Universitat de les Illes Balears

Artificial Intelligence

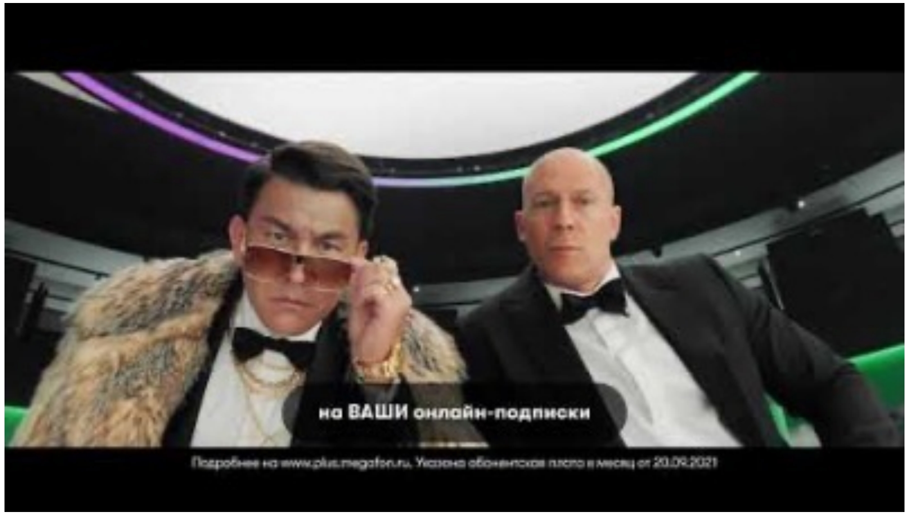
Lesson 3.4

Local Search & Genetic algorithms

Noticias > Bruce Willis, retirado de la actuación, podrá seguir protagonizando películas. Bienvenidos al futuro

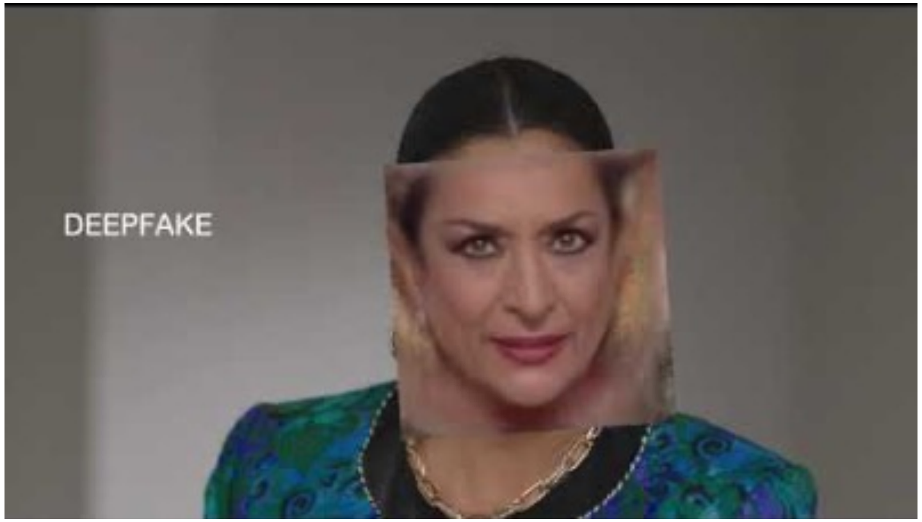
Actualidad

Bruce Willis, retirado de la actuación, podrá seguir protagonizando películas. Bienvenidos al futuro



