Neuroevolution

Elliot Greenlee and Jared M. Smith

CS581 Algorithms, April 20, 2017

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Test Questions

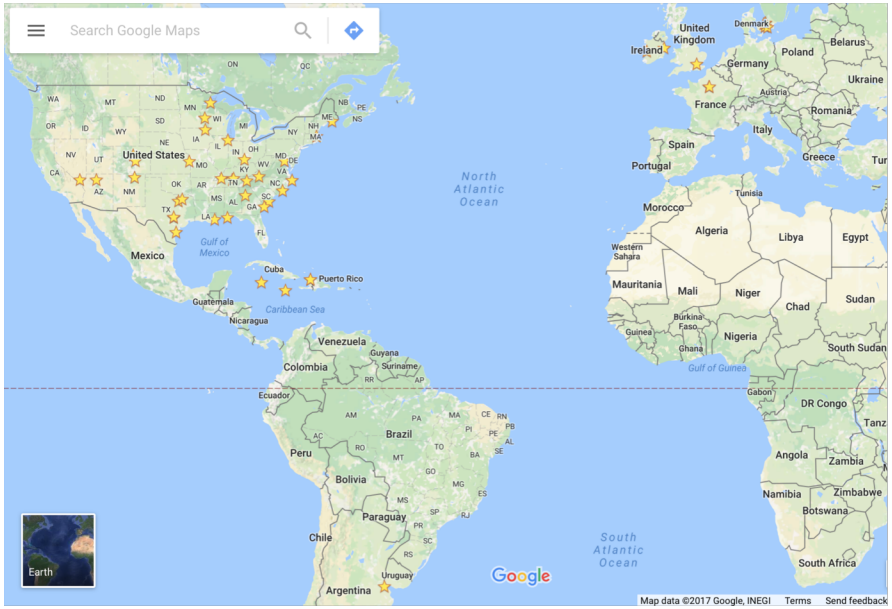
1. What is the typical training method for neural networks?

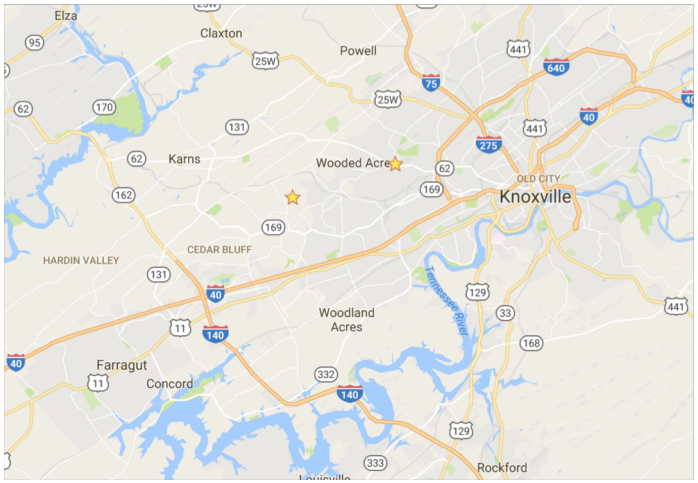
1. What three Darwinian processes are used in genetic algorithms?

1. What is one application of neuroevolution?

About Elliot

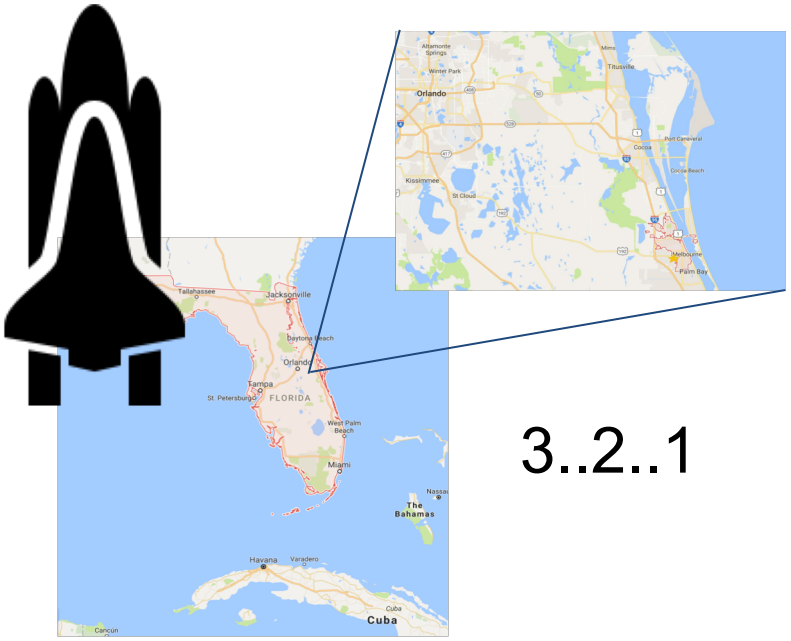
- Knoxville, Tennessee
- MS in Computer Science
- PhD in the future
- Rock climbing, cooking, travel
- Security research at ORNL
- Machine learning and computer vision GRA with Dr. Hairong Qi





About Jared

- Melbourne, Florida
- HackUTK and VolHacks founder
- Research Staff and PI at ORNL
- Computer security and networking GRA with Dr. Max Schuchard
- Hiker, backpacker, industry conference teacher (7 so far)



