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

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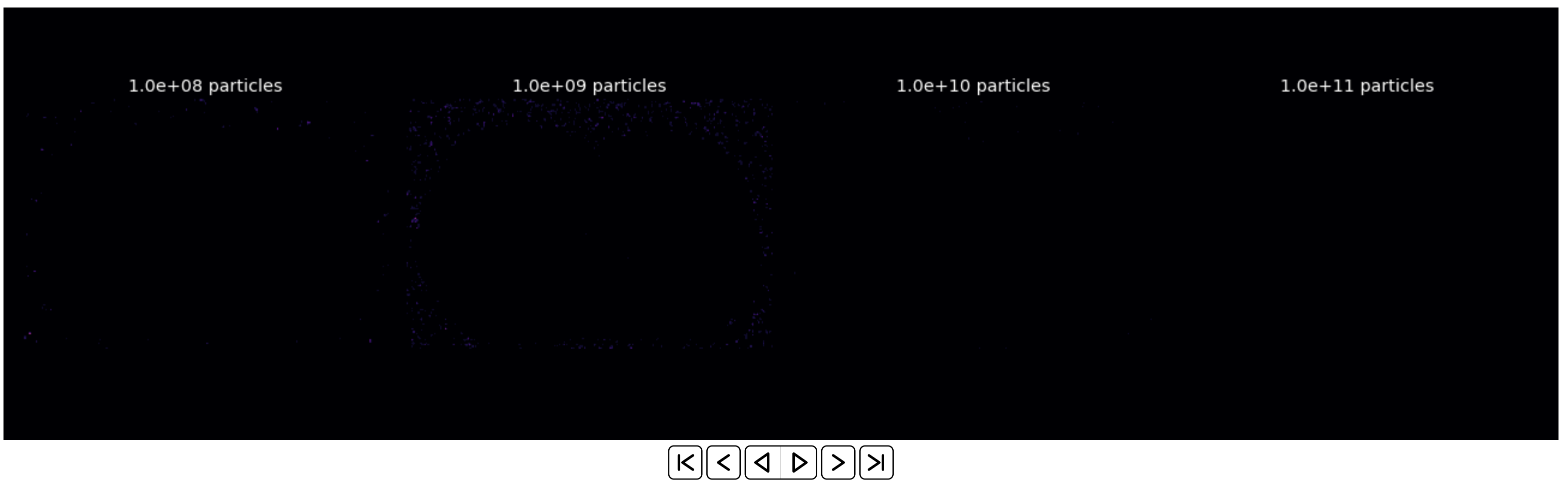

Figure 1: Patient case: Monte-Carlo dose simulation with different numbers of simulated particles.

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 [2]. 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 [3]. 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.

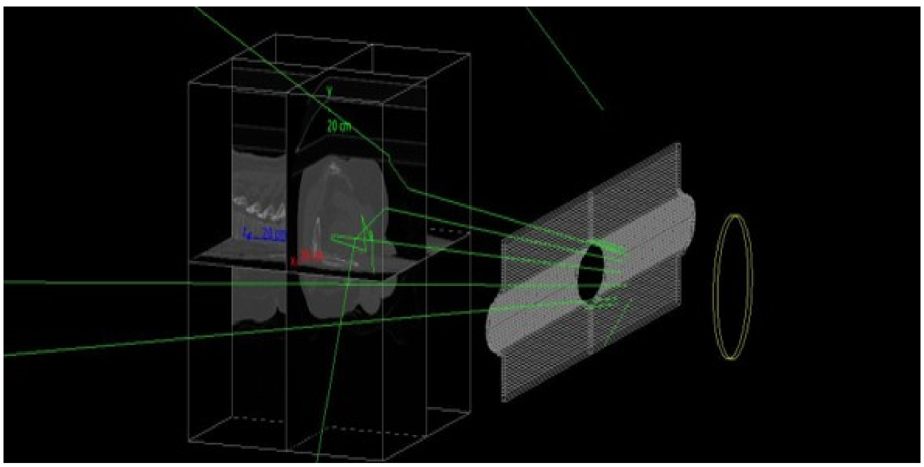

Figure 2: View of the OpenGate simulation of the MLC. The golden circle shows the location of the source that yielded the phase space.

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 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

5 Acknowledgments

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References

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

[2] 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.

[3] “VarianTrueBeam_6MV_01.IAEAphsp”. In: *http://www-nds.iaea.org/phsp/photon/* (2011).