Machine Learning Assisted Evaluations in 3D Graphic Statics

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Abstract

Manipulating the force diagram to control the magnitude of the internal forces in structural form finding is a unique property of geometry-based structural design methods such as 3D graphic statics [1]. For instance, subdividing the force diagram and its polyhedrons using various rules results in a variety of structural forms for a given boundary condition with different load bearing capacities. A recent study showed that the load-bearing capacity of funicular forms could be significantly improved if the force diagram is subdivided for internal members and exterior forces [2]. However, in each subdivision step, the complexity of the structure including the number of nodes and members drastically increases. Since the solution space of all possible forms resulted from various subdivision techniques for a given boundary condition is enormous, it is almost impossible to iterate through all possible forms, and calculate the structural performance for each, and find the best solution within the time limit. Recent advances in machine learning techniques offer promising data-driven approaches to learn the nonlinear and high-dimensional relations between forces and the structural performance of the generated forms [3].

As a part of ongoing research, in this paper, we show how by using different predictive machine learning techniques such as feeding forward neural networks and ensemble methods one can train a surrogate model to accelerate the structural performance assessment of various possible forms without the need to go through the slower process of geometric operations. After training, the surrogate model has the ability to evaluate an inputted data including the boundary conditions and subdivision rules, and output the predicted value of the load path and the buckling force within milliseconds. Then by comparing the outputs of all possible solutions, the form with smaller load path and larger local buckling force can be found in a much shorter time. Further, this will result in more advanced sampling methods, where the machine learning models assist the designers in choosing different design strategies.

References

[1] M. Akbarzadeh, *3D Graphic Statics Using Polyhedral Reciprocal Diagrams*. PhD thesis, ETH Zürich, Zürich, Switzerland, 2016.

[2] A. T. Ghomi, M. Bolhassani, Nejur, and M. Akbarzadeh, "The effect of subdivision of force diagrams on the local buckling, load-path and material use of founded forms," in *Proceedings of IASS Symposium 2018*, (MIT, Boston, USA), 2018.

[3] L. Fuhrimann, V. Moosavi, P. Ohlbrock, and P. Dacunto, "Data-driven design: Exploring new structural forms using machine learning and graphic statics," in *Proceedings of IASS Symposium 2018*, (MIT, Boston, USA), 2018.