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

I. Intro to Neuroevolution

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?

²
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 of two individuals produces two offsprings with a mixed heritage.

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

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.

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
\textsuperscript{5,6})
- Based on \textit{Complexification}:
  - Network topology
  - Behavior

How Can We Complexify?

- Can optimize not just weights but also topologies
- Solution: Start with minimal structure and complexify\textsuperscript{8}
- Can search a very large space of configurations!

How Can Crossover be Implemented?

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

21

Later Poor Strategy

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

22

First Successful Strategy

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

23

Old West-Style Standoff

• Gen 95 vs. gen 90 champ.
• Extended standoff

24
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.

III. Composite Agents

Crowd Modeling with Composite Agents

A simple idea of “proxy” can:
- Help simplify task specification.
- Lead to emergent, realistic behavior.
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.

Proxy: Trail Proxy

• Trail proxy enforces authority.

Proxy: Embassy Evacuation Example

• 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


