PregDose: Protocol and Software Structure

Neutron Dose Estimation in Proton Therapy

Developed as part of the SONORA Project
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1 Purpose

PregDose is a clinical tool designed to estimate neutron equivalent dose to the fetus during proton therapy. It converts DICOM-based treatment planning data into input scripts for TOPAS Monte Carlo simulations [1], supporting accurate field-level neutron dose estimation.

2 Overview

PregDose:

- Parses a full DICOM treatment study including CT, RTSTRUCT, RTPLAN, and RTDOSE.
- Uses external beam model and SPR-to-material tables.
- Outputs TOPAS-compatible input files for dose simulation.
- Supports field-specific geometry generation and dose verification.

3 System Requirements

- Python ≥ 3.8
- TOPAS (installed and configured)
- Python packages: `pydicom`, etc. (see `setup.py`)

4 Installation

```
git clone https://github.com/your-org/pregdose.git
cd pregdose
python3 -m venv .venv
source .venv/bin/activate
pip install -e .
```

When prompted, select "yes" to install all options.

5 Input Requirements

The input directory (`study_dir`) must include:

Type	Description	Format
CT Series	DICOM image data	CT*.dcm
RS File	RTSTRUCT (structure set)	RS*.dcm
RN File	RTPLAN (treatment plan)	RN*.dcm
RD File	RTDOSE (TPS dose)	RD*.dcm

Additional required files:

Parameter	Description	Example
-b / --beam-model	Beam model CSV	DCPT_beam_model__v2.csv
-s / --spr-to-material	SPR to material table	SPRtoMaterial__Brain.txt
-p / --beam-model-position	Beam model distance to isocenter (mm)	500.0

6 Usage Example

```
PYTHONPATH=. python3 pregdos/main.py \
  -v \
  -b=res/beam_models/DCPT_beam_model__v2.csv \
  -p 500.0 \
  -s=res/spr_tables/SPRtoMaterial__Brain.txt \
  res/test_studies/DCPT_headphantom/
```

Generates:

- `topas_field1.txt`
- `topas_field2.txt`
- `topas_field3.txt`

7 Command-Line Options

```
usage: main.py [-h] [-b BM] [-s SPR_TO_MATERIAL_PATH] [-p BEAM_MODEL_POSITION]
               [-f FIELD_NR] [-N NSTAT] [-v] [-V]
               study_dir [output_base_path]
```

Option	Required	Description
study_dir	Yes	Path to input folder (CT, RS, RN, RD)
output_base_path	No	Output base name (default: topas.txt)
-b / --beam-model	Yes	Beam model CSV file
-s / --spr-to-material	Yes	SPR-to-material mapping file
-p / --beam-model-position	No	Beam model position (mm)
-f / --field	No	Export only a single field
-N / --nstat	No	Number of primary protons
-v	No	Verbose output
-V	No	Show version and exit

8 Output

PregDose produces one TOPAS input file per treatment field, including:

- Voxelized CT geometry
- Structure definitions (e.g. fetus ROI)
- Field and beam configuration

9 Internal Module Structure

Module	Functionality
`pregdos/main.py`	CLI parsing and main execution logic
`import_rtstruct.py`	Handles RTSTRUCT parsing, extracts ROIs
`import_rtplan.py`	Parses RTPLAN and beam geometry
`export_study_topas.py`	Converts study data to TOPAS geometry files
`utils/`	Shared utilities and helpers

10 Dose Verification

PregDose reads RTDOSE (TPS dose grids) to allow for Monte Carlo vs TPS dose comparison. This supports:

- QA for simulation accuracy
- Clinical research into fetal dose metrics

11 Fetus ROI Scoring

Ensure the fetus ROI is properly defined in the RTSTRUCT file. PregDose will:

- Isolate the ROI using contour data
- Define a scoring volume for neutron dose estimation

12 Licensing and Acknowledgements

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13 Planned Features

- GPU-accelerated simulation integration
- Automated fetus detection and scoring
- 3D visualization of dose volumes
- GUI-based front-end for clinical researchers

References

[1] J. Perl, J. Shin, J. Schümann, B. Faddegon, and H. Paganetti, "TOPAS: an innovative proton Monte Carlo platform for research and clinical applications," *Medical Physics*, vol. 39, no. 11, pp. 6818–6837, 2012. Publisher: Wiley Online Library.