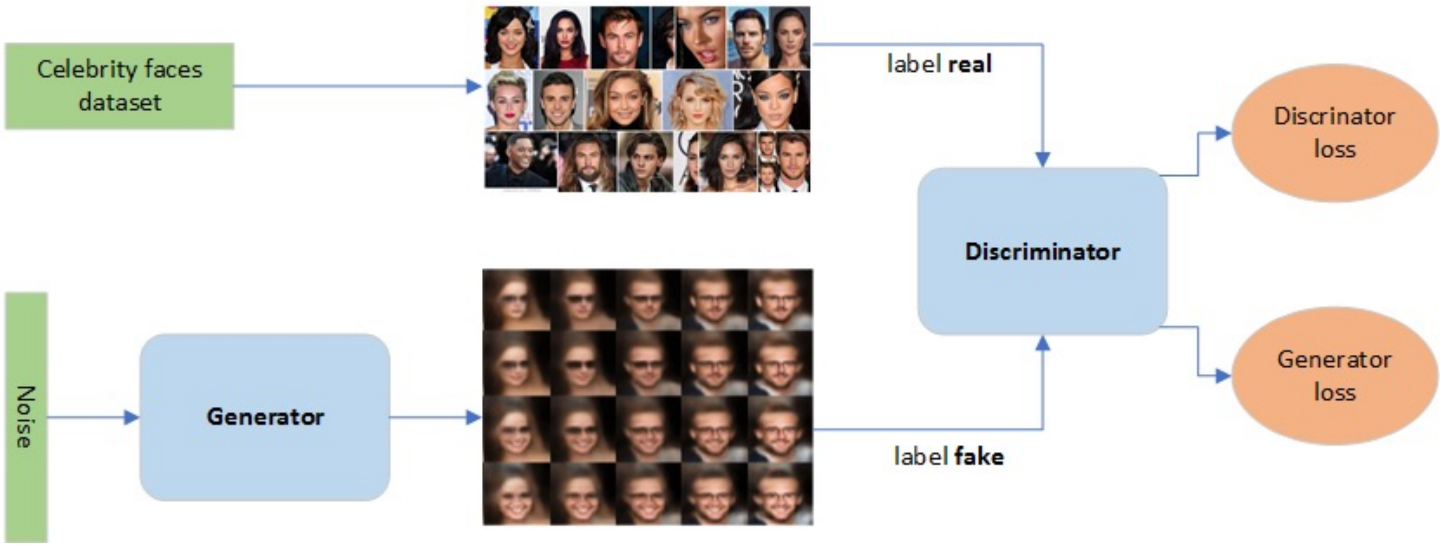
https://youtu.be/YI_kf5GcHTA

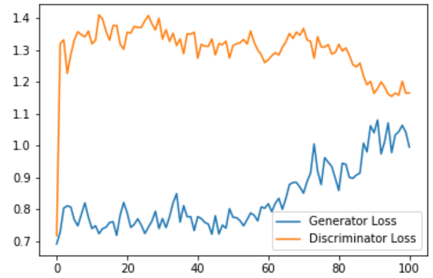
https://youtu.be/ir2GDC1Xo7A



https://youtu.be/BQLTRMYHwvE

Generative adversarial networks





A GAME!!

Local search

- In many problems, the **path** to the goal is irrelevant; the goal state itself is the solution
  - Examples: n-Queens, VLSI layout, airline flight schedules

- State space = set of the "complete" problem states

- Idea: to explore the state space
  - Keep a single "current" state, or small set of states (memory efficient!)
  - **Iteratively** try to improve it / them

Example: n-queens

Goal: Put n queens on an n×n board with no two queens on the same row, column, or diagonal.

Initial: Queens in different columns
Next node: Move a queen in a column
Search: Go to the "Next"

Considerations of local search

- Representation of the problem
- Definition of “complete state”
- Definition of ”goal”
  - How to measure the cost or the value of a state?

