Markerless lung tumor tracking using AI-DE imaging

Liangjia Zhu[1], Felipe Arrate[1], Paul Baturin[1], Pascal Paysan[1], Hassan Mostafavi[1], John van Heteren[1], Roberto Cassetta Jr[2], John C. Roeske[2], and Stefan Scheib[1]

[1]Varian Medical Systems, Palo Alto, CA

[2]Loyola University Medical Center, Department of Radiation Oncology, Maywood, IL

Purpose

To investigate the potential of using AI-based dual energy (DE) imaging to improve markerless lung tumor tracking with an on-board kV imaging system.

Methods

A convolutional neural network (CNN) [1] was trained to produce low energy from high energy projection images, allowing AI-DE images to be created using log subtraction. The CNN model was trained on simulated forward projections (60 and 120 kVp) using 1000 CTs. A different set of 84 4D-CTs with known GTV contours were used to simulate projections in the same way. A sequence of projections was created from simulated projections of a 4D-CT at a given gantry angle for three imaging modes single energy (SE), DE, and AI-DE, respectively. A machine-learning-based algorithm [2] was applied to track the GTV motion in the sequence. Tracking accuracy was evaluated against ground truth motion (4D-CT) using precision curves representing the percentage of correctly tracked GTV center-of-mass (COM) for a range of distances and overlap (Dice coefficient) thresholds.

Results

Figure 1 shows an example of projections simulated from a 4D CT. The visibility of GTV was increased in both DE and AI-DE images. Figure 2 shows the averaged precision plots for GTV tracking accuracy of 1294 sequences over all angles from these 84 4D-CTs. The area-under-the-curve (AUC) scores of COM precision curves normalized to a distance threshold of 12mm (30 pixels) were 0.72, 0.75, 0.74 for SE, DE, and AI-DE, respectively. For a COM error threshold of 3.5mm, the precision of SE was 0.72, while DE and AI-DE had 0.76 and 0.75, respectively. The AUC score of Dice precision were 0.90, 0.91, 0.91 for SE, DE, and AI-DE, respectively. For a Dice threshold of 0.9, the precision of SE, DE, and AI-DE were 0.80, 0.83, 0.83, respectively. While the performance of GTV tracking in SE was promising, both DE and AI-DE further improves the tracking accuracy with comparable performance. In addition, the average processing speed was 6ms/projection.

Conclusions

While the performance of GTV tracking in SE was promising, both DE and AI-DE further improves the tracking accuracy with comparable performance. The use of AI-DE imaging may provide a cost-effective method for providing DE capacity on any linear accelerator with an on-board kV imaging system. Next steps include improving this model and applying to real projections with kV noises and MV scatters.

References

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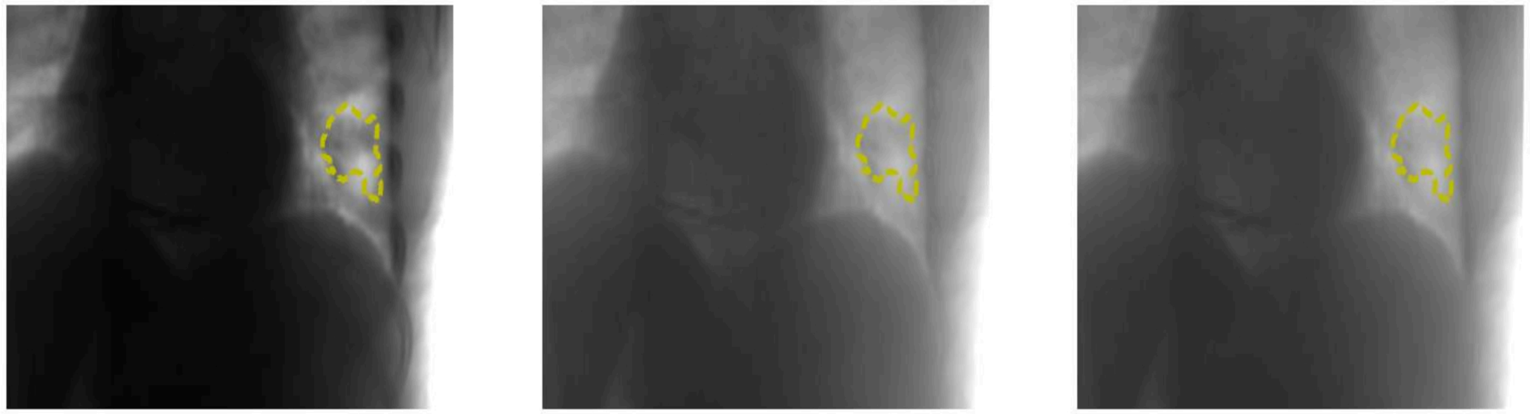

Fig. 1 Example of projections simulated from a 4D CT. From left to right: SE, DE, and AI-DE images with GTV contour (yellow).

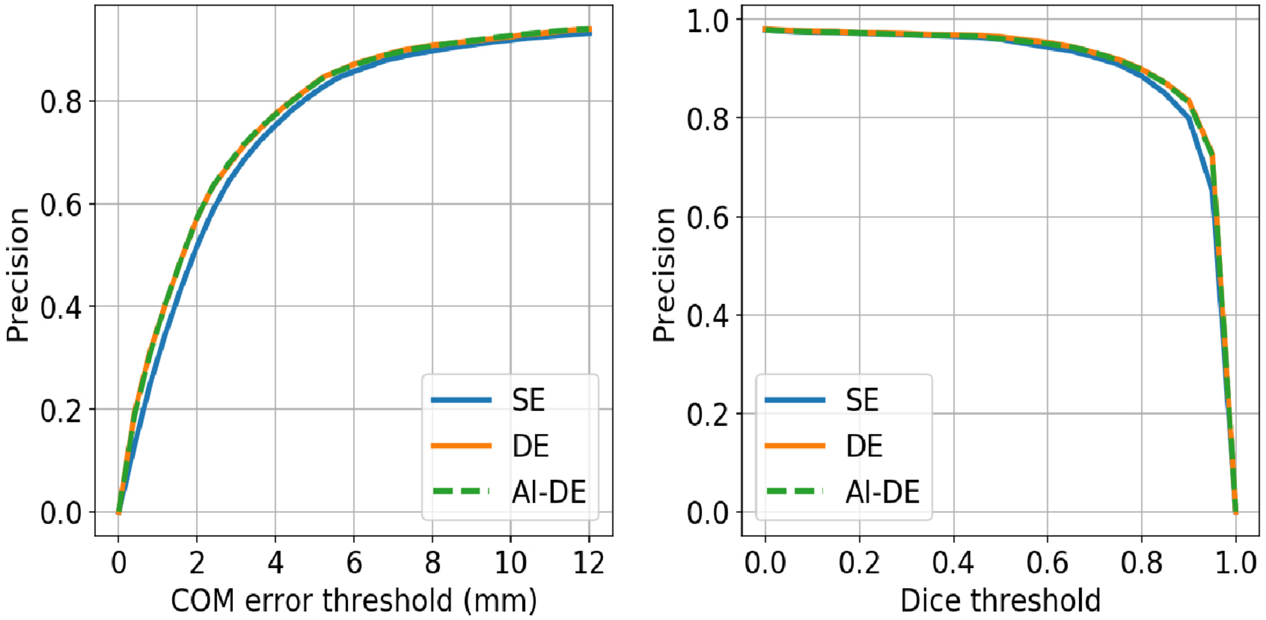

Fig. 2 Precision plots for GTV tracking accuracy.