Senior Project – Computer Science – 2015

Evolving Scalable Soft Robots

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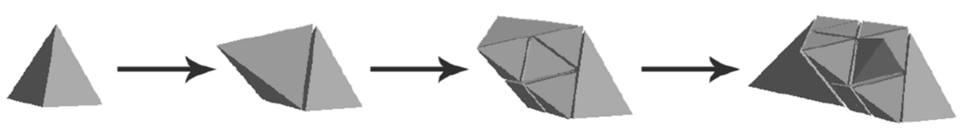
Abstract

Designing soft robots is difficult, time-consuming, and non-intuitive. Here, we would like to design a soft robot that can move when vibrated. Instead of requiring humans to engineer this complex system, we can have computers invent designs for us. This research aims to do this with genetic algorithms that can evolve designs for robots that will move when vibrated.



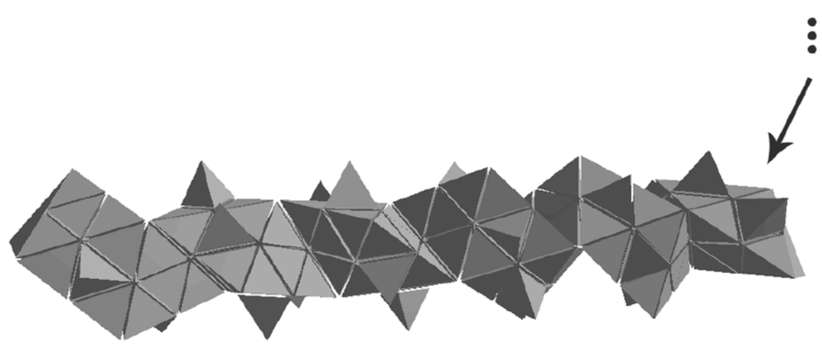
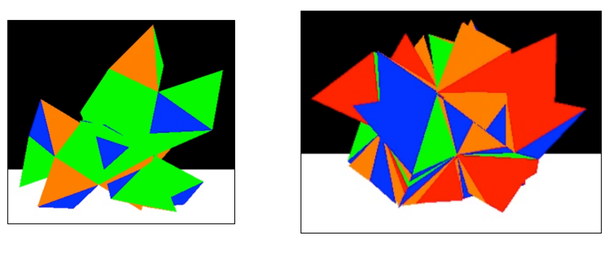


Figure 1. This image shows the growth process of a robot as we apply the rules of the generative encoding multiple times.
Image from: John Rieffel and Schuyler Smith. A face-encoding grammar for the generation of tetrahedral-mesh soft bodies. In ALIFE, pages 414–420, 2010



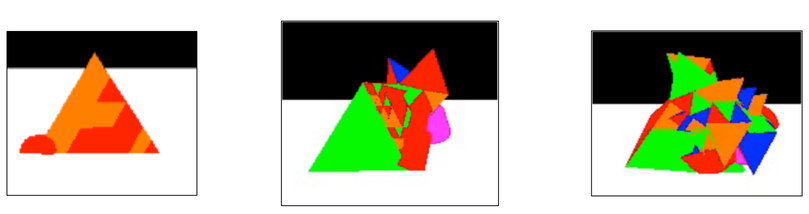


Figure 2. These images are some examples of robots that have been tested in simulation. The red cylinder represents the motor used to vibrate the robot.

Generative Encodings

Generative encodings are used to represent designs and are modified during the evolutionary process. A generative encoding is a set of rules that describe how to construct a 3D object. If the rules are applied over and over, it will create a larger and more complex robot.

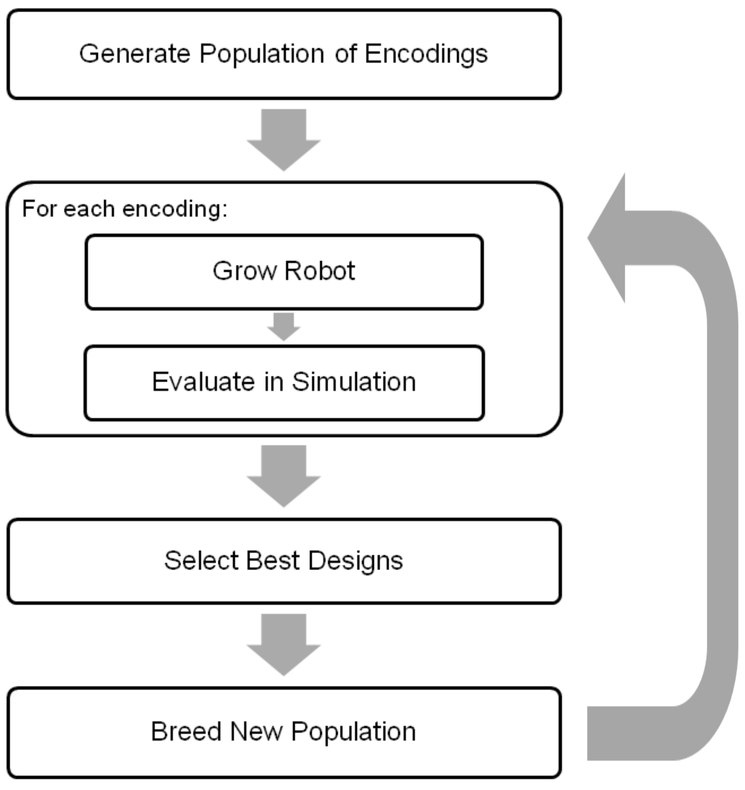


Figure 4 (right). This image illustrates the genetic algorithm process we use to evolve good designs. A population of designs are created and tested in simulation. Bad designs are discarded and good designs are used to breed a new population for the next round of testing. Over time, we get evolve better and better designs.

