Integration of Deep Learning Algorithms with PPIR and AI4MED for advanced medical Image analysis and simulations in radiotherapy

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Abstract

Last developments in Artificial Intelligence and Deep Learning Algorithms have significantly advanced medical image processing, enabling precise, automated extraction of morphological and quantitative parameters from radiological data. Unlike conventional computational approaches, DLAs employ hierarchical feature learning to detect subtle anatomical variations and pathological signatures. Architectures such as Convolutional Neural Networks (CNNs), U-Net, consistently achieve the performance in segmentation, classification, and anomaly detection across MRI, CT, PET, and multimodal imaging. In 2023 the project "Development of simulation and forecasting models and integration with the TCIA database of medical images" introduced a Deep Convolutional Neural Network (DCNN) module into PPIR. A major advance is the integration of DLAs with PPIR (Program për Procesim Imazhesh në Radioterapi), a MATLAB-based module created in 2014 for radiotherapy simulations of tumour control (TCP) and tissue complications (NTCP). In 2019, PPIR was enhanced with advanced radiobiological models such as the Eudmodel for dose–volume histograms, enabling more realistic simulations of fractioned treatments based on tumour radiosensitivity, volume, and cell density. In this work, our focus is the integration of PPIR with AI4MED platform ([www.ai4med.net]), which provides the collaborative infrastructure for deploying and validating this integrated DLA and PPIR model. This integration enhances the automation of target and organ-at-risk segmentation, the quantification of morphological parameters, and the generation of reproducible imaging for treatment planning. By embedding DLA model into PPIR, the professionals of radiotherapy teams benefit from greater contouring precision, reduced inter-observer variability, and more efficient development of individualized treatment protocols. Through this, AI4MED supports real-time annotation, cross-institutional validation, and seamless interoperability with medical image data (PACS system). Research contributions of AI4MED research group emphasize the necessity of algorithmic robustness, broad generalization across diverse imaging datasets, and adherence to international radiotherapy guidelines. Our work demonstrates that embedding DLAs within PPIR and making them accessible via AI4MED marks a paradigm shift toward precision radiotherapy, facilitating more consistent tumour delineation, optimized treatment planning, and improved patient outcomes.

References

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