CZECH TECHNICAL UNIVERSITY IN PRAGUE

Faculty of Electrical Engineering
Department of Cybernetics

Coevolution

Petr Pošík

Coevolution and its basic types

What is “coevolution”?

Coevolution and its basic types

- What?
- Types
- 1-pop comp.
- 2-pop comp.
- N-pop coop.
- 1-pop coop.

Problems in coevolution

What is “coevolution”?

Coevolution in EAs:

- The fitness of individuals in a population
  - is not given by the characteristics of the individual (only), but
  - is *affected by the presence of other individuals in the population*.
- It is closer to the biological evolution than ordinary EAs are.

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Coevolution can help in:

- dealing with increasing difficulty of the problem
- providing diversity in the system
- producing not just high-quality, but also robust solutions
- solving complex or high-dimensional problems by breaking them into nearly decomposable parts

Types of coevolution

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By relation type:

- cooperative (synergic, compositional)
- competitive (antagonistic, test-based)

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By the entities playing role in the relation:

- 1-population
  - intra-population
  - individuals from the same population cooperate or compete
- N-population
  - inter-population
  - individuals from distinct populations cooperate or compete

1-population competitve coevolution

Example: The goal is to evolve a game playing strategy

- successful against diverse opponents!!!

How would you proceed in an ordinary EA?

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Solution: Intra-population competitive coevolution

- by playing several games against other strategies in the population.
- All individuals of the same type.
- In the beginning, all are probably quite bad, but some of them are a bit better.
- The fitness (the number of games won) may not rise as expected since your opponents improve with you.

2-population competitive coevolution

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- able to sort any sequence of numbers
- correctly and quickly.

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- Test only a fixed set of sequences? Which ones?

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- Fitness evaluation:
  - Algorithm: by its ability to sort. How many sequences is it able to sort correctly? How quickly?
  - Test case: by its difficulty for the current sorting algorithms. How many algorithms did not sort it?
- Predator-prey relationship

N-population cooperative coevolution

Example: The goal is to evolve a team consisting of

- a goalie, back, midfielder, and forward
- so that they form a good team together.

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Cooperation:

- symbiotic relationship
- good performance of the team $\Rightarrow$ high contribution to fitness of all members

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Principle:

- better individuals similar to others already in population are thrown away in favour of worse, but diverse individuals
- the selection process is affected by the presence of other individual in the neighborhood

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Some important classifications of fitness

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Ideally, external fitness

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External fitness in coevolution:

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Internal fitness in coevolution:

- **relative**: affected by other individuals
- **dynamic**: affected by evolving individuals (needs re-evaluation)
- **stochastic**: usually evaluated against a smaller number of individuals

“Fitness” in sport

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Football league:

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Football league:

- all teams play against all others
- points awarded for win, draw, and loss
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- each player is assigned a level, based on historic results
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None of these systems is static:

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The same holds for fitness assessment in coevolution!

Problems with fitness assessment: 1-pop. competitive coevolution

Cycles, etc.

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  - A player that wins by the most total points on average?
- Often, additional matches are executed.
- But, do you want to spend your fitness budget
  - on evaluating current individuals more precisely, or
  - on searching further?

2 competitive populations (illustration)

Lotka-Volterra model (Predator-prey population dynamics):

$$\frac{dx}{dt} = \alpha x - \beta xy$$
$$\frac{dy}{dt} = -\gamma y + \delta xy$$

where x is the number of prey (rabbits) and y is the number of predators (wolves).

Assumptions:

1. The prey population has always food enough.
2. The predators eat only the prey.
3. The rate of change of population is proportional to its size.
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Meaning:

- The change of the prey population (dx/dt) is composed of
  - increase due to the newly born individuals (proportional to the population size, αx) and
  - decrese caused by the predation (which is proportional to the rate of predator-prey meetings, βxy).
- The change of the predator population (dy/dt) is composed of
  - decrease due to natural death (proportional to the population size, γy) and
  - increase alowed by the food suply (proportional to the rate of predator-prey meetings, δxy).

2 competitive populations (illustration)

