Sudden change detection in moving tumors for dynamic tracking in lung cancer radiation therapy

The University of Tokyo — Chhatkuli Ritu Bhusal
The University of Tokyo Hospital — Haga Akihiro
The University of Tokyo — Demachi Kazuyuki

Image guided radiation therapy (IGRT) has played a major role in the precision of radiation therapy especially while tracking moving tumors. The IGRT units are capable of 2D planar imaging, fluoroscopy etc. As lung tumor tends to move and deform during respiration, it also undergoes a sudden phase change in motion due to sudden cough or sneezing during the treatment which leads to the treatment beam missing the target. In this study we propose an algorithm for tracking moving tumors during radiation therapy for the detection of sudden change or anomaly.
In University of Tokyo Hospital, real time projection images are acquired using the XVI (X-ray volume imaging system) during the treatment. These real-time images are used for the tracking of moving tumors and the detection using the cross correlation analysis. The preliminary results states that the sudden change can be detected with significant accuracy.

Keywords: Lung cancer, radiation therapy, projection images, tracking, anomaly

1. Background and Introduction

Radiation therapy has a long-lasting history in the treatment of lung tumors. Imaging at the time of radiation treatment have increased the precision and confidence for the treatment using radiation therapy. Recent advancement in IGRT has improved the accuracy of tumor localization as it plays a major role in tumor tracking in modern radiation therapy. The most important feature of IGRT is it allows the changes in tumor position, size and shape to be measured during the course of radiation therapy.

Fig.1. shows the Elekta X-ray Volume Imaging (XVI) system with a rotating gantry, used in the University of Tokyo Hospital, the treatment mega voltage beam (MV) and the diagnostic kilo voltage beam are used simultaneously. As precision has been a major challenge in lung cancer IGRT because the amplitude of motion can be clinically significant (~2-3cm) [1] hence limiting the radiation to the target and sparing the surrounding healthy tissue is a major concern.

We have already reported prediction of moving tumor using images [2], in this study we investigate an algorithm for the detection of anomaly in moving tumors believed to be caused by cough or sneeze or abnormal breathing during the treatment.

〒113-8656, Room 721, Engineering Building 8
7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan
E-mail: ritu@nuclear.jp

To our knowledge this is the first study for the detection of sudden change using the real-time images during the treatment.

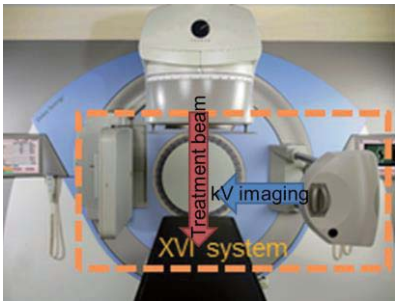

Fig.1. Elekta Synergy with XVI system used for image guidance in University of Tokyo Hospital

2. Sudden change detection algorithm

2.1 Acquisition of in-treatment images: During the treatment, time series images are acquired in quasi- real-time at the rate of 0.18 secs per frame using the XVI system. The difference in the gantry angle is in average 0.20 to 0.21 degrees in each frame. This is a part of treatment procedure in the University Hospital for lung tumor stereotactic body radiation therapy (SBRT). These images are used offline as the training and testing images in this study.

2.2 Sudden change detection algorithm: The algorithm for the detection of sudden change is illustrated in Fig.2.

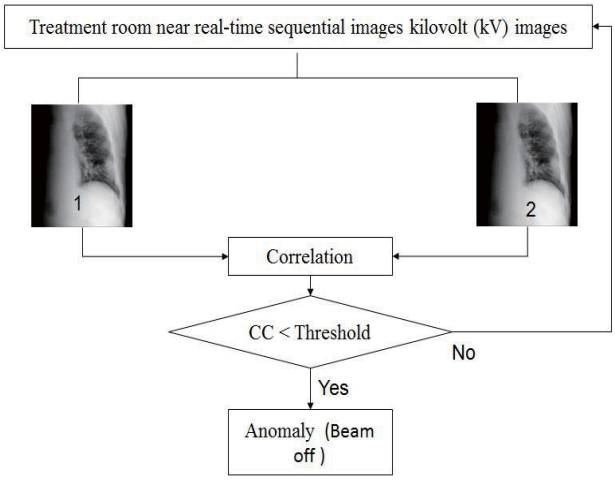

Fig.2. Algorithm for the detection of sudden change using the time-series in-treatment images

