Coevolution

CS 5764
Evolutionary Computation
Hod Lipson
Co-evolving parasites improve simulated evolution as an optimization procedure - Hillis - 1991
Why coevolution

- Large (infinite) search spaces
- No objective measures exist
- Objective measure difficult to formalize or unknown
- Certain types of structure in search space
What is co-evolution

• Single or multiple populations, where the relative ranking among two individuals depends on a third individual
  – E.g. game of chess against co-evolving partners

• Can take care of gradient problem of chess
  – But can introduce other problems: Collusion.
Evolved Virtual Creatures

Kari Sims
Other type of coevolution

• Body-brain coevolution – not separately evolving
Predator Prey
Symbiosis
Teacher Learner
Types of coevolution

• Antagonistic: Predator–prey
• Cooperative: Symbiosis
• Asymmetric: Host-parasite, teacher learner
Symbiogenesis

- Independent sybionts merge into single individual
  - can only reproduce together
Objective vs. subjective fitness

- **Objective**: Ground truth – usually unknown except for toy problems
- **Subjective**: Fitness as measured using co-evolving metric
Coevolution and GP

• How would you apply coevolution to Symbolic regression?
Models: Expression trees
Subject to mutation and selection

Experiments: Data-points
Subject to mutation and selection
Solution Accuracy

Coevolved Dataset

Entire Dataset

$f_2 = e^{|x|}\sin(x)$

Total Effort (point evaluations)
Solution Complexity

![Graph showing solution complexity over generations for the Entire Dataset and Coevolved Dataset.](image)

- **Entire Dataset**
- **Coevolved Dataset**
The Numbers Game

• Evolve integer numbers
  – Range 0-100
  – Encoded as unary notation

• Goal: Grow large numbers

• Fitness?
  – Objective – the absolute value of the number
  – Subjective – how many numbers it is larger than in competing population

“Well, in our country,” said Alice, still panting a little, “you’d generally get to somewhere else — if you run very fast for a long time, as we’ve been doing.”

“A slow sort of country!” said the Queen. “Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!”
Multidimensional Game

• Now each individual has 10 dimensions.
• Competition is along the dimension where individual are closest
Multidimensional Game

• Now each individual has 10 dimensions.
• Competition is along the dimension where individual are closest
• Who wins: A(8,5) or B(5,7)? B, because it wins on the closest dimension. How can A win? By reducing its 5 to 3, thereby shifting the game to the first dimension
Coevolution

- Subjective fitness
  - Misleading progress
    - Rank the fitness
  - Cycles of forgetting
    - Hall of fame
- Collusion
  - Fitness design
Structural Damage Diagnosis

With Wilkins Aquino
Coevolution and GP

• How would you apply coevolution to TSP?
Cooperation

• How do we co-evolve cooperation?
  – Joint fitness
    • Leads to “hitchhikers”

• Credit assignment problem
Historical Examples: Intertwined Spirals

Juillé & Pollack 1996

- Coevolves genetic-program classifiers, where payoff to Player $i$ is:
  - $G(i, j) =$ \#points "covered" by Player $i$ that are not covered by Player $j$

- Difficult classification problem
- Motivated by study of neural networks
- 194 data points to classify
- Finds modular solutions to problem:
  - Divides space, solves each region independently