Parareal Physics-Informed Neural Networks for Transient Electromagnetic Field Problems

TECHNISCHE UNIVERSITÄT DARMSTADT

B.Sc./M.Sc. Thesis, Project/HiWi Work, Internship
Electrical Engineering, Computational Engineering
Start: Immediately or upon agreement

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Description

Artificial Neural Networks (NNs) have provided transformative results in numerous and diverse engineering domains, e.g. image processing or pattern recognition. In recent years, NNs have also been utilized for solving Partial Differential Equations (PDEs). Therein, one of the most popular approaches are Physics-Informed Neural Networks (PINNs) [2].

A major drawback of PINNs is the computational cost arising due to the use of large datasets and NNs with many degrees of freedom. As a remedy, a recent work has proposed a combination of the Parareal and PINN algorithms, resulting in a method referred as PPINN [1]. The PPINN algorithm splits long-time problems into many independent short-time problems, supervised by an inexpensive and fast coarse-grained conjugate gradient solver. The benefit of PPINN is that it decreases the computational cost of training a DNN by reducing the size of the training set and the number of d.o.f.s per network.

The task of the thesis is to implement the PPINN algorithm to a suitable, transient electromagnetics problem, a test case that has not appeared in the literature so far. A comparison against standard PINNs will complement this work.

Tasks

- Literature study on artificial NNs, PINNs and the Parareal algorithm.
- Familiarization with Tensorflow and/or PyTorch.
- Implementation of the PPINN algorithm and application to transient electromagnetic field problems.
- Evaluation of results, comparison against standard PINNs in terms of convergence rate, accuracy, and computational cost.

Prerequisites

Basic knowledge of electromagnetic field theory, experience in python (or willingness to learn it), interest in machine learning.

[1] X. Meng, Z. Li, D. Zhang, and G. E. Karniadakis. “PPINN: Parareal physics-informed neural network for time-dependent PDEs”. In: *Computer Methods in Applied Mechanics and Engineering* 370 (2020), p. 113250.

[2] 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”. In: *Journal of Computational Physics* 378 (2019), pp. 686–707.