Genetic algorithms explained

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Optimization problems are everywhere in today's world. From minimizing costs to maximizing efficiency, the goal is often to find the most effective solution for a given task. These challenges typically involve identifying the maximum or minimum value-such as reducing fuel costs for a transportation company. One of the most powerful and valuable methods for tackling these problems is the use of genetic algorithms, a technique inspired by Darwin's theory of evolution.

What are genetic algorithms?

Genetic algorithms are heuristic search algorithms inspired by the process of natural evolution (heuristic algorithms are used to find good but not necessarily optimal solutions - prioritizing computational efficiency over solution quality). In simple terms, species evolve over generations, with each population differing slightly from the previous one. Not all individuals are equally suited to survive and reproduce in their environment, so **only the fittest survive.** These individuals pass on their genes, creating new generations of offspring. During reproduction, two key processes occur: **crossover-the** combination of parent genes-and **mutation,** which introduces random changes in the genome. Over time, evolution gradually converges toward stronger individuals, who are better adapted to survive and reproduce.

When applied correctly, this concept can be adapted to solve a wide range of optimization problems. Genetic algorithms involve specific terminologies, many of which are borrowed from evolutionary theory, as outlined below:

Population: A subset of solutions.

Individual (or solution, or chromosome): A single solution to a problem, typically represented as a finite vector of variable components.

Gene: A single variable component of a chromosome.

Parents: Individuals from a generation used to create offspring.

Fitness function: A function that assigns a fitness value to each individual, determining the individual's quality.

Selection: The stage where the best solutions are chosen to be used in the next generation.

Crossover: The recombination of genes from different parents to generate new solutions.

Mutation: A process that maintains genetic diversity in a population, usually involving random changes.

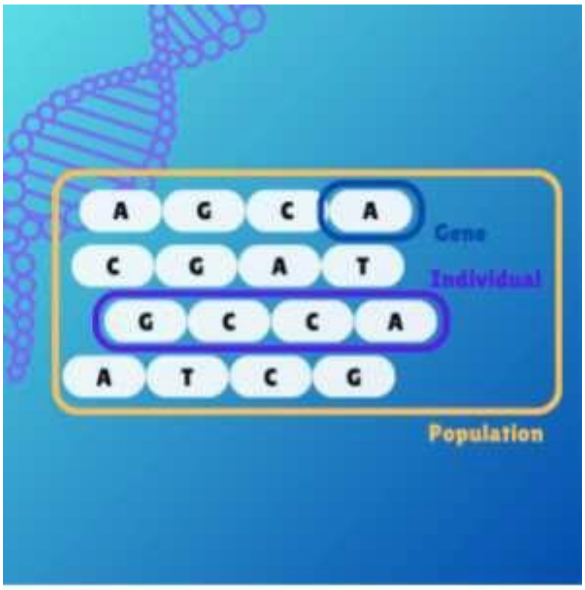

Image 1 Visualization how population is made of individuals with multiple genes.

How do genetic algorithms work?

The working of a genetic algorithm could be separated into 5 steps:

(1) Initialization

First step of running a genetic algorithm is to initialize the starting population. This is usually done by randomly generating a set of individuals.

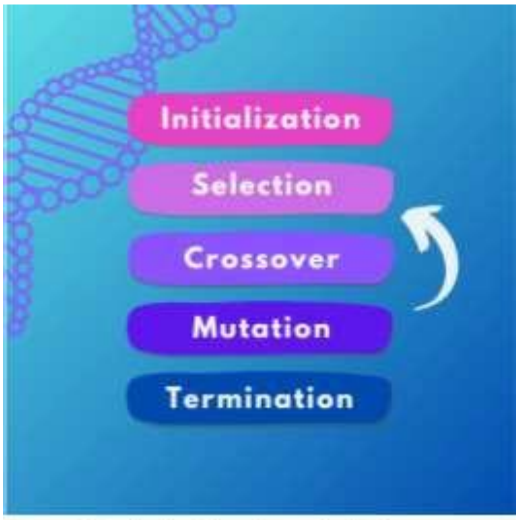

Image 2 Genetic algorithm phases visualised.

(2) Selection

Selection is a stage, where each individual in the generation is assigned a fitness value using a fitness function and then a few are selected to be parents to the new generation. Some of frequently used selection methods are:

Roulette Wheel
Selection Stochastic
Universal Sampling

- **Tournament**
Selection
Elitism selection

-

(3) Crossover

When parents are selected, their
genomes are combined to create
offspring, similar as it is in nature.
Crossover should preserve some characteristics of the parents while still producing a new and improved individual. Some of the ways to perform crossover:

One Point Crossover

- Two Point
Crossover
Uniform
Crossover

(4) Mutation

Mutation is the last step in a single cycle of a genetic algorithm. It introduces some randomness allowing the discovery of potentially better individuals that could never be reached using only starting population and crossover. Mutation can be done as:

Flip Bit
Mutation
Gaussian
Mutation
Swap
Mutation

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(5) Termination

At some point the algorithm must stop, which can be achieved in two different ways:

- **Algorithm reaches the maximum number of generations set by user**
- **Algorithm reaches a desired level of fitness**

Conclusion

The basic principle of a genetic algorithm is straightforward: you choose which method to apply at each step, and the algorithm takes care of the rest. However, in practice, selecting these methods requires careful consideration and often involves a lot of trial and error. Despite this, genetic algorithms are a powerful tool, especially when faced with optimization problems where the function you're trying to optimize is unknown.

References

Article by *AnalytixLabs:*

https://medium.com/@byanalytixlabs/a-complete-guide-to-genetic-algorithm-advantages-limitations-more-738e87427dbb

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