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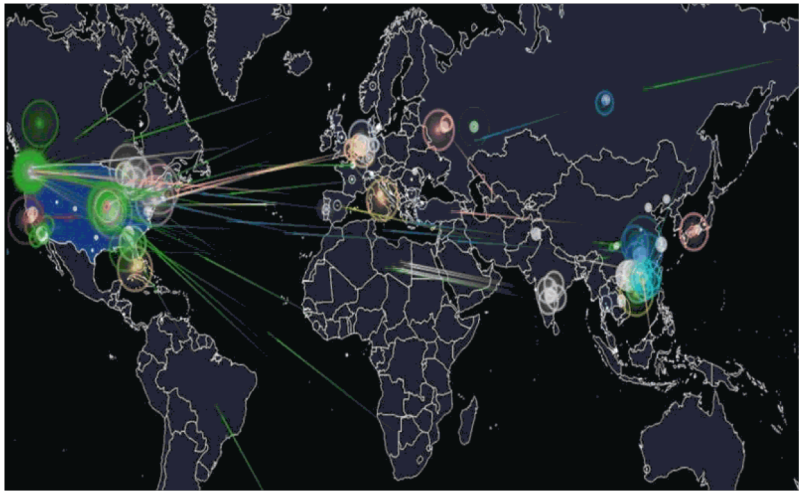
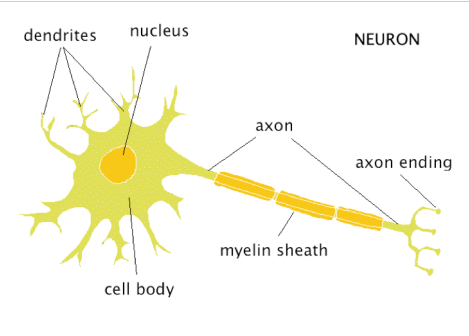


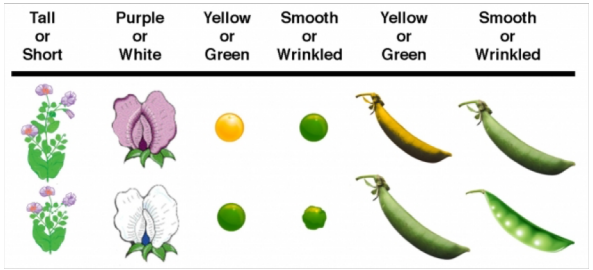
Outline

- Overview
- History
- Algorithms
- Applications
- Implementations
- Open Issues
- Discussion

Overview



Human brain



Darwinian processes

Neural networks

Genetic algorithms

Self-improving neural networks

Overview

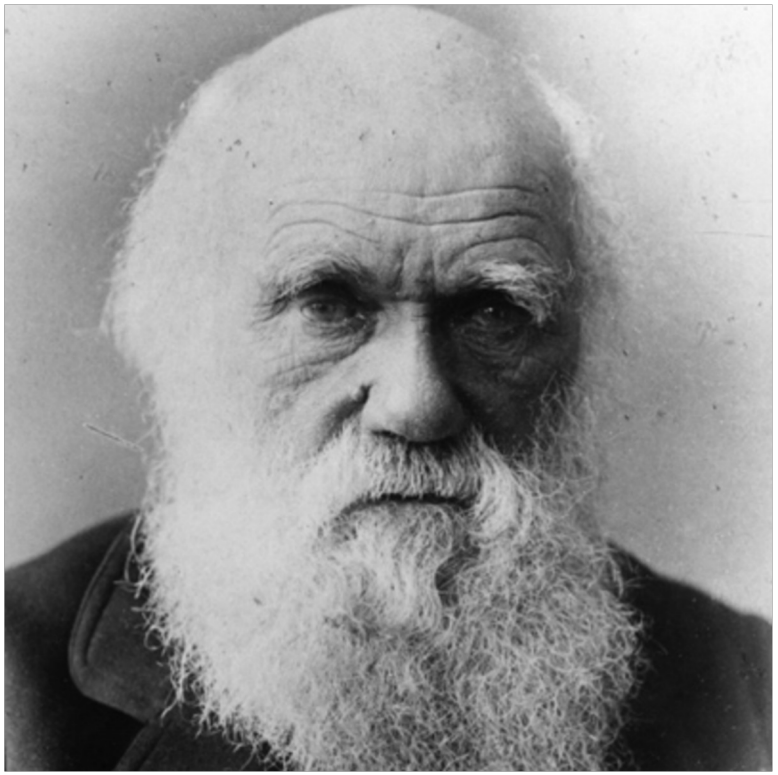
- Applications include: robotics, video game AI's, and personal assistants

History

- Gregor Mendel
  - Pioneer in genetics
  - Discovered inheritance
  - Used peas in his experiments
  - “Mendel’s Peas”

History

- Charles Darwin
  - “Father of Evolution”
  - Natural selection
  - Studied ancestral relationships in the Gálapagos Islands



History

- Marvin Minsky
  - Former Professor at MIT
  - “Father of Artificial Intelligence”
  - Came up with perceptrons, the foundation of artificial neural networks

