



NEAT: NEUROEVOLUTION OF AUGMENTING TOPOLOGIES

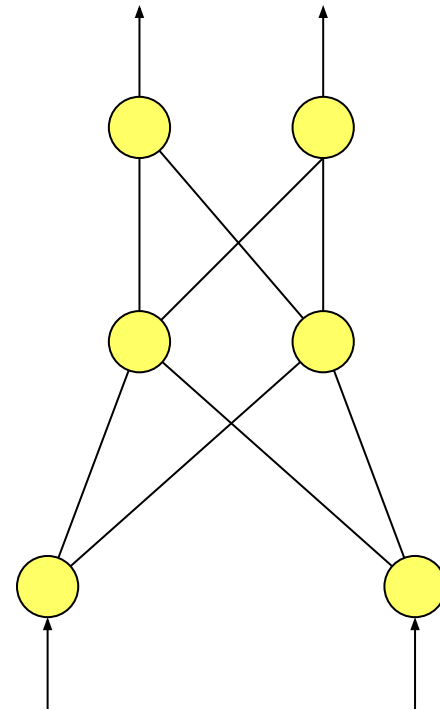
Michael Prestia

COT 4810

April 8, 2008

RECAP: ARTIFICIAL NEURAL NETWORKS

- Composed of neurons and weights
- Sum products of weights and inputs to activate

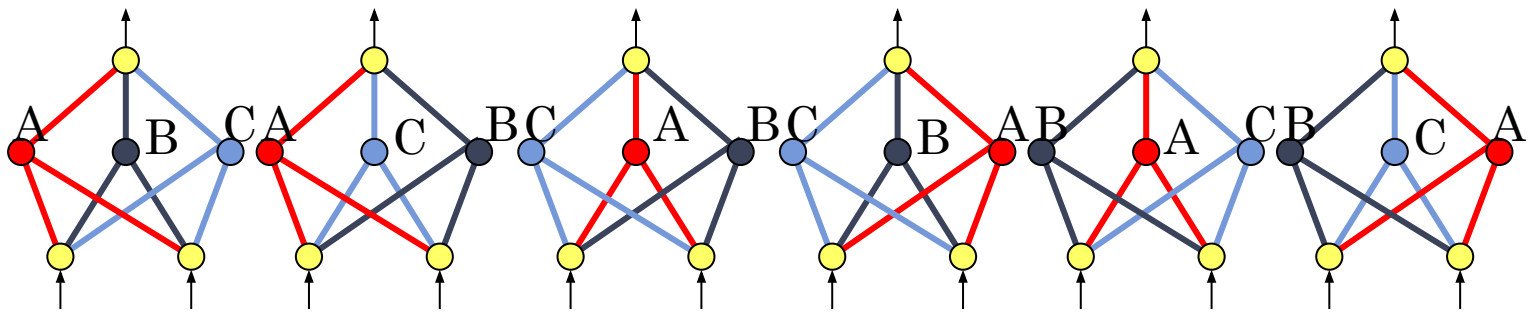


RECAP: NEUROEVOLUTION

- Evolves weights of a neural network
- Genome is direct encoding of weights
- Weights optimized for the given task



COMPETING CONVENTIONS PROBLEM



$3! = 6$ different representations of the same network



NEUROEVOLUTION OF AUGMENTING TOPOLOGIES

- Uses node-based encoding
- Keeps an historical record of innovations
- Keeps size of networks to a minimum
 - Start with minimal topologies and random weights
- Biological motivation



NEAT GENOME

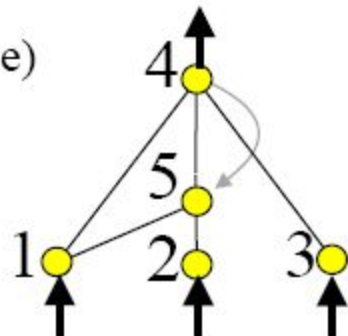
- List of neuron genes
 - ID number
 - Node type
- List of link genes
 - Start node
 - End node
 - Weight
 - Enabled flag
 - Innovation number



