Artificial Intelligence

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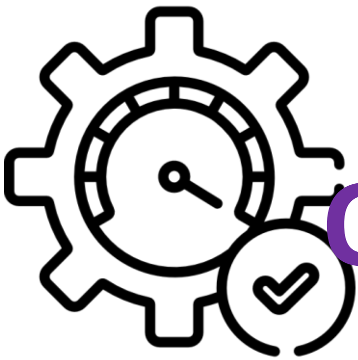
Genetic Algorithm

What is Genetic Algorithm?

A brief Introduction:

In computer science and operations research, a genetic algorithm (GA) is a metaheuristic inspired by the process of natural selection that belongs to the larger class of evolutionary algorithms (EA).

Genetic algorithms are commonly used to generate high-quality solutions to optimization and search problems by relying on biologically inspired operators such as mutation, crossover and selection. Some examples of GA applications include optimizing decision trees for better performance, solving sudoku puzzles, hyperparameter optimization, causal inference, etc.



Optimization problem

What do we mean by an optimization problem?

We have the function $f(x)$ which $x = (x_1, x_2, x_3, \ldots, x_n) \epsilon\, \mathbb{R}^n$

Purpose :

Finding the minimum value of $f(x)$ which is represented by x^*

What are Evolutionary Algorithms?

An Inspiration from Biology

To answer this question we need to take a look at scientific theory of Evolution by Natural Selection which was expressed by Charles Darwin.

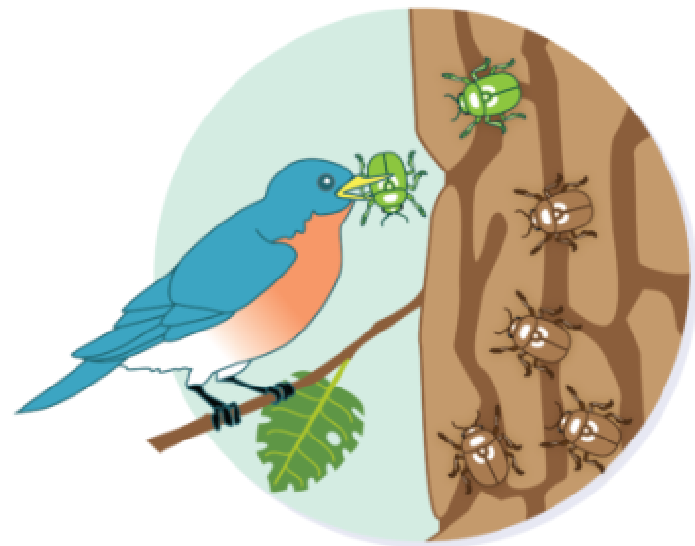
Evolution by Natural Selection

Natural selection is one of the basic mechanisms of evolution, along with mutation, migration, and genetic drift.

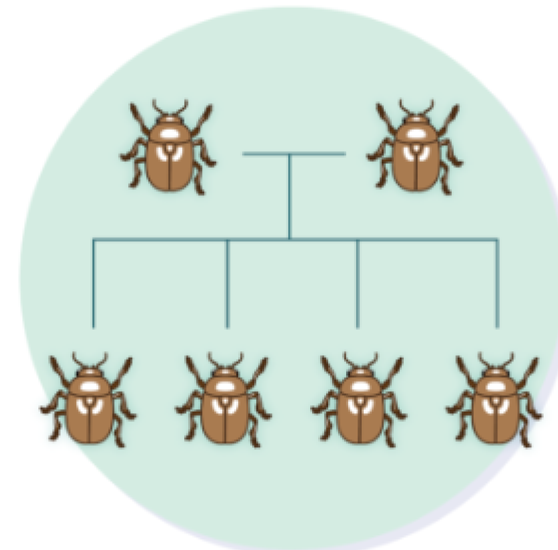
Darwin's grand idea of evolution by natural selection is relatively simple but often misunderstood. To see how it works, imagine a population of beetles:

1. **There is variation in traits.**
   For example, some beetles are green and some are brown.

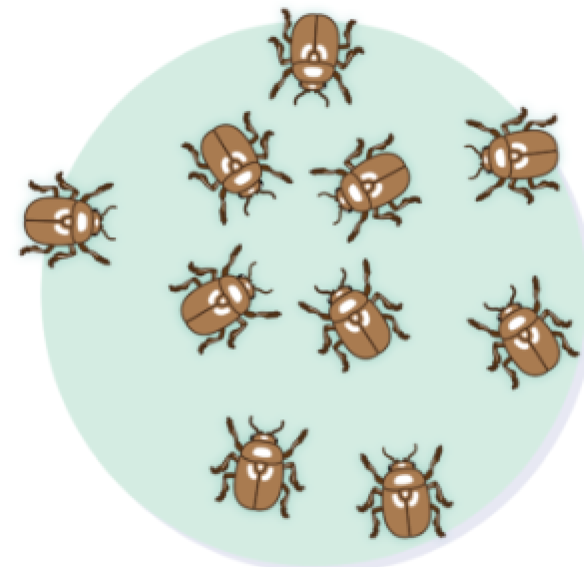
2. **There is differential reproduction.** Since the environment can't support unlimited population growth, not all individuals get to reproduce to their full potential. In this example, green beetles tend to get eaten by birds and survive to reproduce less often than brown beetles do.



