Monte-Carlo Dose Simulations
for
Volumetric-Modulated Arc Therapy Patients

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Figure 1: Patient case: Monte-Carlo dose simulation with different numbers of simulated particles.

1   Overview

To design safe radiotherapy treatments, checking the delivered dose is crucial to validate the treatment plan. The Monte-Carlo method remains the best tool we have today to model radiation transport. Nevertheless, despite hardware advances, it is still too time-consuming to be used in clinic. Our project aims at accelerating Monte-Carlo computations using Deep Learning methods. In order to investigate this, we creates the Monte-Carlo VMAT dataset, using a patient cohort comprising 50 radiotherapy patients with different with various cancer locations (pelvis, head and neck ...)

2 Making-Of

The dataset was created using OpenGate [3]. We modelled the multi-leafs collimator (MLC) and the jaws of a linear accelerator using `KillActors`. We defined the source as the phase space of a Varian TrueBeam 6MV photon beam [4]. The positions over time of the MLC leafs and jaws were extracted from the patients' radiotherapy plans.

To reach an uncertainty below 3%, we chose to simulate $1e^{11}$ particles per patient case. Monte-Carlo computations were CPU-based and parallelized over the Joliot-Curie supercomputer [1]. No variance reduction techniques were used. Therefore for each patient, 1000 sub-simulations with $1e^8$ particles were computed in parallel in order to amount to the wished highly precise simulation. The total computation time for a single patient was approximately 4000 hours.
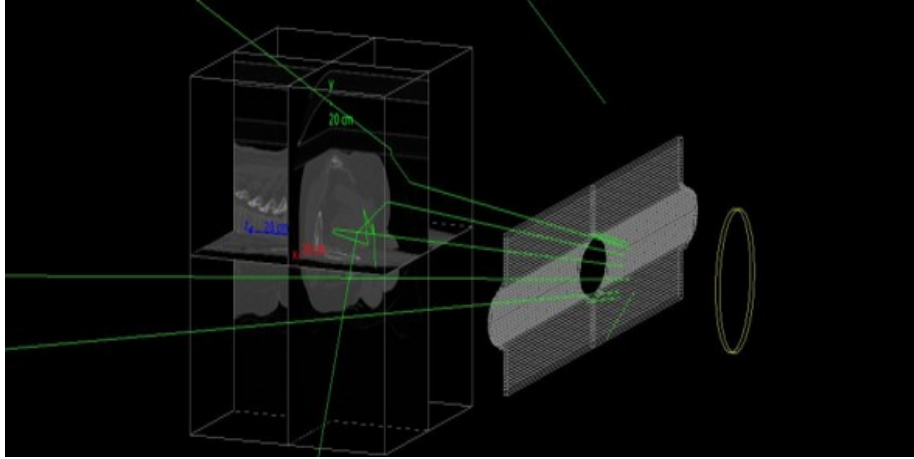

Figure 2: View of the OpenGate simulation of the MLC. The golden circle shows the location of the source that yielded the phase space.

3 Description

The folder `final_simulations` contains several folders, each comprising a patient's Monte-Carlo dose simulations for various numbers of simulated particles. All volumes are saved in `.nii.gz` format. Dose volumes are named following the rule:

```
*patient number* _ *number of particles* _ *simulation duplication number*.nii.gz
```

In a patient's directory you will also find the dose volumes' corresponding squared dose volumes, which were used to compute the uncertainty volumes.

For example, the directory tree of patient case `3125` looks as follows:

```
final_simulations
└── 3125
        ├── 3125_500000000_3.nii.gz
        ├── 3125_squared_500000000_3.nii.gz
        ├── 3125_uncertainty_500000000_3.nii.gz
```

- `3125_500000000_3.nii.gz` : This is the patient's dose volume simulated with 5×10^8 particles.

- `3125_squared_500000000_3.nii.gz` : The patient's squared dose volume generated by OpenGate.

- `3125_uncertainty_500000000_3.nii.gz` : The corresponding uncertainty volume that was computed using the original dose volume and the squared dose volume.

4 How to cite the dataset [2]

If you use our dataset in your pojects, please cite:

```
@misc{MartinotMonteCarlo2021,
  author = {Martinot, Sonia and Bus, Norbert
  and Vakalopoulou, Maria and Robert, Charlotte
  and Deutsch, Eric and Paragios, Nikos},
  title = {Monte-Carlo Dose Simulations for
  Volumetric-Modulated Arc Therapy Patients},
  year = {2020},
  note = {Data hosted at
          \url{https://hosting.therapanacea.eu/data/miccai2021/}},
}
```

5 Linked Publications

- *Fast Monte-Carlo dose simulation with recurrent deep learning*, S. Martinot, N. Bus, M. Vakalopoulou, C. Robert, E. Deutsch and N. Paragios, European Society for Therapeutic Radiology and Oncology (ESTRO) - Abstract and oral, 2021

- *Weakly supervised 3D ConvLSTMs for Monte-Carlo radiotherapy dose simulations*, S. Martinot, N. Bus, M. Vakalopoulou, C. Robert, E. Deutsch and N. Paragios, Medical Imaging for Deep Learning (MIDL) - Short paper, 2021

- *High-particle simulation of Monte-Carlo dose distribution with 3D ConvLSTMs*, S. Martinot, N. Bus, M. Vakalopoulou, C. Robert, E. Deutsch and N. Paragios, Medical Image Computing and Computer Assisted Intervention (MICCAI) - Paper and oral, 2021

6   Acknowledgments

References

[1] `http://www-hpc.cea.fr/en/complexe/tgcc-JoliotCurie.html`.

[2] Sonia Martinot et al. *Monte-Carlo Dose Simulations for Volumetric-Modulated Arc Therapy Patients*. Data hosted at `https://hosting.therapanacea.eu/data/miccai2021/`. 2020.

[3] David Sarrut et al. "A review of the use and potential of the GATE Monte Carlo simulation code for radiation therapy and dosimetry applications". In: *Medical physics* 41.6Part1 (2014), p. 064301.

[4] "VarianTrueBeam_6MV_01.IAEAphsp". In: *http : // www − nds . iaea . org/ phsp/ photon/* (2011).