# Genetic Algorithms

Prof. Alessandro Lucantonio

Aarhus University - Department of Mechanical and Production Engineering

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# An example - The one-max problem

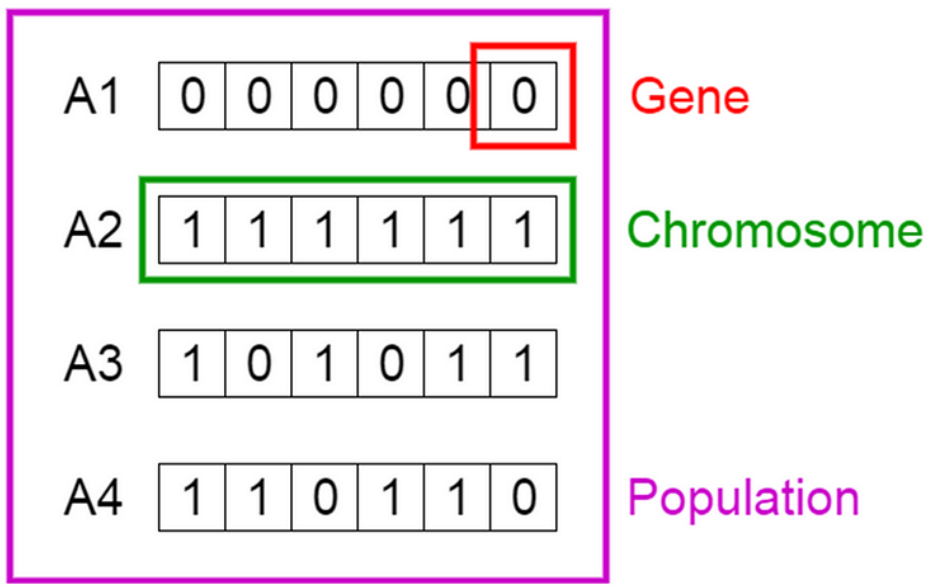
Consider the problem of maximizing the number of digits of a bitstring of length $N$. This problem is called **one-max problem**.

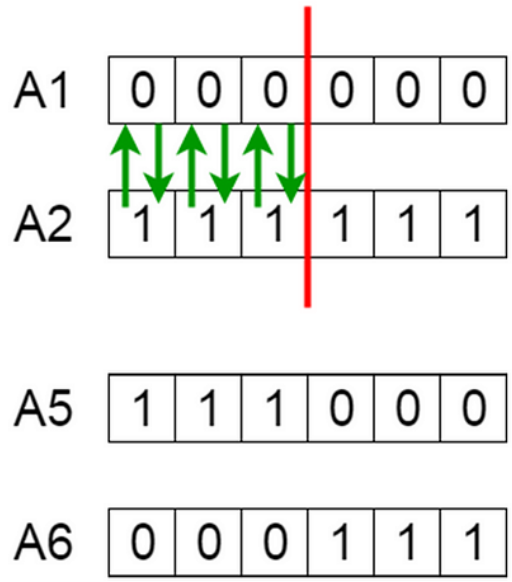
Formally, we can describe this problem as follows. Find a string $x = [x_1, \ldots, x_N]$ with $x_i \in \{0, 1\}$ that maximizes

$$F(x) := \sum_{i=1}^{N} x_i$$

Clearly, the optimal solution is the string with all bits equal to 1, but this is the most famous benchmark of **genetic algorithms** (GA).

