Pareto Coevolution and Progress

Anthony Bucci

http://www.cs.brandeis.edu/~abucci

The Big Picture

- Pareto coevolution effectively solves the problem of maintaining a *direction* of progress.
- It does so in a non-competitive manner, rewarding *tests* for being good tests (not for clobbering someone else).
- However, Pareto coevolutionary dynamics can get stuck. Representation issues are what cause the stoppage.

Whirlwind Coevolution Primer

- Coevolution is a process by which individuals change in response to the presence of other individuals. A key feature is that a given individual changes differently depending on which others are present.
- Naive coevolutionary algorithms are vulnerable to intransitive superiority cycles (rock paper scissors) which are common in interesting problems.

Whirlwind Coevolution Primer

- Traditional coevolution is *competitive*. The task of an individual is to maximize its fitness against everyone else present.
- It is subject to *memory loss*, *loss of gradient*, and similar problems because the individuals carrying that information (memory, gradient) can be outcompeted.
- A number of mechanisms, like hall of fame have tried to fix this problem. But the problem is really raw competition...

Pareto Coevolution

- By contrast, Pareto coevolution is partially *cooperative*. The task of an individual is to do well against at least one other individual.
- The key idea which makes Pareto coevolution different is the split in roles between *candidates*, who perform, and *tests*, which enable candidates to perform.
- The split in roles is necessary because being a good candidate is NOT THE SAME as being a good test!

Short History

- Bucci and Pollack (mathematical -- FOGA 2002, GECCO 2002)
- Watson and Pollack (SEAM -- ECAL 2001)
- Noble and Watson (poker-playing strategies -- GECCO 2001)
- Ficici and Pollack (PPSN 2000; ECAL 2001)

Related Work

- Compare new against some past
  - Stanley and Miikkulainen, Dominance tournament
  - Rosin, Hall of Fame
  - Cliff and Miller, Tracking the Red Queen
- Compare new against all current
  - Traditional coevolution
  - Ficici and Pollack, Simple Coevolutionary Algorithm
- Compare new against some current
  - Ficici and Pollack, Pareto Coevolution
  - Watson and Pollack, SEAM

The Search for the Right Tests

- Bucci and Pollack says finding the right tests is crucial!
- Naive coevolution ignored the split between roles. When it worked, it was lucky. Cold.
- Hall of Fame and similar approaches looked for tests, but not in a principled way. Still cold, but getting warmer.
- Fitness sharing is warmer still...
- Pareto coevolution + informativeness is hot!

The Numbers Game

- Watson and Pollack (GECCO 2001) describe a minimal substrate in which to test coevolutionary dynamics. Affectionately called ”the numbers game.”
- Individuals are points in an n x n grid of integers.
- The paper describes two versions, transitive and intransitive. Edwin De Jong recently added an intransitive, asymetric one.

The Numbers Game

- The transitive version is the greater than game -- one point is bigger than another only if it is higher on all dimensions.
- The intransitive game compares two points on their *nearest* dimension. E.g., (2,3) and (0,2) compare on the second, so (2,3) is bigger. Then you have cycles like (1,1) > (0,3) > (2,2) > (1,1).

Numbers Game Results

- Naive two-population coevolution disengaged on the intransitive game. One population would outstep the other, resulting in loss of gradient. Mutation bias kept all individuals mediocre.

Numbers Game and Pareto Coevolution

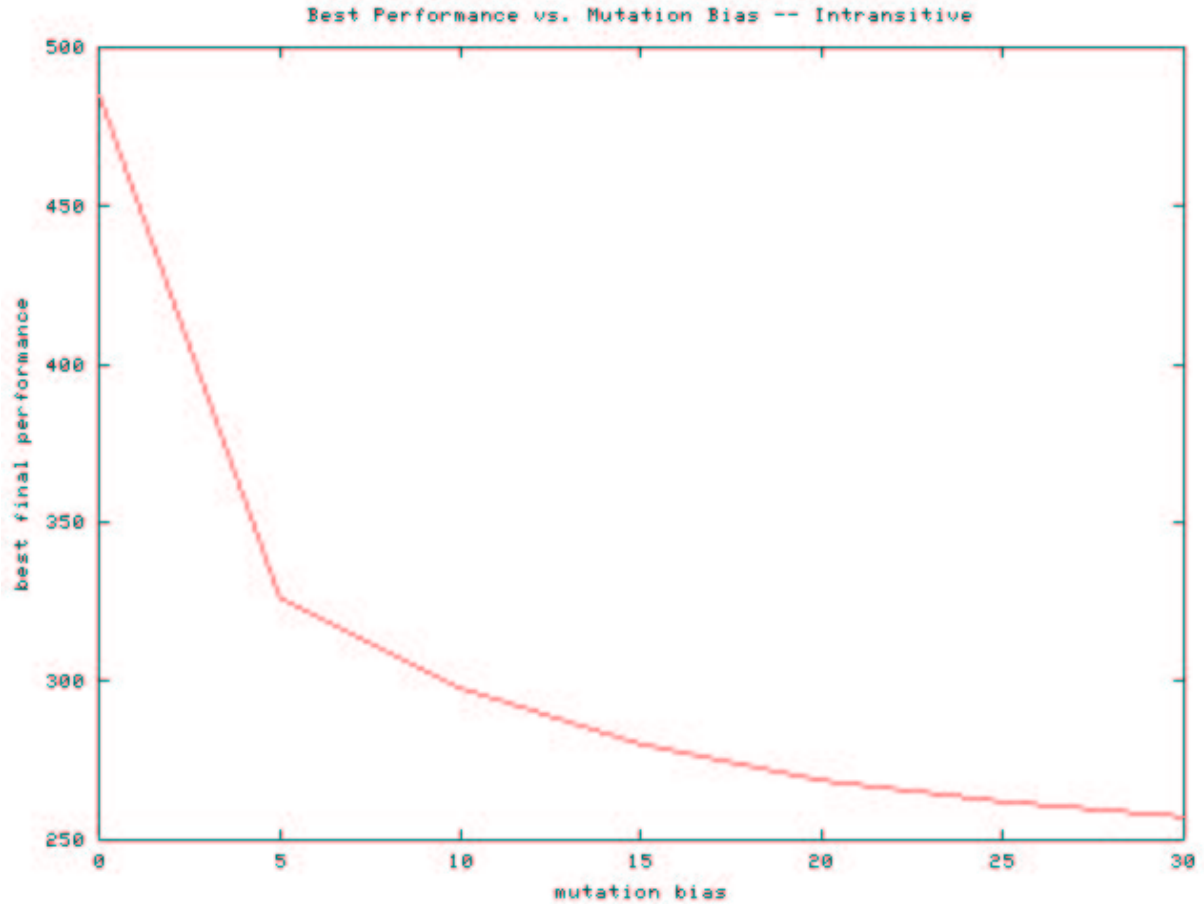
- Reproduction of transitive and intransitive two-population numbers games. However, use *Pareto hillclimbers*.
- Candidates are rewarded for being better *against their parents*, when tested against the current tests.
- Tests are rewarded for being *more informative than their parents*, when tested against the current candidates.

