Investigation of tilted dose kernels for portal dose prediction in a-Si electronic portal imagers

Krista Chytyk
MSc student
Supervisor: Dr. Boyd McCurdy
Introduction

- The objective of cancer radiotherapy is to destroy the malignancy by maximizing the dose to the tumour while minimizing the dose to the normal tissues.
- The accuracy of this delivery directly affects patient outcome because small variations in dose may lead to large discrepancies in tissue response.
  - dose errors of greater than 3% can have a considerable effect on patient outcome.*

• Geometric verification of treatments reduces the uncertainty in the delivery location
  – carried out with radiographic film, but has been largely replaced by electronic portal imaging devices (EPIDs)
  – a-Si EPIDs have shown potential as a radiation dosimeter

*http://www.varian.com
• Performing dosimetric verification while the treatment is administered allows for appropriate adjustments to be made for the remainder of the treatment or treatments

• Measured and predicted portal images can be compared to determine whether the plan is delivering correct dose distributions
• There had been no investigation into the accuracy of a-Si portal dose image prediction using the parallel kernel assumption
  – applying parallel dose kernels in a divergent clinical geometry where radiation fluence is not truly parallel
Methods and Materials

- Monte Carlo Simulations
  - Dose kernels for the EPID were obtained at a number of incident angles for a range of monoenergetic photon energies using EGSnrc
  - 0° to 14° every 2°
  - 0.1, 2, 6 and 18 MeV
  - user code DOSXYZnrc
• Simulated detector design
  – specifications provided by Varian Medical Systems (Palo Alto, CA)
    • uniform epoxy front cover followed by a 22 mm air gap and the imaging cassette
      – 1 mm thick copper buildup plate, a Lanex Fast-B phosphor (gadolinium oxysulphide) screen and an a-Si photodiode array
    • 3 cm slab of uniform water buildup was added directly upstream of the detector front cover
    • simulated area of the detector for dose kernel generation was approximately 40 x 40 cm²
• Dose Kernel Analysis
  – The effect of angle on the symmetry of the dose kernel about the incident pencil beam was investigated
  • kernels were divided into the negative-x half (proximal half) and the positive-x half (distal half), as in figure
• Tilted vs. Parallel Kernels
  – Clinical impact was investigated by applying the parallel and tilted kernels to a step function representing incident fluence
  – The convolution (parallel kernels) and superposition (tilted kernels) methods of dose calculation were employed for two field sizes and two SDDs
    • 27.2 x 20.4 and 30 x 30 cm$^2$ at isocenter
    • 105 and 140 cm

\[
D = \iiint_{\text{detector}} \varphi(x', y') \cdot k(x - x', y - y') \, dx' \, dy'
\]
– For the superposition method, the appropriate tilted kernel for an angle of incidence for a voxel was interpolated from the available kernels

• This kernel was then rotated azimuthally and translated to the position of the voxel of interest, then regridded to the EPID image pixel coordinates

– The results of the convolution versus full superposition approach were evaluated by the $\chi$-comparison test* with $\Delta d = 0.784 \text{ mm}$ (the detector resolution) and $\Delta D = 1.0\%$

\[
\chi = \frac{D_c(r) - D_r(r)}{\sqrt{\Delta D^2 + \Delta d^2 \cdot \|\nabla D_r\|^2}}
\]

Results

- Dose Kernel Comparison
• Superposition vs. Convolution
Discussion and Conclusions

• Increasing asymmetry in the $\chi$-comparison distributions with increasing incident photon beam energy
  – Positive values of the $\chi$-comparison indicate the parallel kernel assumption underestimates the tilted kernel superposition results
  – Slightly greater tendency for the parallel kernel assumption to underestimate the superposition results with increasing incident photon energy

• This study validates the practice of applying parallel dose kernels in a divergent clinical geometry to determine the dose deposited in an a-Si EPID
  – A full superposition is not required for dosimetric accuracy of better than 1.5% for extreme cases and 1.0% for clinically relevant scenarios
Questions?