# Genetic Algorithms



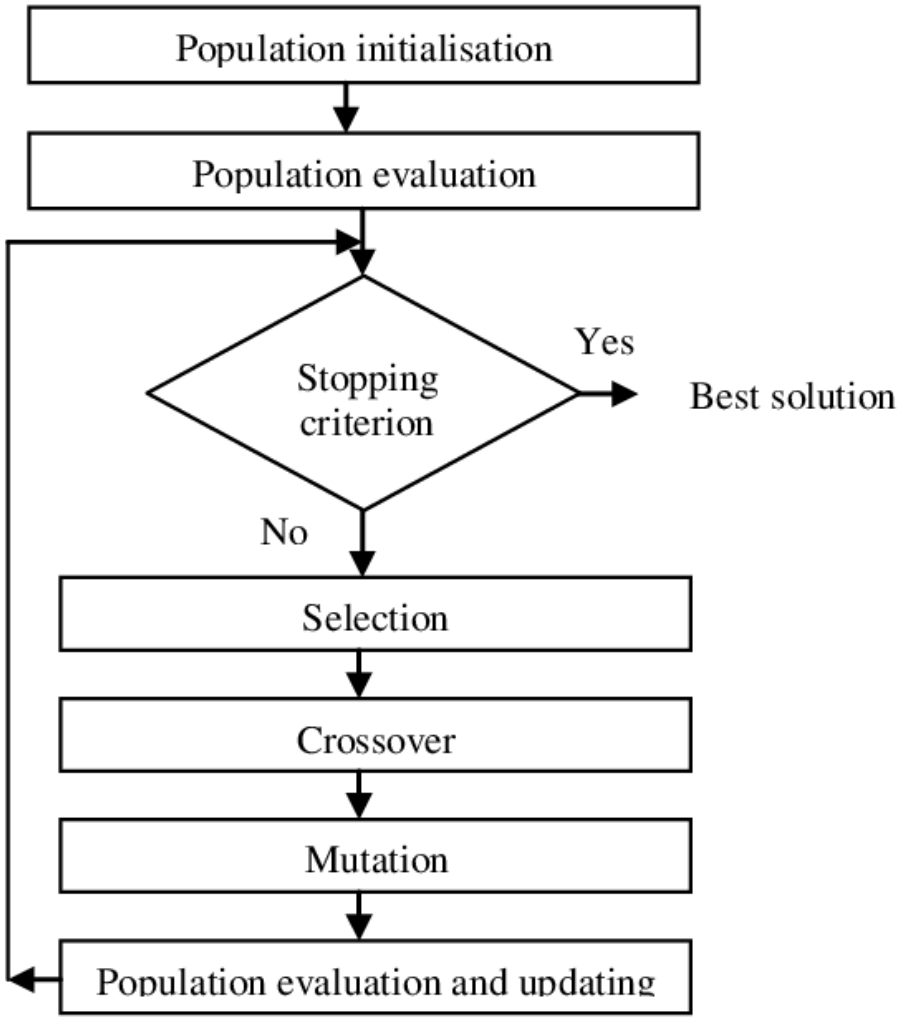
# GA - Some properties

- Highly inspired by biological evolution.
- Gradient-free optimization solver.
- Good choice when the problem is constantly changing.
- Good choice when the search space is too large.
- Simply to develop

# Basic terminology

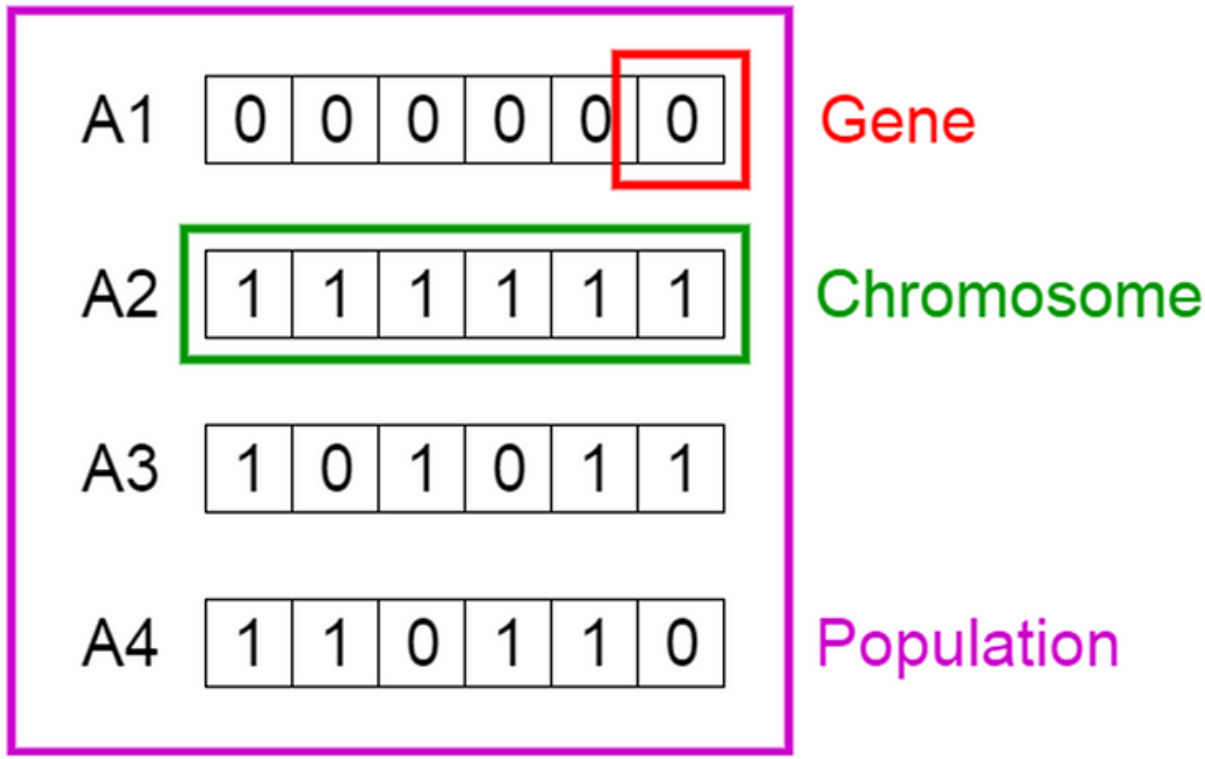
- **Population**. A collection of candidate solutions.
- **Individual**. A possible solution to a given problem. It is also called **chromosome**.
- **Gene**. The indivisible building block making up an individual.
- **Mutation**. The operation in which genes in an individual are randomly altered to create new traits.
- **Crossover**. The operation in which different individuals are combined to create a new candidate solution.
- **Selection**. The operation that picks individuals to breed the next generation.
- **Fitness**. The objective function to be maximized. It is a score that measure how good is an individual.

# GA general scheme



# GA general scheme

GA starts with an initial population, i.e. a set of individuals. Usually the population is generate randomly, to provide a uniform coverage of the search space.




Next, we compute the fitness function on each individual.

# GA general scheme

After this stage, the algorithm decides whether we should terminate or not, based on a termination criteria. This is an optional step: we can choose to stop the evolution after a fixed number of generations.

Next, the individuals are selected according to a selection operation. The higher the fitness of an individual, the higher is the probability to select it.

Then, apply crossover and mutation operations to the selected individuals to create new ones. Finally, the new population goes back to evaluation phase and the process starts again.

# A variant

In the general scheme, the new population completely replace the old one, even though the best fitness decrease.

A variation of the GA scheme that takes in account this fact works as follows. Let $n$ be the starting population size. After the evaluation process we generate $n$ new individuals by crossover and mutation. Finally, we select the $n$ best individuals among the $2n$ (old population + new individuals generated).

In this way the best fitness of each generation consists of the best fitness found so far.