GENETIC ALGORITHMS

Nature is all we need
Hyper parameter tuning

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Acknowledgment

- Images and examples created by
  - **Mayank Jain**

Black-box Optimization

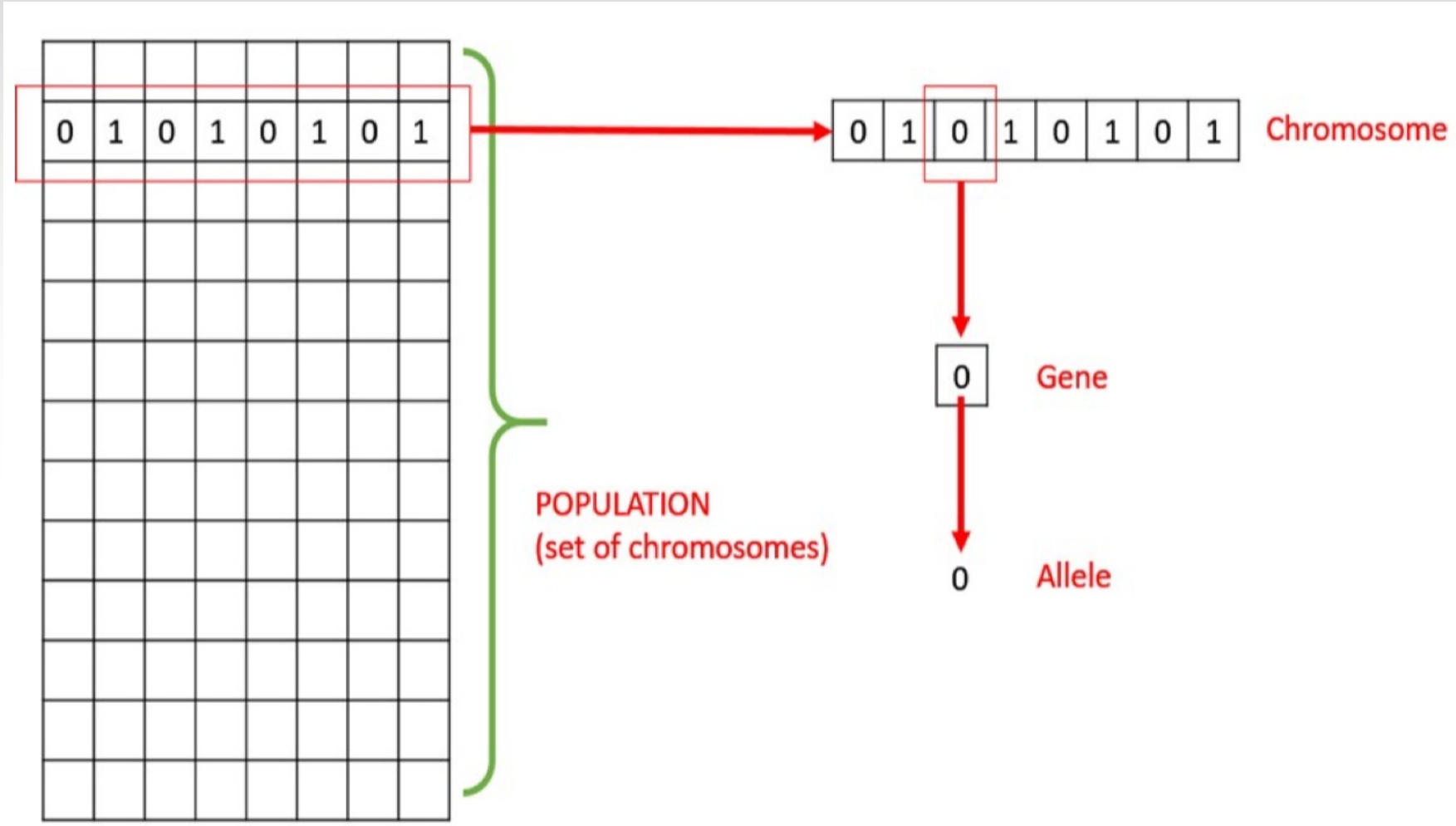
- $\min f(x)$
  - No assumption on f
  - Gradient not available or hard to compute
- Hyper parameter selection
  - $x =$ vector of all hyper parameters
  - Mixture of discrete and continuous values
- Objective function f
  - Accuracy or F1 on validation
  - Not differentiable although easy to compute