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- Summary

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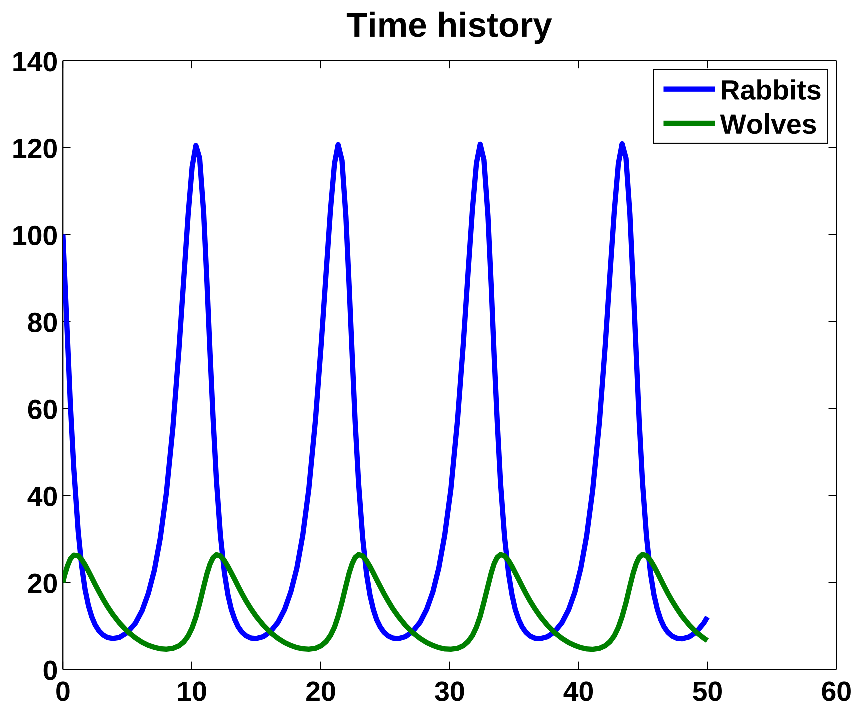

Problems with fitness assessment: 2-pop. competitive coevolution

Arms races

- one population learns a trick and forces the second population to learn a new trick to beat the first one. . .
- one population may evolve faster than the other:

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- Solution:
  - detect such situation (but how?)
  - delay the evolution of the better population until the worse one catches up

Problems with fitness assessment: N-pop. cooperative coevolution

Hijacking (in team of goalie, back, midfield, and forward):

- a really good forward takes over one population, any team will play well thanks to him
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- Solution: apply some form of *credit assignment*

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- when evaluated by average score, worse (but more robust) individual B1 will have higher score than better (but volatile) B2
- use maximum score (more tests needed)
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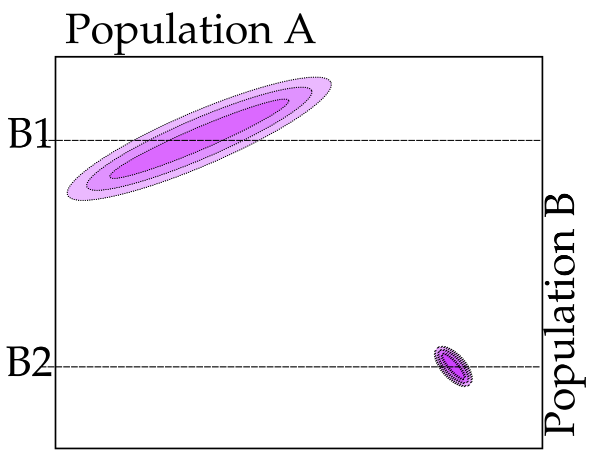

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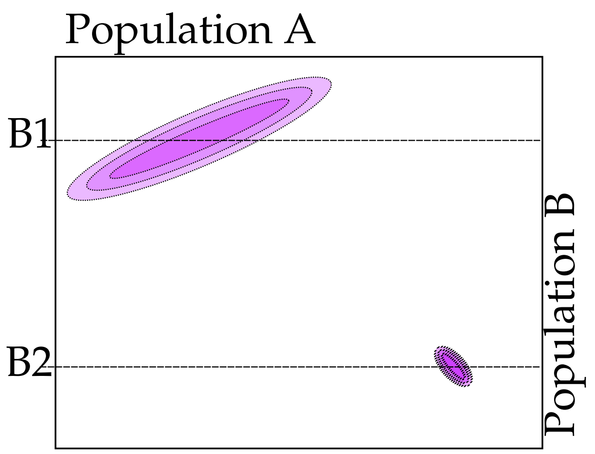

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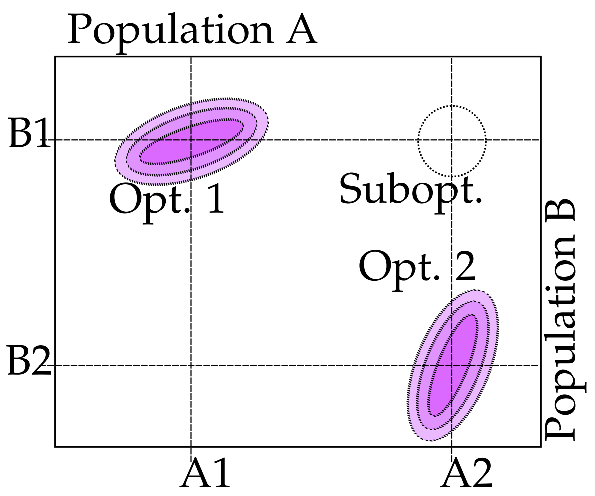
Miscoordination



- when the team components are not independent
- Pop. A evolved A2 (but not A1), pop. B evolved B1 (but not B2)
- Neither A2 nor B1 survives

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- can take place in 1 population or in more populations
- fitness is not fixed during evolution
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Appropriate when

- no explicit fitness function can be formed
- there are too many fitness cases
- the problem is modularizable (divide and conquer)