Chapter 10
Metaheuristic Optimization for Generative and Explainable AI in Biomedical Imaging

Ketan Sarvakar
https://orcid.org/0000-0003-4486-0224
Ganpat University, India

Aniket Patel
https://orcid.org/0000-0001-7616-2610
Ganpat University, India

Chandrakant Devabhai Patel
https://orcid.org/0000-0003-2340-4457
Ganpat University, India

Paresh M. Solanki
https://orcid.org/0000-0002-6895-1094
Ganpat University, India

Hiral B. Patel
https://orcid.org/0000-0002-4194-146X
Ganpat University, India

Meghna Babubhai Patel
https://orcid.org/0000-0003-1210-8556
A.M. Patel Institute of Computer Studies, Ganpat University, India

Rakshaben Karshandas Patel
https://orcid.org/0000-0002-1441-9000
Ganpat University, India

Prachi Diwan
https://orcid.org/0009-0003-0436-1970
University of Hertfordshire, UK

ABSTRACT

The medical imaging field is undergoing transformation through the integration of generative AI and explainable AI (XAI), enabling advanced diagnostics and transparent decision-making. This chapter explores the synergistic integration of these AI frameworks with metaheuristic algorithms, including Genetic Algorithms,

DOI: 10.4018/979-8-3373-0523-3.ch010

Particle Swarm Optimization, Ant Colony Optimization, and Differential Evolution, to enhance system performance and reliability. Metaheuristic approaches address optimization challenges while augmenting Variational Autoencoders and Generative Adversarial Networks in applications from synthetic image generation to rare pathology modeling. Case studies demonstrate how metaheuristic-optimized GANs improve image quality and address class imbalance, while metaheuristic algorithms enhance interpretability mechanisms including saliency maps, SHAP, and LIME, fostering trust in AI-driven diagnostics while ensuring regulatory compliance. This integration enables biomedical imaging systems to achieve superior performance, enhanced interpretability, and ethical implementation.

INTRODUCTION TO METAHEURISTICS

A magnificence of optimization techniques referred to as metaheuristics is supposed to identify powerful solutions to hard, high-dimensional, and nonlinear optimization troubles(Naheed et al., 2020)(Fontes et al., 2024). By the usage of stochastic methods and nature-inspired algorithms, metaheuristics can also cope with a lot of optimization troubles, in contrast to classical optimization strategies that would have problems with massive answer areas or necessitate gradient-based approaches. When the problem domain is distinctly nonlinear and the search area is large and unstructured, the algorithms are pretty useful.

Overview of Metaheuristic Algorithms

An effective class of optimization techniques, metaheuristic algorithms are made to address difficult issues wherein conventional optimization techniques might not be enough, mainly in excessive-dimensional and nonlinear are trying to find areas. Inspired by social behaviors or natural procedures, these algorithms might also explore huge, unstructured solution regions. Metaheuristics(Kumar et al., 2024), which do not require gradient information or exact issue structure, can successfully traverse great search areas and discover near-most excellent solutions using stochastic strategies. When the hunt area is simply too large for exhaustive techniques or the optimization problem is tough to formally version, they're especially beneficial.

Differential Evolution (DE), Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), and Genetic techniques (GA) are some famous metaheuristic techniques. GA mimics natural choice and evolution by using employing crossover, mutation, and preference to shift a population of solutions within the direction of optimality(Borys et al., 2023). PSO modifies particle placements in line with individual and collective stories, drawing thought from the social conduct of fish or