Introduction to Genetic Algorithms

Genetic Algorithm (GA)

- Genetic Algorithm is a search-based optimization technique based on the principles of Genetics and Natural Selection.
- It is frequently used to find optimal or near-optimal solutions to difficult problems which may take a lifetime to solve.
- Inspired by Charles Darwin's theory of natural selection where the fittest individuals are selected for reproduction in order to produce offspring of the next generation.

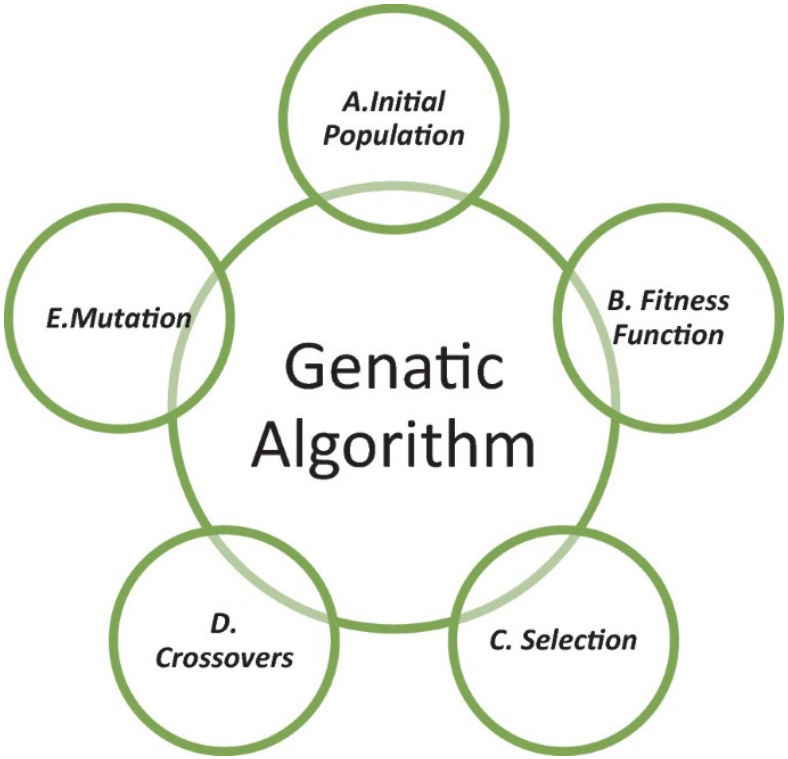
Genetic Algorithm (GA)

- Natural Selection
  - The process of natural selection starts with the selection of fittest individuals from a population.
  - They produce offspring which inherit the characteristics of the parents and will be added to the next generation.
  - If parents have better fitness, their offspring will be better than parents and have a better chance at surviving.
  - This process keeps on iterating and at the end, a generation with the fittest individuals will be found.

Genetic Algorithm (GA)

- This notion can be applied for a search problem. We consider a set of solutions for a problem and select the set of best ones out of them.

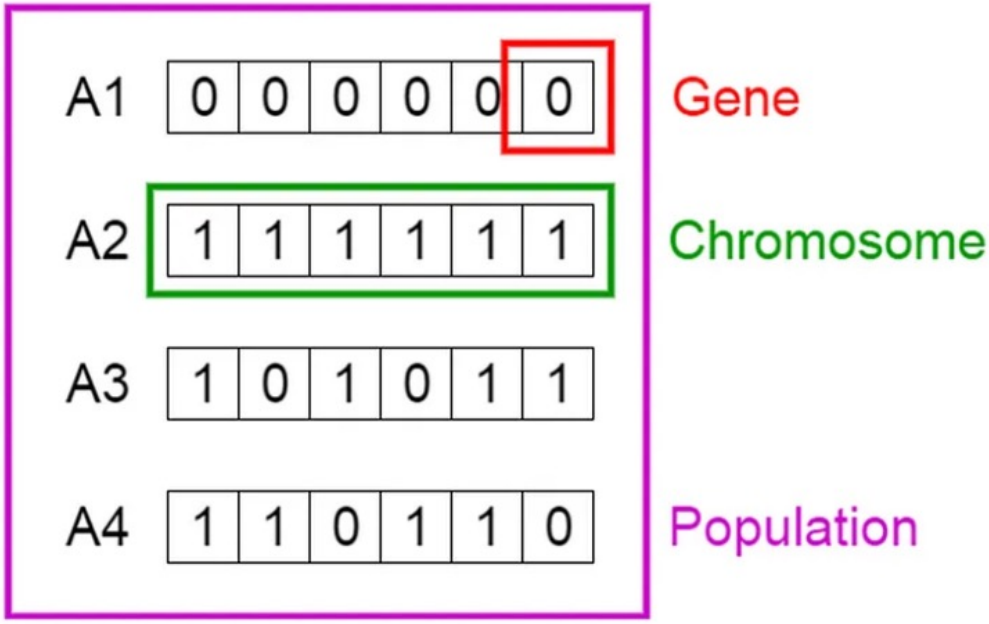
- Five phases of GA
  - Initial population
  - Fitness function
  - Selection
  - Crossover
  - Mutation