3. **There is heredity.**
   The surviving beetles (more of which are brown) have offspring of the same color because this trait has a genetic basis.



4. **End result:** The more advantageous trait, brown coloration, which allows the beetle to have more offspring, becomes more common in the population. If this process continues, eventually, all individuals in the population will be brown.



Some Examples

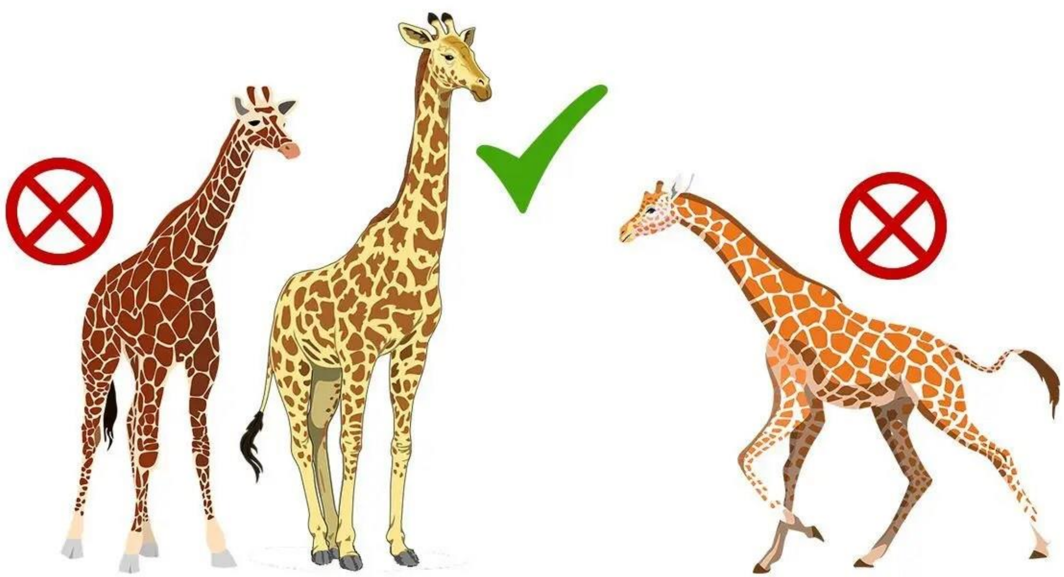
1. Arctic Animals' White Fur:

Arctic animals, such as polar bears and Arctic foxes, have evolved white fur that allows them to blend seamlessly into the snowy landscape.

