Karlsruhe Institute of Technology

Autonomous Learning Robots (ALR)

Prof. Gerhard Neumann

Project Type

- ☑ Master Thesis
- ☐ Bachelor Thesis
- ☑ Research Project

Supervisors

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Difficulty

Algorithmic

Math

Application

Smooth Grounding Graph Network Simulators

Description

Accurate simulation of physical systems lies at the core of numerical engineering. Yet, classical simulators are often highly specialized and require prohibitively large amounts of compute to produce accurate results. In recent years, data-driven general-purpose Graph Network Simulators (GNS) [1] have become a fast, differentiable and general-purpose alternative to such classical simulators. These learned simulators can be further improved with auxiliary information from physical sensors, e.g., by grounding them in a point cloud observation [2]. Figure 1 provides an example.

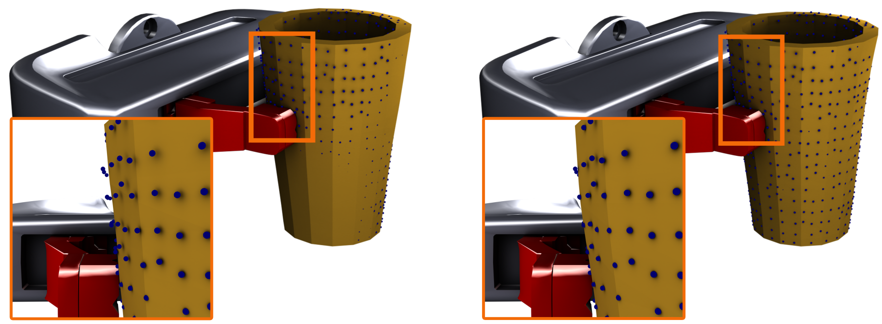

Figure 1: A robot maintains an internal simulation of a deformable object (orange) for two consecutive simulation steps (left, right). This prediction accumulates errors over time. However, the true object state can be inferred from point clouds (blue), which the model can use to correct its prediction. Here, the point cloud is used to contract the simulated cavity at the bottom and extend it at the top, causing the points to better align with the mesh surface.

Our previous work on grounding simulations with sensory data [2] only considers individual simulation steps, leading to cycles of error accumulation and rapid model corrections when, e.g., a point cloud is provided.
In this work, we want to alleviate these issues by maintaining a global latent state that gradually integrates sensory information to allow for a smoother and more consistent prediction over time. The resulting architecture can use additional observations as a reference, inferring a belief of unknown simulation parameters over time. We will evaluate our method on simulated tasks with varying material properties that need to be inferred during the simulation. This thesis builds on a previous thesis that explored recurrent neural networks on a global graph node. It is intended to improve and extend these results and lead to a workshop or conference publication.

Tasks

- Literature Review: Get familiar with Grounding Graph Network Simulators, Recurrent Architectures, and the theory behind the two.
- Algorithm Design: Extend the grounding mechanism for GNS to maintain a global belief of the simulation state to allow for a smoother prediction.
- Evaluation: Evaluate your algorithm on different simulations that require an accurate estimate of unknown simulation variables and compare it to existing approaches.

References

[1] Tobias Pfaff, Meire Fortunato, Alvaro Sanchez-Gonzalez, and Peter Battaglia. Learning mesh-based simulation with graph networks. In *International Conference on Learning Representations*, 2020.

[2] Jonas Linkerhägner, Niklas Freymuth, Paul Maria Scheikl, Franziska Mathis-Ullrich, and Gerhard Neumann. Grounding graph network simulators using physical sensor observations. In *The Eleventh International Conference on Learning Representations (ICLR)*, 2023.