Localization of lung tumours for navigated radiotherapy

Lucia Vences[1], Otto Sauer[1], Kajetan Berlinger[2], Michael Roth[2], Achim Schweikard[3]

[1]Klinik und Poliklinik für Strahlentherapie, Universität Würzburg, Josef-Schneider-Str. 4
97080 Würzburg
{vences_l, sauer_o}@ klinik.uni-wuerzburg.de
[2]Medical Applications Research Group, Technische Universität München, Boltzmannstr. 3
D-85748 Garching b. München
{berlinge, rothms}@in.tum.de
[3]Institut für Robotik und Kognitive Systeme, Universität Lübeck, Ratzeburger Allee 160
23538 Lübeck

Abstract. Through a rigid registration between a planning CT and therapy CT the Interfractional movement is identified. In the case of lung tumours, the respiratory movement can displace a tumour in the order of one centimetre. This means that it is not enough to verify patient position on treatment couch, but the radiotherapy has to take into account the intrafractional movement as well. We captured tumour intrafractional motion during free respiration. We used the results from the 3D-3D rigid registration to localize the longitudinal position where the tumour was found. In this fix position several transversal slices are achieved a long 15 seconds. Ordering these slices chronologically and comparing them with the 3D treatment CT we can calculate and even have a 3D reconstruction of tumour displacements during a respiration cycle.

Introduction

The localization of lung tumours for an effective radiotherapy must take into account both interfractional and intrafractional motion. In [1, 2] we presented an application to control tumour position just before a radiotherapy session takes place. The system we presented compares tumour information in the planning 3D CT and the therapy 3D CT. Through a rigid registration between both volumes the Interfractional movement is identified. In the case of tumours located in thorax, the respiratory movement can displace a tumour in the order of one centimetre during the treatment. Therefore, it is not enough to verify patient position on treatment couch, but the radiotherapy has to consider the intrafractional movement as well.

Some authors have tried to control or reduce intrafractional movement by controlling the patient's respiration [3, 4]. In this work we observe how the respiration displaces a tumour, to take appropriate adjustments.

Methods and materials

Two steps are realized to achieve tumor localization. Firstly, we find out the Interfractional tumor's motion. As noted in [1, 2], the Clinic of Radiotherapy and Oncology at the University of Würzburg disposes of CT scanner in therapy room. Thus, having the patient in the therapy position, we achieve a new CT and, by a 3D-3D local rigid registration with the planning CT, locate tumor's current position.

This registration is achieved as follows. A region of interest (ROI) has been identified in the planning CT. The experience of the doctors and the data from the therapy plan helps to find in the therapy volume a coarse approximation of new tumor's position. Around this position, a search region in the treatment volume is defined to be twice bigger as the ROI. Then, an automatic rigid body registration between the ROI and the search region is achieved to get the actual couch location.

Secondly, we analyze tumor's movement due to respiration. We identify an appropriate cranial-caudal position with the results from the 3D-3D rigid registration (see Fig. 2). In this position, several transversal CTs are achieved in about 15 seconds to observe the free respiratory cycle.

We reconstruct the tumor's motion with each slice from this time study. These slices are sorted chronologically according with their time stamps. Each slice is compared with the 3D therapy CT and organ displacement is calculated. These displacements are obtained using also a rigid registration between a slice and the volume CT. As the registration starts looking around this cranial-caudal position and, again searches a rigid body

transformation, this process is achieved in few seconds using a PC. The displacements are then applied to the ROI to reconstruct its motion.

Fig. 1. Result of the 3D-3D local rigid registration. The first row corresponds to the planning CT, from left to right, transversal, sagittal and frontal view and the second row corresponds to the region found in the therapy CT.

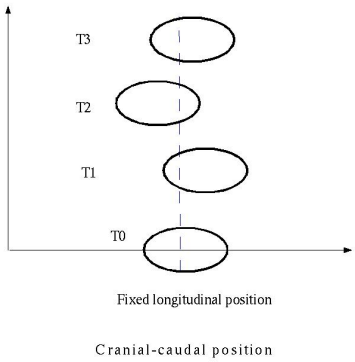

Fig. 2 The longitudinal position found in the 3D-3D registration is fixed and several CT slices are realized in this coordinate. Comparing each slice taken in T1, T2, T3 with the therapy 3D CT, taken in T0, we determine tumour's displacement

Results

We have tested this application with data from 4 different lung patients and a total of 8 studies and compared our results with the results of an expert. In the 3D-3D registration, we had 3D volumes with 5mm space between the slices (cranial-caudal direction).When comparing our results, one has to keep in mind that a human has to choose the "best slice" and round his coordinates. The application can reconstruct and interpolate volume between the slices. However, we observe error of the order between +/-5mm in right-left and cranial-caudal directions. In the dorsal-ventral direction we observed bigger differences from about 10mm.

Taking into account the respiratory movement we reduced the discrepancy between our results and experts coordinates in +/- 3mm. As there is no gold standard for this problem, it is difficult to establish absolute errors.

Discussion

We have presented an application to localize tumor position in thorax taking into account the respiratory motion. We are aware, that our results are not conclusive, but encouraging. We are looking forward to testing with a

wider population. As there is no gold standard to establish absolute errors, we are investigating further simulations of tumor motion in order to win confidence in the results.

We are using rigid body transformations, because they are a compromise between accuracy and processing time. When the program achieves its task, the patient is already waiting in therapy room. Thus, a short processing time is a requirement for such a system. At this stage, the program reports in few seconds tumor's position and movement with the respiration.

Our goal is the navigated radiotherapy. Observing the respiratory movement, we want to infer tumor's position from the respiratory state. To this end, we use infrared emitters attached to patient and a tracking camera system to characterize it. To establish a correlation between respiratory state and tumor position we are examining non rigid deformable methods and we plan a 4D CT model.

Fig. 3. In the therapy volume, the isocentre was found in the longitudinal position 4.3mm (left) by the registration of the 3D planning CT and the 3D therapy CT. Registration of the 3D therapy CT and the first time study slice localizes the tumour in longitudinal coordinate 9.3

References

1. L. Vences, O. Sauer, M. Roth, K. Berlinger, M. Doetter, A. Schweikard,Local Rigid Registration: A tumour localization application. *On: The XIVth International Conference of the Use of Computers in Radiation Therapy. Seoul, Korea, May, 2004* pp. 612-614. Editors Byong Yong Yi, Seung Do AHN, Eun Kyung CHOI, Sung W.HA
2. L. Vences, O. Sauer, M. Roth, K. Berlinger, M. Doetter, A. Schweikard.Localisation of moving targets for navigated radiotherapy *Scientific Workshop Medical Robots, Navigation and Simulation, MRNV 2004,* RheinAhr Campus, Remagen, Germany, March, 2004
3. Remouchamps VM, Letts N, Yan D, Vicini FA, Moreau M, Zielinski JA, Liang J, Kestin LL, Martinez AA, Wong JW. Three-dimensional evaluation of intra- and interfraction immobilization of lung and chest wall using active breathing control: a reproducibility study with breast cancer patients. *Int J Radiat Oncol Biol Phys. 2003 Nov 15;57(4):968-78.*

4. Cheung PC, Sixel KE, Tirona R, Ung YC. Reproducibility of lung tumor position and reduction of lung mass within the planning target volume using active breathing control (ABC) Int J *Radiat Oncol Biol Phys. 2003 Dec 1;57(5):1437-42.*