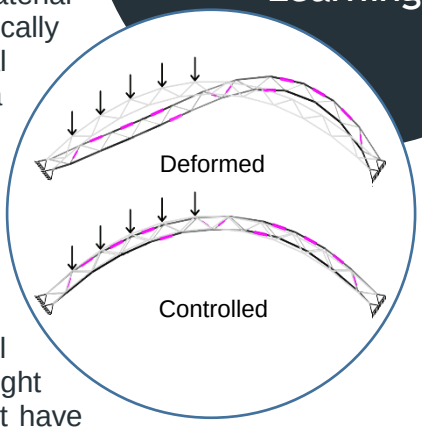
University of Stuttgart
Germany
Department for Stochastic Simulation
and Safety Research for Hydrosystems (LS³)

Adaptive Control Strategies through Knowledge-Infused Reinforcement Learning



M.Sc. Topic (BAU/Architecture/SimTech/CompSci)

Adaptive structures can modify their shape and internal forces through sensing and actuation to counteract the effect of external loading. Hence, passive resistance through material is replaced by actuation energy. Well-designed adaptive structures can achieve significant savings in material mass and in whole-life energy/carbon. The active components are typically linear actuators strategically placed on some of the structural elements. However, the optimal placement of actuators remains a challenging task due to its combinatorial nature. In addition, little attention has been given to control models that can "learn" from experience to deal with effects of ageing and damage.

This MSc project will develop a new strategy based on reinforcement learning to control adaptive structures. Given the structural state under loading (state p), and a target state (state a,), the controller is responsible to provide actuator commands to change the structural state from p to a. During damage, however, one or more actuators might not work at full capacity, and one or more structural elements might have collapsed. Then, the control model must re-direct the stress away from critically stressed elements.

The method to design the controller will be based on reinforcement learning while using existing knowledge of the system. Agents based on actor-critic framework (e.g., such as Deep Deterministic Policy Gradient) will be implemented to learn the "policy" and the "value" functions. To incorporate knowledge of the structure-control system, graph neural networks (GNNs) will be employed to encode information about the structural layout (e.g., topology, element sizing, etc.) as well as the actuation layout (actuator position). Different propagation operators will be tested to pass messages (such as displacement, forces, and control inputs) among the elements of the system. The use of GNNs will not only enable learning the optimal placement of actuators and control laws but will also make the overall framework more interpretable.

Supervision (in English!):

- Gennaro Senatore, Institute for Lightweight Structures and Conceptual Design **(ILEK)**
- Wolfgang Nowak, Stuttgart Centre for Simulation Science **(SimTech)**

Key requirements:

- Bachelor's degree in civil engineering, architecture, SimTech and/or computer science.
- Knowledge of structural mechanics including dynamic analysis.
- Knowledge of (or a strong interest to learn) machine learning.
- Knowledge of (or a strong interest to learn) mathematical and structural optimization.
- Knowledge of (or a strong interest to learn) MATLAB/Python programming language.
- Advanced spoken and written English.

Apply now!

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