Karlsruhe Institute of Technology

Autonome Lernende Roboter (ALR)
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Project Type

- [x] Master Thesis
- [ ] Bachelor Thesis
- [x] Research Project

Supervisors

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Difficulty

Algorithmic

Math

Application

Automatic Mesh Refinement using Graph Neural Networks

Description

Many interesting real-world problems, for example predicting the movement of a deformable object such as cloth, often lack analytical solutions. A common idea to deal with this complexity is to use finite element meshes [1], which essentially represent a complex object with a set of geometric shapes. These meshes can be used for simulation, since their relatively simple structure allows for easier calculation. However, the quality of this demonstration directly depends on the quality of the mesh [2], as can be seen in Figure 1. The mesh on the left is uniform and spends a lot of its resources on areas that are not particularly relevant. The mesh on the right has the same resolution, but concentrates on regions where the cloth wrinkles. This leads to a much more realistic simulation.

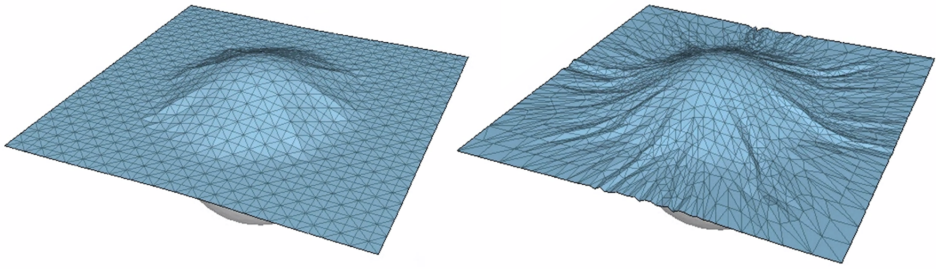

Figure 1: Two cloth-meshes interacting with a sphere.

In this project, we are interested in *automatic mesh refinement*, which transforms some initial mesh (e.g., the left mesh of Figure 1) to one that leads to more accurate simulations (like the mesh on the right). Previous research in this direction [2] has shown promising results[a] by combining a simple message-passing network with a set of greedy update rules on the mesh edges. We want to extend this line of work to more general deep learning architectures such as *Graph Neural Networks* (GNNs) [3] and combine them with useful heuristics to create a precise and reliable algorithm for mesh refinement.

Tasks

- Literature Review: Get familiar with existing meshing algorithms as well as different kinds of deep learning architectures, particularly GNNs.
- Experimental Setup: Design and set up environments for mesh-based simulations that require high-quality meshes.
- Algorithm Design: Develop an approach for mesh refinement using a GNN. This may have the GNN be part of a pipeline, but could also be completely end-to-end.
- Evaluation: Evaluate the performance of the new approach on the chosen environments and compare it to existing solutions.

References

[1] Rahul Narain, Armin Samii, and James F O'brien. Adaptive anisotropic remeshing for cloth simulation. *ACM transactions on graphics (TOG)*, 31(6):1–10, 2012.

[2] Tobias Pfaff, Meire Fortunato, Alvaro Sanchez-Gonzalez, and Peter W Battaglia. Learning mesh-based simulation with graph networks. *9th International Conference on Learning Representations, ICLR*, 2021.

[3] Petar Velickovic, Guillem Cucurull, Arantxa Casanova, Adriana Romero, Pietro Liò, and Yoshua Bengio. Graph attention networks. In *6th International Conference on Learning Representations, ICLR 2018, Vancouver, BC, Canada, April 30 - May 3, 2018, Conference Track Proceedings*. OpenReview.net, 2018.

[a] https://sites.google.com/view/meshgraphnets