Implementation of Neural Models for Accurate Prediction of Robot Trajectories in Hamiltonian Spaces: A Graph Neural Network Approach

Implementierung von neuronalen Modellen zur präzisen Vorhersage von Trajektorien in Hamiltonschen Räumen: Ein Ansatz mit Graph-Neuronalen Netzwerken,

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Abstract

The introduction of the adjoint method for NeuralODEs[1] has created new ways for physics-based trajectory predictions. In the subsequent chapters of this thesis, we look at deep learning models and methods targeted at predicting physical systems' behavior. We use the guiding light of Hamiltonian equations to dive into systems such as the harmonic oscillator and the three-body problem. We are intrigued with exploring graph neural networks' ability to be used in physics informed models: in the N-body problem and in the N-pendulum. This work tests the ability of graph neural networks to generalize the behavior from single realizations of elements at the node level of the graph. In this way, we hope to exemplify how such models can capture highly dynamic physical processes.

1 Introduction

The intersection of physics and deep learning has never been more pronounced than it is today. With advancements in hardware and computational capabilities, we are now positioned to model physical phenomena with unprecedented precision using deep learning techniques, particularly through physics-informed neural networks.
The robotics and machine learning are mostly oriented on dynamics of the robot like manipulators. Such robots are mostly difficult to simulate that they have joints which has property of position and velocity. In dynamics calculation every of those should be calculated in real time. Such fast calculation often bring the inaccuracy in the dynamics of the robot.
With the implementation of the neural networks, we could build a generalised model which is governed trough the dynamics equations. The papers often mention making the model with the Langrage equations[**Delan**]. In the thesis we will use similar equations which are called hamiltonian equations. Those equations brings our dynamics calculations to the simple ordinary differential equation(ODE)

$$\dot{x} = f(x, t) \tag{1.1}$$

or in Hamiltonian Form

$$\dot{\mathbf{z}} = \mathbf{J}\frac{\partial \mathcal{H}}{\partial \mathbf{z}} \tag{1.2}$$

where $\mathbf{z} = [\mathbf{q}, \mathbf{p}]^T$ and $\mathbf{J} = \begin{bmatrix} 0 & \mathbf{I}_n \\ -\mathbf{I}_n & 0 \end{bmatrix}$

This calls for the inspection of neural architectures as multilayer pereceptrons, Gated/Recurrent neural networks, and hamiltonian neural networks.
Manipulator has many joints, Franka Emika Panda for example has 7 joints which means that it has 7 degrees of freedom. Such connections between the joints build a graph. This give us idea to inspect the capabilities of graph neural networks. This will be done on

N-body problem and N-body Pendelum. We hope that the network will be capable not only to learn physical properties in the system but show the accurate predictions of the joints and be trained in reasonable long time.

Bibliography

[1] Ricky T. Q. Chen et al. *Neural Ordinary Differential Equations*. 2019. arXiv: `1806.07366 [cs.LG]`. URL: `https://arxiv.org/abs/1806.07366`.