Chair of Aerodynamics and Fluid Mechanics
TUM School of Engineering and Design
Technical University of Munich

Benchmarking the Current State-of-the-Art in Reservoir Computing

Bachelor's Thesis

Data-driven predictive modeling has for a long time been a farfetched goal of computational scientists in many fields. Where reduced models attempt to construct faster models by reducing the order (ROMs), reducing the modes (DMD), or simulating on a latent dimension with less resolution (NODE), data-driven predictive modeling attempts to train surrogate models, often neural networks nowadays, to predict the future time-evolution of the physical problem in a data-driven fashion without pre-reducing the order, modes, or similar. Reservoir Computing is one of the most prominent, and exciting of these data-driven predictive models. It is closely related to recurrent neural networks, which originate from natural language processing, and works by feeding an input signal into the "reservoir", which is at its core a black-box algorithm with fixed parameters and structure. The output of this black-box algorithm is a latent vector of predefined size, which is then transformed by a readout neural network to the desired output. The core idea here is that if the reservoir is chosen wisely, e.g. containing loosely physics-based updates, the readout neural network can be trained in a data-efficient fashion and much faster than traditional and competing end-to-end neural network approaches. However, most of the current successes of reservoir computing lie in relatively simple physical systems.

In this thesis, we will develop a unified PyTorch-codebase for reservoir computing, based on previous work, and benchmark & probe reservoir computing's performance on Fluid dynamics systems of ever-increasing complexity.

Tasks:

- Begin with the codebase of *"Next Generation Reservoir Computing"* and familiarize yourself with its layout, and data pipeline to apply it ever more difficult fluid dynamics problems.
  - Burgers
  - Kuramoto-Sivashinsky
  - Fluid flow around a rotating cylinder
- Extend the codebase to be able to benchmark different reservoir computing approaches against each other

Requirements:

- Ability to work independently.
- First attempts at playing with PyTorch are beneficial.
- Curiosity to experiment with the approaches, and latent curiosity to dig deeper to understand the strengths and weaknesses of the approach on Fluid Dynamics problems.

Contact: Artur Toshev artur.toshev@tum.de

Ludger Pähler ludger.paehler@tum.de