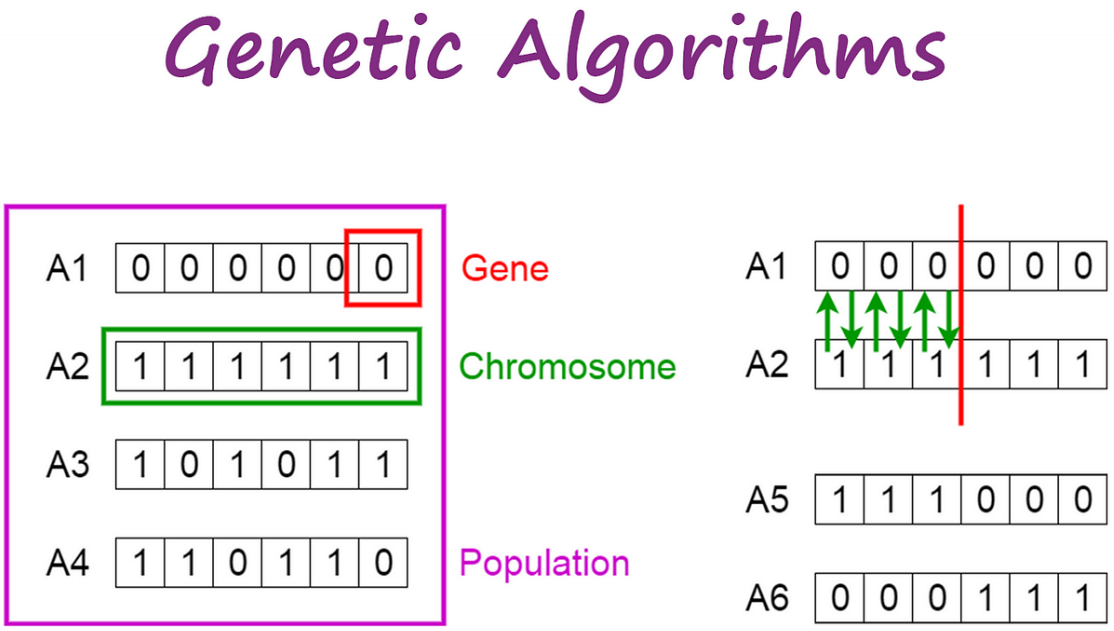
MIS4311
Machine Learning Applications

Fall 2025

Lecture #11

Genetic Algorithms

A **genetic algorithm** is a search heuristic that is inspired by Charles Darwin's theory of natural evolution. This algorithm reflects the **process of natural selection** where the **fittest individuals are selected for reproduction** in order to **produce offspring (child) of the next generation.**



Genetic Algorithms

Notion of 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.**

This notion can be **applied for a search problem**.

Genetic Algorithms

Five phases are considered in a genetic algorithm:

1. Initial population
2. Fitness function
3. Selection
4. Crossover
5. Mutation

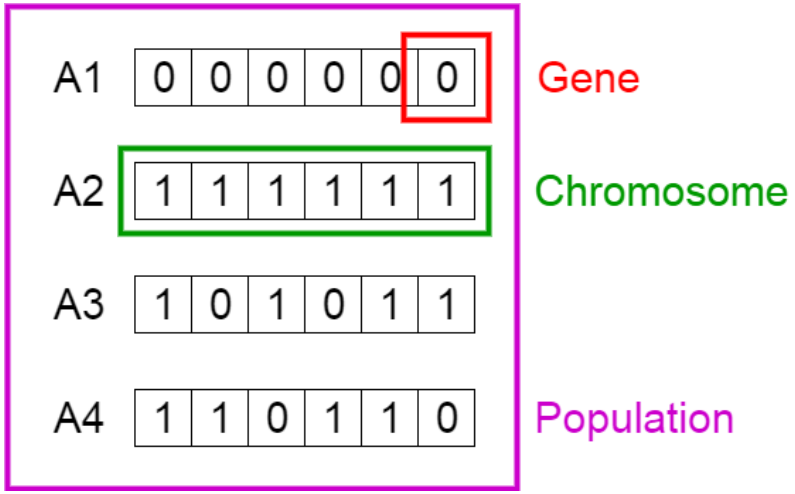
Genetic Algorithms

1. Initial Population:

- The process begins with a set of individuals which is called a **Population**. Each individual is a solution to the problem you want to solve.

- 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.**



Genetic Algorithms

2. 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.

3. Selection

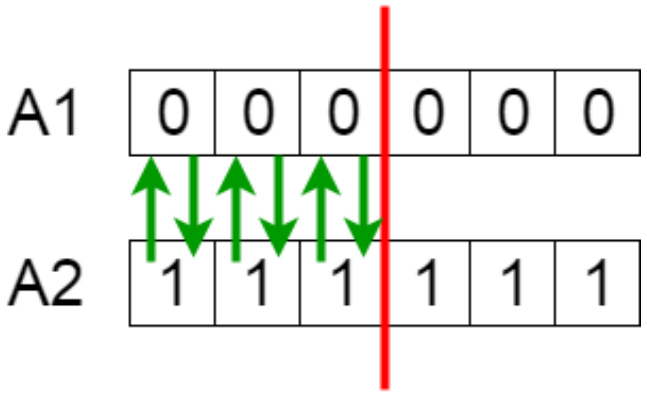
The idea of **selection** phase is to **select the fittest individuals** and let them pass their genes to the next generation.

Two pairs of individuals (**parents**) are selected based on their fitness scores. Individuals with **high fitness have more chance** to be selected **for reproduction**.

