A Continuous Dose Calculation Method for Volumetric Modulated Arc Therapy Using Pencil Beam Convolution in a Homogeneous Phantom

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INTRODUCTION

- Volumetric modulated arc therapy (VMAT) delivers a continuous radiation dose during the Linac gantry rotation.
- However, the radiation dose of a VMAT plan is usually computed using a series of discrete apertures at evenly-spaced gantry angles.
- This angular under-sampling issue for VMAT can potentially lead to a large dose discrepancy between delivered and calculated dose.

AIM

- To propose a continuous dose calculation method for VMAT using pencil beam (PB) convolution in a homogeneous phantom, reducing dose discrepancies due to the under-sampling issue.

METHOD

- BEAMnrc/DOSXYZnrc Monte Carlo (MC) simulations were used to model 6MV pencil beam (1 x 5 mm^2) on a homogeneous (water) cylindrical phantom with 50-cm diameter placed at 100 cm SAD.
- MC generated PB kernels ***(figure 3)*** at varied depths and slices of the phantom in Polar coordinate system were collected for each pixel of a 40 x 40 cm^2 grid at isocenter.
- Intensity ***(figure 4)*** for each pixel was determined by MLC and jaw positions from patient RTP files.
- Dose distributions at a desired depth and slice of phantom can be calculated by a summation of convolutions of the corresponding PB kernels and intensity for each pixel using fast Fourier transforms.
- Calculated and MC simulated dose distributions in Polar coordinate system were compared using gamma analysis.
- Dose distributions in Cartesian coordinate system were obtained by converting dose in polar coordinate system using interpolation.

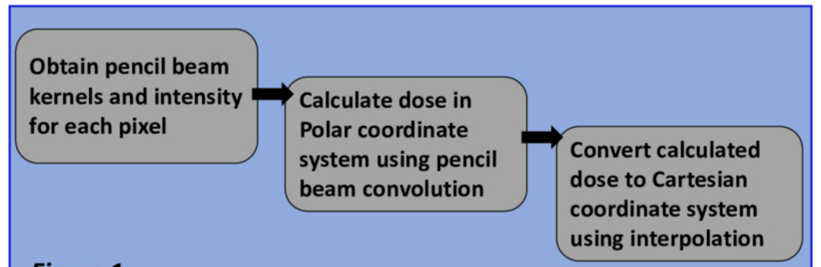

Figure 1. A general workflow for the proposed dose calculation method.

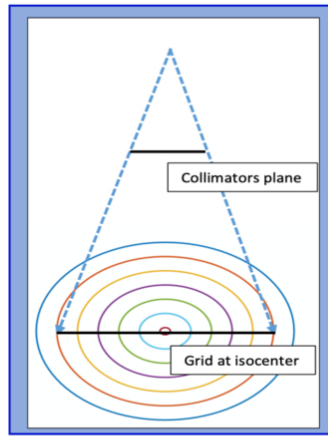

Figure 2. Illustration of phantom placement, pixel grid location, and kernel rings.

A cylindrical phantom of 50-cm diameter with a length of 50 cm was placed at 100 cm SAD. 40 x40 cm^2 pixel grid with 0.1 cm resolution was located at isocenter.

Each ring shown in the figure 2 can be considered as the data points for kernel acquisition at a desired depth in a homogeneous phantom. The resolution of kernel acquisition depends on user's region of interest.