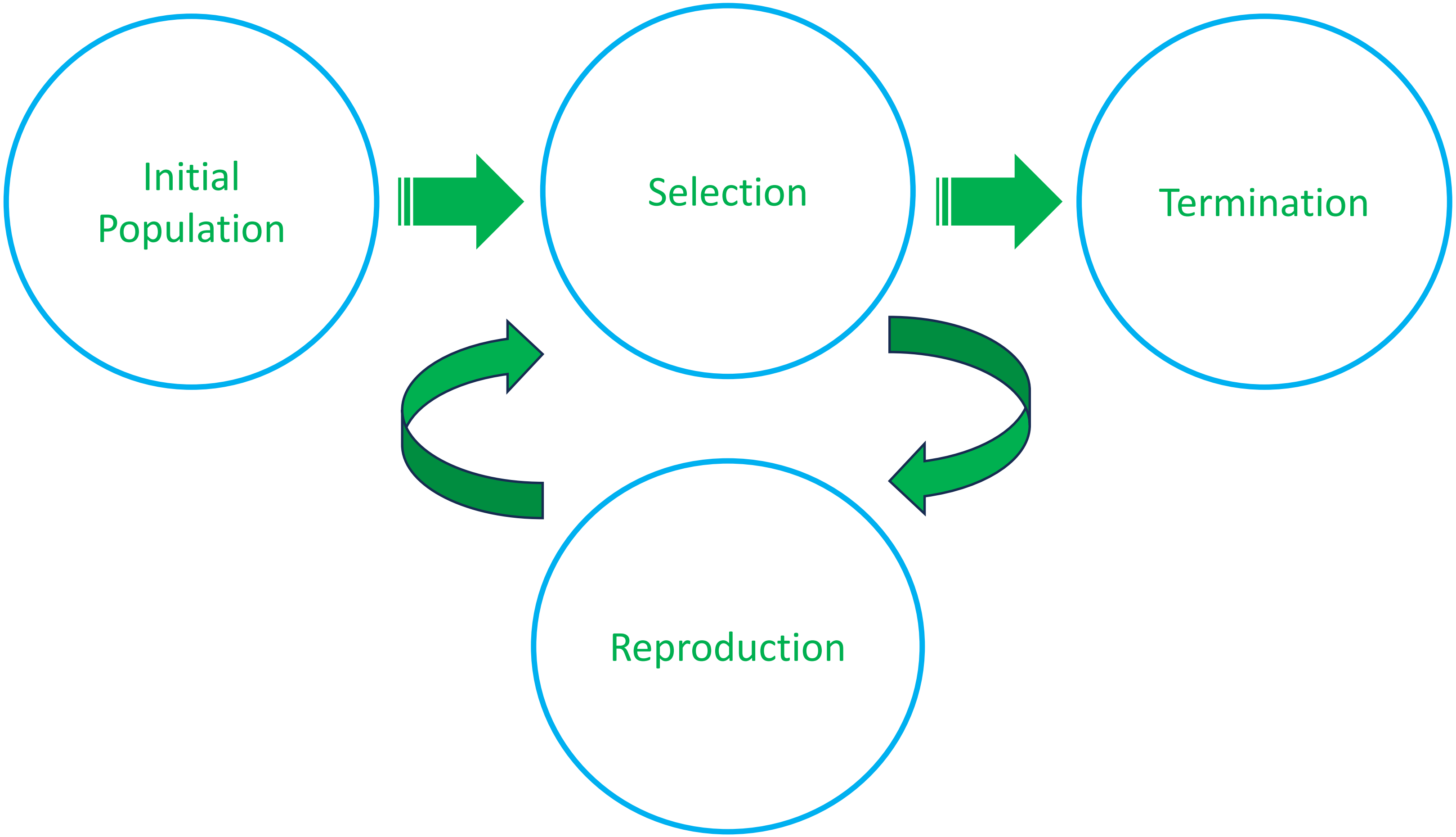
This adaptation helps them hide from predators and sneak up on prey.

2. Giraffes' Long Necks:

Giraffes possess long necks, which evolved over generations. The giraffes with longer necks were better equipped to reach leaves high in trees, providing a competitive advantage for food. This adaptation allowed them to survive and reproduce more effectively.