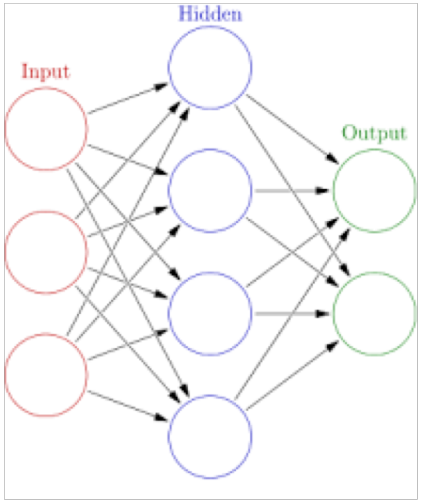
History

- Kenneth O. Stanley
  - Associate Professor at U. of Central Florida
  - “NeuroEvolution of Augmenting Topologies”
  - Developed original NEAT software in C++
  - Many other implementations

Algorithms

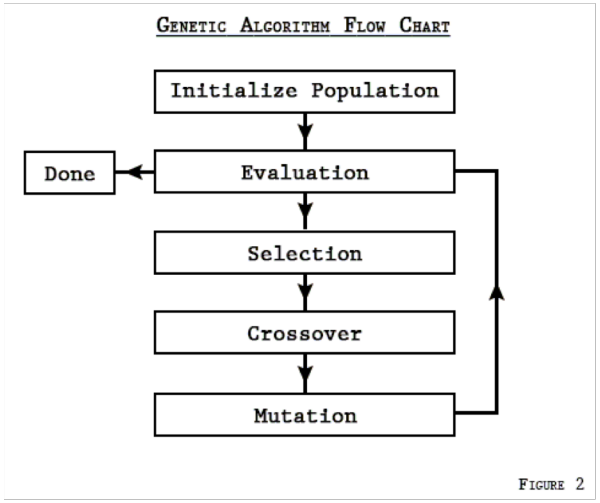
Neural networks

- layers
- weights
- activation function
- backpropagation



Genetic Algorithms

- fitness
- crossover
- mutation
- selection



Algorithms - Genome

Node

- bias
- response
- activation
- aggregation

- distance()
- mutate()
- crossover()

Connections

- weight
- enabled

- distance()
- mutate()
- crossover()

Algorithms - Genetic Processes

- Initialize
- Copy
- Distance
  - node/connection structural similarity
  - individual gene distance metrics

Mutate

- add node
- delete node
- add connection
- delete connection
- change connection genes
- change node genes

Algorithms - Neural Networks

Create

1. For each layer:
    For each node in layer:
        For each connection:

Feedforward

1. For each node:
    For each forward link:
        Calculate

Algorithms

For every generation:

1. Evaluate genome fitness
2. Stop if fitness threshold is reached
3. Do reproduction
4. Check for extinction
5. Speciate

Algorithms - Genetic Processes

Reproduction

1. Remove stagnated species
2. Compute new spawns
3. Find best from prior generation
4. Select two parents randomly
5. Cross parents
6. Mutate child

Algorithms - Genetic Processes

Crossover

1. For all similar connections, crossover
2. Add connections from more fit parent
3. For all similar nodes, crossover
4. Add nodes from more fit parent

Algorithms - Genetic Processes

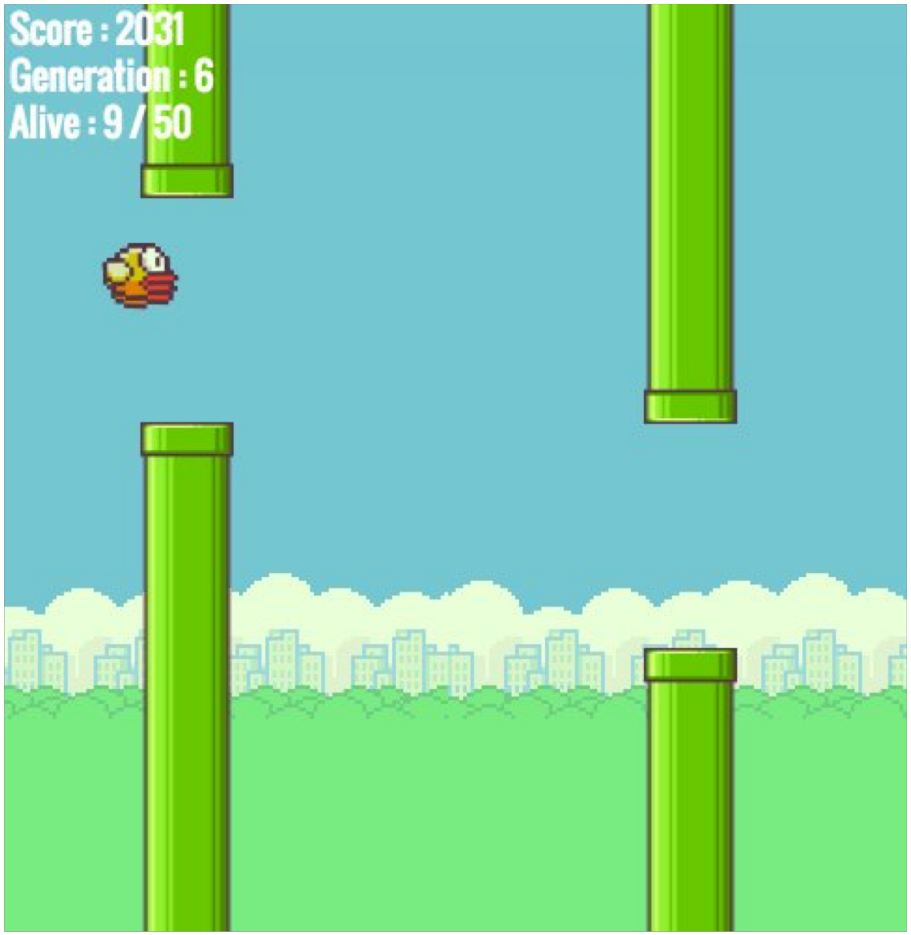
Speciation

1. Compare all new samples to the prior species “representatives”
2. Find most similar new sample
3. Compare all new samples to the new species “representatives”
4. If similar enough, add. If different, new

