Degree project 30 credits in Biomedical Engineering

Physics-Informed Neural Networks for Tumor Response Modeling: An Interactive Visualization Framework for Radiotherapy Monitoring

Biomedical Engineering R&D (MT-FoU) is a research and development department at the Center for Information Technology and Biomedical Engineering at Norrland University Hospital, Region Västerbotten. The department conducts international research, development and education in the field of biomedical engineering, with expertise in, for example, sensors and measurement systems, image and signal analysis and biomechanical models. MT-FoU is also a part of the competence center AI for Medicine in Northern Sweden, AIM North, which supports clinical research projects with technical method expertise in machine learning and AI.

Background

Radiotherapy is a cornerstone in the treatment of many tumors, aiming to reduce tumor volume and slow disease progression. Longitudinal medical imaging enables clinicians to track these changes over time, yet deriving quantitative insights about tumor response remains challenging. Physics-Informed Neural Networks (PINNs) represent a new paradigm in computational oncology, integrating imaging data with partial differential equations that describe tumor dynamics under radiation. PINNs can infer hidden biological and physical parameters, such as tumor decay rates or radiation response factors, thus enhancing interpretability beyond purely data-driven models. To make this approach usable in clinical practice, a **Human-Machine Interface (HMI)** is needed. Such an interface should not only visualize longitudinal images but also embed the outputs of the PINN models, including estimated tumor decay parameters, predictive tumor trajectories, and interactive graphs. This integration will provide clinicians with a unified environment where tumor screening and model-driven predictions converge, supporting treatment monitoring and personalized decision-making.

Aim of the project

This project aims to develop an **interactive Human-Machine Interface (HMI) that integrates Physics-Informed Neural Networks (PINNs) with longitudinal medical imaging data** of tumors under radiotherapy. The objectives are to implement a PINN framework capable of estimating tumor decay factors and predicting tumor evolution under radiation; to design an HMI that embeds both medical images visualization and PINN model predictions, offering clinicians a single platform to analyze imaging data and computational insights.

By merging physical models with interactive visualization, the project will enhance the interpretability of tumor monitoring, foster clinical adoption of PINNs, and support personalized oncology.

Work description

The project will involve the following tasks:

1. **Literature Review and requirements definition:** Analyze current approaches in PINNs for biomedical applications, tumor growth modeling, and visualization tools in radiotherapy.
2. **Model Development:** Implement a PINN framework that integrates imaging-based tumor measurements with differential equations describing radiation-induced tumor decay. Preprocess longitudinal medical images datasets and align them with PINN model inputs.
3. **HMI Design and Development:** Design an intuitive interface that enables: visualization of tumor images at different time points; interactive exploration of tumor volume evolution; graphical outputs of PINN-inferred decay factors and treatment response parameters.
4. **Reporting and Documentation:** Document methods, implementation, and results, producing a final report that includes both technical contributions and clinical insights.

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