Fitnessless Coevolution

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Intro

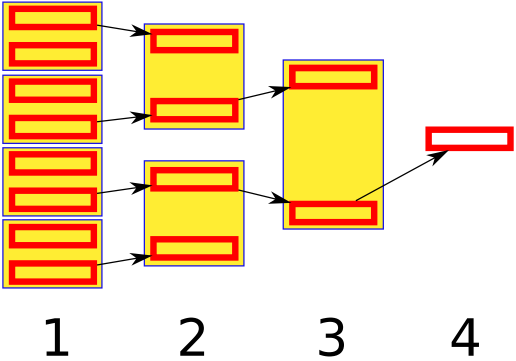
- Coevolutionary algorithm = individual's fitness depends on other individuals
  - The *objective* fitness function absent or not known.
- This paper: *one-population competitive coevolution* = direct competition between individuals in *one* population.
- Mostly explored in the context of games, hence the game theory nomenclature.

Typical approaches

- Non-archive methods:
  - Round robin tournament
  - K-random opponents (kRO)
  - Single ellimination tournament (SET)
- Archive-based methods
  - IPCA, LAPCA, DECA, ...
- Fitnessless coevolution $\in$ non-archive methods

Single-elimination tournament (SET)

- Applied globally to the entire population.
- The individuals are paired at random, play games against each other, and the winners pass to the next stage.
- The fitness of an individual = the number of stages it passed in the tournament.



Fitnessless coevolution (FC): The motivation

- Games a selective by nature.
- Writing down the result of games as a fitness and then using it in the selection phase seems superfluous.
- The idea: Combine the evaluation phase and selection phase, so that the games directly determine the outcome of selection.

Fitnessless coevolution: The algorithm

- The combined evaluation+selection process:
  - A group G of individuals randomly drawn from the population.
  - Applying SET to G
  - The winner of the last game becomes the result of the selection process
- Similar idea suggested in (Tettamanzi 1996)
- Note: ‘Fitnessless’ does not mean lack of selection pressure

The dynamics of fitnessless coevolution

- Follows the line of reasoning of (Luke & Wiegand 2002)

Theorem

A single-population coevolutionary algorithm employing fitnessless selection (i.e., fitnessless coevolution) is dynamically equivalent to an evolutionary algorithm with tournament selection using the objective function f, if

$$\forall_{i,j} f_i > f_j \iff a_{ij} > a_{ji}. \quad (1)$$

(See the paper for proof)

- The consequence:
  If the payoff matrix A is transitive, there always exists an objective function f, such that the evolutionary algorithm using f as a fitness function is dynamically equivalent to fitnessless coevolution using A.
- Does not need to know f explicitly; the existence of f is enough.

Remarks

- For transitive problems, one can argue that it would be easier to construct f it explicitly, and run a traditional evolutionary algorithm using f

However:

- Occam's razor principle
- Numerical fitness may be over-interpreted by attributing to it more meaning than it actually has

The experiment

- The goal: compare fitnessless coevolution (FC) with single-elimination tournament (SET) and k-random opponents (kRO) ($k = 1...10$)
- The problems:
  - Transitive
    - Tic Tac Toe (Noughts and Crosses)
    - The Nim game
  - Non-tranisitive
    - Optimization of Rosenbrock function
    - Optimization of Rastrigin function
- Following the setup of (Angeline & Pollack 1993) and (Panait & Luke 2002)

The parameters

- All methods use tournament selection of size 2
- Evolution stops after reaching the total of 100,000 of games played
- 50 independent runs for each architecture
- Implementation based on ECJ

A

1	2	3
		*

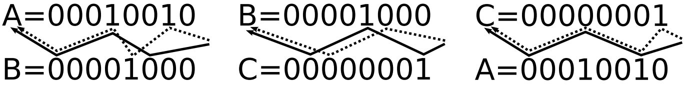
B

3		
2		
1		*

C

		1
	2	
3		*

$$A > B > C > A$$



Handling noise

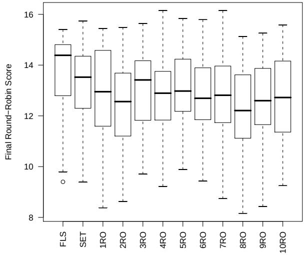
- Noise = reversing the game outcome (thus swapping players' rewards) with a given probability.
- n% of noise means n% of games have the result reversed.
- Note: *all* problems become intransitive in the presence of noise.

The results

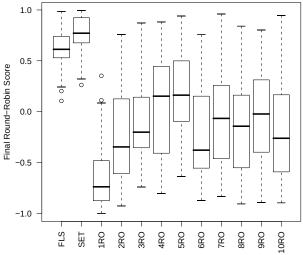
Performance of FC against the other methods.

	Tic Tac Toe				Nim				Rosenbrock				Rastrigin			
	kRO			SET	kRO			SET	kRO			SET	kRO			SET
Noise	$<$	$=$	$>$		$<$	$=$	$>$		$<$	$=$	$>$		$<$	$=$	$>$	
0%		2	8	$=$			10	$<$			10	$>$			10	$>$
30%		10		$=$	2	5	3	$=$			10	$>$		4	6	$>$
40%	4	6		$>$	3	6	1	$=$	6		4	$>$	6	1	3	$>$
Total	4	18	8		5	11	14		6		24		6	5	19	

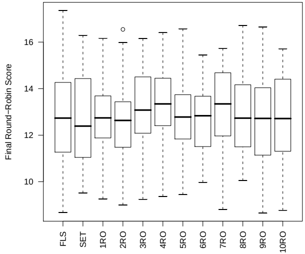
Results for games



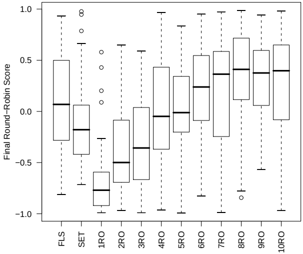
TTT, no noise



Nim, no noise

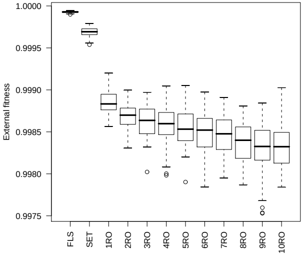


TTT, 30% noise

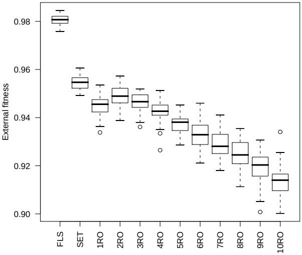


Nim, 30% noise

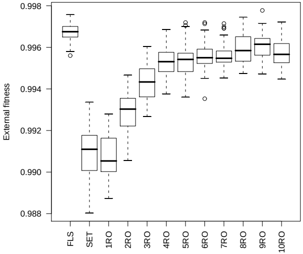
Results for function optimization



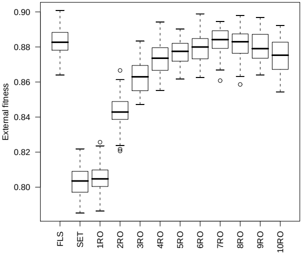
Rosenbrock, no noise



Rastrigin, no noise



Rosenbrock, 30% noise



Rastrigin, 30% noise

Conclusions

- Fitnessless coevolution:
  - comparable to SET and *k*RO on intransitive problems (games).
  - significantly better than SET and *k*RO for transitive problems (function optimization).
- Reasonable immunity to noise; less affected than SET
- Simplicity and elegance
- Locality (works with a small subset of individuals) – convenient for distributed processing