Stagnation

Applications

- Robotics
- Artificial Life
- Video Games
- Substitute for reinforcement learning



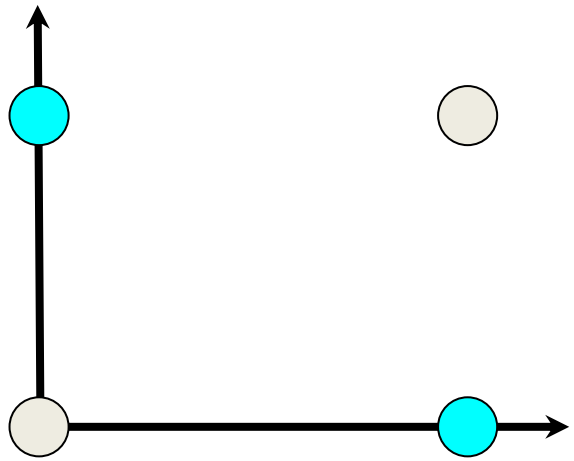
Implementations

- XOR
- Single Pole Balancing
- Lunar Lander

XOR

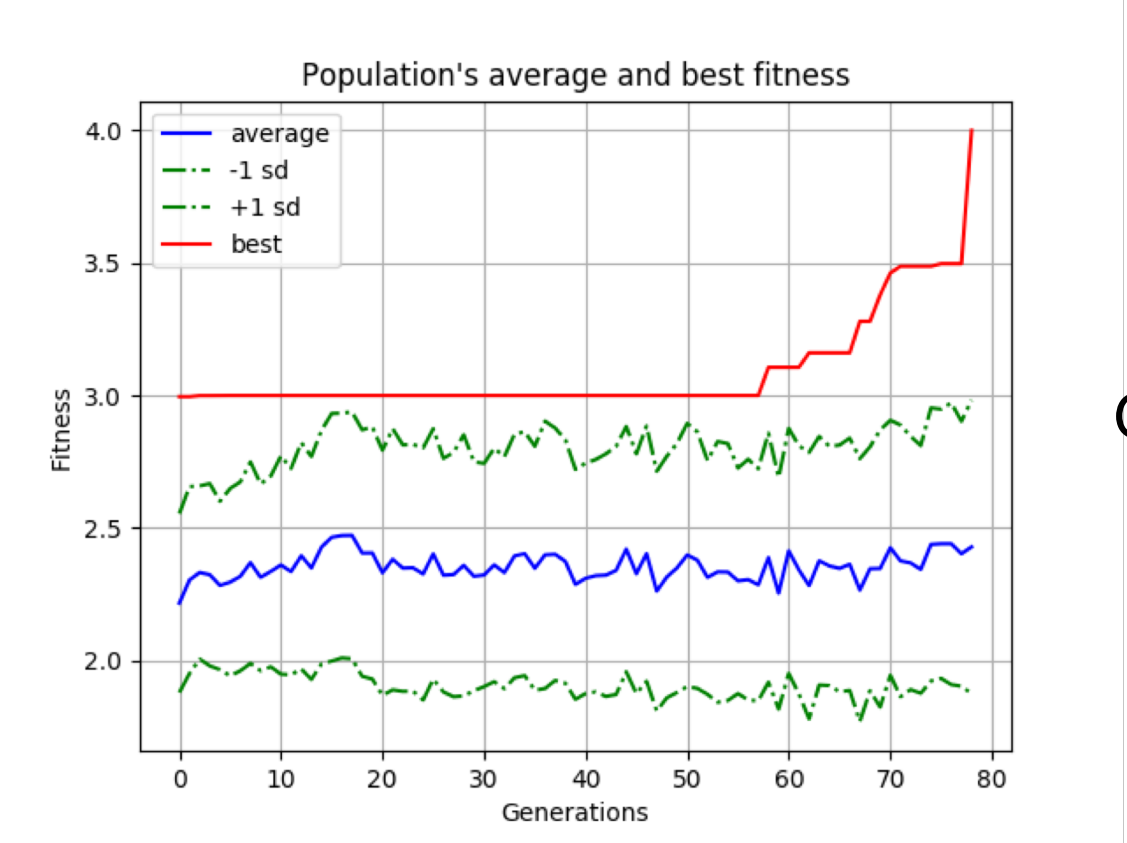
- Not linearly separable

Input 1	Input 2	Output
0	0	0
0	1	1
1	0	1
1	1	0



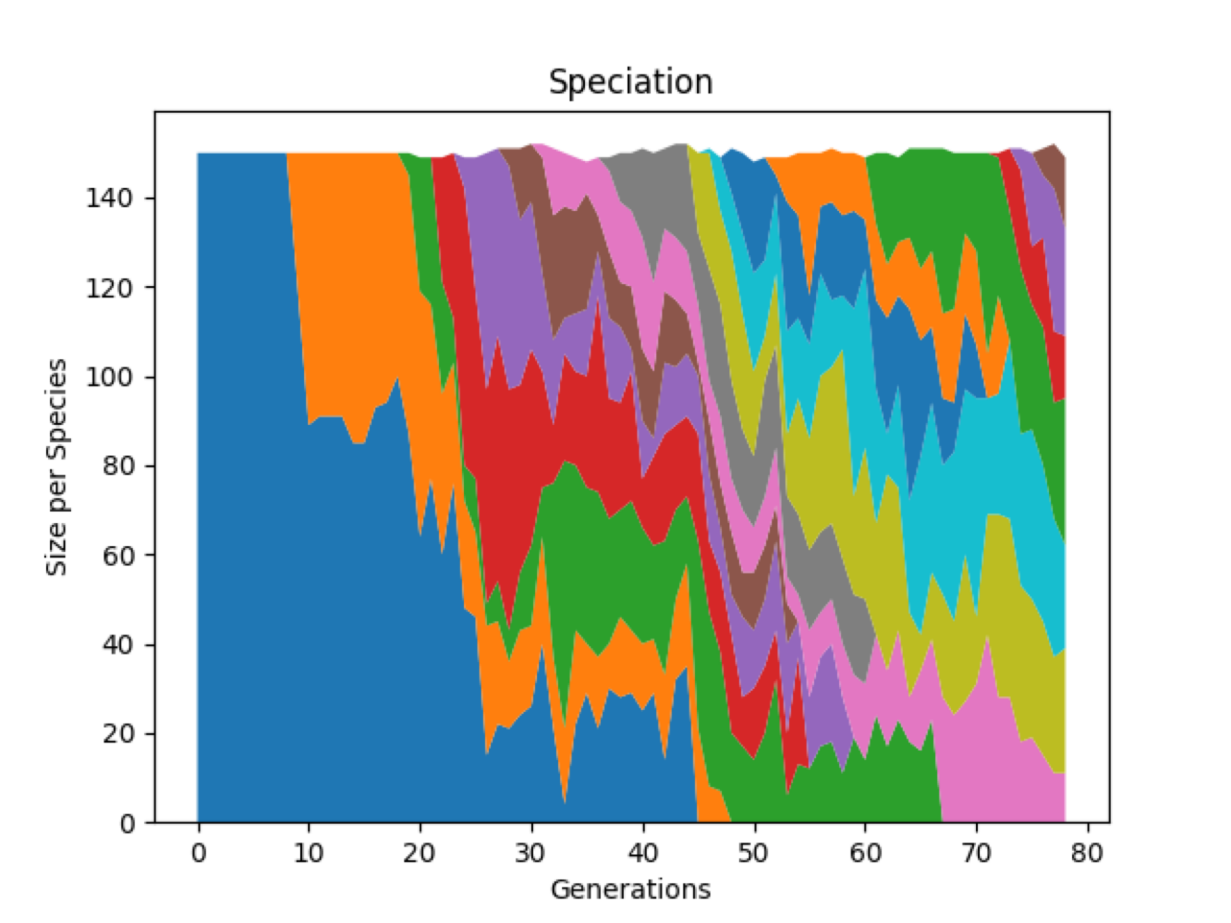
XOR

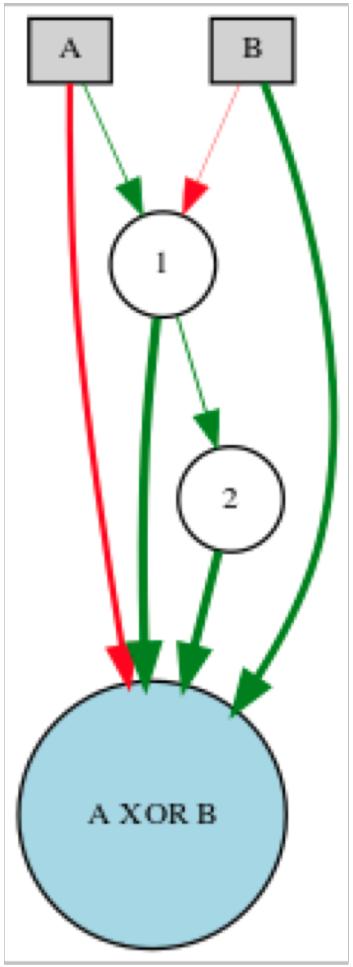
- Average # of generations over 5 runs: **102.4**



