

Prediction of the position of internal points using a recurrent neural network trained with real-time recurrent learning for latency compensation in lung cancer radiotherapy

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During the treatment of lung cancer with radiotherapy, the radiation delivered to the healthy tissues around the tumor needs to be minimized which is difficult because of the breathing motion and the treatment machine latency. In this study, we use chest CT scan images of four patients with lung cancer and extend artificially these four image sequences to provide enough training and testing data. Internal points are selected and their motion during the breathing process is computed from the Lucas Kanade pyramidal iterative optical flow registration algorithm. We evaluate the performance of a recurrent neural network (RNN) trained with real-time recurrent learning (RTRL) for the prediction of their position.

Keywords : Optical flow, Recurrent neural network, Real-time recurrent learning, Lung Cancer, Radiotherapy

1. Introduction

During the treatment of lung cancer with radiotherapy, positioning the X-ray beam correctly to minimize damage to healthy tissues is difficult because of the tumor motion due to breathing. The typical treatment machine response time of approximately 500ms leads to inaccuracies in the beam delivery, which results in turn to unwanted damage to the tumor surrounding tissues. To overcome this latency, predicting the position of the tracked surrogates is necessary.

2. Materials and Method

We used one chest 4D-CBCT image sequence and three chest 4DCT image sequences of patients with lung cancer, acquired by the Elekta Synergy therapy machine in The University of Tokyo Hospital and the Brilliance Big Bore system in Virginia Commonwealth University. Artificial drift in the spine direction and Poisson noise are added to create four sequences of 2400 3D images. The deformation vector field (DVF) in the chest is calculated using the pyramidal optical flow Lukas-Kanade technique. 3 points near the tumor of each patient are selected and their 3D position is predicted using a RNN trained with RTRL [1] and gradient clipping. The first 2000 images are used for training, the following 200 images for cross-validation, and the remaining 200 images for evaluation.

3. Results and Discussion

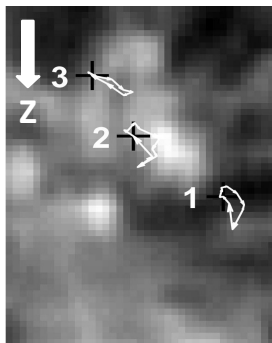


Fig. 1. Selection of three initial points around the tumor of the patient 3 and their trajectories between t1 and t10

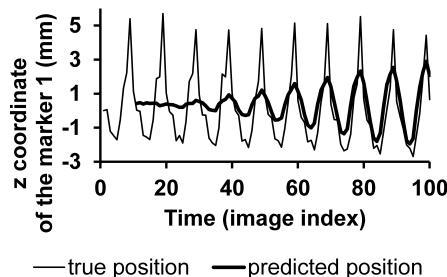


Fig. 2. RNN training for predicting the position of the marker 1 of the patient 3 between t1 and t100

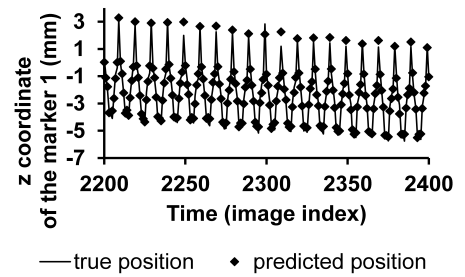


Fig. 3. Prediction of the position of the marker 1 of the patient 3 on the test data.

The maximum prediction error averaged over 10 runs and the 4 patients is 1.48mm, whereas that same error is equal to 1.80mm in the case of linear prediction. In each of the four sequences, the maximum error is below 2mm when using the RNN, which satisfies the recommendation from Murphy [2], whereas linear prediction results in an error equal to 2.30mm for the patient 2.

4. Summary

RNN trained with RTRL are efficient at predicting regular breathing signals for latency compensation in lung cancer radiotherapy. RNNs indeed benefit from non-linear data processing and the RTRL learning method enables real-time adaptation to the signal being predicted.

References

[1] Haykin, Simon. *Neural Networks and Learning Machines*, 3/E. Pearson Education India, 2010.

[2] Murphy, Martin J. "Tracking moving organs in real time." *Seminars in radiation oncology*. Vol. 14. No. 1. WB Saunders, 2004.