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Poster

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Lung Tumor Motion Monitoring using Deep Learning Methods on Single Energy and Dual Energy Images

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Abstract

Objective: Attained accurate tumor position during set-up phase must be preserved throughout the Stereotactic Body Radiotherapy (SBRT) treatment delivery to guarantee accurate dose delivery. A solution to monitor tumor motion during treatment delivery will enable mitigation strategies for tumor motion. This study compares the ability of three deep learning algorithms (Mask RCNN, EfficientDet D4 and YOLO v4) to monitor a moving lung tumor. In addition, the added value of Dual-Energy (DE) imaging over Single-Energy (SE) imaging is demonstrated.

Methods: The “Lungman” Multipurpose Chest Phantom N1 (Kyoto Kagaku) is equipped with spherical lung tumors of HU density +100 which measure 5, 8, 10 and 12 mm in diameter. For training purposes, a static Lungman is set up such that no tumors are located at the isocenter. Full-fan spotlight CBCTs of 60 kV (4500 mAs) and 125 kV (1350 mAs) are acquired with the on-board kV imager of a Varian TrueBeam®. The tumor ground truth positions are generated semi-automatically with a final manual verification. The 360-degree-scan imaging data is split into a training and validation set (804 and 89 images). The 125 kV images serve as an input to train the networks for SE. For DE two approaches are investigated: The approach “DE_Calculate” consumes one-channel images containing a precalculated DE image using the soft-tissue weighted log subtraction (weight W=0.35) as an input for the networks. The approach “DE_Stack” on the other hand consumes 3-channel images containing precalculated DE images using the soft-tissue weighted log subtraction (weight W=0.50), together with the original 60 kV and 125 kV images from which they are derived.
Tumor motion is assessed by acquiring 1048 projection images over 360 degrees at 60 kV and 125 kV while Lungman is subjected, in treatment position with the 10 mm tumor at isocenter, to two different breathing motion patterns: a one-dimensional (longitudinal) sinusoidal breathing motion pattern and a more complex three-dimensional breathing motion pattern.

Results: For the 10mm tumor moving with the sinusoidal breathing pattern and SE imaging, the mean 2D tracking errors for MaskRCNN, EfficientDet D4 and YOLO v4 are 0.58/0.67/0.39 mm respectively, with a standard deviation of 0.50/0.53/0.29 mm. Detection rates are 2/6/6 Hz on an NVIDIA GTX 1080Ti, with tracking rates (proportion of images with a predicted position) are 83/85/100 % respectively. For the complex three-dimensional breathing pattern, the mean 2D tracking errors are 0.85/0.79/0.43 mm respectively, with a standard deviation of 0.56/0.46/0.33 mm. Tracking rates are 92/88/100 % respectively. Since YOLO v4 outperforms the other networks both in tracking error and tracking rate for SE, the DE results are illustrated for this network only. For YOLO v4 and the sinusoidal breathing pattern the mean 2D tracking errors for SE, DE_Stack and DE_Calculate images are 0.39/0.33/0.38 mm respectively, with a standard deviation of 0.29/0.21/0.29 mm. Tracking rates are 100/100/99 % respectively. For the complex three-dimensional breathing pattern the mean 2D tracking errors are 0.43/0.34/0.50 mm respectively, with a standard deviation of 0.33/0.21/0.33 mm. Tracking rates are 100/100/99 % respectively.

Conclusion: The three deep learning algorithms show potential for sub-second, sub-mm 2D tumor motion monitoring during treatment delivery. DE projection images can improve object detection and tracking accuracy in specific cases.