Evolutionary generation of spatial structures through force-based grammar

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Abstract

Computational methods that provide instant feedback on performance requirements, that allow for fast exploration of alternative solutions and that unveil unexpected structural typologies, are crucial for the generative, conceptual design of structures. Design, being primarily based on qualitative criteria, is an ill-structured and costly problem whose complexity can significantly increase during the process due to emerging requirements. This paper presents an approach for structural design exploration that exploits a new force-based grammar. Precedent studies use interactive evolutionary algorithms as a means of structural generative design [1,2] but are limited to fixed topologies. Other two-dimensional explorative approaches, based on grammar rules, were either limited to context specific rules [3] or operated as a sequence of dependent rules [4,5], which led to inconsistent transfer of information during genetic permutations [5].

In this paper, the exploratory power of grammar rules is amplified by controlling them with genetic algorithms operating at a higher level. Rather than defining the set of successive grammar rules, the chromosome's genetic information embeds generalizable decision schemes that define what, how and when grammar rules are applied during the course of a design. Its syntax is carefully chosen to avoid information loss during crossover or mutation operations. A universal grammar rule which is freed from specific structural typologies is proposed. The rule is applied incrementally and aims at the transition from a state in interim static equilibrium to one that is in global equilibrium. The rule allows for direct control over the number of interim forces in interim networks. Its inception and originality are assisted by graphic statics which is exploited to identify the degrees of freedom present in interim networks. The generation of three dimensional truss systems is used as a case study of the methodology.

References

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