Bayesian optimization for truss structures

Frans van der Meer

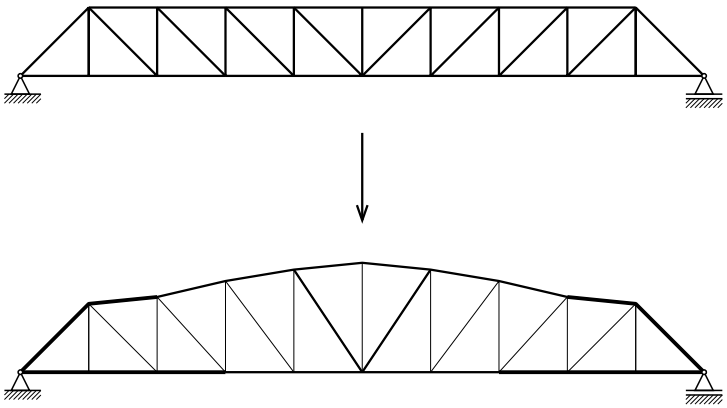
CEGM2003 project

Background

Structures that make optimal use of the material they are made of reduces the cost and environmental impact of their construction as the amount of material required. Optimization of structural design is a challenging task because of the high number of design parameters and the relatively expensive evaluation of the suitability of any given design. Standard optimization techniques in high-dimensional design space require a very large number of possible designs that need to be evaluated. In structural analysis, where evaluating the objective function and checking the constraints involves the solution of a structural mechanics problem, e.g. with finite elements, this quickly becomes very expensive, even if the model is relatively simple from structural point of view. Bayesian optimization is a machine-learning-based optimization technique that aims to reduce the number of evaluations of the objective function through data-driven exploration of the design space with a probabilistic surrogate.

Objective

The aim of this project is to find an optimal truss design. A truss topology is given along with structural requirements on the lowest natural frequencies. The goal is to find an optimal set of nodal coordinates and cross-sectional properties. The primary objective is to minimize the total weight of the structure, while satisfying structural requirements. Optionally, additional objectives can be included, e.g. on the minimization of cutoff waste when reusing components from an existing inventory of elements.



Tasks

A python finite element solver is provided that can analyze the structural response including the natural frequencies of a given truss design. In this project, you will need to embed this finite element solver in a Bayesian optimization algorithm. The objective of weight minimization has to be combined with the requirements on structural performance in a single objective function that fits the Bayesian optimization framework. A probabilistic surrogate for this objective function needs to be constructed. This surrogate will be used in combination with an appropriate acquisition function which allows for balancing exploration versus exploitation in the search for the globally optimal solution.

The outcome of the project is twofold, the immediate result to be presented is an optimal truss design. On a higher level, a reflection on the suitability of Bayesian optimization for this type of problem is expected, including an evaluation of the different choices that have been made in setting up the framework. Aspects to consider in this discussion are how the method scales with the dimensionality of the problem and how structural requirements can be included effectively in the Bayesian framework.

Support

This project is supervised by PhD students and staff from the Applied Mechanics section and the SLIMMLab: Iuri Rocha, Marina Maia, Anne Poot, Leon Riccius, Joep Storm, Robin Oval and Frans van der Meer.