A Whole Body Atlas Based Segmentation for Delineation of Organs in Radiation Therapy Planning

Sharif M. Qatarneh [1], Simo Hyödynmaa [2], Marilyn E. Noz[3], Gerald Q. Maguire Jr.[4], Elissa L. Kramer[3], and Joakim Crafoord[5].

[1]Department of Medical Radiation Physics, Karolinska Institute and Stockholm University, Box 260, S- 171 76 Stockholm, Sweden.
Sharif@radfys.ks.se
[2]Department of Oncology, Tampere University Hospital, Tampere, Finland.
[3]Department of Radiology, NewYork University, New York, USA.
[4]Department of Teleinformatics, Royal Institute of Technology, Stockholm, Sweden.
[5]Department of Radiology, Karolinska Hospital, Stockholm, Sweden.

Optimal radiation therapy (RT) can be achieved when accurate knowledge about the exact location of the target volume to be treated with respect to all organs at risk is available. A whole body atlas (WBA) can be utilized to convert the anatomy of a "standard man" into individual patients by applying warping on anatomical images and the anatomy of the atlas can be adjusted to an individual patient [2,3]. The purpose of this work is to propose a semi-automatic segmentation procedure that utilizes polynomial warping together with active contour models, which could be used with WBA to delineate different organs in RT planning [4].

Materials and Methods

The Visible Human Male Computed Tomography data set (VHMCT) was considered reference-man geometry. The body sections of interest were the hepatic region and the chest, while the liver, the spinal cord and the right lung were the organs of interest in this case. The organs were outlined manually in each of the VHMCT organ slices and a set of 7 landmarks for each particular VHMCT slice was selected [1]. Five organ CT slices from each of 12 patient studies were selected and matched with the closest slice from the VHMCT data set. After the corresponding 7 match points were selected on the patient's slice, the drawn outline of the organ was transformed from the VHMCT slice into the patient's slice. The initial warped contour was then refined by active contour model to find the true outline of the patient's organ (Figure 1).

Evaluation and Discussion

The snake-refined organs' outlines were compared to outlines manually drawn on the patient's slice by a radiologist. The area inside the snake-refined contour and the area inside the manually drawn contour agreed within –5 to +7% for the liver, while the values for the spinal cord were in the range of ± 28% or ca. ± 1cm^2. In the case of the lung study, that range was found to be -11 to -2%. The approximate volumes of liver

W. Niessen and M. Viergever (Eds.): MICCAI 2001, LNCS 2208, pp. 1168-1169, 2001.

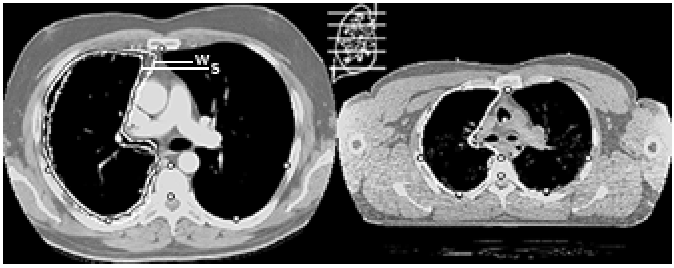

Fig. 1. The landmarks and the contour drawn on a VHMCT slice (right). The patient's match points, the warped contour (w) and the snake-refined outline (s) around the patient's lung (left).

for both segmentation methods agreed within ± 4%. The volumes of the abdominal spinal cord were found to agree within ± 21%, while lung volumes agreed within -8 to -5%. The average CT-number values inside the manually drawn liver and lung outlines were slightly lower and the standard deviation was found to be higher than in the case of active contour segmentation, which might be due to the partial volume effect. The center of gravity of the snake-refined liver contour was shifted to the left of the patient and posteriorly where structures of similar attenuation to liver are close.
The active contour model has shown some limitations, particularly for the liver, where other structures of similar attenuation characteristics are close to the boundary [4]. The small size of the spinal cord provided limited control of the active contour but the high attenuation difference between the spinal cord and the spinal vertebrae has overcome that problem to a large extent. The large size of the lung and its high attenuation difference with surrounding tissue provided an ultimate environment of control and freedom for the active contour to find the lung boundaries.
The semi-automatic segmentation procedure can be applied to multiple organs at the same time for the purpose of radiation therapy. Active contour models can segment many organs, which have more attenuation difference when compared to surrounding organs and they have less shape complexity than the liver. The study addressed using 2D contours only, but 3D tools for warping and segmentation are needed, however, if a reliable whole body atlas is to be used with actual patients.

References

1. Crafoord J., Siddiqui F. M., Kramer E. L., Maguire Jr. G. Q., Noz M. E., and Zeleznik M. P., Comparison of Two Landmark Based Image Registration Methods for Use with a Body Atlas, Physica Medica XVI(2): (2000) 75-82.
2. Kimiaei S, Noz M. E., Jonsson E, Crafoord J. and Maguire Jr. G. Q. Evaluation of Polynomial image deformation using anatomical landmarks for matching of 3D-abdominal MR images and for atlas construction, IEEE Trans. Nucl. Sci. 46 (1999) 1110-1113.
3. Noz M. E., Maguire Jr. G. Q., Birnbaum B. A., Kaminer E. A., Sanger J. J., Kramer E. L. and Chapnick J. Graphics Interface for Medical Image Processing, J. Med. Systems 17 (1993) 1-16.
4. Qatarneh S. M., Crafoord J., Kramer E. L., Maguire Jr. G. Q., Brahme A., Noz M. E. and Hyödynmaa S. A Whole Body Atlas for Segmentation and Delineation of Organs for Radiation Therapy Planning. Nucl. Instr. and Meth. A (2001) (in press).