78 Generation Example

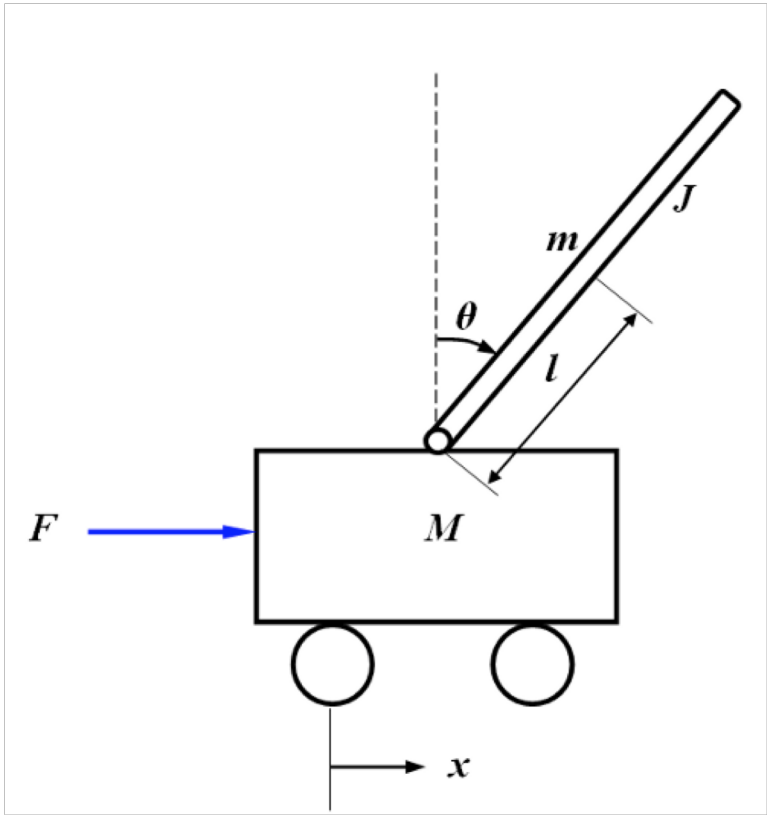
XOR


Speciation
Size per Species
Generations
0
20
40
60
80
100
120
140
0
10
20
30
40
50
60
70
80


A
B
1
2
A XOR B

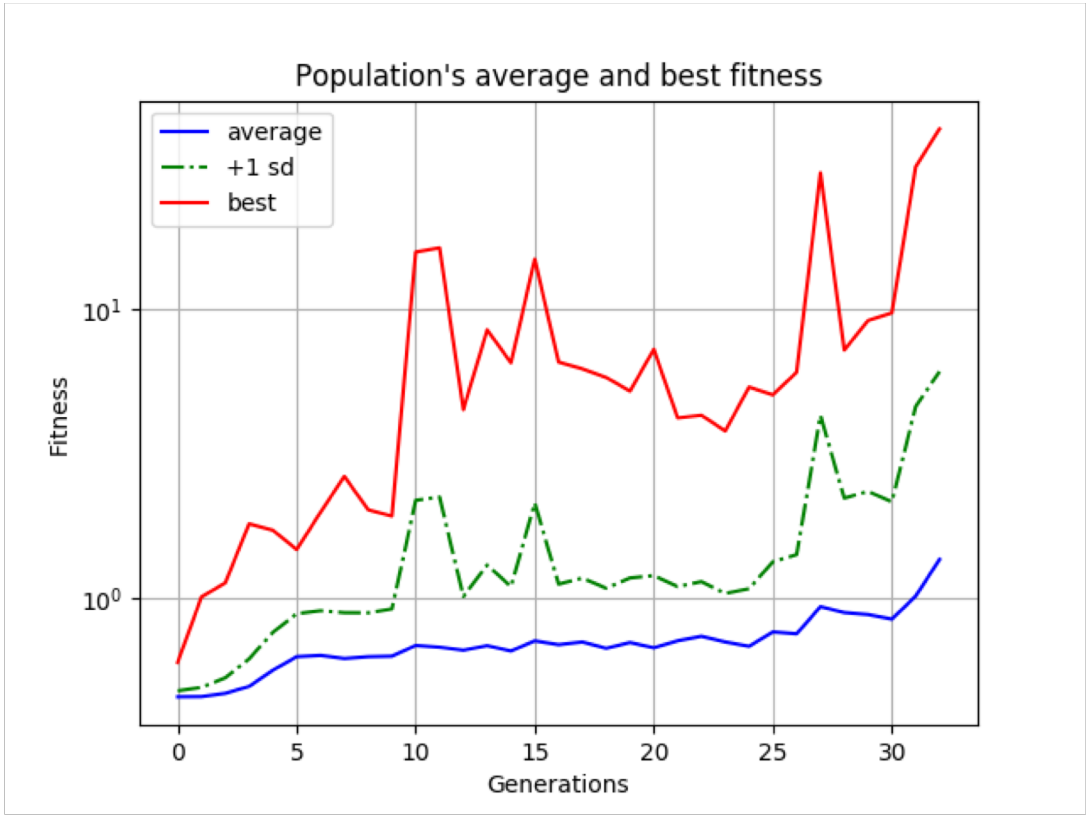
Pole Balancing

- Balance a single pole on a cart
- Can move horizontally (x) and a pole that can change angle w.r.t. the cart (Θ)