GENETIC ENCODING IN NEAT

Genome (Genotype)							
Node	Node 1	Node 2	Node 3	Node 4	Node 5		
Genes	Sensor	Sensor	Sensor	Output	Hidden		
Connect. Genes	In 1	In 2	In 3	In 2	In 5	In 1	In 4
	Out 4	Out 4	Out 4	Out 5	Out 4	Out 5	Out 5
	Weight 0.7	Weight -0.5	Weight 0.5	Weight 0.2	Weight 0.4	Weight 0.6	Weight 0.6
	Enabled	DISABLED	Enabled	Enabled	Enabled	Enabled	Enabled
	Innov 1	Innov 2	Innov 3	Innov 4	Innov 5	Innov 6	Innov 11

Network (Phenotype)



MUTATION IN NEAT

- Four types of mutations
 - Perturb weights
 - Alter activation response
 - Add a link gene
 - Add a neuron gene
- Adding of a link gene or neuron gene is an innovation



WEIGHT PERTURBATION

- Works similarly to previously discussed method
- Each weight modified depending on mutation weight
- Weights can be completely replaced
 - Controlled by user-defined parameter



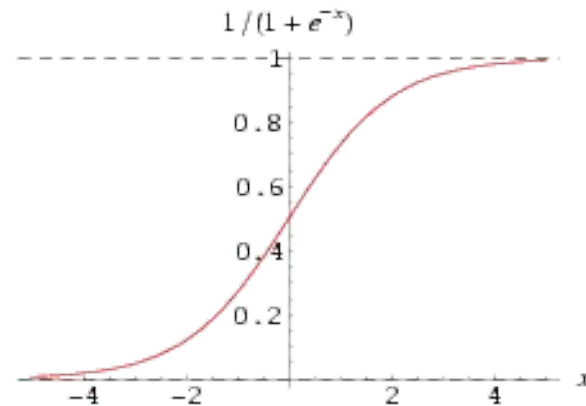
ACTIVATION RESPONSE MUTATION

- Activation response determines curvature of activation function

Neuron j
activation:

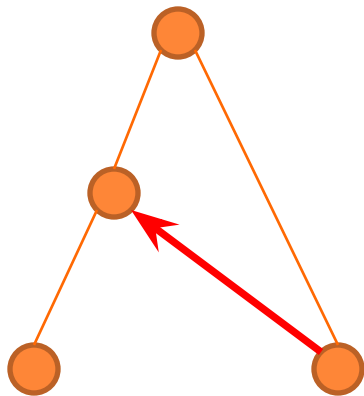
$$H_j = \sigma \left(\sum_{i=1}^n x_i w_{ij} \right)$$

$$\sigma(x) = \frac{1}{1 + e^{-a/p}}$$

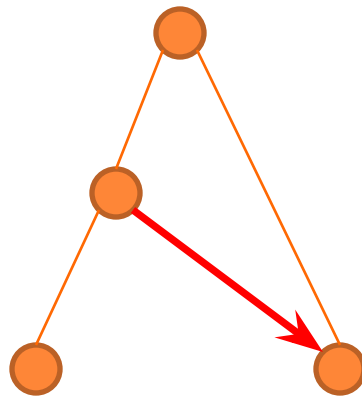


ADDING A LINK GENE

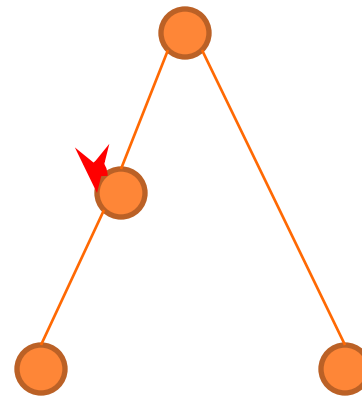
- Adds a connection between any nodes in the network
- Three types of links