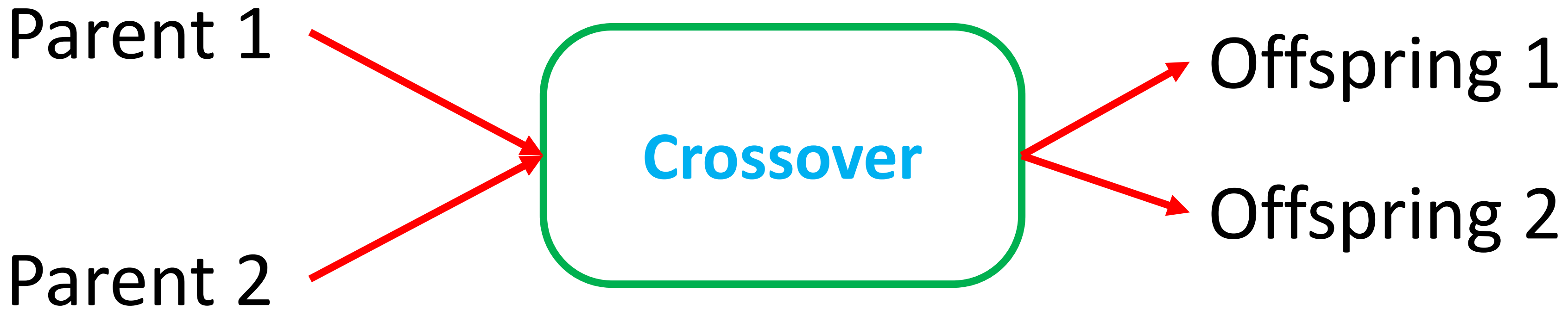
Evolutionary Algorithms



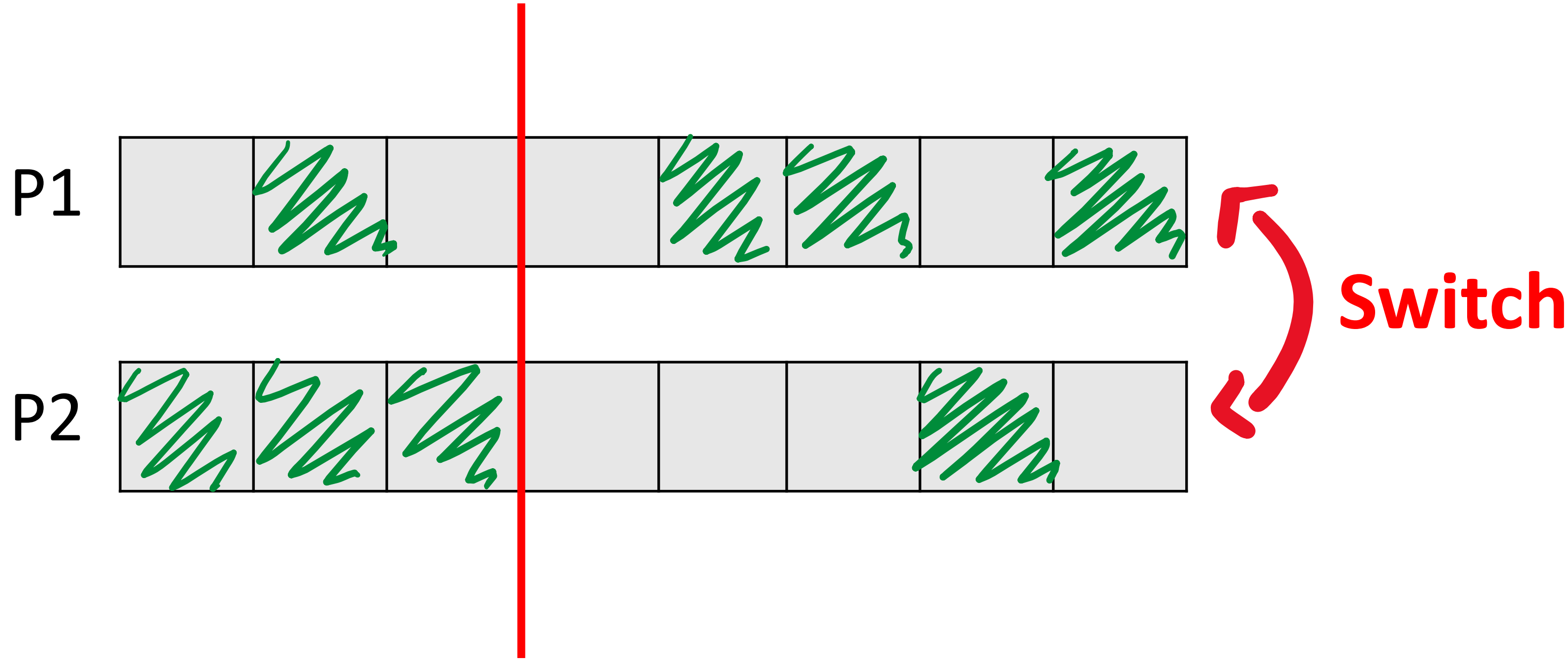
Genetic Algorithm

1. Initialization
2. Select Parents
3. Crossover => offsprings
4. Mutate offsprings
5. Merging offsprings and main initial population
6. Evaluate
7. Sort
8. Select
9. Go to step 2 if It’s needed.

