Internship proposal

Title : PINNs [1] models for optimal control strategies of structured epidemiological models.

Co-supervision :
Didier GEORGES, Grenoble-INP, GIPSA-lab
Infinity team
didier.georges@gipsa-lab.grenoble-inp.fr
http ://www.gipsa-lab.grenoble-inp.fr/user/didier.georges/

Clémentine PRIEUR, Université Grenoble Alpes, Laboratoire Jean Kuntzmann,
AIRSEA team / Inria project
clementine.prieur@univ-grenoble-alpes.fr
https ://ljk.imag.fr/membres/Clementine.Prieur/

Keywords : complex dynamical systems, compartmental models in epidemiology, physics-informed neural neural networks, optimal control.

Required level : Master 2 internship or engineering school internship.

Required skills : numerical methods for PDEs, control theory and/or neural networks neural networks, Python programming skills . . .

Internship summary :

The aim of the project is to develop optimal control strategies for a structured compartmental system. The case study is a propagation model of the recent Covid-19 pandemic, taking into account loss of immunity and vaccination. It is a dynamic compartmental model with distributed parameters of the 2D advection-reaction type (1 dimension linked to the age of immunity and 1 dimension linked to the age of infection). Each compartment corresponds to a health status (susceptible, exposed, infectious, recovered, vaccinated, hospitalized, deceased). Model trajectories are simulated using a semi-implicit numerical scheme in time.

In order to derive an optimal vaccine control strategy, we define a cost function to be minimized. Evaluating the cost function at a point requires solving the direct system and its adjoint. Most optimization algorithms require numerous evaluations of the function to be optimized. For this reason, the main objective of the course is to speed up each evaluation by approximating the cost function with a neural network.

Traditional neural networks have a number of limitations : multiple possible solutions, failure to take into of physical phenomena and need for a large learning base. The PINNs (Physics-Informed Neural Networks in [1]) represent a new class of neural networks that hybrids machine learning and physical laws. In our context, where the equations equations governing the propagation of the epidemic are explicit, it seems interesting to optimize the cost function by learning a neural network belonging to the PINN class.

It is important to emphasize that the scientific approach we propose is generic and could be be transposed to other application domains involving complex dynamics governed by potentially non-linear equations.

Reference :

[1] M. Raissi, P. Perdikaris, and G. E. Karniadakis. Physics-informed neural networks : A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. *Journal of Computational physics*, 378 :686–707, 2019.

1. Physics-Informed Neural Networks