Title

Heart-PINNs: Using Physics-Informed Neural Networks to Characterize Cardiac Properties

Organizers/Confirmed Speakers

Dr Marta Varela (MV), City St George's University of London & Imperial College London, UK

Annie Ching-En Chiu (AC), Imperial College London, UK

Dr Francisco Sahli Costabal (FS), Pontificia Universidad Católica de Chile, Chile

Dr Cian Scannell (CS), Eindhoven University of Technology, Netherlands

Dr Simone Pezzuto (SP), Università degli Studi di Trento, Italy

Workshop Description

PINNs are an increasingly popular deep learning framework that explicitly incorporates physical equations into the data learning process. PINNs approximate a solution to a given physical process which simultaneously agrees with the known data and conforms to the known equations and associated boundary/initial conditions.

By incorporating mechanistic knowledge into their loss function, PINNs can learn from much smaller amounts of data than conventional neural networks (NNs). Moreover, they can be constructed to be consistent with the known physics laws, making them more trustworthy than conventional NNs.

In the cardiovascular field, PINNs have been used for simulation of physiology and pathophysiology, inverse estimation of cardiovascular parameters, characterization of pathology and high-resolution analysis of cardiac signals and images.

The tutorial will:

1. Introduce the PINNs technique and research using PINNs for cardiovascular applications, focusing on their unique advantages and potentialities for cardiovascular problems.

2. Demonstrate how PINNs can be used in forward mode to solve ordinary and partial differential equations in cardiovascular science, and in inverse mode to estimate model parameters.

3. Present the latest developments in PINNs which address some shortcomings of its earlier formulations.

4. Discuss opportunities and challenges for PINNs in cardiovascular science, especially in the context of clinical applications.

For this, we plan to complement oral presentation sessions with Python-based tutorials to demonstrate how to implement PINNs in practice. By the end of the tutorial, attendees should understand PINNs, be familiar with some of its applications in cardiovascular science, be able to implement it in code, and appreciate its advantages, shortcomings and potential.

For this tutorial, we will build on the materials created for a tutorial on "PINNs for Medical Imaging" successfully presented at MICCAI 2024 by two of the applicants – see https://annien094.github.io/PINNs-tutorial-MICCAI-2024/.

Tentative Schedule

Talk: Introduction to PINNs (MV)

Talk: PINNs for Myocardial Perfusion (CS)

Practical: Write your own PINNs code (AC)

Talk: Image Registration with PINNs (FS)

Talk: Identifying Cardiac Fibre Orientations with PINNS (SP)

Talk: The Future of PINNs (MV)

Preferred Duration and Date

Half a day, preferably on Thursday, but Sunday is also possible.