Crossover



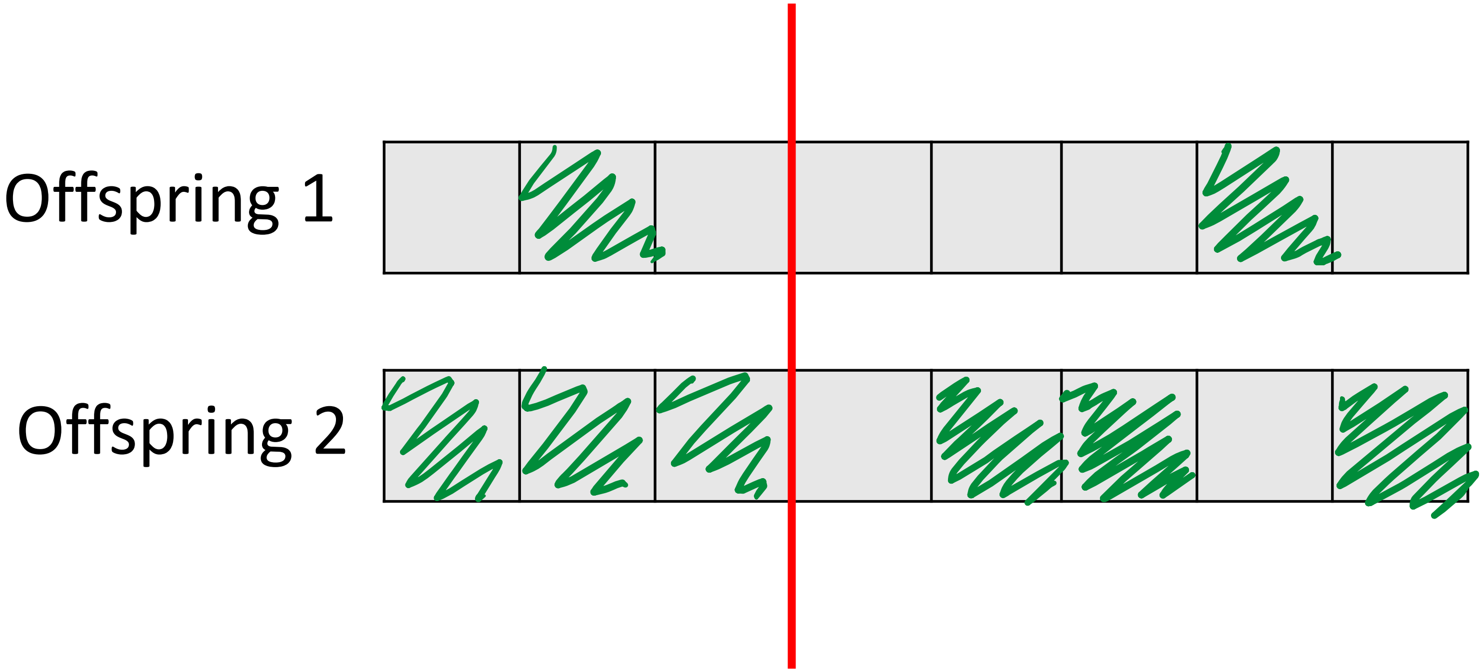
Single-point crossover



$$p1 = (0,1,0,0,1,1,0,1)$$

$$p2 = (1,1,1,0,0,0,1,0)$$

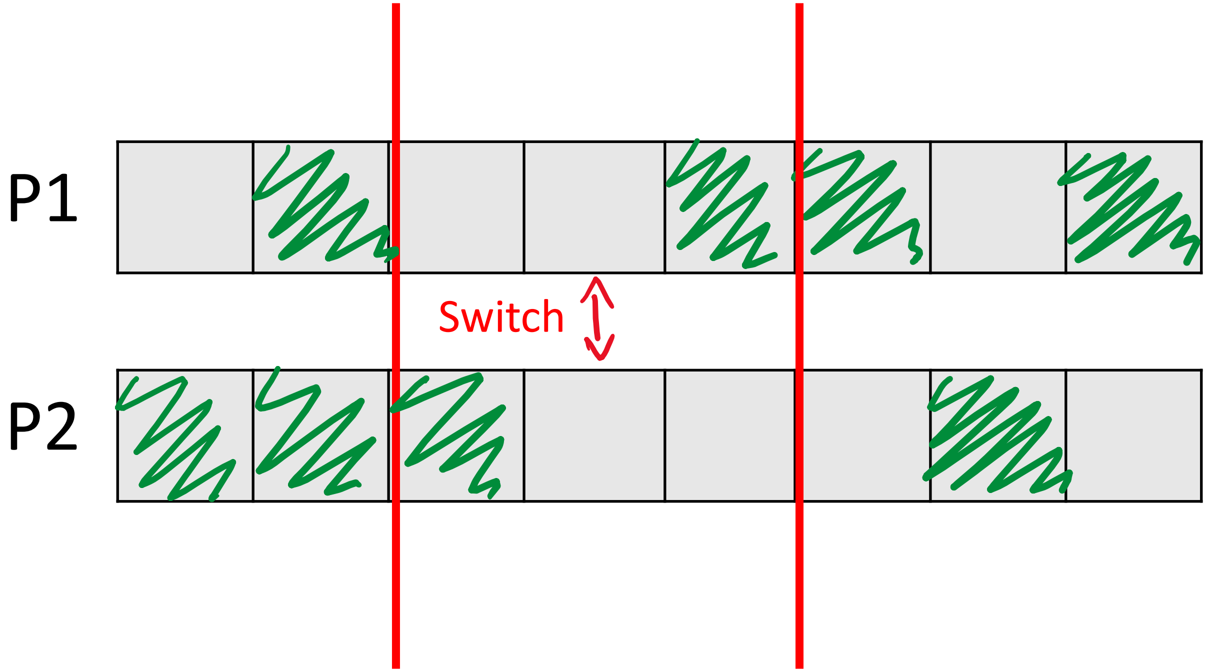
Single-point crossover



$$offspring1 = (0,1,0,0,0,0,1,0)$$

$$offspring2 = (1,1,1,0,1,1,0,1)$$

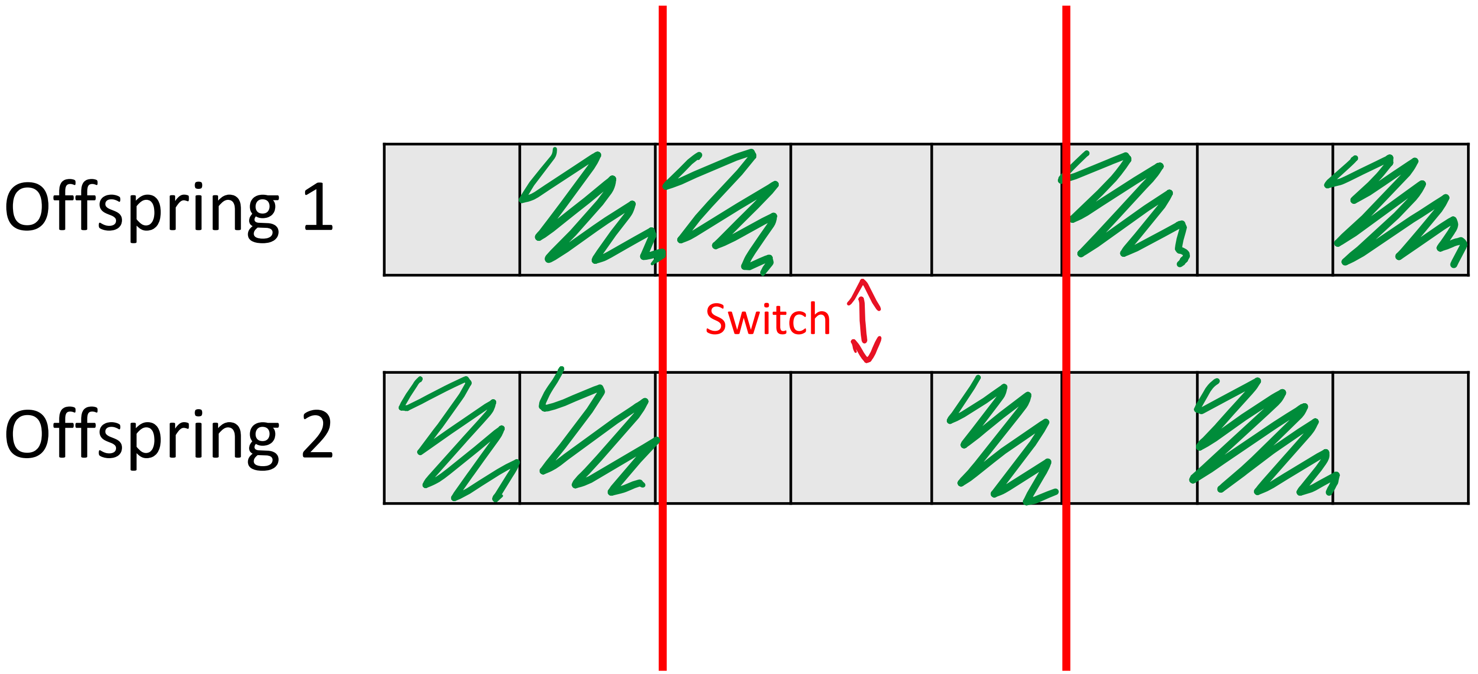
Double-point crossover



$$p1 = (0,1,0,0,1,1,0,1)$$