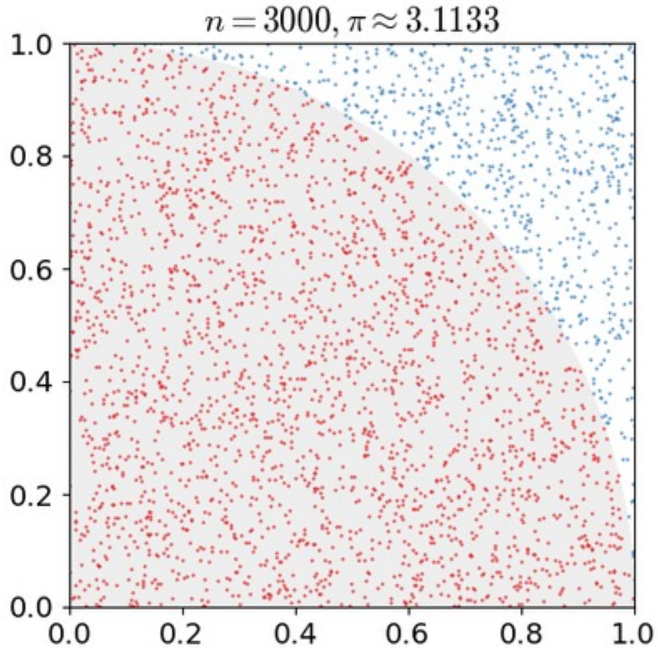
- Definition of “go to the next”, what “next”?
  - Or, what is a “step” from one state to another?
  - How can you compute the ”next state”?

Bootstrapping

Bootstrapping is a statistical technique that is based on **random sampling** with replacement

An example:

The Monte Carlo method



Bootstrapping for local search

- Using stochastic local search methods
- That is, the method return different solutions for each trial & initial state
- Using many random restarts improves your chances
- Report the best result found across many trials

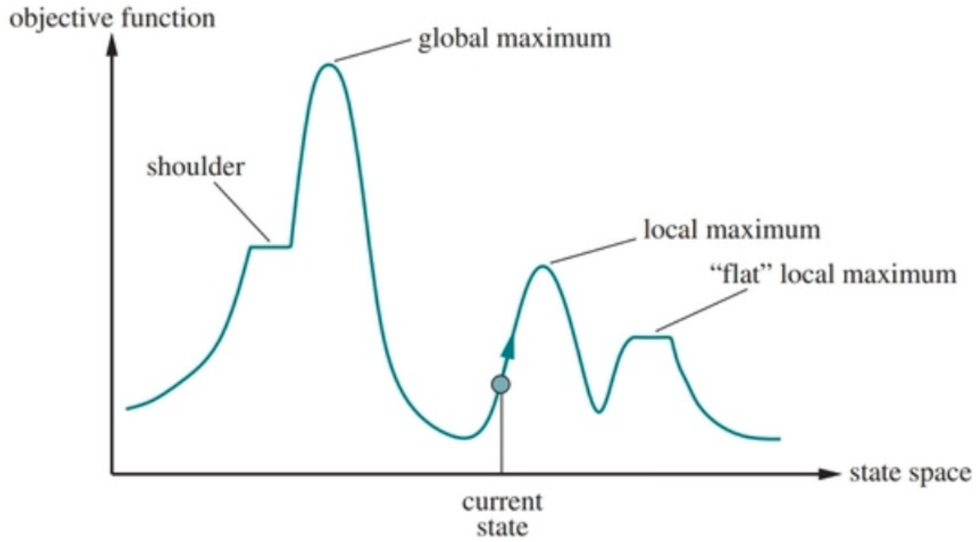
Local search algorithms

- Hill-climbing
- Simulated annealing
- Local beam
- Genetic algorithms

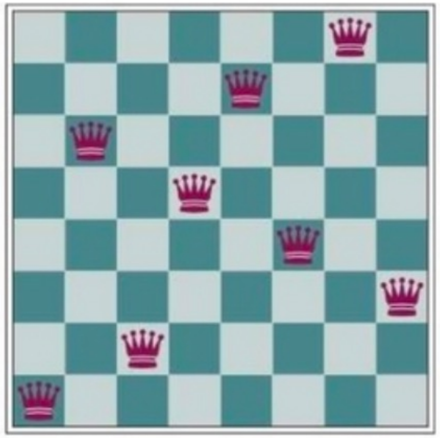
Hill-climbing search

Hill climbing keeps track of one current state and on each iteration moves to the neighbouring state with highest value—that is, it heads in the direction that provides the **steepest ascent**

t terminates when it reaches a "peak" where no neighbour has a higher value.



