Coevolution

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Coevolution and its basic types

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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!!!

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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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  - ✘ 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

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- ✔ 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

Problems in coevolution

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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 competitions

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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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The same holds for fitness assessment in coevolution!

Problems with fitness assessment: 1-pop. competitive coevolution

Cycles, etc.

- ✔ What if A beats B, B beats C, but C beats A?

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  - ✘ A player that wins by the most total points on average?
- ✔ Often, other tests 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.
4. The environment is static.

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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
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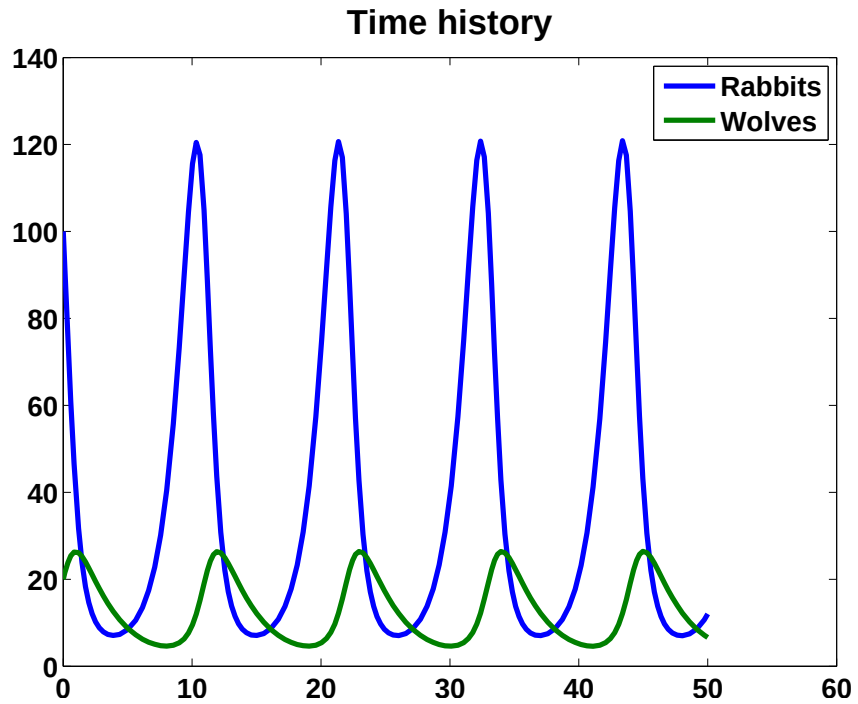

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Arms races

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- ✔ one population may evolve faster than the other:

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- ✔ not exactly what was shown by Lotka-Volterra, but similar
- ✔ 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

- ✔ a really good forward takes over one population, any team will play well thanks to him
- ✔ members of all other populations have almost the same fitness $\Rightarrow$ uniform random selection
- ✔ Solution: apply some form of *credit assignment*

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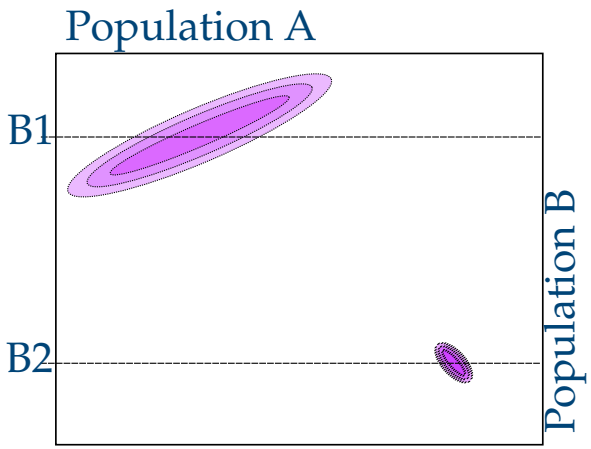

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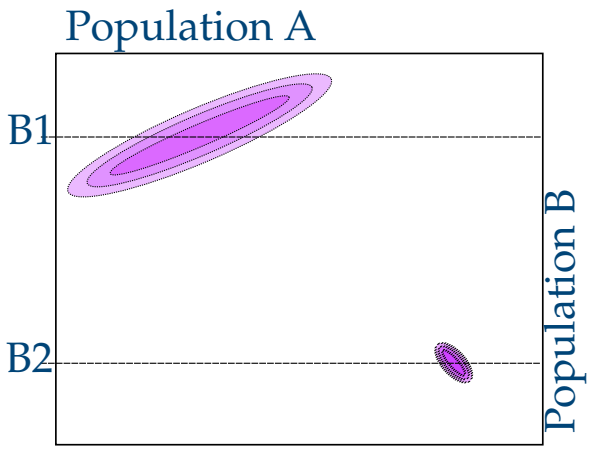
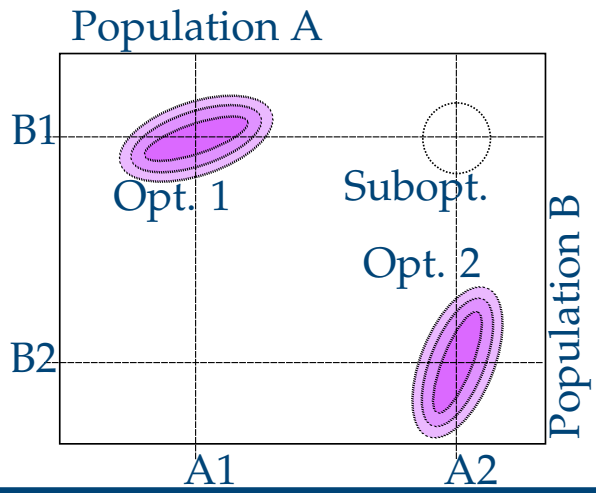


Miscoordination

- ✔ 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



Summary

Coevolution

- ✔ can be cooperative or competitive (or both)
- ✔ 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)