while an outer optimisation loop updates estimates of tissue conductivity and geometry.

The project will investigate the following key questions:

- How accurately can tissue conductivity and geometry be recovered from surface electrical measurements?
- How robust is the inversion to measurement noise and modelling assumptions?
- How can the computational framework be extended towards realistic biomedical applications?

Collaborators and partners on the project:

We collaborate with the Department of Bioengineering and Imperial-X on this topic.

Further reading:

[1] D Farina, L Mesin, S Martina, R Merletti (2004) [A surface EMG generation model with multilayer cylindrical description of the volume conductor](#), IEEE Transactions on Biomedical Engineering, 51(3):415–426.

[2] K Maksymenko, AK Clarke, I Mendez Guerra, S Deslauriers-Gauthier, D Farina (2023) [A myoelectric digital twin for fast and realistic modelling in deep learning](#), Nature Communications, 14:1600.

[3] B Chen, CE Heaney, CC Pain (2026) [Neural Physics: Using AI Libraries to Develop Physics-Based Solvers for Incompressible Computational Fluid Dynamics](#), Computers & Fluids, 308:106981.

[4] R Huang, CE Heaney, M van Reeuwijk (2026) [Parameter estimation for land-surface models using Neural Physics](#), Geoscientific Model Development, 19:8801–8814.

Who are we looking for?

We are looking for a student interested in environmental flows with a strong mathematical and computational background and a good degree in, for example, mathematics, physics, computer science, bio-engineering or earth sciences. Experience in programming, numerical modelling, scientific computing or machine learning would be advantageous, although applicants with a strong mathematical foundation and a willingness to learn are encouraged to apply.

The student will develop expertise in numerical modelling, scientific machine learning, inverse problems with application to biomedical imaging. There will be opportunities to present at conferences, publish in scientific journals and interact with collaborators within and beyond ESE.