Hill-climbing search: an example

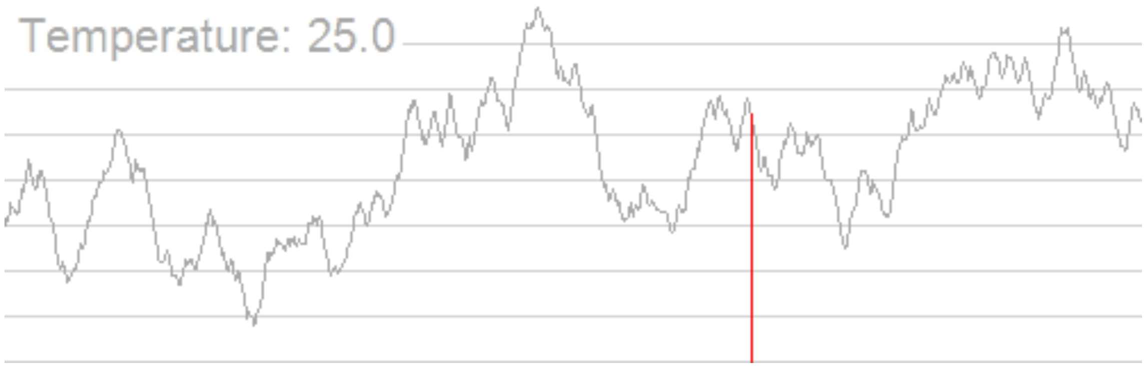


Simulated annealing

Idea: escape local maxima by allowing some "bad" moves but gradually decrease their frequency

That is, combine hill climbing with a random walk

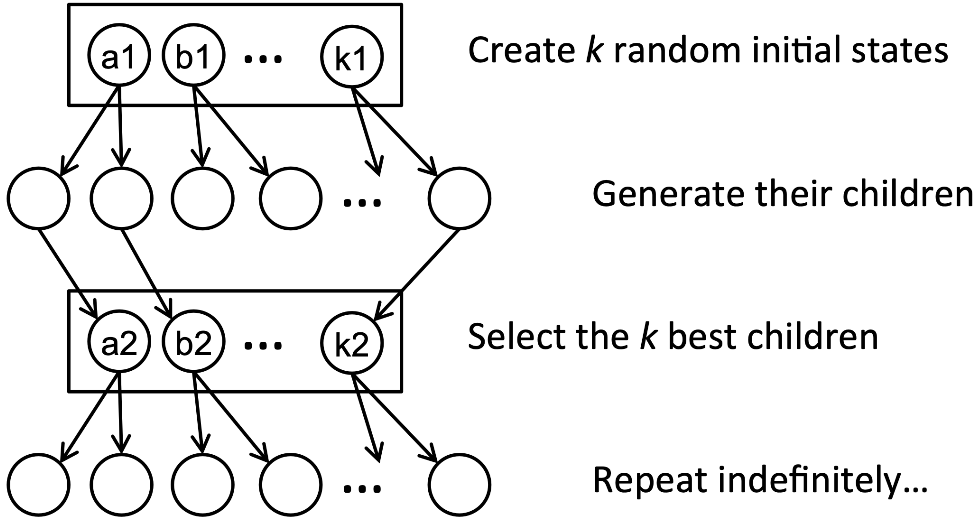
Typical annealing schedule usually use a decaying exponential



Local beam search

Keeping just one node in memory might seem to be an extreme reaction to the problem of memory limitations. The local beam search algorithm keeps track of k states rather than just one

In a local beam search, useful information is passed among the parallel search threads



Stochastic beam search: instead of choosing the top k successors, the beam search chooses successors with probability proportional to the successor's value, thus increasing diversity.

