3D internal points position prediction using a recurrent neural network for tumor tracking during 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 need to be minimized which is difficult because of the breathing motion and the treatment machine latency. In this study we use chest 4DCBCT images of a patient breathing, with lung cancer, and extend artificially the sequence to provide enough training and testing data. Internal points are selected and their motion during the breathing process are 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 use 10 4D-CBCT (cone beam computed tomography) images of a patient's moving chest with lung cancer, corresponding to different breathing phases, acquired by the Elekta Synergy therapy machine in The University of Tokyo Hospital. The image sequence is repeated and Poisson noise is added to create a sequence of 2,400 images. The deformation vector field (DVF) in the chest is calculated using the pyramidal 3D optical flow Lukas-Kanade technique [1]. 3 points near the tumor are selected and their 3D position is predicted using a RNN trained with RTRL [2]. The first 2,200 images are used for training and the remaining 200 images are used for testing. 6 time steps are used to predict the 7th, and the network uses 1 hidden layer with 6 neurons. Gradient clipping [3] is used to improve the stability of the learning process.

3. Results and Discussion

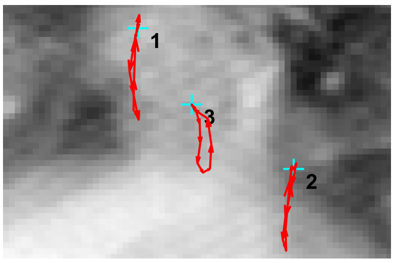
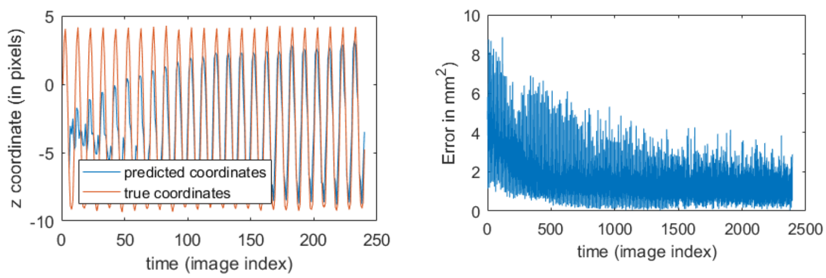


Fig. 1. Selection of three initial points around the tumor and their trajectories based on optical flow



Prediction of the z coordinate of the 3rd point

Loss function

Fig. 2 Prediction results with the RNN

The mean prediction error over 1,000 runs is 1.85mm and the associated 95% confidence interval is [1.82mm, 1.89mm]. In contrast, the mean position error without prediction is 3.19mm. 0.15% of the prediction attempts resulted in numerical errors due to instabilities in the learning process. The calculations were done with Matlab on a computer with Intel Core i3 3.7 GHz 12 Gb RAM and the mean prediction time per image index is 0.59ms.

3. Summary

This is to our knowledge the first study concerning RNN trained with RTRL for the prediction of the position of the tumor for latency compensation in lung cancer radiotherapy. The non-linearity of the RNN enables to predict complex signals and the RTRL learning method enables real-time adaptation to the signal being predicted.

References

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