

Chapter 12

Metaheuristics in Deep Learning for 3D Medical Imaging

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ABSTRACT

The integration of metaheuristic algorithms, such as genetic algorithms and particle swarm optimization, with deep learning techniques has significantly advanced 3D medical imaging, particularly through transfer learning. Transfer learning allows pre-trained models to be adapted to new tasks, addressing challenges posed by limited annotated datasets. Metaheuristic algorithms optimize deep learning models by refining hyperparameters and neural network architectures, enhancing accuracy and efficiency. This synergy improves model generalization, reduces computational costs, and tackles domain-specific challenges in medical imaging. Applications include tumor detection, organ segmentation, and diagnostics, with attention to ethical considerations and future research directions. This integration aims to develop more robust and efficient AI-driven solutions for medical imaging.

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INTRODUCTION

The application of artificial intelligence significantly enhances the performance of three-dimensional imaging techniques. At the same time, new other medical devices create new opportunities and increasingly higher demand for advanced accuracy, efficiency, and scalability in diagnostic systems. However, barriers such as the lack of annotated medical data, and the difficulties associated with high-dimensional medical imaging need to be overcome in order to develop dependable models. Often, the implementation of metaheuristics, in combination with transfer learning, is one of the most appealing options to improve model performance in the presence of sparse data. Transfer learning is the method of knowledge from other similar domains, while metaheuristics apply powerful optimization techniques to reconfigure deep learning frameworks' parameters. Alternatively, transfer learning can be used for data-scarce domains where images need to be annotated. Such resource and time intensive processes in domain applicable medical imaging applications render transfer learning highly advantageous because they broaden access to data. Recent advancements in TL, particularly through the application of metaheuristic algorithms, have further enhanced model performance and adaptability in medical imaging tasks (Zhang,Z., 2023; Alam et al., 2024).

Overview of Transfer Learning and Metaheuristics in Biomedical Imaging

Transfer learning (TL) is a key machine learning method in 3D medical imaging, addressing the issue of having small labeled dataset sowing to high cost, ethical concerns, and annotation complexity by transferring information from abundant source domains to scarce target domains using pre-trained networks like those from ImageNet to learn low-level information such as edges and textures for MRI, CT, and PET scans (Kim et al., 2022; Zhang, Z., 2023). TL enhances segmentation for tasks such as tumor detection and organ localization by enabling accurate boundary detection from complex volumetric data using fewer datasets, with 15-30% greater accuracy through fine-tuning than training from scratch, along with the advantages of reduced computational costs and increased convergence for faster clinical deployment (Kushibar et al., 2019; Salehi et al., 2023; Fu et al., 2023; Altaf et al., 2019). This is supplemented by data augmentation techniques, such as random block-wise flipping, as presented in **Figure 1**, showing the study design with augmentation and TL components to ultimately facilitate timely diagnostics and treatment in clinic environments.

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