Genetic algorithms

Genetic or Evolutionary algorithms can be seen as variants of **stochastic** beam search that are explicitly motivated by the metaphor of natural selection in biology

The theory of evolution was developed by Charles Darwin in “On the Origin of Species by Means of Natural Selection” (1859). The central idea is simple: variations occur in reproduction and will be preserved in successive generations approximately in proportion to their effect on reproductive fitness

Nature & Genetics

Darwin's theory was developed with no knowledge of how the traits of organisms can be inherited and modified. The probabilistic laws governing these processes were first identified by Gregor Mendel (1866). Much later, Watson and Crick (1953) identified the structure of the DNA molecule.

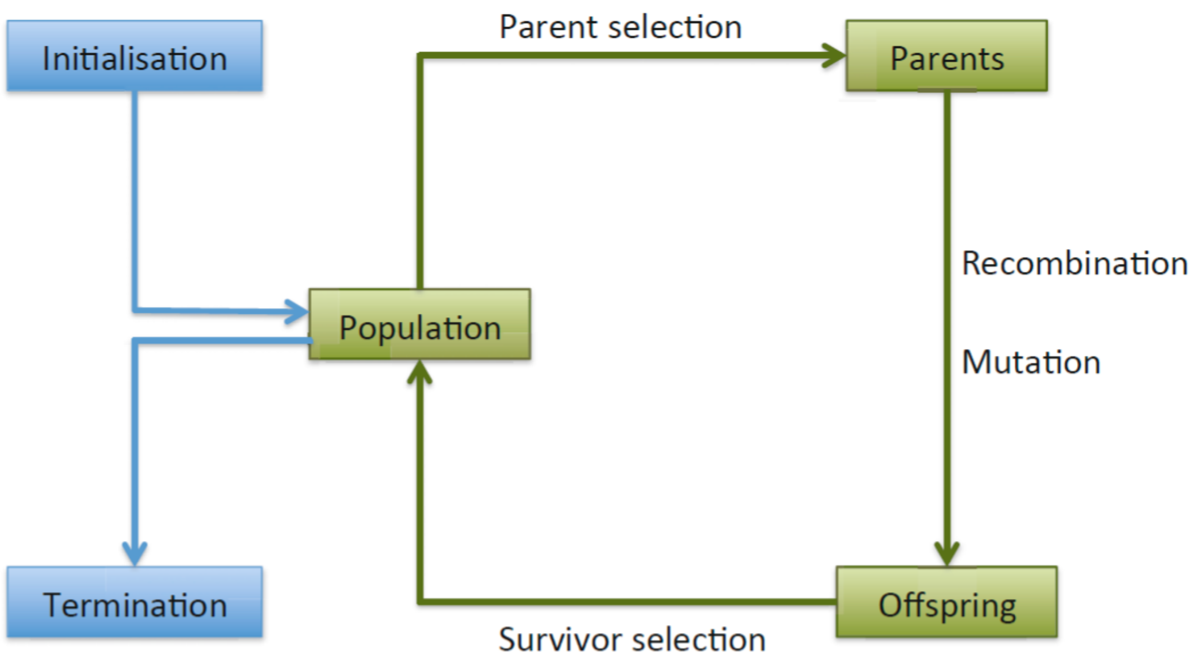
DNA usually occurs as chromosomes. The set of chromosomes in a cell makes up its genome; the human genome has approximately 3 billion base pairs of DNA arranged into 46 chromosomes. The information carried by DNA is held in the sequence of pieces of DNA called genes.

Transmission of genetic information in genes is achieved via complementary base pairing. In the standard model, variation occurs both by point mutations in the letter sequence and by "crossover" (by combining long sections of DNA from each parent)

Genetic algorithms: problem formulation

- State = a string over a finite alphabet (an "*individual*")
- A successor state (action) is generated by combining two parent states ("*reproduction*")
- Start with *k* randomly generated states ("*population*")
- Evaluation function ("*fitness function*"), higher values for "better" individuals
- Select individuals for next generation based on fitness
  - Prob(indiv. in next gen) = indiv_fitness / total_population_fitness
- Reproduction:
  - Fit parents to yield next generation (offspring)
  - Mutate the offspring randomly with some low probability

