Cellular Automata in Structural Design[1]

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Abstract

The goal of this project was to introduce NKS to engineering design problems and estimate a true potential of this approach. It was an initial step in exploring the world of simple programs for engineering design applications as well as introducing a novel methodology presented in Wolfram's A New Kind of Science. The motivation for this research was based on the fact that even designers of complex and sophisticated engineering systems (bridges, tall buildings, space structures, etc.) use only a relatively small set of design/decision rules to develop design concepts. Hence, it is plausible that even very complex designs of engineering systems can be modeled using simple programs like cellular automata (CA).

Two potential ways of attacking this problem are based on the following observations. First, one of the important problems in engineering design is the problem of topological optimum design, where one seeks the optimal configuration of design elements satisfying some constraints, and optimizing a certain objective function, e.g. deflection, or weight, of a steel structure. This search for the optimal configuration of design elements sometimes yields very interesting patterns. It is possible that the search for such interesting structural patterns can be vastly enhanced using CA and other simple programs. Second, it is usually the case that engineering designs have repetitive forms. CA can generate both very simple and repetitive behavior as well as complex forms and configurations. It is definitely worth exploring whether the complex configurations of engineering systems will be better than traditional designs.

The initial exploration of the space of simple programs has been focused on one-dimensional CA (1D CA) and two-dimensional CA (2D CA). 1D CA have been used to generate design concepts of wind bracing systems in tall buildings. These experiments were performed using both elementary CA where two possible types of bracings were used and more complex 1D CA involving 7 possible types of bracing elements. In another set of experiments 2D CA were used. Several types of totalistic 2D CA were studied, including Moore neighborhood and von Neumann neighborhood. The fitness of the generated design concepts was determined based on rigidity of the structural systems and measured by their maximum deflection.

Results of the conducted experiments have shown that CA can generate interesting structural shaping patterns. They included both traditionally known patterns for this class of buildings like vertical and horizontal trusses, but also some novel arrangements of wind bracings characterized by high fitness values. The best results in the reported experiments were obtained using 1D CA. 2D CA also have the potential of producing interesting structural patterns but the search space is vastly larger compared to the 1D CA case and much larger number of experiments is necessary.

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[1] *Citation:*
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