Optimal pretension in cable nets

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Abstract

Cable nets are pretensioned to stiffen the net with respect to live loads. This initial tension should prevent slack cables under all load conditions, while ensuring that the axial stress does not exceed the cables' strength. The goal of this research was to develop a method to determine the pretension in a complex cable network designed by the artist Tomás Saraceno. The design consists of a three-dimensional cable net forming a regular grid of connected polyhedrons, which will be accessible to visitors. In order to stabilize and stiffen this net under live loads, we have developed an optimization approach to determine the necessary pretension in the cables, based on the approach developed in [1], and similar to [2]. The undeformed lengths of the connection cables are chosen as the design variables, as these determine the level of pretension in the network. The distance of the deformed geometry to the target geometry, determined by the artist, is minimized to guarantee the aesthetic quality of the artwork. Meanwhile, the normal forces in the cables are constrained to prevent slack cables on the one hand, and cable failure on the other hand. In order to ensure a fast and stable finite element analysis at each iteration of the optimization, implicit dynamic relaxation is applied [3]. The required derivatives are determined analytically to limit the calculation time.

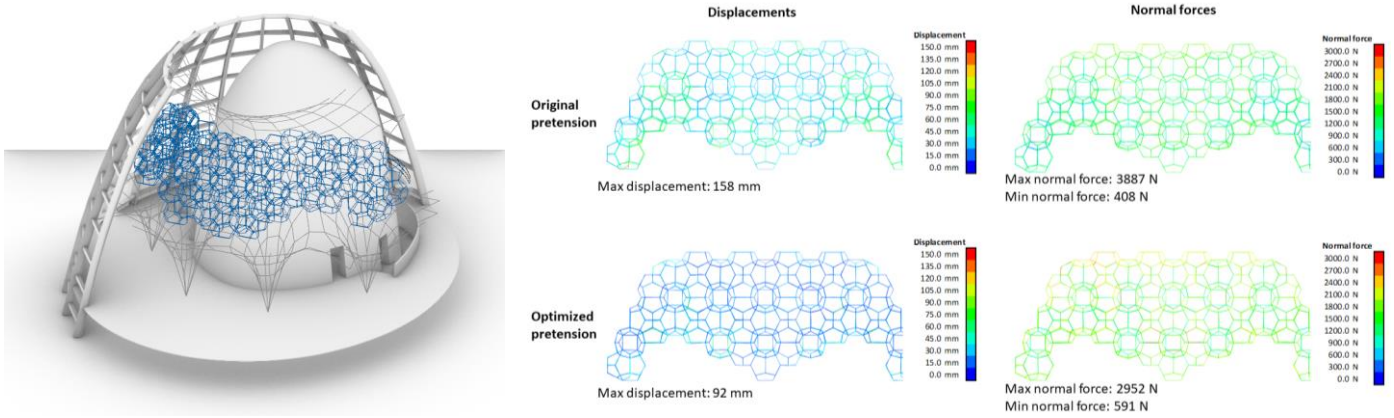

Figure 1. The distance to the target net under live loads is minimized by optimizing the tension in the outer cables.

The algorithm is implemented in Python and integrated in the COMPAS framework developed by the Block research group [4]. Despite the large complexity of the cable net, the optimization tool manages to fit the target geometry under all considered load cases within an acceptable tolerance, while fulfilling all necessary constraints.

Keywords: Form finding, Optimization, Cable nets

References

[1] J. Rombouts, G. Lombaert, L. De Laet and M. Schevenels, "A novel shape optimization approach for strained gridshells: design and construction of a simply supported gridshell", *Engineering structures*, vol. 192, pp. 166-180, 2019.

[2] A. Liew, Y. R. Stürz, S. Guillaume, T. Van Mele, R. S. Smith and P. Block, "Active control of a rod-net formwork system prototype", *Automation in Construction*, vol. 96: pp. 128-140, 2018.

[3] J. Rombouts, G. Lombaert, L. De Laet and M. Schevenels, "A fast and accurate dynamic relaxation approach for form-finding and analysis of bending-active structures", *International Journal of Space Structures*, vol. 34, issue 1-2, pp. 40-53, 2019.

[4] T. Van Mele, A. Liew, T. Méndez Echenagucia, M. Rippmann and others. "COMPAS: A framework for computational research in architecture and structures", 2017.