Simulation of Structurally Stable Tower Construction by an Autonomous, Decentralized Robotic Swarm

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Human construction consists of two main steps – designing a structure and physically constructing the designed structure. Insect swarms, on the other hand, build stable structures in an adaptive fashion, reacting to changes in the environment as they occur instead of relying on a central plan or blue print. In order to explore how the concept of adaptive design can be applied to modern human construction, we created a simulation of a robotic swarm achieving construction. Each member-agent of the "virtual swarm" is capable of analyzing the structure locally and, based on that analysis, make design decisions. The agents are restricted to one unit of material, measurable structural properties, and independent action (no communication). A significant challenge was calculating the structural properties. The simulation relies on SAP2000, a high-end structural analysis program, for these calculations. Using this method, we have simulates swarms creating towers as tall as 1000 feet. The simulation is also capable of mimicking a wind-like load, to which the individual agents have shown adaptive behavior.

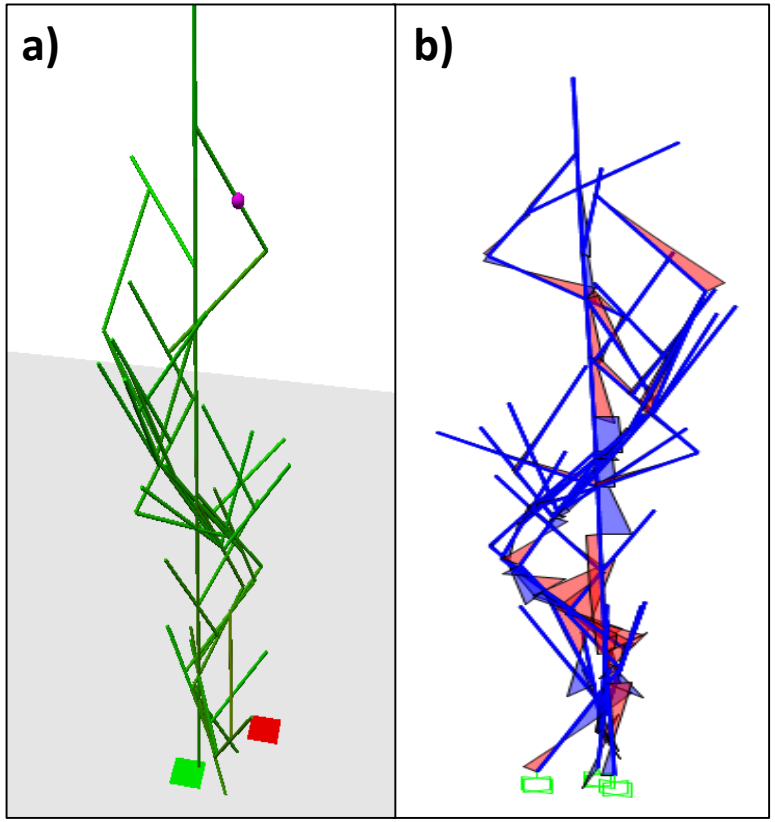

Figure 1-1. A resulting structure

(a) Simulated structure created by a single swarm agent after 4997 steps. Green is start point, red is material point, and purple sphere is the agent.

(b) Analysis model of structure with visualization of moment of force. Scale factor of 3.