Genetic Algorithm (GA)

- Search-based optimization technique based on the principles of Genetics and Natural Selection.
  - Frequently used to find optimal or near-optimal solutions to difficult problems
- Search based algorithms based on the concepts of natural selection and genetics
- Subset of a much larger branch of computation known as Evolutionary Computation

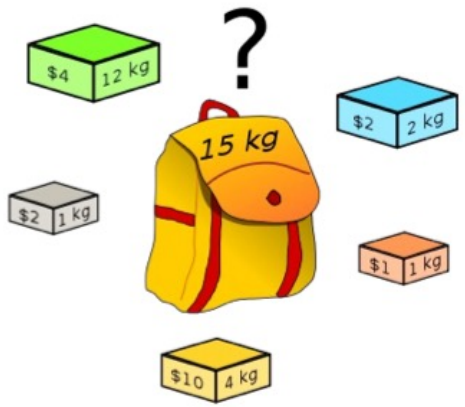
Terminology

- Population
  - Subset of all the possible (encoded) solutions to the given problem
- Chromosomes
  - A chromosome one such solution to the given problem
- Gene
  - A gene one element position of a chromosome
- Allele
  - Value a gene takes for a particular chromosome

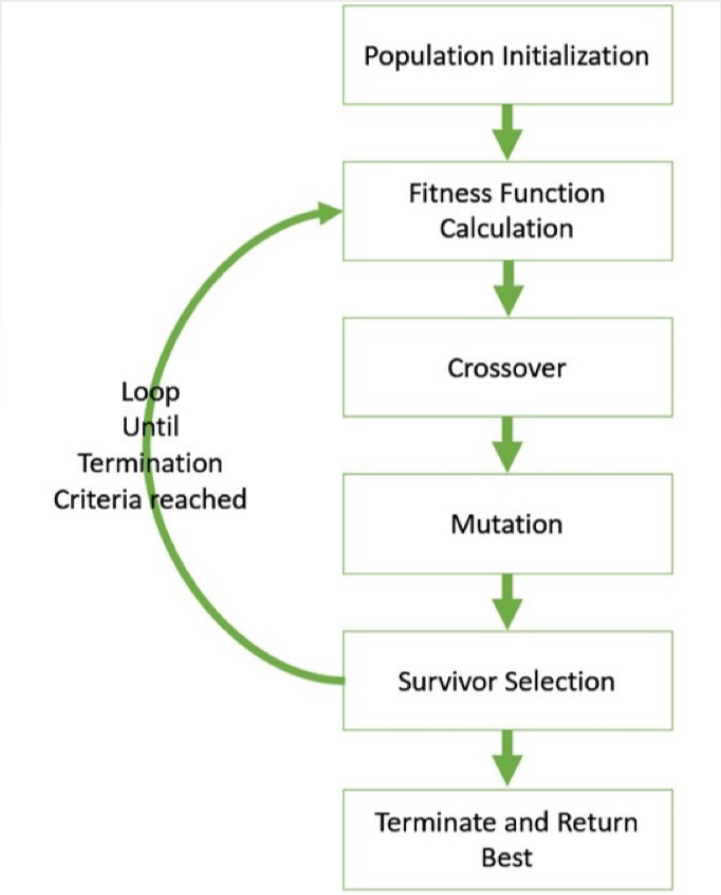

0 1 0 1 0 1 0 1
0 1 0 1 0 1 0 1
Chromosome
0
Gene
POPULATION
(set of chromosomes)
0
Allele

The Knapsack Problem

- Pack a set of items into a backpack
  - The backpack has a capacity
  - Each item has volume and benefits
  - Maximize benefits subject to items fitting in the backpack

