


# Chapter 2

## Metaheuristics

### Developing Intelligent Solutions for Complex Optimization Problems

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#### **ABSTRACT**

*Metaheuristics are a category of optimization algorithms constructed to tackle complex real-world problems which traditional approaches struggle to address. This chapter analyzes the classification, application and evolution of metaheuristics algorithms in dealing with large-scale, NP-hard and nonlinear constraints. Metaheuristics, involving swarm intelligence, physics-based models, and evolutionary approaches, provide robust search framework by maintaining a balance between exploration and exploitation techniques. The discussion includes their contribution in biomedical image processing, finance, artificial intelligence and robotics. The study also investigates the computational problems of metaheuristics, focusing on parameter tuning, trade-offs in performance and process of hybridization with machine learn-*

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*ing. The observations highlight the adaptive behaviour of metaheuristics in dynamic surroundings, offering solutions spanning various domains.*

## **INTRODUCTION**

Optimization is an elementary means to handle non-linear problems in real life. Large-scale, high-dimensional and multi-objective optimization problems are now an intrinsic challenge of quickly evolving branches of science and engineering (Tian et al., 2023). Stochastic algorithms with randomness and uncertainty and deterministic algorithms with stringent rules represent two major categories of optimization algorithms designed to address such challenges (Yang, 2011).

Classic deterministic algorithms are effective for well-structured problems like computational geometry, graph traversal, and string matching; however, they are inadequate for ill-posed, non-differentiable, or combinatorially explosive problems. To fill this gap, metaheuristic algorithms particularly for NP-hard problems have proven to be handy tools that can achieve near-optimal solutions within acceptable computing timescales (Abualigah et al., 2021; Mohapatra et al., 2023).

Their function as strategic principles directing subordinate heuristics in the process of search is seen in the term “metaheuristic,” derived from the Greek prefix meta- above or higher level (Yang, 2011). During search activities, metaheuristics are caused to successfully strike a balance between exploitation (intensification) and exploration (diversification). Recent trends illustrate growing flexibility in metaheuristics through domain adaptation, deep learning incorporation, and hybrid approaches. Ghosh et al. (2023), for example, suggested a deep neuroevolutionary framework for hyperparameter tuning of neural networks based on metaheuristics. Likewise, a domain-specific adjustment-focused hybrid version of the Grey Wolf Optimizer was presented by Jaberipour et al (2022) for biomedical image segmentation exclusively. In addition, Kaur and Kumar (2023) noted recent progress in swarm intelligence and multi-agent coordination when they examined nature-inspired algorithms.

With emphasis on biomedical image processing, the chapter is devoted to giving a concise and complete outline of metaheuristic algorithms, from their taxonomy to algorithmic formulation and uses. We start by sketching classification frameworks, and then stress fundamental algorithm forms, uses, and research needs to guide future study.

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