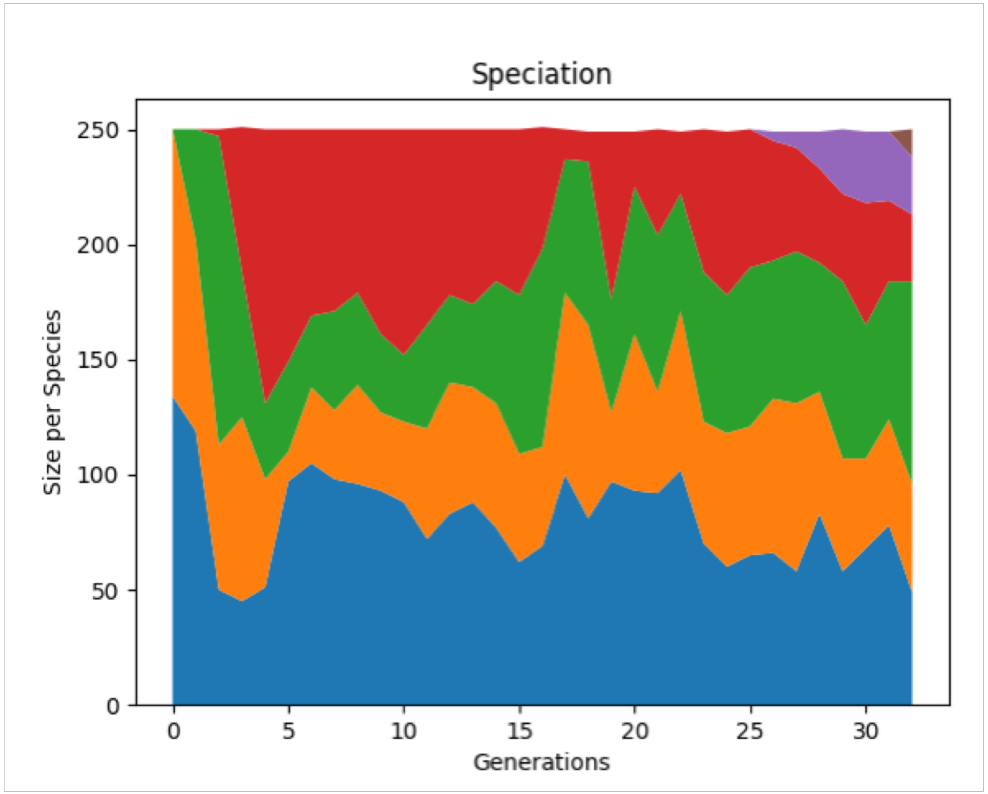
Pole Balancing

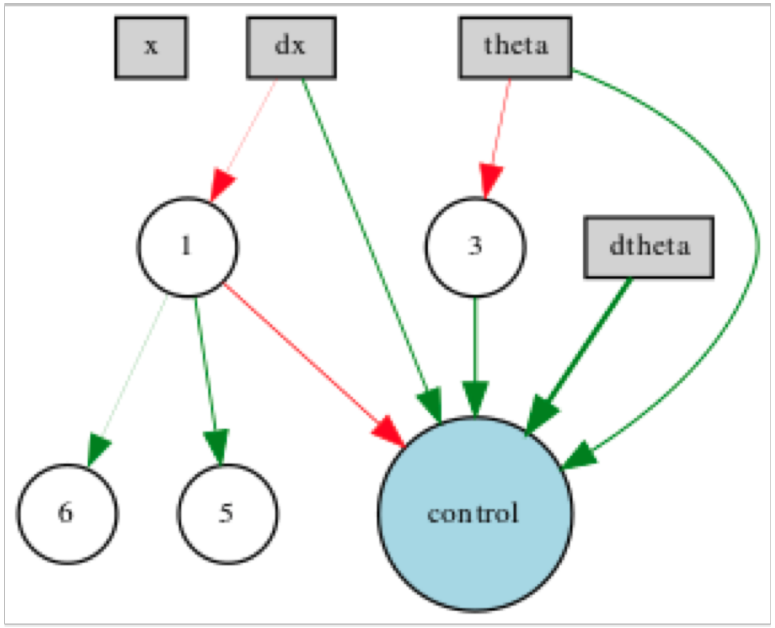
- Average # of generations over 5 runs: **28**



