



Compressing Radiation-Transport Simulations using Neural Networks

Posing the estimation of spatially resolved radiation fields as a reconstruction task to create acceleration structures for computational dosimetry

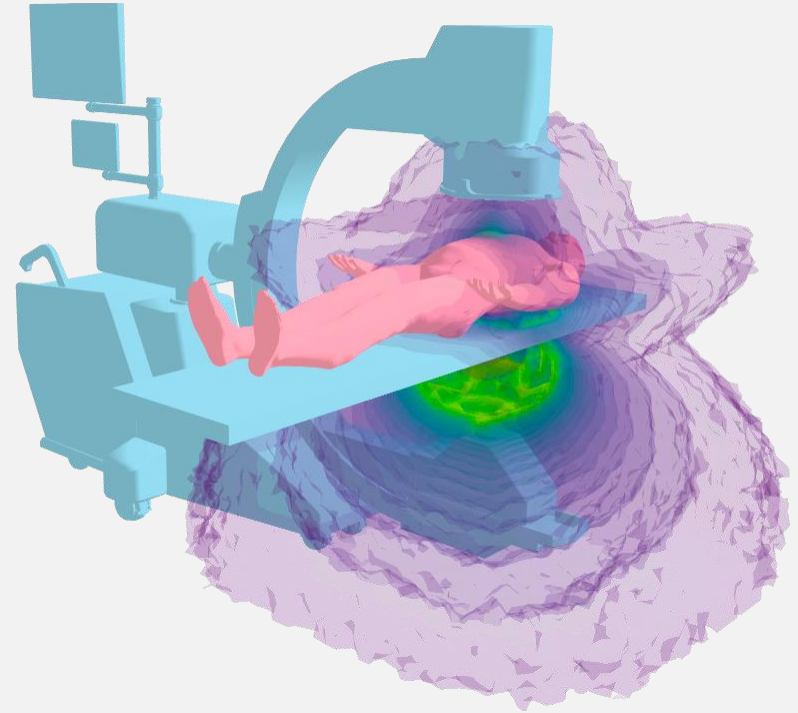
Computational Personal Dosimetry

Introduction

Context

- Occupational dosimetry
- Interventional Radiology
 - Cardiac Catheter insertions
 - Angiography

→ WG 12 Task 1.4 on AI of Jérémie



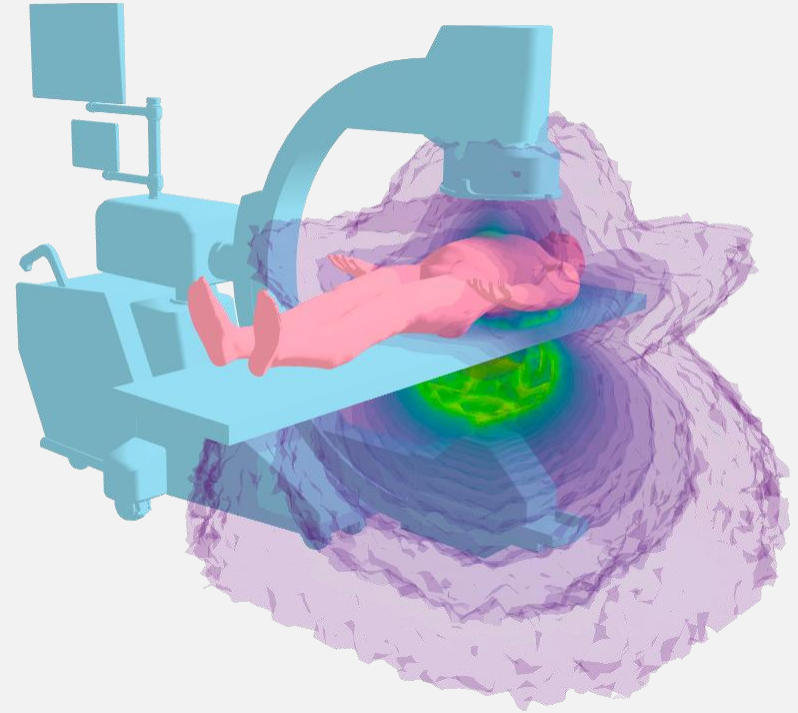
[Calculated using RadField3D]

Computational Personal Dosimetry

Introduction

Goals

- Dosemeter-less (personal) dosimetry
→ real-time capability: 0.3 to 1 fps
- Improved training of staff
 - Existing systems would benefit from VR/AR visualizations of radiation fields
→ real-time capability: 80 to 120 fps



[Calculated using RadField3D]

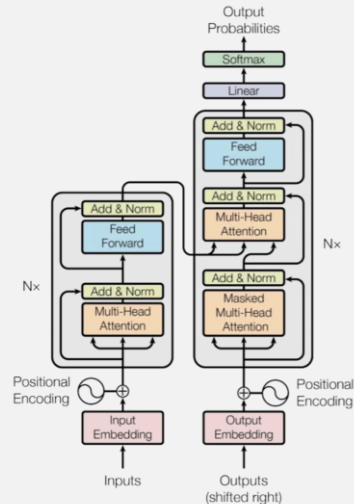
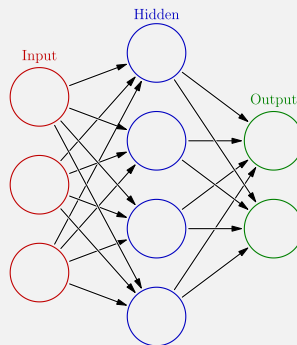
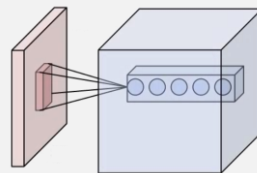
Accelerating Radiation Transport Simulation