$$p2 = (1,1,1,0,0,0,1,0)$$

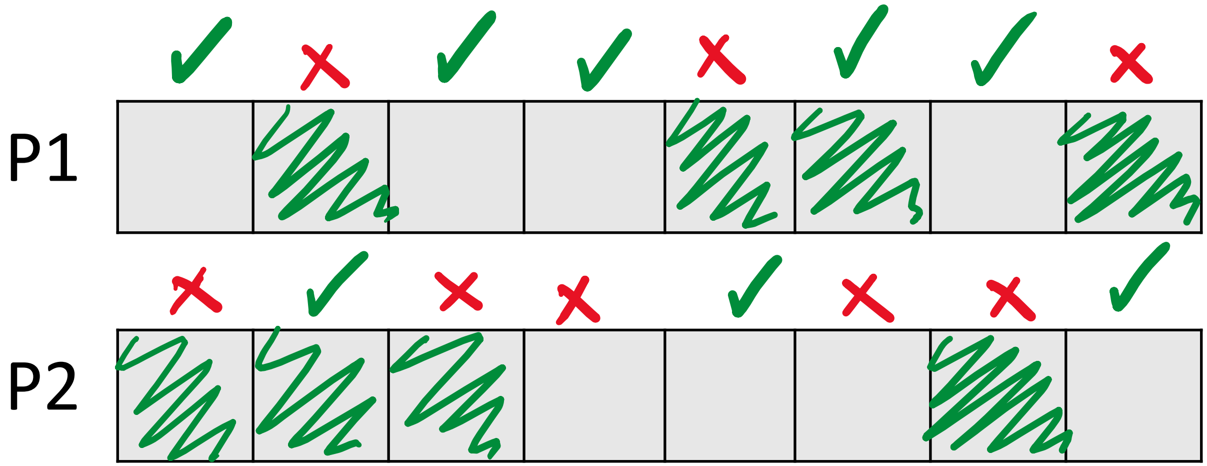
Double-point crossover



$$offspring1 = (0,1,1,0,0,1,0,1)$$

$$offspring2 = (1,1,0,0,1,0,1,0)$$

Uniform crossover



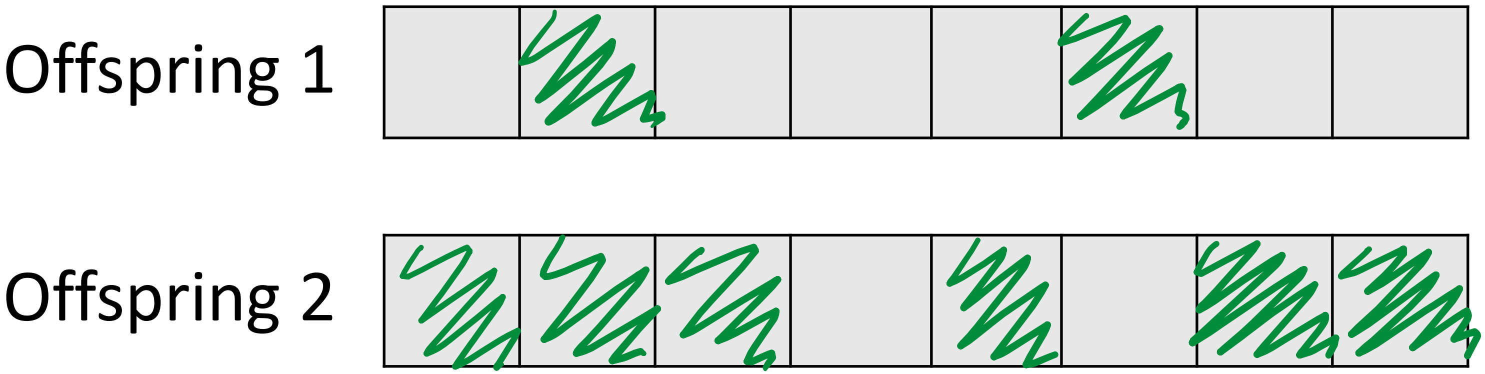
$$p1 = (0,1,0,0,1,1,0,1)$$

$$p2 = (1,1,1,0,0,0,1,0)$$

$$\alpha 1 = (1,0,1,1,0,1,1,0)$$

$$\alpha 2 = (0,1,0,0,1,0,0,1) = 1 - \alpha 1$$

