Analyzing the Optimization of Mechanical Neural Networks

Reimer, Alexander (School: Gymnasium Eversten Oldenburg)
Friedrich, Matteo (School: Gymnasium Eversten Oldenburg)

A mechanical neural network (MNN) is made of many springs connected in a repeating pattern. Through adjustment of the spring constants, a MNN can be “taught" to exhibit one or more desired reactions to forces (behaviors). Using springs adjustable in real-time additionally enables creating an intelligent material capable of learning and adjusting to damage and environmental changes. While the research on MNNs is new and still mostly theoretical, their applications could be wide and far-reaching – a single material used in anything from better wings to bridges and houses resisting natural disasters by adjusting their resonance frequencies. In this project, we analyzed the optimization of MNNs towards desired deformation behaviors, especially concerning the effects of different hyperparameters. We also attempted the optimization of resonance curves, which had not yet been attempted in the reviewed literature. Not having found anything suitable, we developed our own software capable of visualizing and optimizing MNNs in simulations. By programmatically testing various combinations of hyperparameters like network size, we qualitatively determined their effects, thus matching and expanding the results of existing research. Additionally, our successful optimization of their resonance behavior showed the potential of MNNs to react to oscillating forces as desired, not just deformation. Confirmation of our simulation-based new findings with a physical MNN is still required, and one optimization algorithm performed significantly worse than described in the literature, necessitating further software development. But overall, we demonstrated the potential of MNNs to become the intelligent material of the future.

Awards Won: