Chapter 15

Metaheuristic Algorithms and Optimizing Neural Networks for Biomedical Image Processing

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ABSTRACT

Biomedical image segmentation plays a critical role in medical diagnostics, enabling precise identification of pathological regions in various medical imaging modalities. However, existing deep learning-based segmentation models often suffer from high computational complexity, increased inference time, and suboptimal accuracy due to inefficient feature extraction. To address these challenges, we propose MO-FANet, a metaheuristic-optimized deep learning framework that integrates Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) for enhanced feature

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selection and segmentation accuracy. The proposed model significantly reduces computational cost while improving segmentation performance. Furthermore, our model reduces parameters to 6.89M, making it lightweight and efficient for real-time medical applications. The results confirm the effectiveness of MO-FANet in achieving superior segmentation performance while ensuring computational efficiency.

INTRODUCTION

Medical diagnoses, treatment planning, and disease monitoring all heavily rely on biomedical image processing. Healthcare practitioners may now precisely assess internal structures because to developments in medical imaging technologies including ultrasound, computed tomography (CT), X-rays, and magnetic resonance imaging (MRI). However, strong segmentation, classification, and enhancement methods—which are frequently made possible by deep learning models—are needed to derive valuable insights from these photos. Even with their achievements, biomedical image processing presents many difficulties for conventional deep learning-based models. Their efficacy in practical medical applications is hampered by these restrictions. We go over some of the main issues and the necessity of optimization using metaheuristic methods below. The Biomedical image processing challenges include:

High Computational Complexity

Because medical imaging data is frequently high-dimensional, its analysis necessitates a large amount of computational power. Millions of parameters are used in deep learning models, especially Convolutional Neural Networks (CNNs) and Transformer-based models, which require a lot of memory and processing power. For instance, volumetric processing is necessary for 3D medical pictures (such MRI and CT scans), which raises the cost of computing.

- It takes a lot of time to train deep learning models on big datasets.
- It is difficult to diagnose medical conditions in real time using devices with limited resources.
- When analyzing sensitive medical data, cloud-based processing raises privacy issues.

Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) are two examples of metaheuristic algorithms that can optimize network designs and minimize computing overhead without sacrificing accuracy.

Integration of Higher-Order Time-Frequency Statistics and Neural Networks: Application for Power Quality Surveillance

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