Genetic algorithms: algorithm's scheme



Genetic algorithms: operators

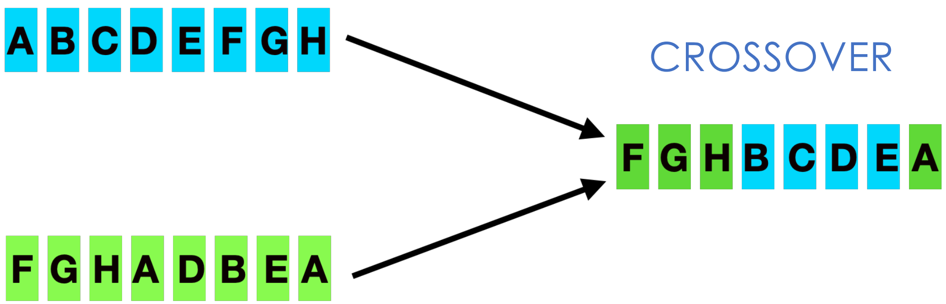
- **Selection:** select individuals for next generation based on fitness
  - prob(indiv. in next gen) = indiv_fitness / total_population_fitness

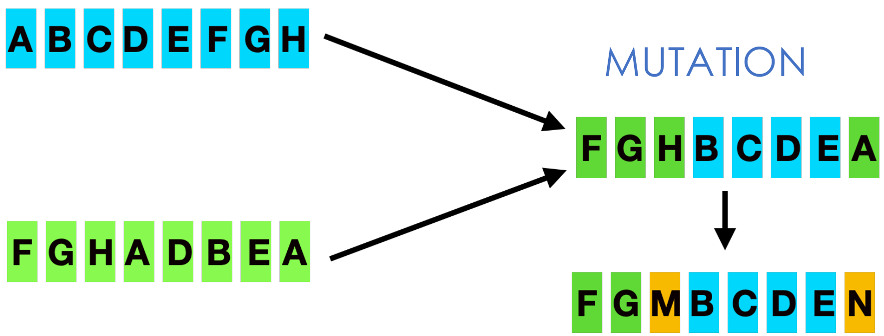
- **Crossover:** Fit parents to yield next generation (offspring)
  - randomly select a crossover point to split each of the parent strings, and recombine the parts to form two children, one with the first part of parent 1 and the second part of parent 2; the other with the second part of parent 1 and the first part of parent 2.

- **Mutation:** Mutate the offspring randomly with some low probability

- **Culling**: all new individuals below a given threshold are discarded, can lead to a speedup (a practice called elitism, which guarantees that overall fitness will never decrease over time)