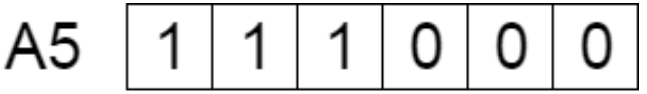
Genetic Algorithms

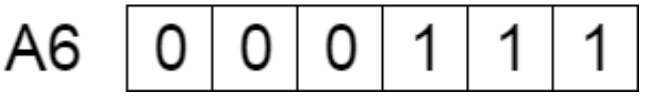
4. Crossover

Crossover is the **most significant phase** in a genetic algorithm. For each pair of parents to be mated, a **crossover point** is chosen at random from within the genes.



Offspring are created by exchanging the genes of parents among themselves until the crossover point is reached.





The new offspring are added to the population.

Genetic Algorithms

5. Mutation

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.

Before Mutation

A5	1	1	1	0	0	0

After Mutation

A5	1	1	0	1	1	0

Mutation occurs to maintain **diversity within the population** and prevent premature convergence.

Genetic Algorithms

6. Termination

The algorithm terminates if **the population has converged** (does **not produce offspring** which are significantly **different from the previous generation**). Then it is said that the **genetic algorithm has provided a set of solutions to our problem.**

The population has a fixed size. As new generations are formed, **individuals with least fitness die**, providing space for new offspring.

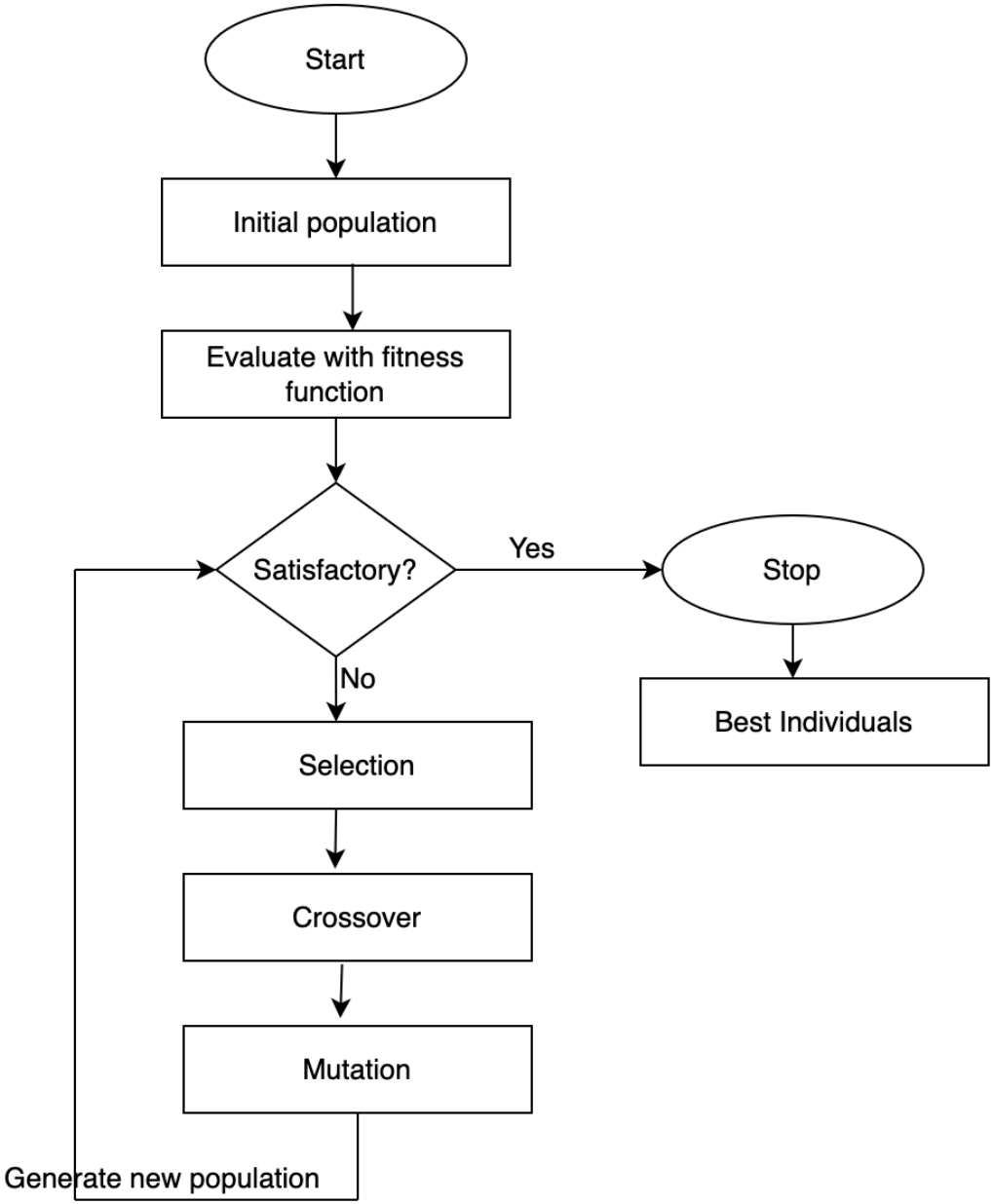
The **sequence of phases is repeated** to produce individuals in each new generation which are better than the previous generation.

Genetic Algorithms

Pseudo-Code for GA

START
Generate the initial population
Compute fitness
REPEAT
    Selection
    Crossover
    Mutation
    Compute fitness
UNTIL population has converged
STOP

Genetic Algorithms



Genetic Algorithms

Application:

Y = w1x1 + w2x2 + w3x3 + w4x4 + w5x5 + w6x6

Maximize solution when input values are

(x1,x2,x3,x4,x5,x6)=(4,-2,7,5,11,1)

Next Week

- **Image Processing**

Thank you for your participation ☺