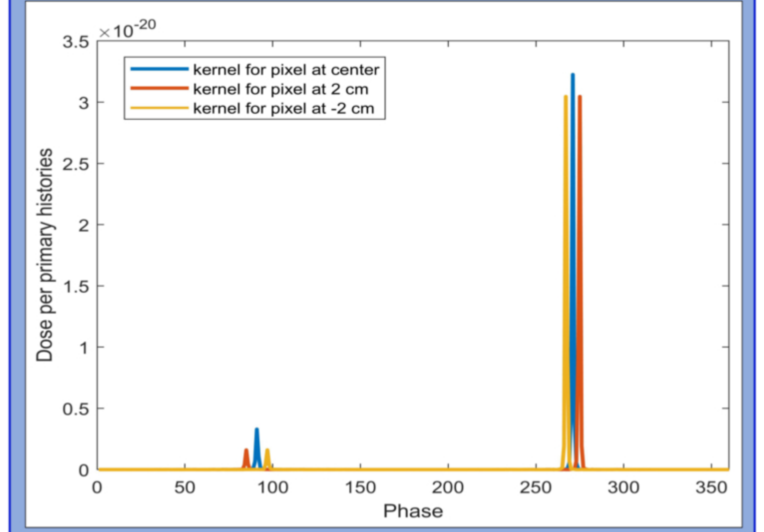

Figure 3. An example of pencil beam kernels in the Polar coordinate system at 2 cm depth in the central slice of the phantom.

Kernels for the central pixel and the pixels at ± 2 cm are shown. Note: each pixel of the 40 x 40 cm^2 grid has kernels at different depths and slices of the phantom.

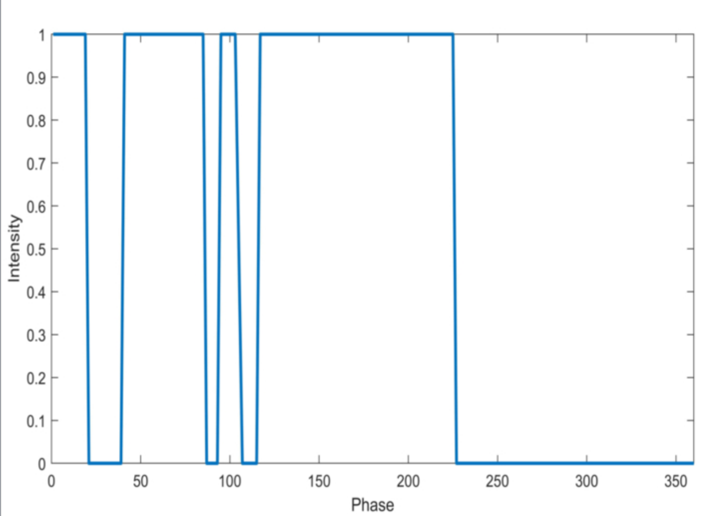

Figure 4. An example of the intensity at the central pixel of the grid for a VMAT plan with 115 control points.

Intensity at each pixel was determined by MLC and jaws positions from RTP files. The intensity will be further corrected for the scatter effect, off-axis, and MLC transmission in the future.

RESULTS

Dose distributions in the Polar coordinate system for these two methods matched each other well.

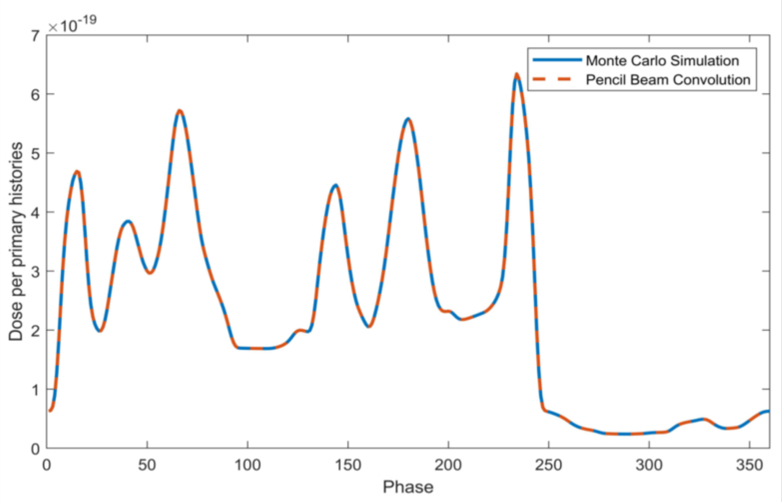

Figure 5. Dose distributions at 2 cm depth in the central slice of the phantom for both Monte Carlo simulation and pencil beam convolution in the polar coordinate system.