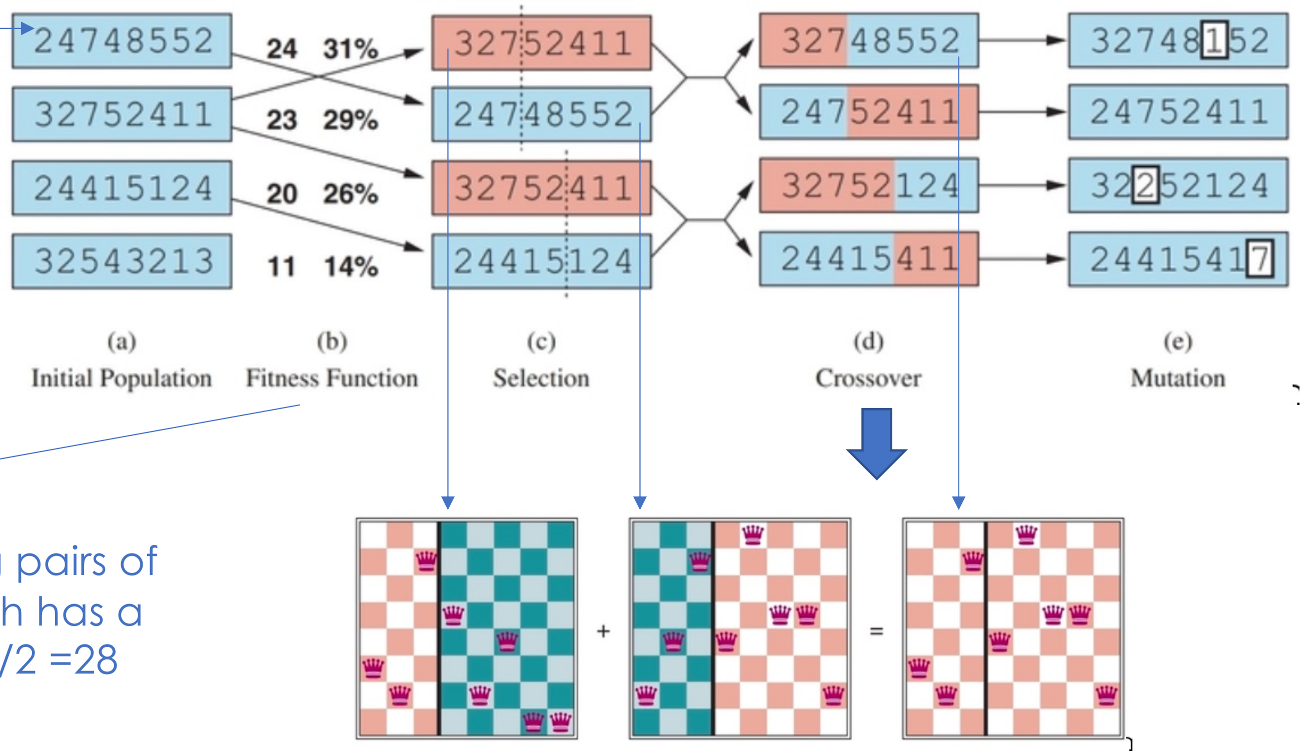
Genetic algorithms: operators





Genetic algorithms: example 8-queens

The digit in position c represents the row number of the queen in column c.



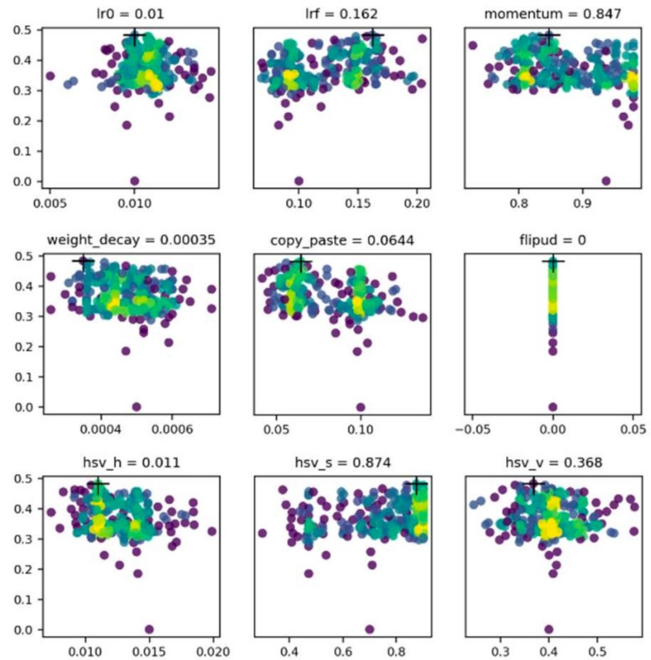
number of nonattacking pairs of queens, which has a value of 8 x 7/2 =28 for a solution.

Application: parameter optimization

YOLOv5 (deep learning)

Approx 30 hyperparameters

GA for selecting…



Summary

- **Local search**: if the path to the goal is irrelevant, therefore we could use local search methods to the state-space exploration

  - **Hill-climbing** search moves to the neighbouring state with highest value
  - Using **Simulated annealing** is possible to escape local maxima
  - In a **local beam** search, useful information is passed among the parallel search threads
  - **Genetic algorithms** are explicitly motivated by the metaphor of natural selection in biology