Cross correlation coefficient (CC) is one of the widely used index for matching or calculating the similarity between the images. In this study we use CC and to verify the result from CC we also use structure similarity index (SSIM) in order to compare the consecutive images as illustrated in Fig.2. A threshold value for the CC and SSIM is determined. Once the correlation exceeds a certain threshold it is regarded as anomaly. The response kit from Elekta Synergy allows to stop the beam in case of sudden change or anomaly.

For a preliminary study, a training set was created using the real time images by switching the order in one time step (at the 70th step) image to images from further steps for two case of patients data. The region of interest (i.e. the tumor and its maximum anticipated range of motion) was selected for the cross correlation and SSIM calculation.

3. Results and Discussions

Fig.3. shows the result for the induced sudden change in the images from one of the patient case used as a preliminary study. The sudden drop in coefficient value is observed in case of both cross correlation and structure similarity index in the 70th and the 71st steps of the time-series images. Similar results were obtained in the other patient case.

This indicates that the sudden change can be detected using the proposed algorithm. The calculation time for the correlation and SSIM is less than 100ms in average for each case.

The result for the cross correlation and SSIM indicates that the value hugely depends upon the angle of the images. As stated earlier Elekta is a rotating gantry system with a certain difference in angle between each image.

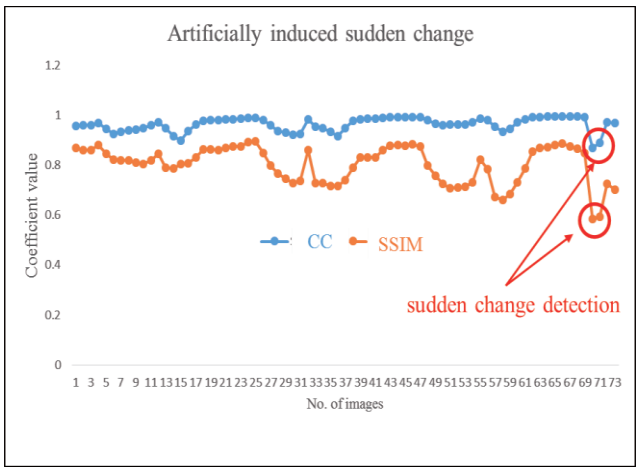

Fig.3. Result for the artificially induced sudden change for using cross correlation coefficient and structure similarity index.

Hence the threshold depends upon the each angle of the image. For example, in the angle where the tumor is covered with the bony structure the value of correlation seems to decrease.

4. Summary and future work

So far we have verified the detection algorithm for its application to the detection of sudden change. The preliminary study shows that correlation coefficient and structure similarity index can be used for the detection of sudden change with high accuracy.

However, optimum threshold must be calculated as the result indicates its angular dependency. Detection of natural sudden change during the respiration is also a huge challenge in this study as the tumor does not go out of the certain motion range. Hence the detection of natural sudden change which can be caused by cough or sneezing or sudden movement of the patient is the next step for this study.

5. Reference

1. L.I. Cervino et al. Diaphragm as an anatomic surrogate for lung tumor motion. Physics in Medicine and Biology, Volume: 54 Issue (2009) Pages: 3529-3541

2. Chhatkuli, Ritu Bhusal, et al. "Dynamic Image Prediction Using Principal Component and Multi-Channel Singular Spectral Analysis: A Feasibility Study." Open Journal of Medical Imaging 5.03 (2015): 133..