Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

AI in the Sciences and Engineering **Spring Semester 2024**

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Project 3

Due date: Wednesday 26 June 2024, 23:59

The main objective of the project is to apply the concepts learned in class related to Neural Differential Equations and Hybrid Workflows.

1. Inverted pendulum

The objective of this task is to control the inverted pendulum problem using a Neural Network. The inverted pendulum is a classic problem in control theory, where the goal is to balance a pendulum in an upright position by applying an external force F to the cart that holds the pendulum. The system is described by the following differential equation:

$$(M+m)\ddot{x} + ml\ddot{\theta}\cos(\theta) - ml\dot{\theta}^2\sin(\theta) = Fl\ddot{\theta} + g\sin(\theta) = 0 \tag{1}$$

where θ is the angle of the pendulum with respect to the vertical, $g = 9.81$ m/s^2 is the acceleration due to gravity, $l = 1.0$ m is the length of the pendulum, $m = 0.1$ kg is the mass of the pendulum, $M = 1.0$ kg is the and F is the force applied to the cart in Newtons.

Solving the coupled ODE system

First, we need to solve the coupled ODE system to simulate the dynamics of the inverted pendulum. I used Runge-Kutta 4th order method to solve the system. First we simulated the system with a sinusoidal force $F(t) = 10\sin(t)$ and

Learning to balance the pendulum

2. Task 2

3. Bonus Task

References

[1] Boris Bonev, Thorsten Kurth, Christian Hundt, Jaideep Pathak, Maximilian Baust, Karthik Kashinath, and Anima Anandkumar. Spherical fourier neural operators: Learning stable dynamics on the sphere, 2023.

[2] Jean Kossaifi, Nikola Kovachki, Zongyi Li, and Anima Anandkumar. Training a sfno on the spherical shallow water equations. `https://neuraloperator.github.io/neuraloperator/dev/auto_examples/plot_SFNO_swe.html`, 2024. Accessed: 2024-05-20.

[3] Zongyi Li, Nikola Kovachki, Kamyar Azizzadenesheli, Burigede Liu, Kaushik Bhattacharya, Andrew Stuart, and Anima Anandkumar. Fourier neural operator for parametric partial differential equations, 2020.

[4] Bogdan Raonić, Roberto Molinaro, Tim De Ryck, Tobias Rohner, Francesca Bartolucci, Rima Alaifari, Siddhartha Mishra, and Emmanuel de Bézenac. Convolutional neural operators for robust and accurate learning of pdes, 2023.