The MLC, jaw positions and fractional Mus used for dose calculation were obtained from a real VMAT plan with 115 control points.

Comparison of 2D Dose distributions in the Cartesian coordinate system for MC simulation and Pencil Beam convolution.

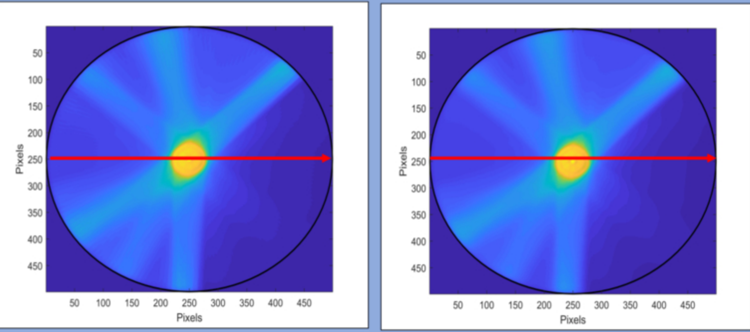

Figure 6 and figure 7. The 2D dose distributions at the central slice of the phantom from MC simulation (left) and Pencil Beam convolution (right).

1D dose distribution in the Polar coordinate system at different depths (0.5 cm to 24.95 cm with 0.1 cm resolution in order to improve the accuracy for coordinate conversion) were first calculated using pencil beam convolution, then converted to the Cartesian coordinate system using interpolation to build a 2D dose distribution.

In **Polar** coordinate system, the gamma passing rate between calculated and simulated dose distributions was 100 % (1%/1mm).
In **Cartesian** coordinate system, the gamma passing rate between calculated and simulated dose distribution was 96% (1%/1mm) and 98% (2%/2mm).

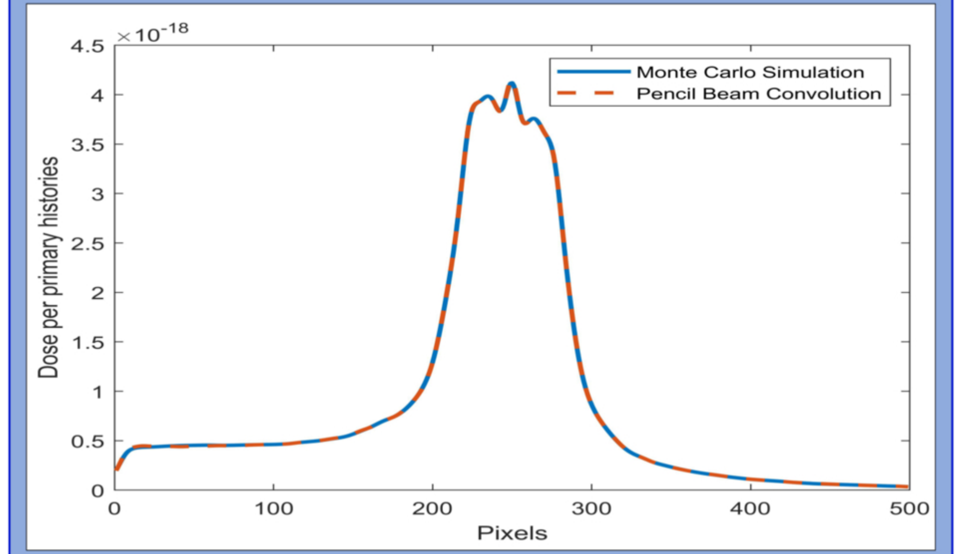

Figure 8. Dose profile along the red arrows shown in figure 6 and figure 7 for MC simulation and Pencil Beam convolution in the Cartesian coordinate system.

CONCLUSIONS

- The results suggest that the proposed method can be implemented for VMAT dose calculation in a homogeneous phantom without the under-sampling issue, which improve the accuracy of VMAT dose calculation.
- The computational efficiency of the proposed continuous method should be better than discretized method since the convolution is applied to the cylindrical system in our method, whereas the convolution for discretized aperture method needs to be done for each discretized angle.

REFERENCES

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