Fabrication aware optimization of space-frame structures

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Abstract

The application of space-frame structures on large scale free-form designs has significantly increased their fabrication and construction complexity, due to the variance introduced in their members. Incorporating fabrication criteria at early stages of their design can have a positive effect in their construction complexity, particularly on the joints, as they can represent up to 30% of the material cost[1]. Havelia's work [2] has proven that minimizing the variance in the joints according to fabrication inputs can significantly reduce the construction complexity of space-frame structures, while Koronaki et al [3] developed a single-pass clustering algorithm which geometrically optimizes the space-frame's structural depth to minimize the number of different joint groups required. Building on the latter approach, this paper proposes a novel computational tool for the comparative evaluation of the complexity that different fabrication processes introduce to the construction of a given structure. A geometrical optimization if afterwards carried out to reduce the variance in the joints' geometry an in effect the overall fabrication and assembly cost.

The complexity of a structure is initially identified as a factor of the variance in the joints' geometry. An unsupervised machine learning algorithm is used to calculate the maximum variance as a function of the number of different joint clusters, *k*. Mapping this against the variance that different fabrication processes allow for, enables engineers to comparatively evaluate the complexity that each process will induce to their designs and make informed decisions regarding the fabrication of their structures. Once the requirements of the specific fabrication process have been determined, an evolutionary algorithm geometrically optimizes the structure's depth, to reduce the number of different joint clusters required and enhance the overall construction process.

Developed in a user-intuitive environment, the proposed computational tool provides a direct insight into the fabrication complexity of a given structure at early stages of the design. This process can substantially reduce the construction complexity of space-frame structures and hence promote efficient and better engineered solutions.

References

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