Three-dimensional CT Image Prediction from multiple points tracking for delay compensation in lung radiotherapy

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During lung cancer with radiotherapy, the radiation delivered to healthy tissues around the tumor need to be minimized which is difficult because of the breathing motion and the treatment machine latency. This work presents a new method for predicting 3D chest images from limited information based on multiple points position tracking and prediction through optical flow and linear models.

Keywords : Optical flow, Linear Regression, 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. Image-guided radiotherapy systems, such as the Elekta Synergy XVI, can provide chest images during the treatment but they are subject to a latency of approximately 100ms due to signal acquisition, etc. As a consequence, the real tumor position at a certain time and its position as shown in the image acquired at the same time differs, which entails uncertainty in the radiation delivery. This in turn reduces the efficiency of the treatment as well as increases irradiation to sound tissues. In this work, we present a method to predict three-dimensional chest images of a breathing patient with a lung tumor, to compensate such latency.

2. Materials and Method

The algorithm described below is used with 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. First, we calculate the optical flow between two successive images of the sequence, using the pyramidal 3D Lukas-Kanade technique [1]. Images are filtered beforehand with a Gaussian low-pass filter. Then, linear regression is used to relate the motion of any voxel in the initial image to the motion of three selected voxels near the tumor (Fig. 1). The image sequence is repeated to compensate for the scarcity of available data, and a linear predictor is trained to predict the coordinates of the selected points. The linear predictor and the linear relationship between the motion of any voxel and the selected voxels are used to predict the motion of any voxel. Finally, predicted images are reconstructed from the initial image and the predicted motion using forward-warping with a Gaussian kernel (Nadaraya-Watson regression [2]).

3. Results and Discussion

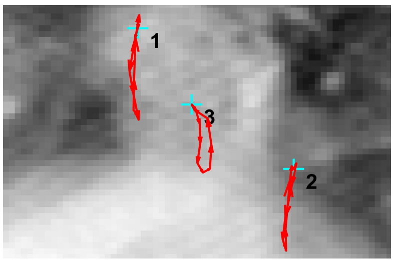
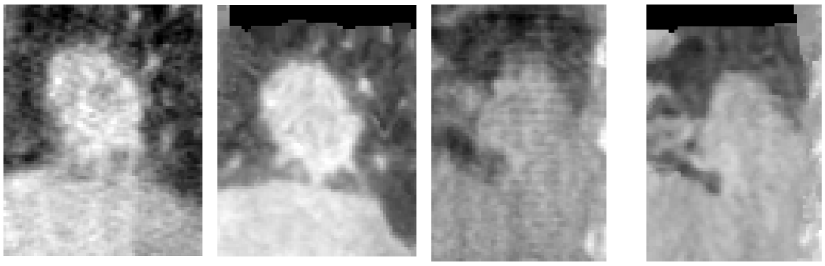


Fig. 1. Selection of three initial points around the tumor and their trajectories based on optical flow



Real coronal slice | Predicted coronal slice | Real sagittal slice | Predicted sagittal slice

Fig. 2 Comparison between real images and images predicted at t = 23.

Predicting the markers position takes 0.059ms and the corresponding RMS error (in voxels) is equal to 0.56. The optical flow reconstruction takes 0.75s per image and warping the initial image 21.29s. The calculations were done with Matlab on a computer with Intel Core i3 3.7 GHz 12 Gb RAM. The cross-correlation coefficient between the original and ten predicted images is equal to 0.795±0.126.

3. Summary

We presented an algorithm for the prediction of 3D chest images containing a lung tumor, which consists in warping the initial image at t=1 according to the displacements of a few points which may represent markers. This is a step towards latency compensation in lung cancer radiotherapy.

References

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