Neuroevolution and Other Techniques for Generating Realistic Behavior

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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?
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).
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

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

Evolving Topologies

- Fixed topology has limitations.
- Idea: Evolve network topology, as well as connection weight.
- Neuroevolution of Augmenting Topologies (NEAT\textsuperscript{5,6})
- 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\textsuperscript{8}
- Can search a very large space of configurations!

How Can Crossover be Implemented?

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

Genome (Genotype)

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Network (Phenotype)

Genes: Connect. Genes
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.
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.
**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.
IV. Wrap Up

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


