Methods for Automatization of Radiotherapy Dosimetry

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Abstract:

Radiotherapy dosimetry is critical in ensuring the precision and safety of cancer treatments. The complexity and variability of treatment planning necessitate advanced methodologies for automation and optimization. This thesis introduces novel approaches aimed at automating the radiotherapy dosimetry process.

The research begins with developing a dosimetry optimizer and comprehensively evaluating existing open-source optimization algorithms for dose optimization. Then, this thesis analyzes the relationships between different treatment plans. This analysis leads to the proposal of a novel framework for multi-objective optimization and robust plan selection using graph theory.

To further reduce the time required for radiotherapy planning, the thesis explores the application of reinforcement learning for dose optimization. The proposed system performs dosimetry for new patients by leveraging dose data from past patients. This fully automated method can adapt to clinical dependencies, reducing the need for manual fine-tuning and easing its adoption in practice.

In addition, the thesis investigates the use of deep learning for dose prediction, proposing a series of models guided by target Dose Volume Histograms (DVH). This guidance facilitates the incorporation of guidelines into the deep-generated doses. Moreover, it allows a single model to be trained instead of one for each clinic.

The contributions of this thesis represent advancements in radiotherapy dosimetry, paving the way for the development of a fully automated, clinically dependent treatment planning system designed to operate with minimal human intervention. These innovations could enhance clinical workflows and improve patient outcomes, making radiotherapy more efficient and effective.

Contributions:

ArXiV: Radiotherapy Dosimetry: A Review on Open-Source Optimizer

This study evaluates the performance of various state-of-the-art open-source optimizers for radiotherapy dosimetry. Newton CG and LBFGS were the most efficient. These insights help guide the selection of optimization tools for more efficient cancer treatment planning.

ESTRO: A Novel Framework for Multi-Objective Optimization and Robust Plan Selection Using Graph Theory

This study presents an innovative framework for optimizing radiotherapy dose distribution by generating and clustering multiple treatment plans with randomized constraint weights. The new proposed framework clusters plans based on dose-volume histogram similarities, which carry most of the clinical meaning.

AIME: Radiotherapy Dose Optimization via Clinical Knowledge-Based Reinforcement Learning

This research introduces a deep learning framework for automating radiotherapy treatment planning by training a reinforcement learning agent to mimic dose distributions from past cases. This method represents a first step towards fully automated, human-less treatment planning systems by navigating towards clinically acceptable solutions based on human planners' optimal dose plans.

ASTRO: Clinically Dependent Fully Automatic Treatment Planning System

This study demonstrates the potential of training reinforcement learning (RL) agents to mimic human-optimized radiotherapy plans by leveraging past clinical dose data, tailored to specific clinic guidelines. The results suggest that a fully automated treatment planning system (TPS) can be customized for each clinic's practices, improving the feasibility and adoption of automated TPS in clinical settings.

SFPM: Dose Volume Histograms Guided Deep Dose Predictions

This study presents a deep-learning model incorporating Dose-Volume Histograms (DVHs) into radiotherapy dose prediction. By integrating target DVH into the model's input, the same model can generate deep doses following a clinical guideline. This technique enables a new workflow where a template of DVHs is used for each clinic, and dosimetrists can fine-tune the target DVHs if needed.

SFRO: Attention Mechanism on Dose-Volume Histograms for Deep Dose Predictions

This study introduces a new approach for radiotherapy dose prediction by incorporating Dose-Volume Histograms (DVHs) into deep learning models using an attention mechanism. This approach slightly improves dose prediction accuracy.