Chair of Aerodynamics and Fluid Mechanics
TUM School of Engineering and Design
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Noether Networks for Fluid Mechanics

Bachelor's Thesis

Predictive modelling in fluid mechanics has been a focus of many research threads for a long time. This began as exercises in dimensionality reduction by identifying the dominating modes, or reducing the order of the model by linear-algebra-based decompositions. These classical techniques have in recent years been succumbed by machine learning-based approaches. The most prominent of these began by imposing the functional form of the problem at hand on the loss function of the machine learning model, and subsequently began to embed more and more knowledge about the problem structure into the model, such as the translational equivariance imposed by constructions based on convolutional neural networks. To move beyond just translational equivariance, and gain more flexibility with respect to the to-be-embedded equivariances and conservation laws, modern-day research has moved attemps to directly identify these equivariances from data, and construct predictive models based on the found equivariance relations / conservation laws.

In this thesis we will build on *Noether Networks: Meta-Learning Useful Conserved Quantities* to extend the approach to fluid dynamics problems and attempt to enforce the physical biases found in fluid dynamics. Noether Networks loosely build on Noether's theorem, which states *"For each continuous symmetry, there is a corresponding conserved quantity in time"*, where one neural network is used to generate a time-series, and a second network attempt to compute the conserved quantities at every time instance. In this fashion the two networks manage to implicitly learn the conserved quantities and conserve them. First familiarizing yourself with the PyTorch code, you will then utilize some of our existing datasets to train models which can autoregressively reconstruct the time evolution of the problems. We will begin by first considering the fluid flow around a rotating cylinder, to then later consider Kolmogorov flows of different configurations.

Tasks:

- Apply the existing Noether Networks framework to fluid-dynamical problems.
    - Fluid flow around a rotating cylinder
    - Kolmogorov Flows
- Investigate the limitations of the Noether Network framework, and identify its weaknesses when applied in practice
    - Have large library of Fluid Dynamics datasets for such purposes

Requirements:

- Ability to work independently.
- Knowledge of PyTorch
- Curiosity to experiment with neural network models to optimize hyperparameters, optimize training outcomes, and find failure modes

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