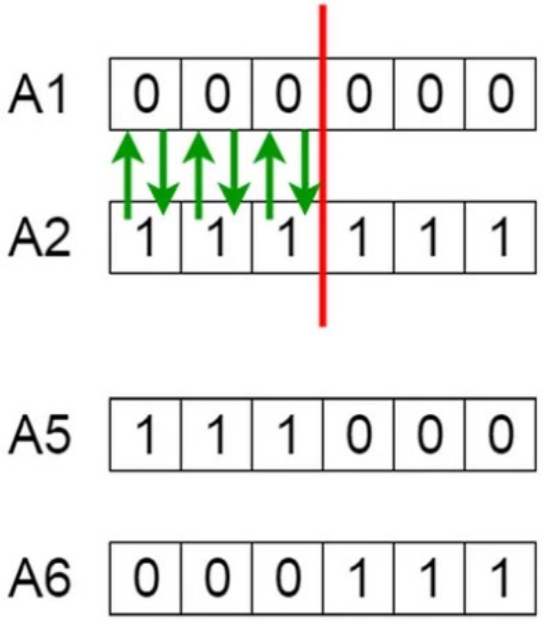


Initial Population

- The process begins with a set of individuals which is called a Population.
- An individual is characterized by a set of parameters (variables) known as Genes. Genes are joined into a string to form a Chromosome (solution).
- In a genetic algorithm, the set of genes of an individual is represented using a string, in terms of an alphabet. Usually, binary values are used (string of 1s and 0s). We say that we encode the genes in a chromosome.

Initial Population





Fitness Function

- The fitness function determines how fit an individual is (the ability of an individual to compete with other individuals).

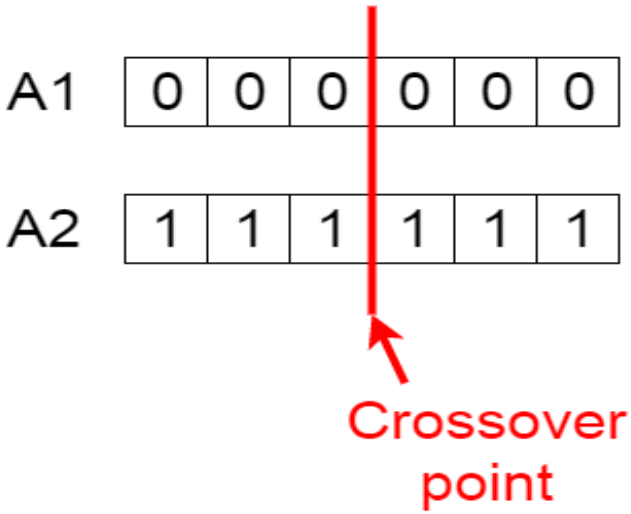
- It gives a fitness score to each individual. The probability that an individual will be selected for reproduction is based on its fitness score.

Selection

- The idea of selection phase is to select the fittest individuals and let them pass their genes to the next generation.
- Two pairs of individuals (parents) are selected based on their fitness scores.
- Individuals with high fitness have more chance to be selected for reproduction.

Crossover

- Crossover is the key genetic operator in a GA.
- Combine the genetic information of two parent solutions to generate new offspring (solutions)
- For each pair of parents to be mated, a crossover point is chosen at random from within the genes.



Crossover

- Offspring are created by the parents
  - 1-Point Crossover
    - ✓ A random point is selected.
    - ✓ The child gets the first part from parent 1, the second part from parent 2.
    - ✓ Example (binary strings):

      Parent 1: 11001 | 011

      Parent 2: 10111 | 100

      Offspring: 11001 | 100

Crossover

- 2-Point Crossover
  - ✓ Two crossover points are selected.
  - ✓ The middle part is swapped between the parents.
  - ✓ More mixing than single-point.
  - ✓ Example (two crossover points are selected?)

Parent 1: 11001011
Parent 2: 10111100

Child 1: 11 (from P1) + 1111 (from P2) + 11 (from P1) → 11111111
Child 2: 10 (from P2) + 0010 (from P1) + 00 (from P2) → 10001000

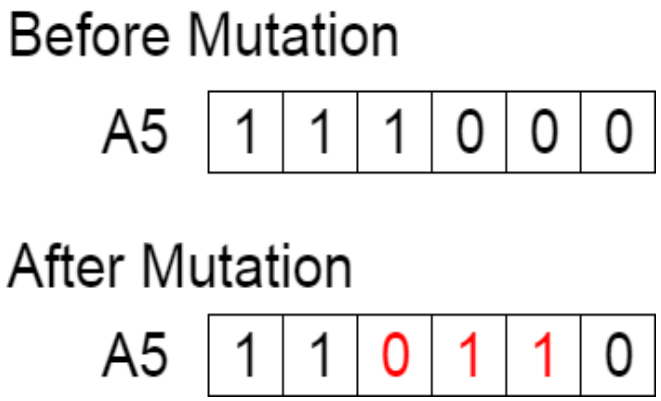
- Multipoint Crossover

  A generalization of single-point and two-point crossover. This leads to more mixing of genetic material, increasing diversity.

Mutation

- Mutation is a genetic operator used to introduce diversity into the population by making small, random changes to individual chromosomes. It prevents premature convergence.

- In certain new offspring formed, some of their genes can be subjected to a mutation with a low random probability. This implies that some of the bits in the bit string can be flipped.



Termination

- The algorithm terminates if the population has converged (does not produce offspring which are significantly different from the previous generation).

- This means the genetic algorithm has provided a set of solutions to our problem.