Coevolution

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Coevolution and its basic types
What is "coevolution"?
Types of coevolution
1-population competitve coevolution
2-population competitive coevolution
N-population cooperative coevolution
1-population cooperative coevolution
Problems in coevolution

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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

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By relation type:

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

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By relation type:

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

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

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Example: evolution of game playing strategies

- ✔ successful against diverse opponents

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- ✔ by playing several games against human player? Against conventional program?

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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 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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Solution: Inter-population competitive coevolution

- ✔ 2 populations, 2 species:
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  - ✘ test cases (sequences to sort)

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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

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

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- ✔ Represent all 4 strategies in 1 genome, evolve them all in 1 population
- ✔ Theoretically possible, but the space is too large
- ✔ May result in a team of players which wouldn't perform well if substituted to another team

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- ✔ Evolve players which would play well with any other team members

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Cooperation:

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

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- ✔ diversity preservation
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Examples of niching methods:

- ✔ fitness sharing
- ✔ crowding

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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

- by its time-dependence:
  - **static**: does not change with time
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Ideally, external fitness

- should be **static**, **deterministic** and **absolute**
- can easilly be used as internal fitness

External fitness in coevolution:

- impossible (hard) to define
- often, it is **relative**, but measured with a carefully chosen, large enough set of other individuals (**static**) sufficiently many times (almost **deterministic**)

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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:

- ✔ all teams play against all others
- ✔ points awarded for win, draw, and loss
- ✔ teams sorted by the earned points

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- ✔ tournaments have different prize money to distribute to tournament winners
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- ✔ each player is assigned a level, based on historic results
- ✔ matches between players of different levels
- ✔ the player's level increases (decreases) if she recently won more (less) matches than expected

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- What if A beats B, but B beats far more individuals than A?

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  - ✘ 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?

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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.

2 competitive populations (illustration)

Coevolution and its basic types

Problems in coevolution

Fitness in coevolution

"Fitness" in competitions

Problems with fitness assessment: 1-pop. competitive coevolution

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Problems with fitness assessment: 2-pop. competitive coevolution

Problems with fitness assessment: N-pop. cooperative coevolution

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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).

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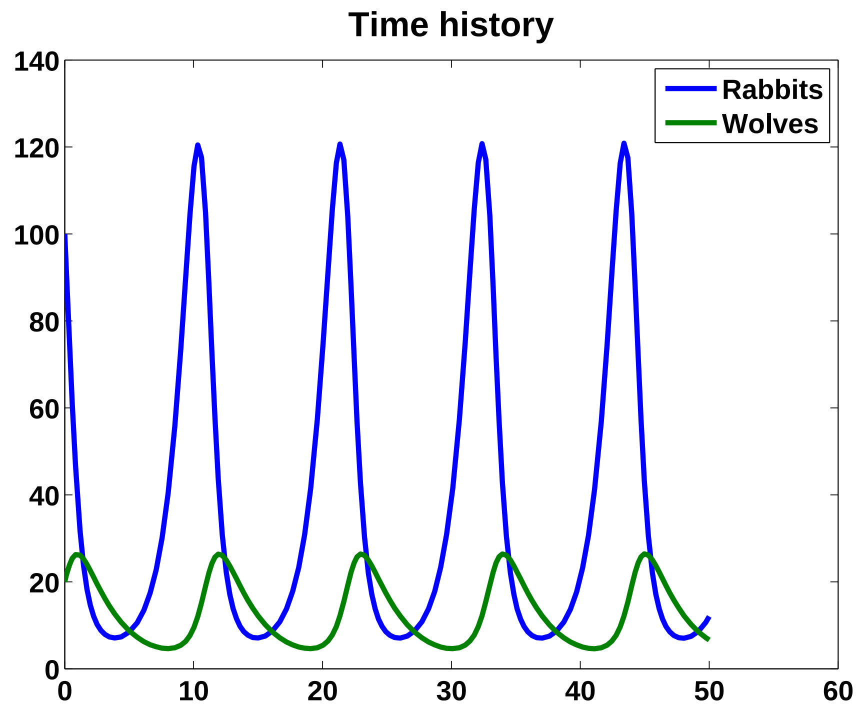

