Niall Madden (Niall.Madden@UniversityOfGalway.ie)

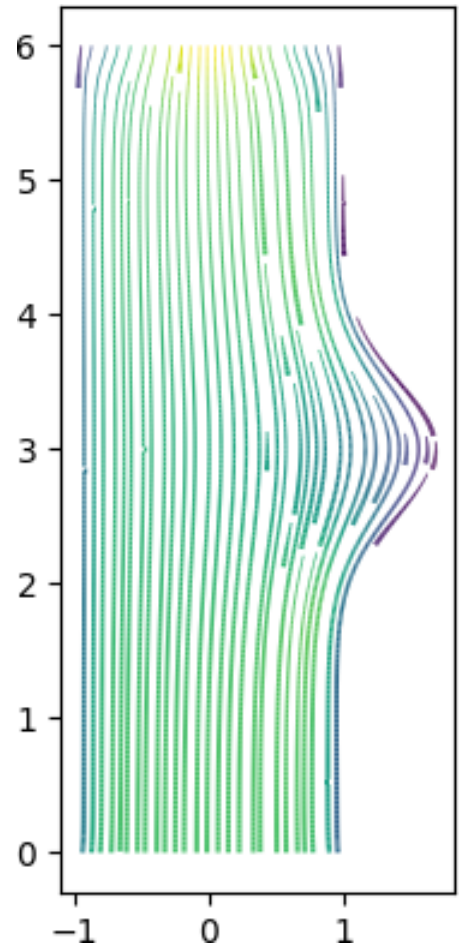
Final Year Project Ideas, 2025/2026

I'm looking forward to supervising any project in the area of **computational mathematics**, and, in particular, algorithms for

(a) solving differential and integral equations

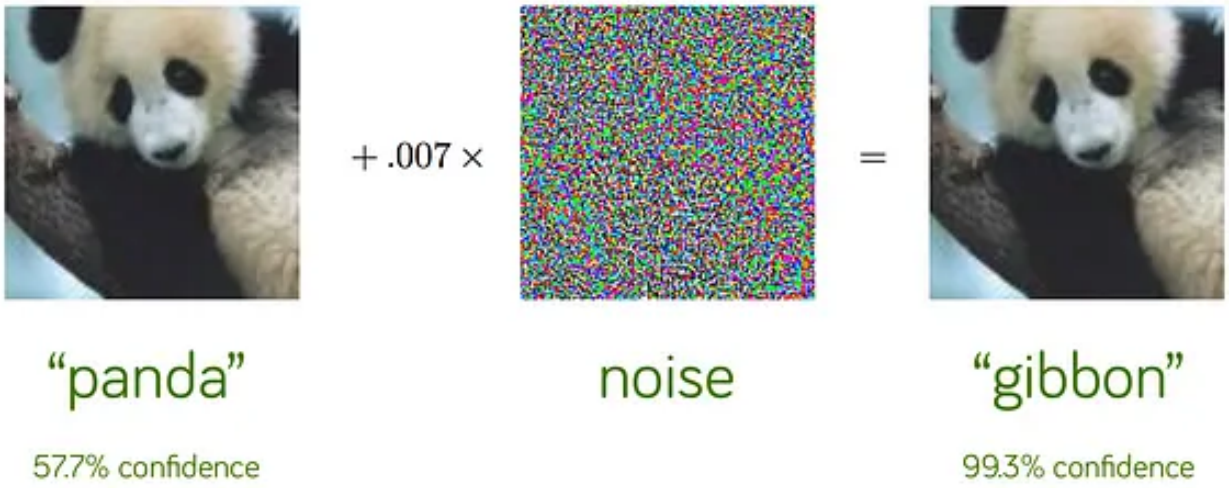
(b) solving linear systems, and/or estimating eigenvalues of large matrices

Such projects will probably involve some coding (e.g., in Python, Julia, R, MATLAB, whatever), at any level.
Can be motivated by theoretical considerations, or applications (e.g., fluids or finance).



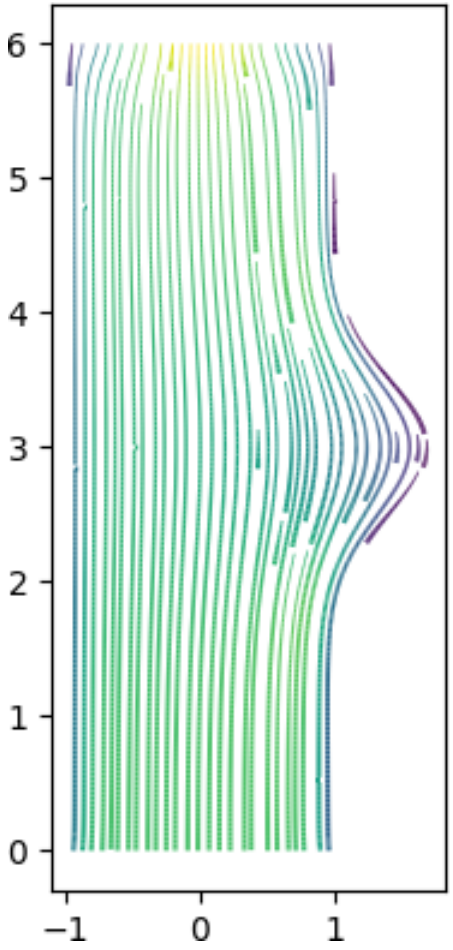
A simple model of an aortic aneurysm, computed with Firedrake/Irksome

1. Adversarial attacks for classifiers



Neural networks can be excellent classifiers, for example learning how to recognise an image of a panda, given a large enough training set.
However NNs are also susceptible to *adversarial attacks*: small, almost imperceptible changes to the training set which makes the NN far less reliable.
In this project, we'll learn about such attacks, from sources such as `https://arxiv.org/html/2309.03665v2` (Higham, 2025), as well as methods for trying to guard against them.
This project can involve quite a lot of computer science and coding, but may also include some advanced mathematics (and theorems!) should you like.

2. Time Integrators for Finite Element Methods



Finite element methods for solving PDEs have been around since the 1950s. Runge-Kutta method for solving time-dependent problems are even older. But both (and especially KR methods) are having a *renaissance* thanks to general purpose, open source libraries like Firedrake and FEniCS.
This project will focus on examining somewhat neglected RK methods – thought to be cumbersome to implement – but which now can be easily employed thanks to the Python Irksome package, originally developed one of our graduates, Patrick Farrell:

- Farrell et al (2020)
  https://arxiv.org/abs/2006.16282
- MacLachlan (2025)
  https://www.arxiv.org/abs/2508.20255

3. Cluster analysis of Irish election results (FY)

Cluster analysis relates to a set of tools for grouping subsets of objects together based connections between them expressed in, say, a network.

In this project we'll encode results from recent (and maybe current!) elections as a network, with transfers between candidates representing connections. Based on that we'll attempt to cluster candidates together. Our goal will be to try to reach an understanding of how the electorate clusters candidates.

The project will involve some mathematics, statistics, computing. And quite a bit of election nerding.

Other sources of projects:

- Mathematical modelling of computer game dynmics, e.g., Evan Freeland (2025) **Population Models of Minecraft Sheep**. https://www.tandfonline.com/doi/full/10.1080/0025570X.2025.2477425?src=
- Catherine Higham, et al. (2025) *Diffusion Models for Generative Artificial Intelligence: An Introduction for Applied Mathematicians*. https://arxiv.org/abs/2312.14977
- Cónall Kelly (2024). **Computation and Simulation for Finance**: An Introduction with Python.