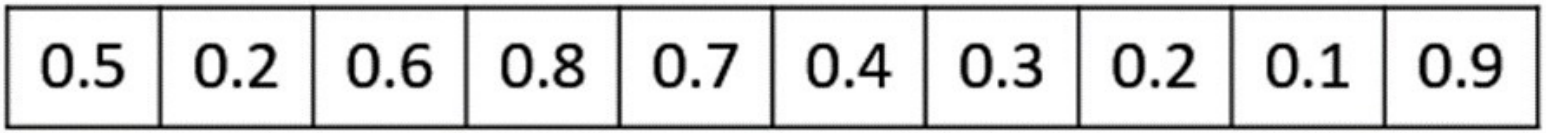


Framework


Population Initialization
Fitness Function Calculation
Crossover
Mutation
Survivor Selection
Terminate and Return Best
Loop Until Termination Criteria reached

Genotype representation

- Representation
  - Binary for continuous
  - One hot for categorical
  - Integer for integer



Population

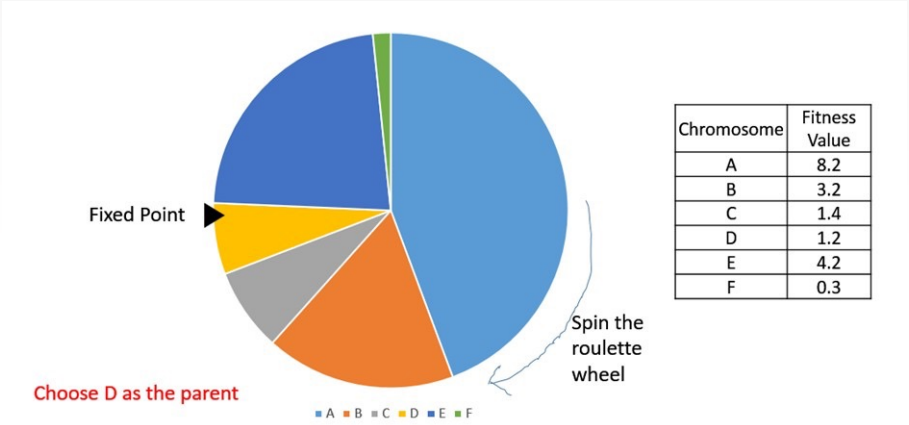
- Subset of solutions in current generation
  - Set of chromosomes
  - Highest level
- Initial population
  - Random initialization
  - Heuristic initialization

Fitness function

- Candidate solution/chromosome as input
  - Computes output/fitness
- Objective to either minimize or maximize a given objective function

knapsack capacity = 15, profit = 18

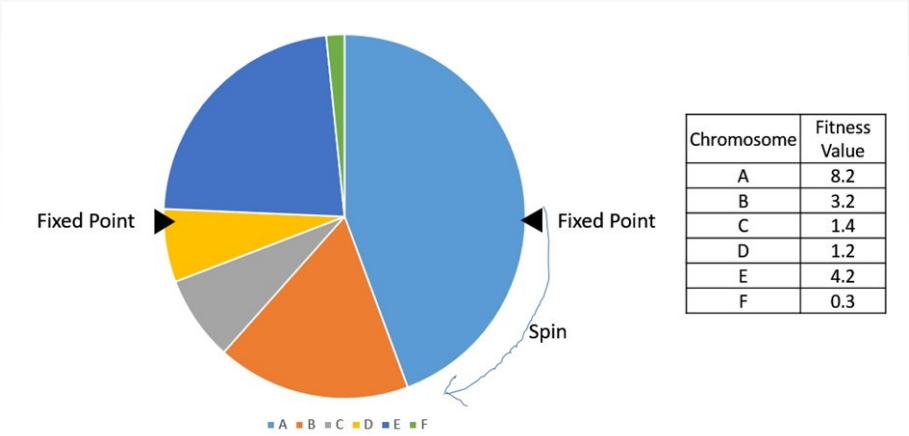
Parent selection: Roulette



Chromosome	Fitness Value
A	8.2
B	3.2
C	1.4
D	1.2
E	4.2
F	0.3

- Select several chromosomes
- Roulette wheel selection
  - Turn fitness scores to probabilities
  - Softmax, division by sum
  - Lack of diversity

