Neuroevolution and Other Techniques for Generating Realistic Behavior

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Yoonsuck Choe, Ph.D. a
Brain Networks Lab & Neural Intelligence Lab.
Texas A&M CSE


Outline

• Introduction to neuroevolution
• Evolving complex behavior through complexification and co-evolution (Stanley, Miikkulainen)
• Composite Agents (Yeh et al.) – if time permits
• Discussion

How to Generate Realistic Behavior, for Games?

Call of Duty ®
Heider and Simmel [ 2 ]

• Which one looks more realistic?
• Which one will show more realistic behavior?

I. Intro to Neuroevolution
Neuroevolution of Complex Behavior

• Neuroevolution: Evolving artificial neural networks to control behavior of robots and agents.

• Main idea: Mimic the natural process of evolution that gave rise to the brain, the source of intelligence.
  – Population
  – Competition
  – Selection
  – Reproduction and mutation

Why Neuroevolution?

• Neural networks are effective but with limitations.

• Can solve tough, complex problems: fin-less rockets, robotic agents.

Neuroevolution Basics

• A single chromosome encodes a full neural network.
  – Inputs hooked up to sensors, and outputs to actuators.

• Each gene, a single bit (or a real number), maps to a connection weight in the neural network.

Neuroevolution Basics: Operators

• Cross-over: Combine traits from both parents.

• Mutation: Introduce randomness (innovation).
Neuroevolution Basics: Cross-Over in Detail

**CROSS–OVER**

- PARENTS
  - $w_1, w_2, w_3, w_4, w_5, w_6, w_7, w_8, w_9, w_{10}, w_{11}, w_{12}$

- OFFSPRINGS
  - $w_1, w_2, w_3, w_4, w_5, w_6, w_7, w_8, w_9, w_{10}, w_{11}, w_{12}$

- Cross-over point

- **Cross-over of two individuals produces two offsprings with a mixed heritage.**

Conventional Neuroevolution (2)

1. **Fitness Evaluation:** Construct NN with chromosome, put in the environment, observe outcome.
2. **Selection:** Choose best ones.
3. **Reproduction:** Mate the best ones and put back in the population.

Problems with CNE

- Evolution tends to converge to a small homogeneous population
  - Diversity is lost; progress stagnates

- Competing conventions
  - Different, incompatible encodings for the same solution

- Too many parameters to be optimized simultaneously
  - Thousands of weight values at once

Advanced Neuroevol.: Evolving Neurons

- Evolving individual neurons: Chromosome = neuron
- Construct network with neurons, evaluate, reproduce, and repeat.
  - Network has fixed topology.
- Fitness of network determines that of participating neurons.
- Shown to improve diversity.
II. Evolving Complex Behavior: Co-Evolution & Topology Evolution

- Fixed topology has limitations.
- Idea: Evolve network topology, as well as connection weight.
- Neuroevolution of Augmenting Topologies (NEAT)
- Based on Complexification:
  - Network topology
  - Behavior

How Can We Complexify?

- Can optimize not just weights but also topologies
- Solution: Start with minimal structure and complexify
- Can search a very large space of configurations!

How Can Crossover be Implemented?

- Problem: Structures do not match
- Solution: Utilize historical markings

Genome (Genotype)

<table>
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<tr>
<th>Node</th>
<th>Genes</th>
<th>Connect.</th>
<th>Genes</th>
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<tr>
<td>Node 5</td>
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</table>

Network (Phenotype)
How can Innovation Survive?

- Problem: Innovations have initially low fitness

- Solution: Speciate the population
  - Innovations have time to optimize
  - Mitigates competing conventions
  - Promotes diversity

Competitive Coevolution

- Progress in evolution is based on competition.
- Better solutions emerge when given tougher opponents.
- Tough opponents do not exist from the beginning.
- Co-evolution solves this problem.
  - Start out with naive populations.
  - Make populations compete with each other.
  - Coevolutionary arms race (poison toxicity vs. tolerance).

Competitive Coevolution with NEAT

- Complexification elaborates on the solution
  - Adding more complexity to existing behaviors
- Can establish a coevolutionary arms race
  - Two populations continually outdo each other
  - Absolute progress, not just tricks

Coevolution Demo (by Ken Stanley)

- Two robots pitted against each other
  - Food sensor, Enemy sensor, Energy difference sensor, Wall sensor
  - Eat food to incr. Energy, Moving around decr. energy.
Early Poor Strategy

- Generation 1 and 3 champs.
- Very goal-directed: eat food, attack opponent

Later Poor Strategy

- Champs from two different population in gen 40.
- No food consumption (poor strategy).
- Waste energy while idly moving (teasing?).

First Successful Strategy

- Gen 80 champ vs. Gen 95 descendant
- Switching behavior between foraging, caution, predation; Final standoff.

Old West-Style Standoff

- Gen 95 vs. gen 90 champ.
- Extended standoff
Later Dominant vs. Early Good Str.

- Gen 221 champ (later dominant strategy) vs. gen 130 champ (first good strategy).
- Caution when seeking food. Switching of strategy observed.

Highest Dominant vs. First Good Str.

- Gen 313 champ vs. gen 95 champ.
- Highest dominant is dominant over all past dominant.

Highest- vs. Prior-Dominant Str.

- Gen 313 champ vs. gen 210 champ.
- Waiting until the moment is just right.
- Food nearby, enemy wasting energy, etc. all considered.

Other Applications of NEAT

- NERO (NeuroEvolution of Robotic Operatives): Interactive neuroevolution for realtime strategy game-like environment (http://nerogame.org)
- Dancing, driving, generation of art, etc.
- See Ken Stanley’s web page.
NERO Details

1. Approach Enemy
2. Hit Target
3. Avoid Fire
4. Approach Flag
5. Stick Together
6. Stand Guard

[NERO Demo]

Summary (NEAT)

- Evolving neural network topologies helps evolve complex emergent behavior.
- Co-evolution ensures continuous progress.
- Diverse applications possible.

Crowd Modeling with Composite Agents

A simple idea of “proxy” can:

- Help simplify task specification.
- Lead to emergent, realistic behavior.

III. Composite Agents

Yeh et al.

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The Concept of “Proxy”

- Proxies are like ghosts attached to the main agent.
- Attaching or dynamically generating “proxies” can greatly simplify behavioral modeling.

Types of Proxies

- Aggression proxy
- Priority proxy
- Trailing proxy

Use default planner with these proxies.

Proxy: Intangible Factors

- Social and psychological factors can be translated into proxies.

Proxy: Aggression Proxy

- Red: aggressor (with black proxy), Green: normal.
Agents with aggression proxy faster to evacuate building.

Priority proxy implements social protocol.

Trail proxy enforces authority.

Trail proxy helps maintain police line.
Discussion and Conclusion

- Neuroevolution evolution is an effective strategy for constructing complex and realistic behavior.
- Composite agents, using various proxies, can also lead to realistic behavior.
- Analyzing the evolved networks is a challenge.

References


