Using a Genetic Algorithm to Optimize Steel Structures

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April 28, 2017

Goal

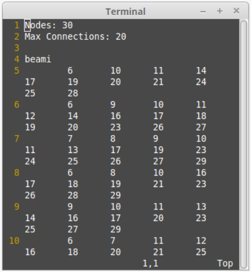
- Simulate the physics on a steel structure
- Determine some metric of "fitness" for these structures
- Systematically breed and cull a population based on this metric.

Modeling the Tower

Steel beams are modeled as springs with a dampening force. Forces cause the beam to expand or contract, but it will tend to draw its endpoints to a predetermined distance.
Each junction is modeled as an angular spring, pushing or pulling beams at that junction to a predetermined angle.

Genome

Each tower has a folder containing three files. One file holds the position of each of its nodes, and whether each node is an anchor point. A second file holds the information about the beams, including which two nodes are at the ends of the beam, and what the length and spring constant of the beam are. A third file holds information about angles between beams, and what the angular spring constants are for those junctions.



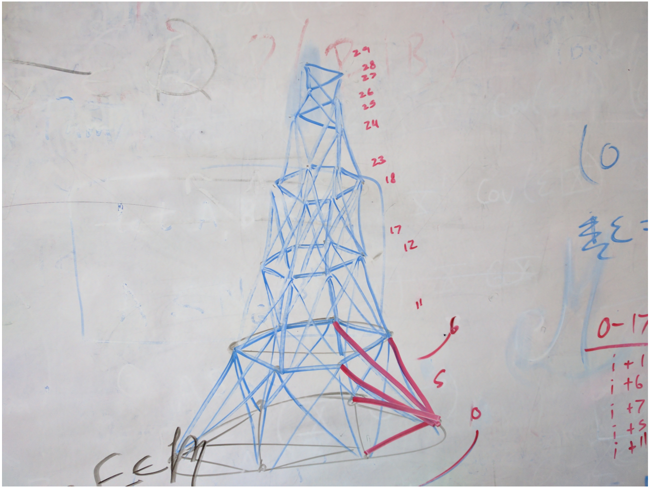

```
Nodes: 30
Max Connections: 20

beami
          6         10        11        14
17        19        20        21        24
25        28
          6         9         10        11
12        14        16        17        18
19        20        23        26        27
          7         8         9         10
11        13        17        19        23
24        25        26        27        29
          6         8         10        16
17        18        19        21        23
26        28        29
          9         10        11        13
14        16        17        20        23
25        27        29
          6         7         11        12
16        18        20        21        25
                              1,1            Top
```

Applying that Model to the Genome

We have a bunch of nodes connected by springs. We know how the connections are organized, and we know where each of the beams are connected.

By alternately calculating the forces on each node and updating their positions and velocity, we can see how the structure responds to gravity and other external forces. Using parallel processing on the graphics cards in Dr. Wyatt's lair, I've sped this up a lot.


29
28
27
26
25
24
23
18
17
12
11
6
5
0
0-17
i +1
i +6
i +7
i +5
i +11

Evolving

Population steps

1. Random Initialization
2. Let structures stabilize and add them to the main population.
3. Remove all structures that have a fitness less than the median.
4. Choose stable structures to be parents based on fitness.
5. Mutate parents to produce children.
6. Let children structures reach a stable state, and add them to the main population.
7. Repeat steps 3-6 until a generation goal is reached.

Random initialization. (Play random initialization)

Generation 100. (video)

Generation X. (video)

What do my results look like?

???

?

Room for Improvement

In actual evolution, entire sequences are spliced together.
Compare to other stochastic processes for building towers.
Metropolis-Hastings?

Images

https://upload.wikimedia.org/wikipedia/commons/d/d0/Steel_tower.jpg

https://iadsb.tmgrup.com.tr/48d616/645/344/0/150/1000/684?u=https://idsb.tmgrup.com.tr/2017/03/23/1490217787968.jpg

Thanks!

- Dr. Wyatt and his lab
- Office of Student Research and Creative Activities
- http://boxcar2d.com