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- ✔ one population learns a trick and forces the second population to learn a new trick to beat the first one…
- ✔ one population may evolve faster than the other:

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  - ✘ external fitness in both populations drops until the gradient re-emerges
- ✔ not exactly what was shown by Lotka-Volterra, but similar
- ✔ Solution:
  - ✘ detect such situation (but how?)
  - ✘ postpone the evolution of "better" population

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 ⇒ uniform random selection
- ✔ Solution: apply some form of *credit assignment*

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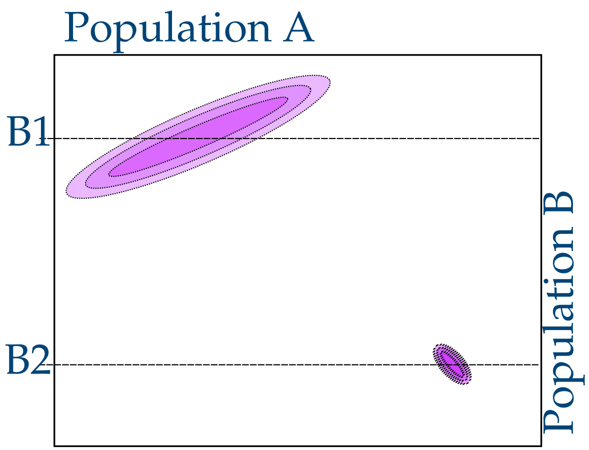
Relative overgeneralization

- ✔ 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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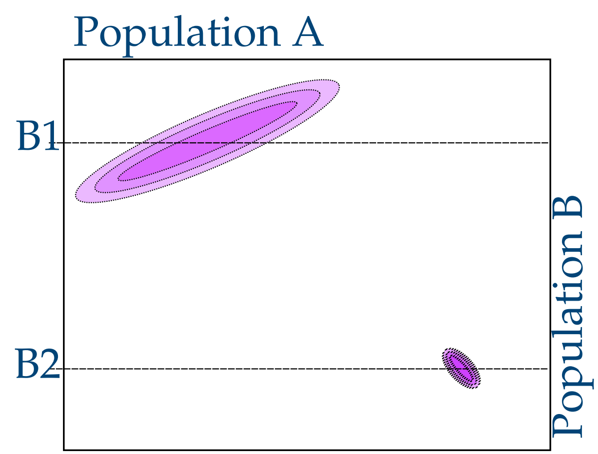
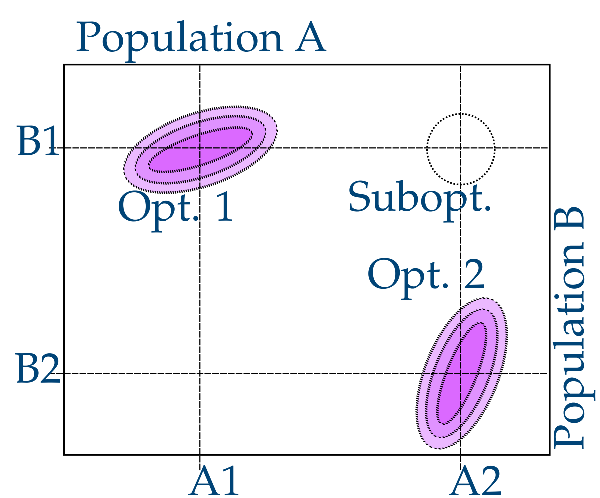


Miscoordination

- 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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Coevolution

- ✔ can be cooperative or competitive (or both)
- ✔ can take place in 1 population or in more populations
- ✔ fitness is not fixed during evolution
- ✔ introduces new unexpected dynamics to the system (new issues to be solved)

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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)