Parent selection: SUS



Chromosome	Fitness Value
A	8.2
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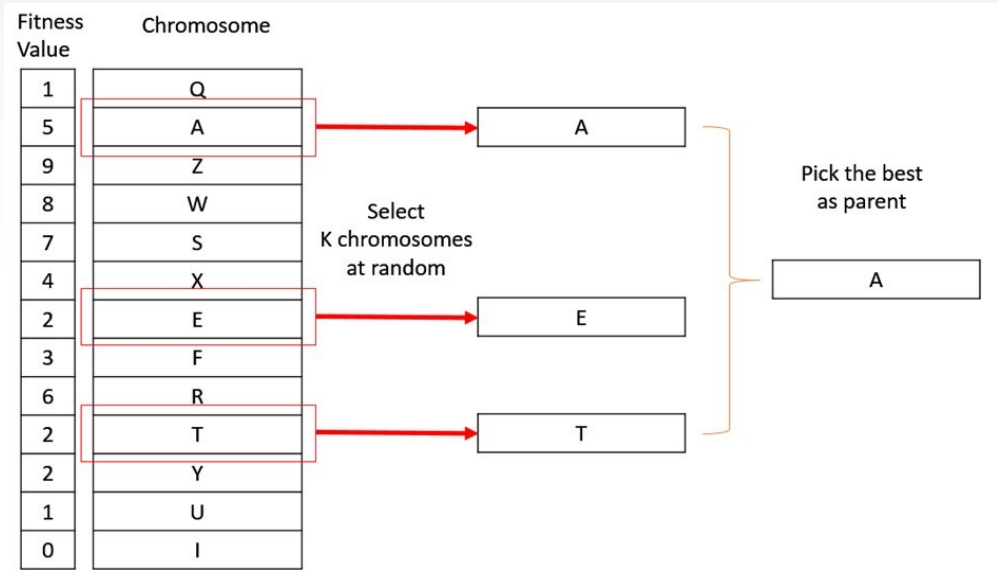
D	1.2
E	4.2
F	0.3

- Stochastic Universal Sampling
- One random number
  - Start from the number
  - Step in equidistant steps
    - Number of them equal to the desired number of selected
  - Select chromosomes encountered
- Much larger variety
- Efficient since only a single random number required

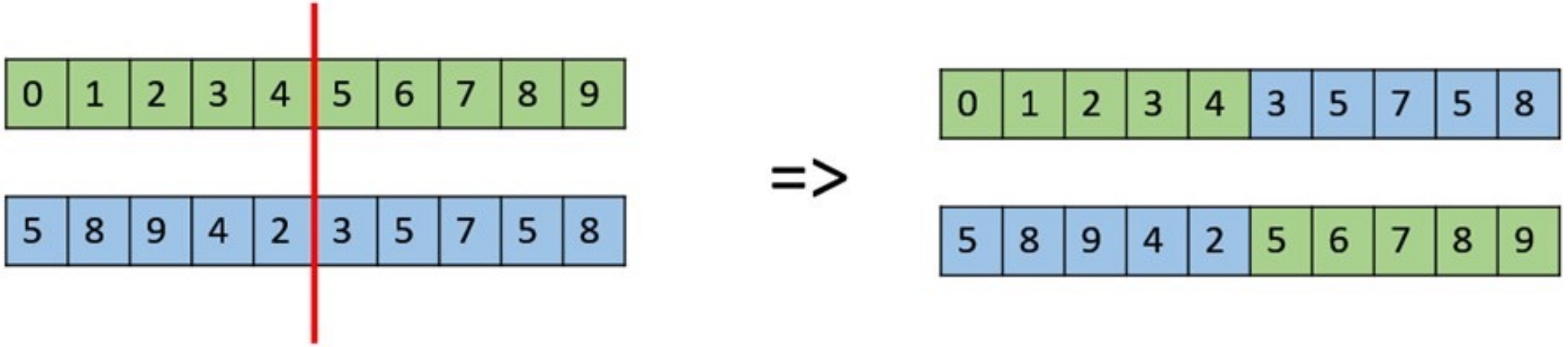
Single selection

- Several chromosomes
- Tournament selection – select a single one
  - Best fitting value