32 Generation Example

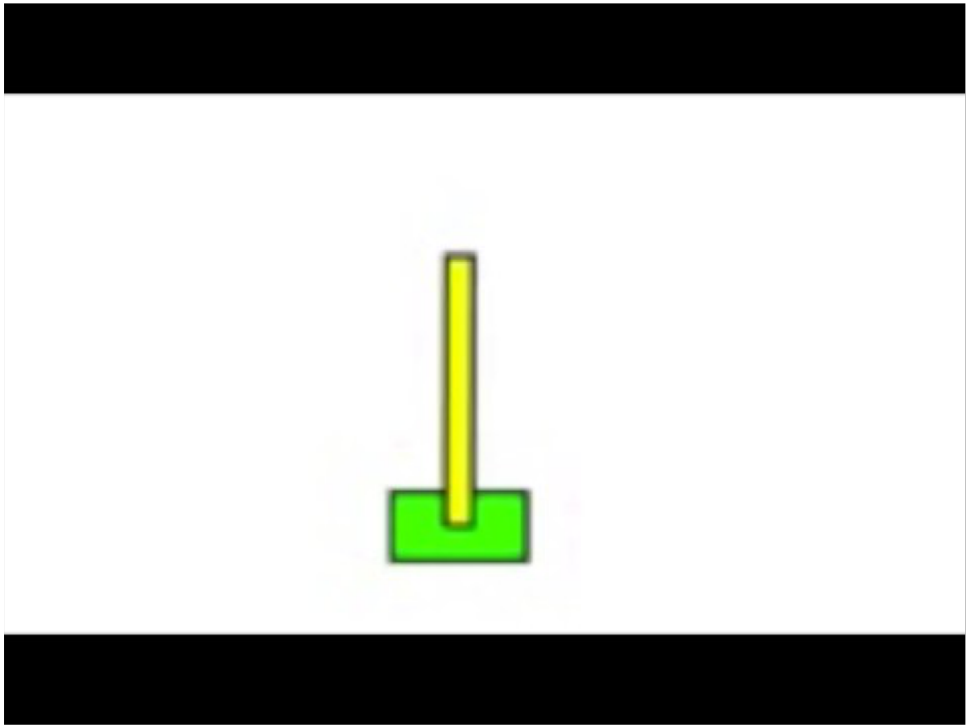
Pole Balancing





Pole Balancing

0, 5, 10, 15, 18 generation videos

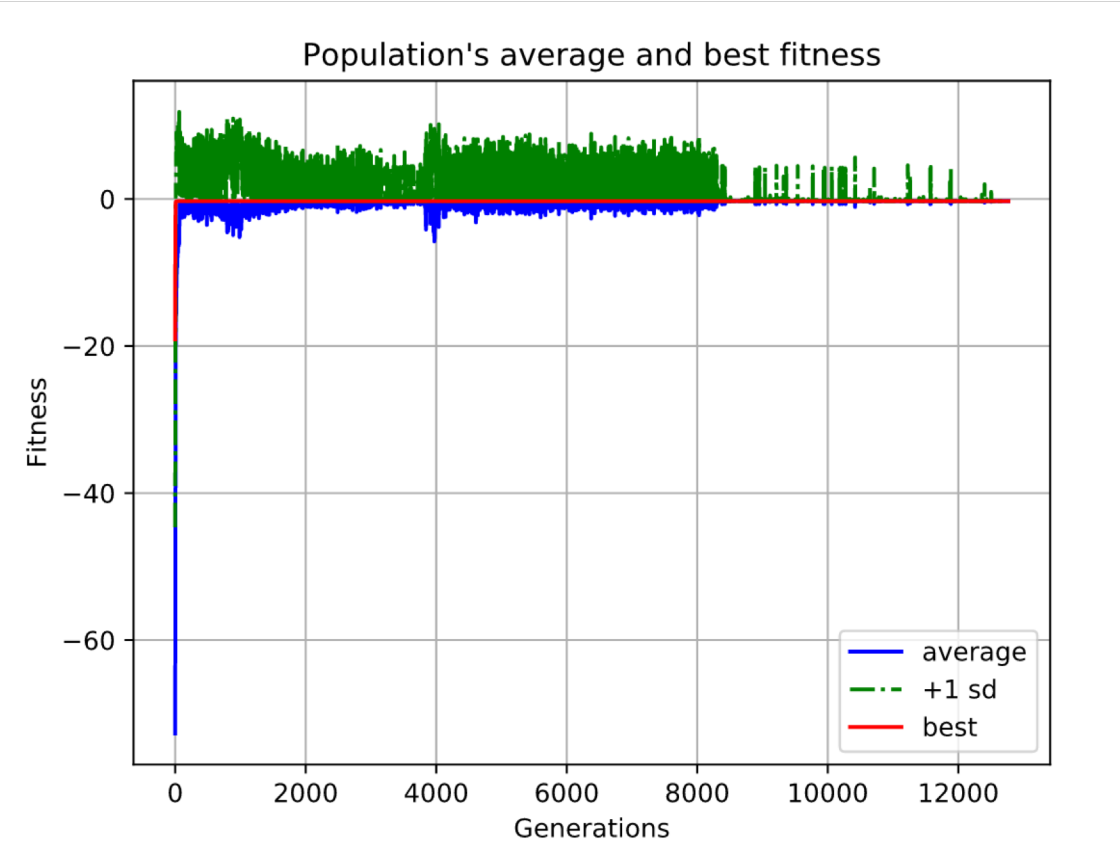


Lunar Lander

- Game in which the goal is to land a spacecraft on flat ground
- Spacecraft has the ability to shoot particles to move the vehicle, which represents small rocket boosters that adjust movement

Lunar Lander

- Limitations of algorithm
  - Initialization
  - Local Minima



Lunar Lander

Demo!

Open Issues

- Integrating with other types of learning
  - Q-Learning, TD-Learning
- Developing better evolutionary methods
  - Competitive and cooperative co-evolution
- Building “General AI”
  - Games, personal assistants, etc. can all benefit from better learning provided by neuroevolution and genetic programming

References

- Kenneth O. Stanley and Risto Miikkulainen. 2002. Evolving neural networks through augmenting topologies. Evol. Comput. 10, 2 (June 2002), 99-127. DOI=http://dx.doi.org/10.1162/106365602320169811
- Michael O'Neill, Leonardo Vanneschi, Steven Gustafson, and Wolfgang Banzhaf. 2010. Open issues in genetic programming. Genetic Programming and Evolvable Machines 11, 3-4 (September 2010), 339-363. DOI=http://dx.doi.org/10.1007/s10710-010-9113-2
- NEAT-Python, https://github.com/CodeReclaimers/neat-python
- OpenAI Gym, https://github.com/openai/gym

Discussion

- How does Neuroevolution compare to typical reinforcement learning?
- What future applications do you see Neuroevolution solving?
- Could you implement biologically-inspired neural networks on hardware? Would it help?

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Neuroevolution

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