Name(s)

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Project Number

S0312

Project Title

CUBOCTimization: Topological Optimization of a Cuboct Truss Bridge Using a Genetic Algorithm

Abstract

Objectives/Goals

Any structure carried into space must be lightweight due to the high cost of space travel. Structures made from cuboct trusses are actively studied by NASA due to their easy modular assembly and extremely high stiffness to mass ratio. A cuboct truss is composed of repeating octahedrons called voxels. The goal for my project was to create lightweight cuboct truss bridges with programmable stiffness properties. My inspiration for the project was the lightweight lattices found in natural bird bones.

Methods/Materials

I created a genetic algorithm in Java that replicated the process of evolution. To begin, the algorithm generated a virtual population of 50 cuboct bridges with random variations (i.e. missing voxels). Children were bred from random pairs of parents from this population. To create a child, voxels (like genes) were randomly selected from either the mother or the father's structure array (or genetic code). Small random mutations were also inserted. Each child's fitness was calculated, and, if the child had a better fitness than its most similar parent, it replaced the parent in the population. This process was repeated until all of the fitness scores of the population members converged. I ran my algorithm four times with varying parameters. Each run took approximately 7800 generations over 72 hours on a 12-core computer. I created 30 real 3D-printed models of the four optimal bridges generated from my algorithm (along with a full envelope and standard bridge) using two different printers at 100% and 50% scale. I stress tested each using an Instron load testing system.

Results

After stress testing five copies of each bridge type, I compared my stiffness predictions from my algorithm to the actual Instron results. I correctly predicted the relative ranking on 4 out of 6 bridges. The error between my measured and predicted displacements averaged 38%, with the best and worst cases being 0% and 127%.

Conclusions/Discussion

I accomplished the first part of my hypothesis by evolving bridges that had a more optimal fitness than the standard and full envelope bridges. The second part of my hypothesis was that the results of real 3D tests would match my algorithm's predictions. Taking measurement error into account, I conclude that my predictions were reasonably accurate in half of the cases.

Summary Statement

I created a genetic algorithm to optimize the fitness of cuboct truss bridges and verified the results with real 3D test samples.

Help Received

I worked in the NASA Ames Coded Structures Lab under the guidance of Dr. Kenneth Cheung and Ph.D. student Daniel Cellucci. Although my project was independent, my mentors helped answer any questions. In addition, they provided lab equipment, 3D printers, and the Instron load testing system.