forward



backward

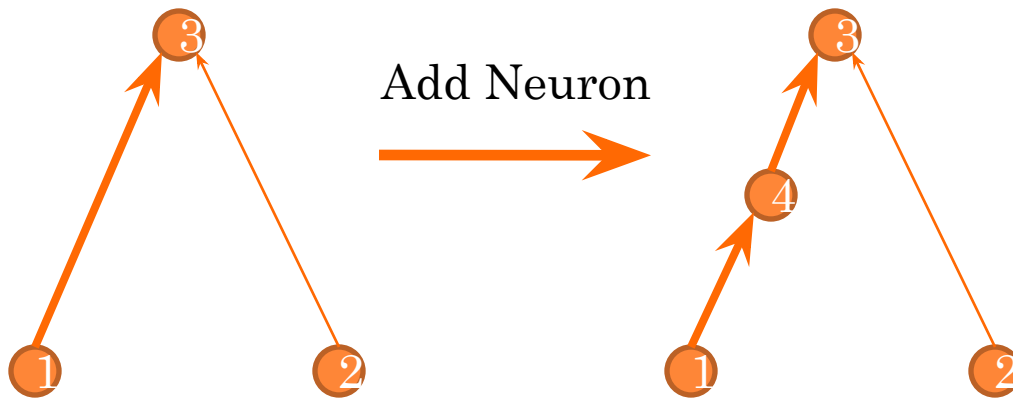


recurrent



ADDING A NEURON GENE

- Link chosen and disabled
- Two new links created to join new neuron
 - One link has weight of disabled link
 - Other link has weight of 1
- Problem: chaining effect



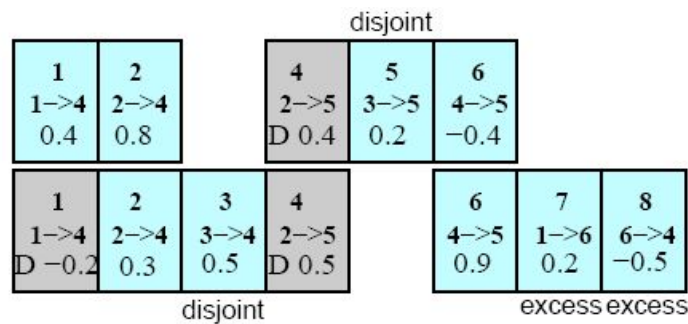
INNOVATIONS

- Global database of innovations
- Each innovation has unique ID number
- Each added neuron or link is compared to database
- If not in database
 - new innovation ID given to gene
 - innovation added to database



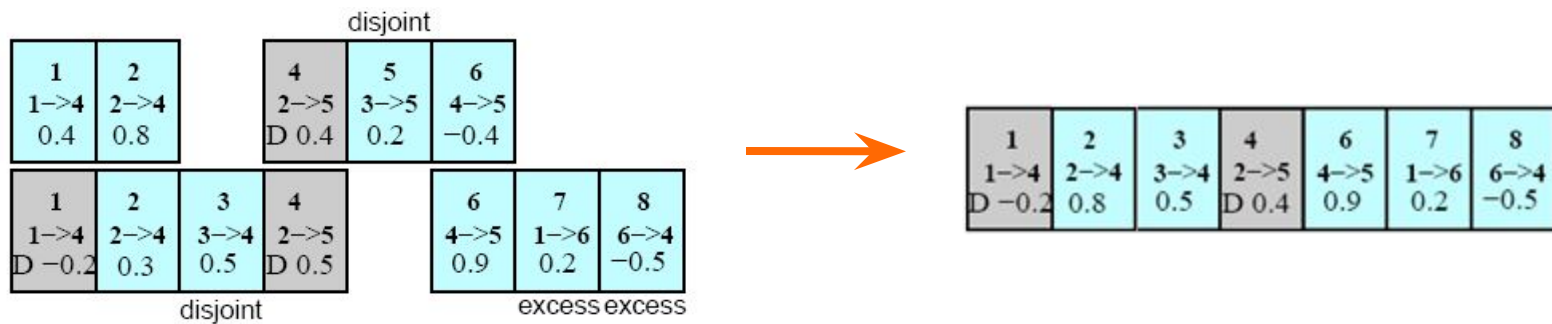
CROSSOVER

- Arrange genes by innovation number
- Non-matching genes are called disjoint genes
- Extra genes at end of genome are called excess genes