Demos!

- Main result is that this setup works for all variants of numbers game tried, including transitive, intransitive, Edwin's diagonal game, and others I have made up.
- An undisplayed result is that the same algorithm shows similar performance characteristics on tictactoe and backgammon strategy coevolution, except that progress stalls.
- One hypothesis is that representation issues are to blame for stalled progress.

Effects of Mutation Bias

- Added a knob to turn up mutation bias:



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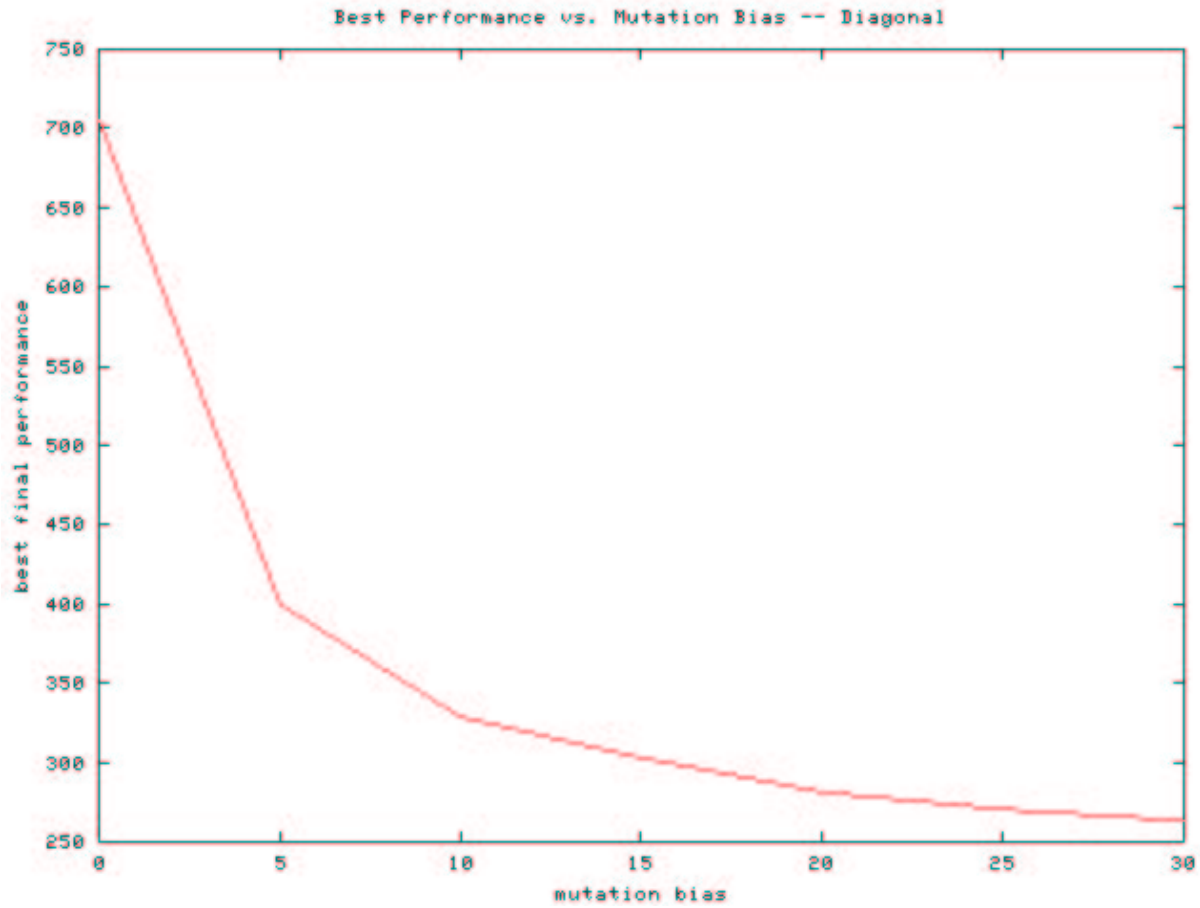

Effects of Mutation Bias

- As mutation bias is increased, best achieved performance goes down. In the absence of mutation bias, progress continues.
- Apparently, mutation bias, which is related to the choice of representation, is having a strong impact on best achieved performance in these numbers games.
- Probably also in board games!