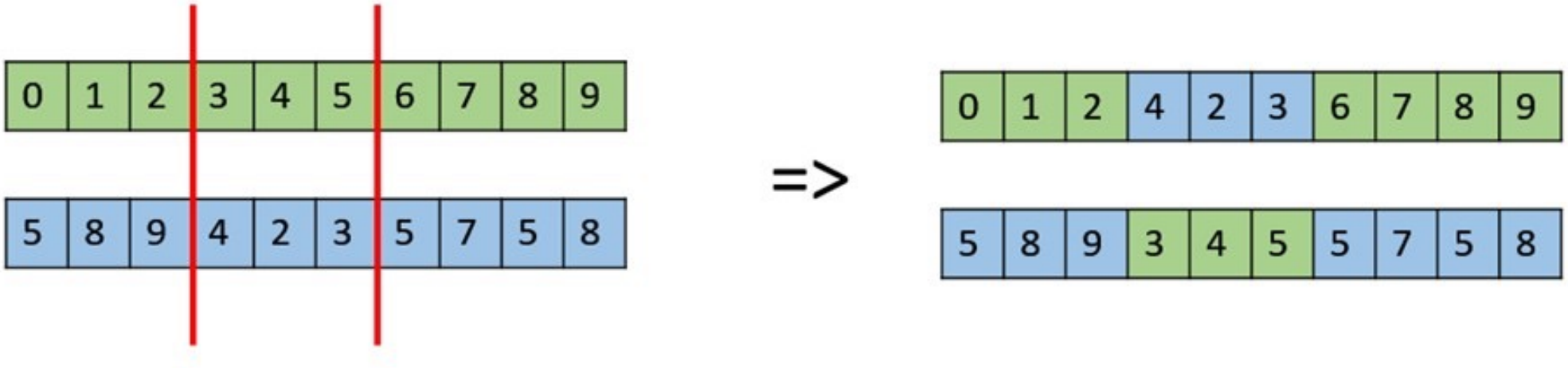
Crossover

- One parent has been selected
- One or more offsprings are produced using the genetic material of the parents
- One point crossover



Crossover

- Multi-point crossover

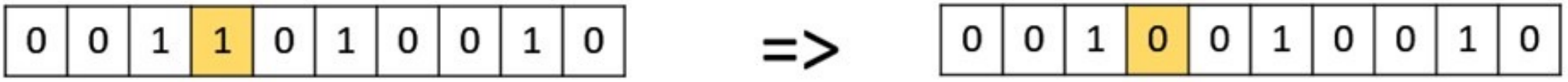


Crossover

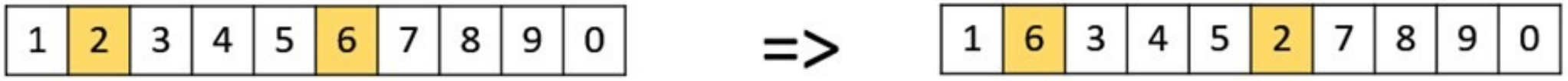
- Uniform crossover

Mutation

- Used to maintain and introduce diversity in the genetic population
- Bit flip mutation