Introduction

Estimating Radiation Fields

Surrogate Models

- Use neural networks
- Learn radiation transport simulation as a whole
- Architectures
 - (3D-)U-Net
 - Fully-Connected-Network
 - Transformers
 - Diffusion models



Datasets

- Starting point for every development of learned approaches
- Very limited availability
- Our use-case:
 - explicit patient mesh geometry (Alderson phantom)
 - full spatial distribution of radiation

→ First task: Development of corresponding datasets

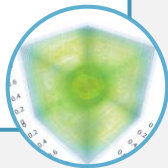


Datasets

3 datasets for interventional radiology with successively growing parameter space

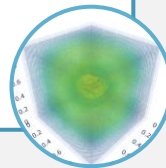
- Free rotating x-ray tube
- Fixed H-100 radiation quality

Dataset-01



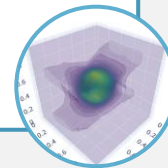
- Free rotating x-ray tube
- Dynamic x-ray tube spectra
 $E_p \in [40, 125] \text{ keV}$
Filters: Al + Cu
 $\angle_{\text{Anode}} \in [8, 12]^\circ$

Dataset-02



- Free rotating x-ray tube
- Dynamic x-ray tube spectra
- Dynamic collimated beam
- Dynamic tube distance

Dataset-03



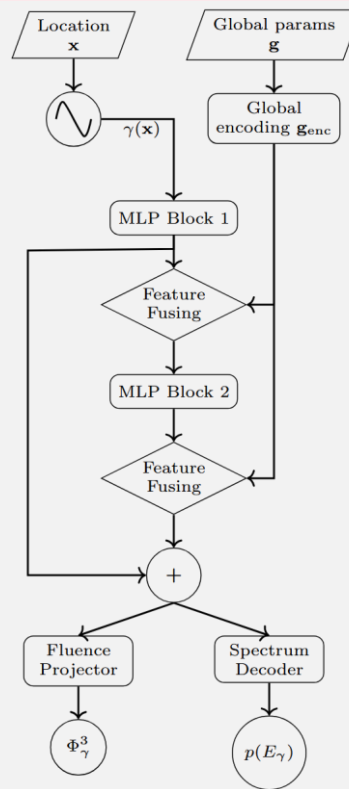
Neural Networks in Dosimetry

Introduction

Estimating Radiation Fields

Fully-Connected-NN

- Voxelwise request for radiation properties
- Depending on global parameter vector
 - Can contain any information (in theory)
 - In practice: tube's direction, distance, spectrum



Neural Networks in Dosimetry

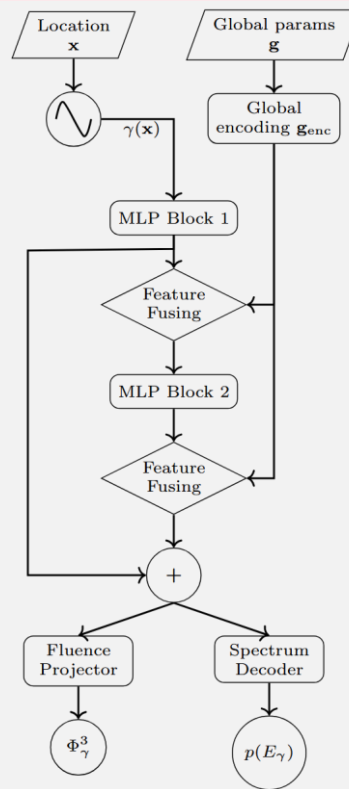
Introduction

Estimating Radiation Fields

Fully-Connected-NN

- Voxelwise request for radiation properties
- Depending on global parameter vector
 - Can contain any information (in theory)
 - In practice: tube's direction, distance, spectrum
- Structure inspired by NeRF approach of Novel View Synthesis (Computer Graphics)
 - Reconstruction of 3D structure from 2D images in real-time

→ Estimates fluence and spectrum at any location



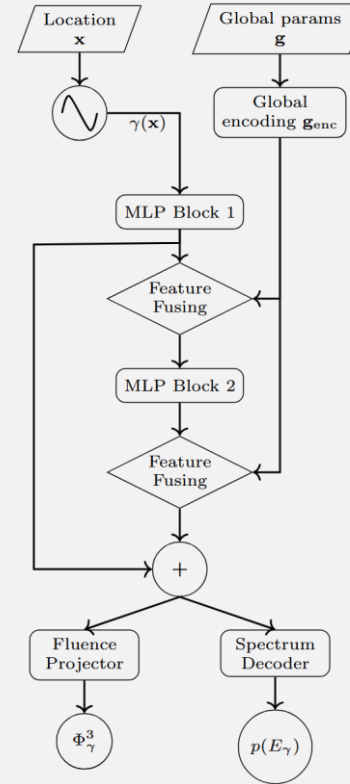
Neural Networks in Dosimetry

Introduction

Estimating Radiation Fields

Fully-Connected-NN

- Variants
 - SRBF: Static Rotatable Beam Field
→ Global parameter is direction
 - SPERF: Spectral Enhanced Radiation Field
→ Global parameters are direction and spectrum
 - PBRF: Parametric Beam Radiation Field
→ Global parameters are direction, spectrum and x-ray tube distance



Neural Networks in Dosimetry: Metrics

Introduction

Estimating Radiation Fields

Evaluate Estimations

Evaluating Neural Networks

- Dataset splitting (Cross-Validation)
 - Training, Validation, Test
- Calculate Metrics – Prediction and Ground-truth

Whole separate topic

- Assessing ... spectrum?

