

# Chapter 3

## Genetic Algorithms for Decision Optimization

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### **ABSTRACT**

*This chapter thoroughly explores the versatile applications of genetic algorithms (GAs) in decision optimization across diverse domains. GAs, inspired by natural selection, adeptly navigate solution spaces, adapting to complex objectives and revealing near-optimal solutions. The exploration encompasses theoretical foundations, customizations for decision optimization, and a variety of GA algorithms demonstrated through real-world case studies, showcasing their adaptability. The GA process iteratively evolves populations, incorporating multiple tailored algorithms that address conflicting objectives and intricate variables. GAs, positioned as optimization keys, redefine decision-making for complex problems where traditional methods fall short. The chapter provides a concise yet comprehensive overview, offering valuable insights into the nuanced applications of GA algorithms in decision optimization.*

### **1. INTRODUCTION**

Scientists of various fields are looking forward towards nature to find out the solution of complex problems. The process of natural selection, the combination of alleles at specific locations of chromosomes, DNA sequences, the genetic makeup of an organism and the way genes are organized at specific locations on chromosomes and mutation diversity have attracted scientists from various fields to see solutions to complex problems in their domains. Computer science is no exception (Gen & Lin, 2023). This chapter will enhance an understanding of various biological concepts of genetics and their conversion into genetic algorithms to solve problems of optimization, cloud and machine scheduling, game playing, robotics, and other fields. The genetic makeup or “genetic constitution” is the genetic information of an organism. It includes the entire set of genes, including both the expressed (coding) and non-expressed

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(non-coding) regions of an organism's DNA. The organism's traits, characteristics, and overall functioning entirely depend on the genetic constitution (Polo-Mendoza et al., 2023). The important key points related to genetic constitution are genes and chromosomes, alleles, mutation, and inheritance. Genes are segments of DNA responsible for specific traits. Their organization on chromosomes determines the genetic constitution of an organism. Alleles are different versions of a gene that can exist at a specific location on a chromosome. The combination of alleles at various gene loci contributes to an organism's genetic diversity and determines its traits (Jia et al., 2023). The genetic constitution is inherited from one generation to the next through reproduction. Changes in genetic material, known as mutations, can alter the genetic constitution. Mutations can occur spontaneously or be induced by external factors. They contribute to the evolution of species over time. Genetic algorithms (GAs) represent optimization and search techniques inspired by principles found in natural selection and genetics. Part of the broader category of evolutionary algorithms, these computational models draw inspiration from biological evolution. Genetic algorithms prove valuable in approximating solutions for optimization and search challenges, especially in cases where conventional methods may prove impractical or inefficient (Bülbül, 2023). The optimization problem's solutions are encoded as chromosomes, typically portrayed as binary strings (0s and 1s). Each chromosome denotes a potential solution, and selection is based on fitness, gauging how effectively a solution addresses the problem. Those with higher fitness are more likely to be chosen. Pairs of selected solutions (parents) undergo crossover or recombination, where parts of their chromosomes are exchanged to create new offspring (solutions) (Fathi et al., 2021; Mahjoob et al., 2022). The new offspring (solutions) replace some of the less fit individuals in the population. The process continues for a set number of generations or until a termination condition (the best possible solution) is met.

## **2. GENETIC ALGORITHM AND ITS TYPES**

The primary role of genetic algorithms encompasses optimization, search and exploration, parallelism, distributed computing, handling complex and nonlinear problems, parameter optimization, feature selection, and evolutionary robotics. Genetic algorithms prove valuable in finding optimal solutions to intricate problems where traditional methods may prove impractical or inefficient. Such problems often involve a vast search space, non-linearity, and multiple constraints. Genetic algorithms excel in exploring extensive solution spaces by generating and evaluating a population of potential solutions. This capability to traverse widely across the solution space proves particularly beneficial in addressing complex and multimodal problems (Alejo-Reyes et al., 2020).

Genetic algorithms inherently support parallelization. Multiple candidate solutions can be evaluated simultaneously, resulting in the efficient use of parallel and distributed computing resources. Genetic algorithms adeptly handle nonlinear, non-continuous problems with multiple objectives. They are well-suited for scenarios where the relationship between variables is not well-defined or dynamically changes. Genetic algorithms are also effective in parameter tuning, optimizing parameters of algorithms or models. For instance, they find application in optimizing hyperparameters of machine learning models to enhance performance. In the field of evolutionary robotics, genetic algorithms play a crucial role in evolving the structure and behavior of robots across successive generations, leading to the development of robots with improved performance in specific tasks. Genetic algorithms are employed to evolve strategies for playing games, encompassing board games, video games, and simulations where an optimal strategy needs development. Genetic algorithms prove useful in solving combinatorial optimization problems,

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