CROSSOVER

- Matching genes inherited randomly
- Disjoint and excess genes inherited from fittest parent



SPECIATION

- New topologies typically poor performer at first
 - High probability individual will die out
- Separate population into species
- Similar individuals only compete among themselves
- Helps prevents premature extinction



COMPATIBILITY DISTANCE

- Species determined by compatibility distance
- Calculated by measuring diversity genomes of two individuals
- $$C.Dist = \frac{c_1 E}{N} + \frac{c_2 D}{N} + c_3 W$$
- Greater distance, greater diversity



EXPLICIT FITNESS SHARING

- Further helps prevent premature extinction
- Shares fitness scores among a species
- individual fitness divided by size of species
- Species killed off if no improvement over set number of generations
 - Exception if species contains fittest



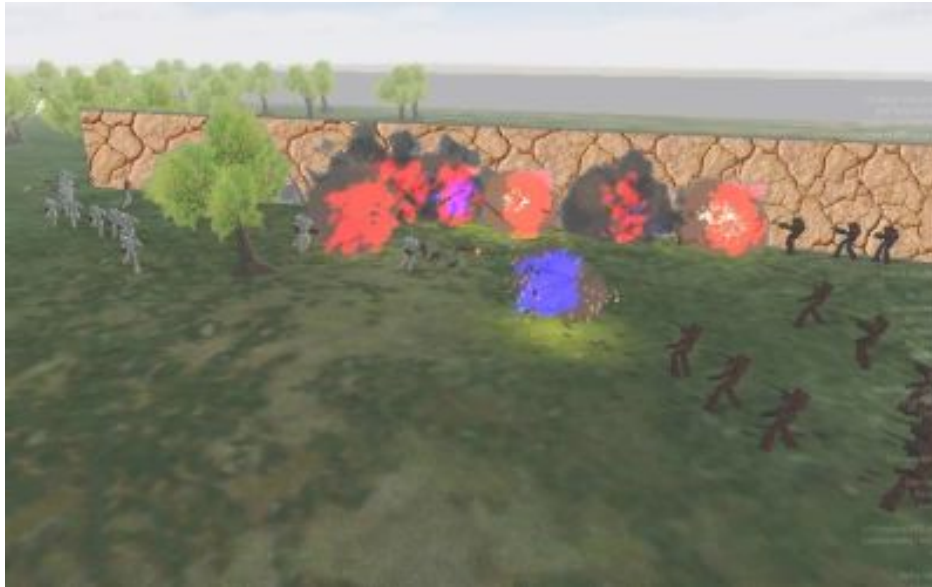
ACTIVATION

- No predefined layers as in other neural networks
 - Needs to activate differently
- Two activation modes
 - Active – uses activations from previous time step
 - Snapshot – iterates through all neurons with each update



APPLICATION OF NEAT

- NERO – Neuro Evolving Robotic Operatives
- www.nerogame.org



<http://nerogame.org/>



REFERENCES

- Buckland, Mat. AI Techniques for Game Programming. Cincinnati: Premier Press, 2002.
- AI for Game Programming: Kenneth Stanley
- Images copied with permission from http://www.cs.ucf.edu/~kstanley/cap4932spring08/dir/CAP4932_lecture13.ppt



HOMEWORK QUESTIONS

- How does NEAT avoid the competing conventions problem?
- What is one way NEAT protect innovation?

