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Mechanics of Tensegrity

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As a class of novel flexible structures, tensegrity holds promise for many potential applications in such fields as materials science, biomechanics, civil and aerospace engineering. In this paper, a method is presented to construct tensegrity structures from elementary cells, defined as structures consisting of only one bar connected with a few strings. Comparison of various elementary cells leads to the further selection of the so-called “Z-shaped” cell, which contains one bar and three interconnected strings, as the elementary module to assemble Z-based spatial tensegrity structures. Graph theory is utilized to analyze the topology of strings required to construct this type of tensegrity structures. It is shown that a string net can be used to construct a Z-based tensegrity structure if and only if its topology is a simple and bridgeless cubic graph. Once the topology of strings has been determined, one can easily design the associated tensegrity structure by adding a deterministic number of bars. Two schemes are suggested for this design strategy. One is to enumerate all possible topologies of Z-based tensegrity for a specified number of bars or cells, and the other is to determine the tensegrity structure from a vertex truncated polyhedron.

Then, we introduce a Monte Carlo form-finding method that employs a stochastic procedure to determine equilibrium configurations of a tensegrity structure. This method does not involve complicated matrix operations or symmetry analysis, works for arbitrary initial configurations, and can handle large scale regular or irregular tensegrity structures with or without material/geometrical constraints.

Finally, we present theoretical and numerical methods to study the static and dynamic mechanical properties of tensegrity structures. The application of tensegrity structures in biomechanics is also briefly discussed.

Keywords: Tensegrity, Form-finding, Stability, Equilibrium