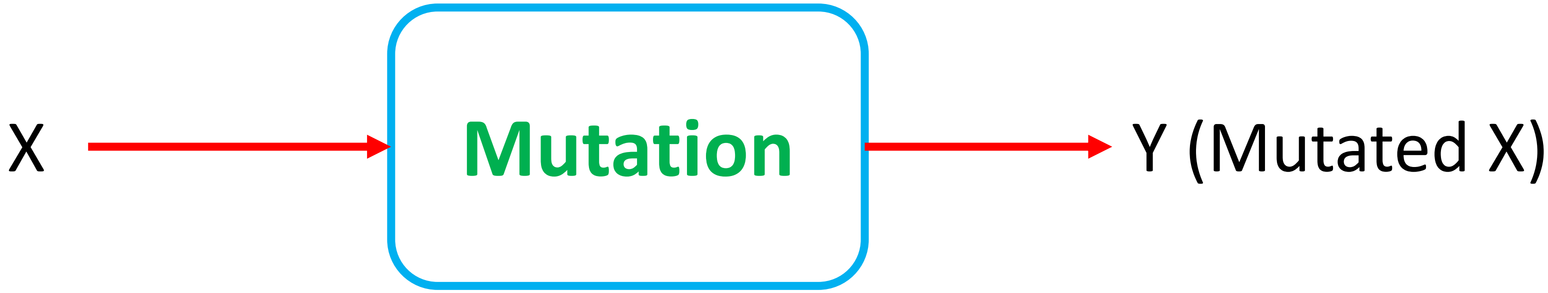
Uniform crossover



$$offspring1 = \ \alpha 1 \, . \, p1 = (0,1,0,0,0,1,0,0)$$

$$offspring2 = \ \alpha 2 \, . \, p2 = (1,1,1,0,1,0,1,1)$$

Mutation



$$X = (x_1, x_2, x_3, \dots x_n)$$

$j \epsilon \{1,2,3, \dots, n\}$ Randomly Selected

$$Y = (y_1, y_2, y_3, \dots y_n) \quad \begin{cases} x_i = y_i & i \neq j \\ x_i \neq y_i & i = j \end{cases}$$