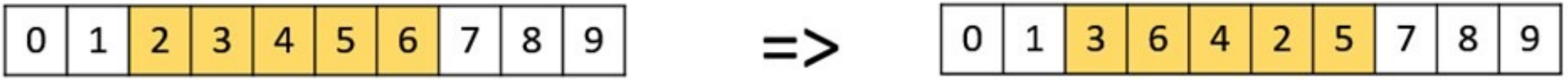


- Random resetting
- Swap mutation

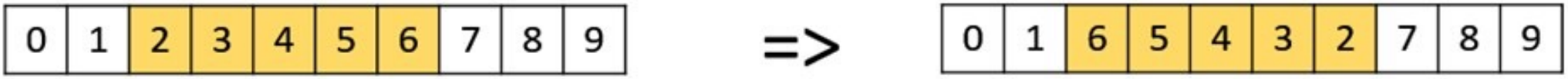


Mutation

- Scramble mutation



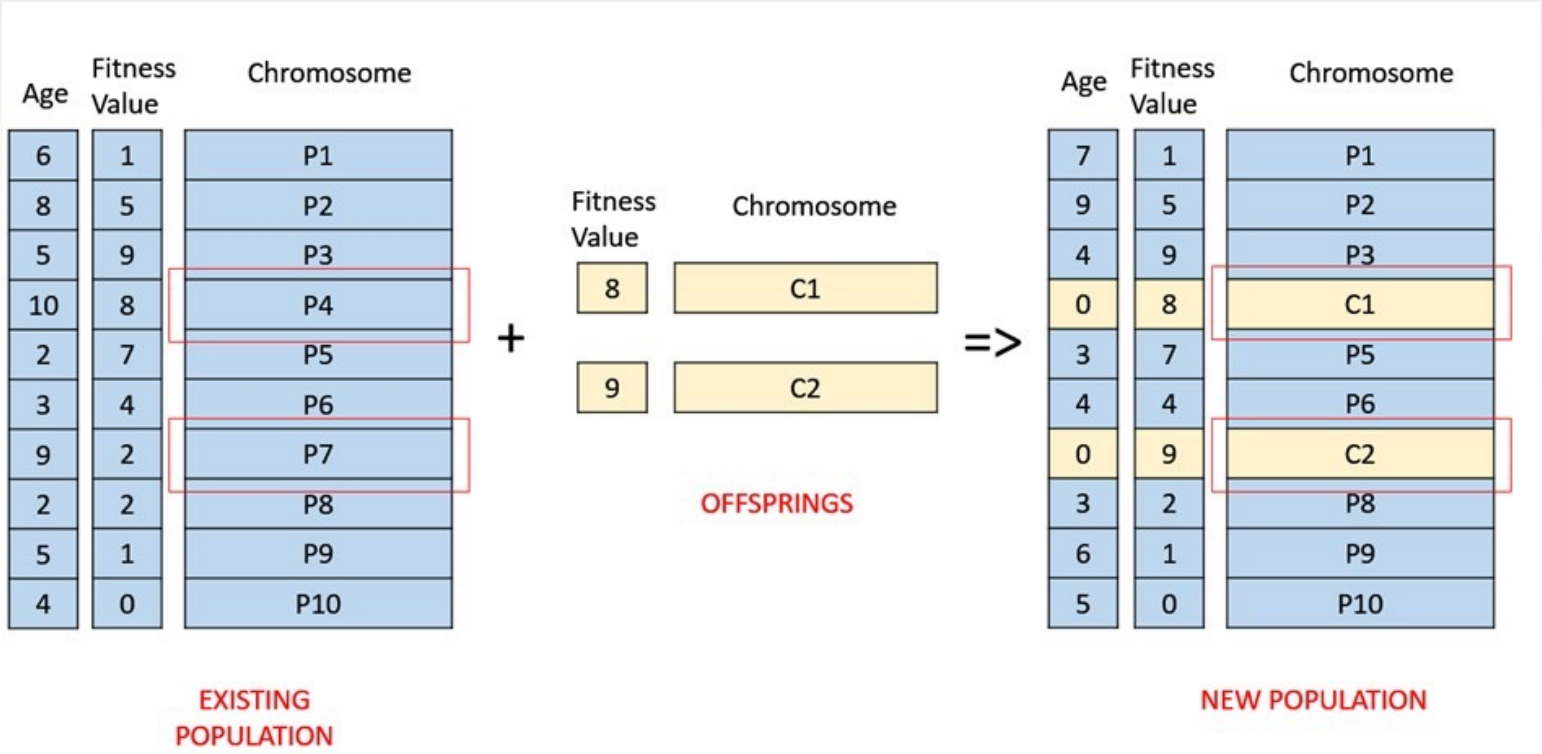
- Inversion mutation



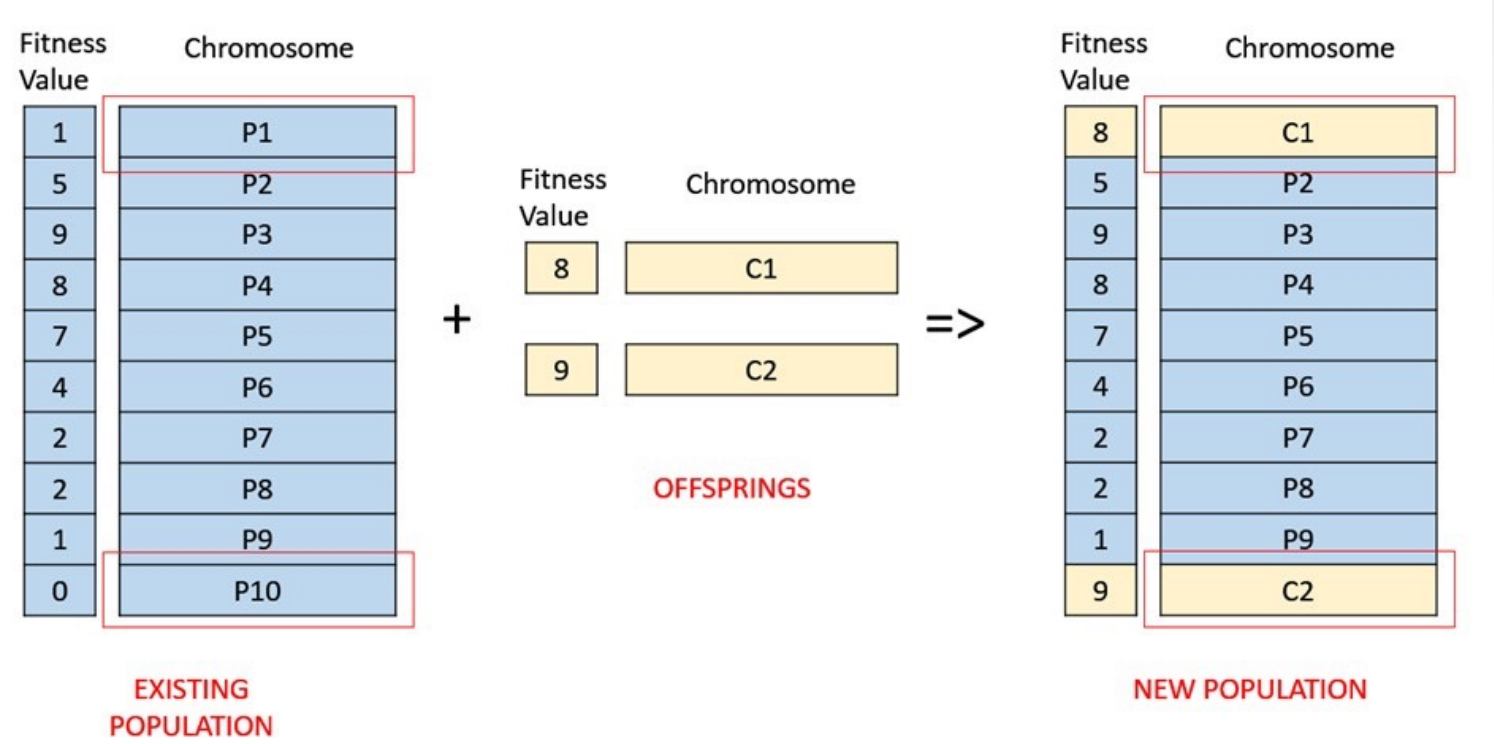
Selection

- Current chromosomes and newly generated chromosomes
  - By means of mutation and crossover
- Selection about how to combine them
- Age based selection
  - Replace the oldest chromosomes
- Fitness based
  - Replace the worst quality (fitness) chromosomes

Age based selection



Fitness based selection



Termination criteria

- No improvement in the population in the last given number of iterations
- Reaching a certain number of iterations
- Fitness is good enough