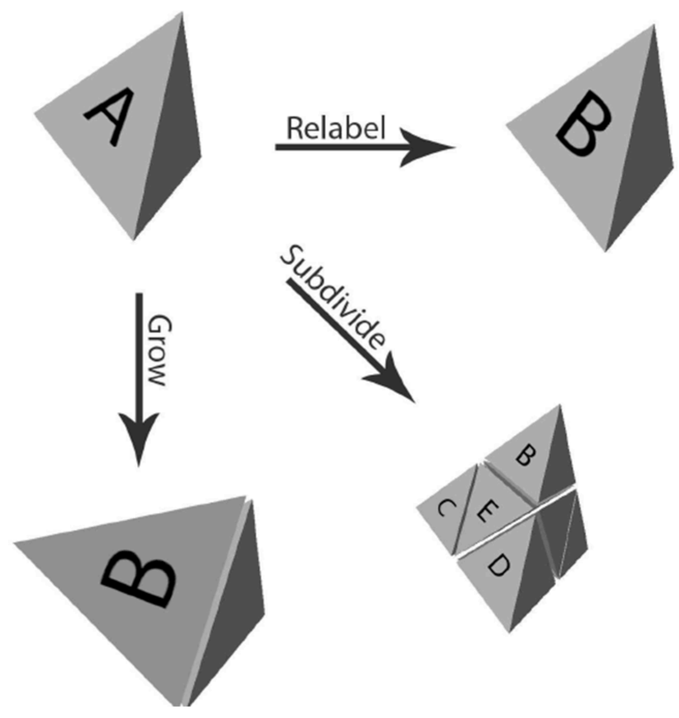
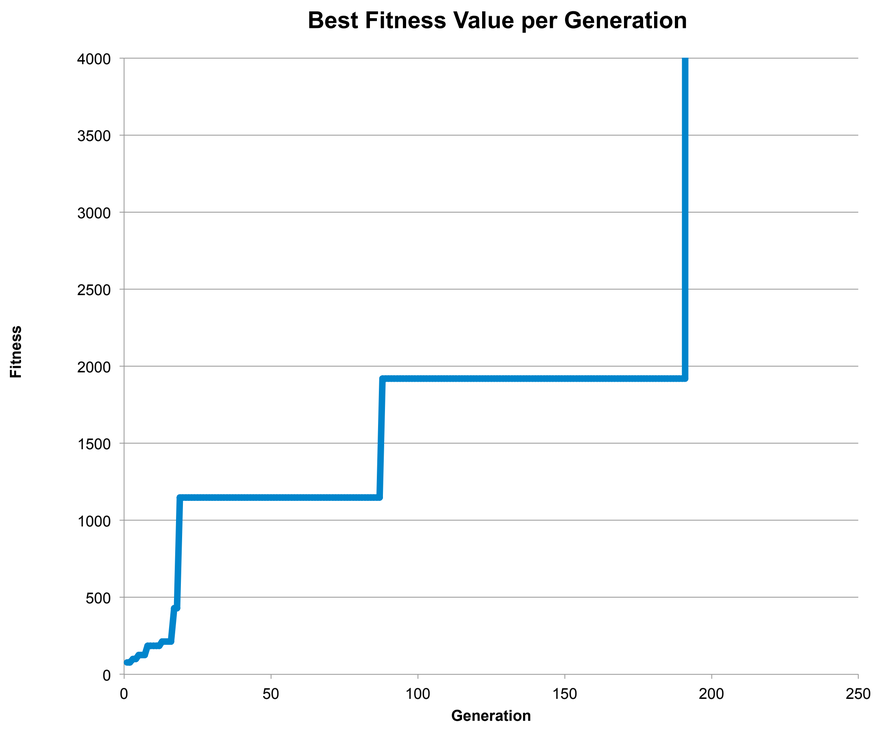


Figure 3. This image shows examples of rules that we can use in a generative encoding to grow a design.
Image from: John Rieffel and Schuyler Smith. A face-encoding grammar for the generation of tetrahedral-mesh soft bodies. In ALIFE, pages 414–420, 2010



Results and Future Work

The simulation software had a number of memory leaks, segmentation faults, and design problems that had to be addressed before evolutionary experiments could be run. For example, Figure 5 shows a bug that renders many experiments useless.

I have fixed many of these issues and am in the process of modifying the genetic algorithm process to create scalable soft robots, capable of moving when vibrated at any size.

Figure 5 (left). This graph shows the best fitness values per generation over the course of an experiment. At generation 192, the fitness jumps from 1,920 to over 40 trillion. This astronomical number indicates a serious bug in the simulation code. This results in individuals with false fitness values and spoils the evolutionary process.