Parent Selection

1. Random Selection:

Totally random

2. Tournament Selection:

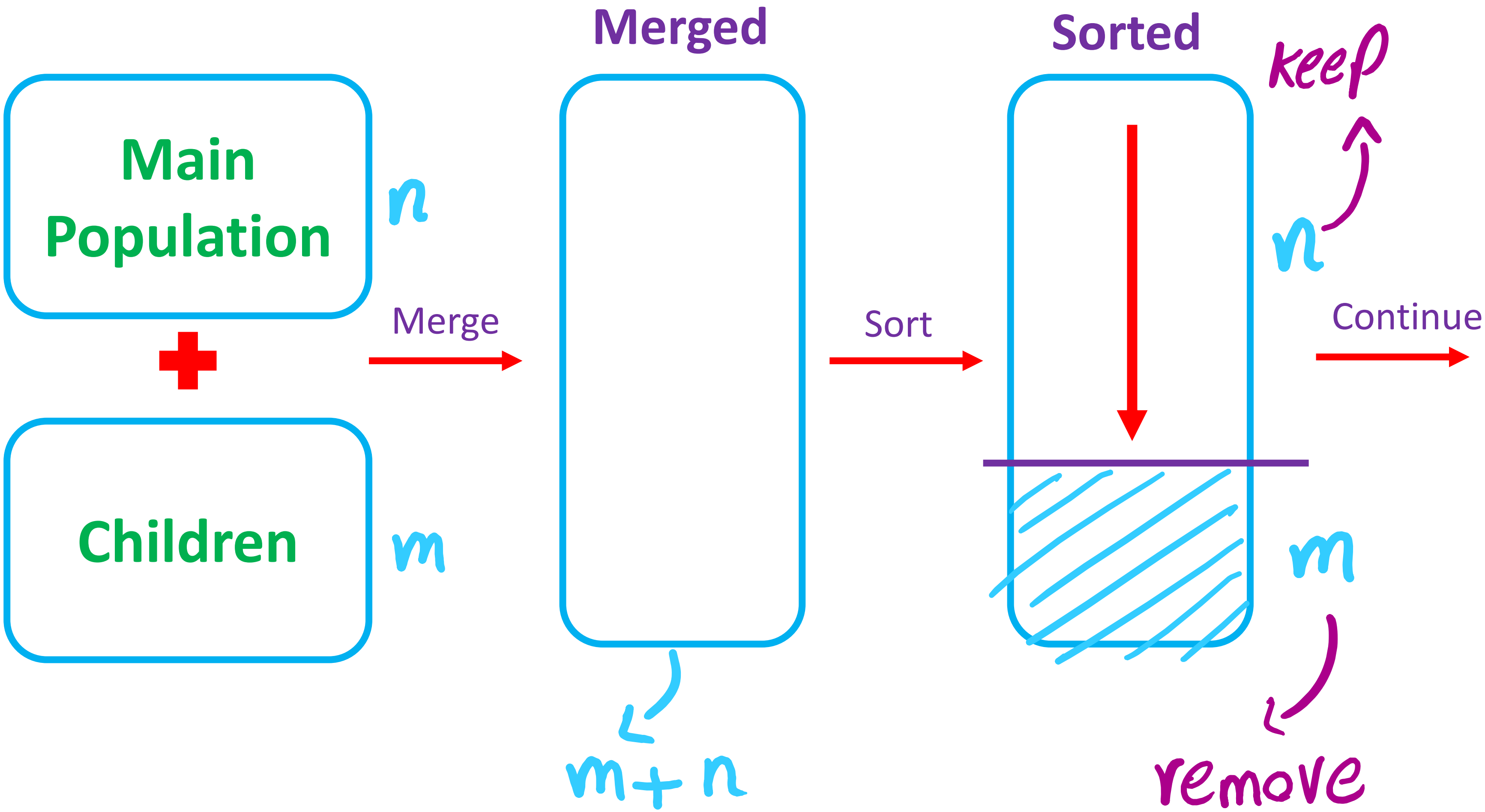
Top parents have priority

3. Roulette Wheel Selection:

Random but top parents have more chance

compared to others

Overview


Main Population
n
Children
m
Merge
Merged
m+n
Sort
Sorted
keep
n
m
remove
Continue