A new algorithm for direct lung tumor tracking in X-ray images

Andriy Myronenko, Jay B. West, Petr Jordan, Jonathan C. Chappelow, and Calvin R. Maurer, Jr.

Objectives: We introduce the latest version of the Xsight® Lung Tracking (XLT) algorithm for direct lung tumor tracking in X-ray images, which was released in CyberKnife® System version 9.6.

Methods: The new algorithm is designed to give more robust and accurate target localization, with less need for user intervention, and represents a complete shift in methodology with respect to the first two versions of XLT. The algorithm divides the target region in the simulated X-rays (DRRs) into a set of small patches, and performs a cross-correlation of each patch with the live X-ray images acquired during treatment. The correlation maps are combined, using the known spatial relationships of the different patches, to create an overall similarity map whose maximum is deemed to be the location of the tumor being tracked. This combination is done in a weighted manner, so that patches where the target itself is the dominant feature in the DRR, rather than other structures projected on top of it, more heavily influence the tracking result. The XLT algorithm has two modes: “joint”, in which the overall similarity maps from the two orthogonal X-ray images taken by CyberKnife are overlaid, using the shared inferior-superior direction in the images, and “independent”, in which the localization task is carried out separately in the two images.

The method was validated using a set of 100 lung cases that had metal fiducial markers implanted in the vicinity of the treatment target. These markers were thresholded out of the CT volumes used to create the DRRs used by XLT, so that they could not be used by the tracking algorithm to aid localization of the target. The target position given by the XLT algorithm was then compared, in each treatment X-ray image, with the target position predicted by localizing the fiducial markers and adding the offset between the marker centroid and target centroid in the planning CT scan.

Results: The new algorithm was found to be robust to differences in relative contrast and image intensity between the DRRs and the live X-ray images. Defining a tracking success as a case in which at least 75% of the X-ray images yielded a target localization that was within 4mm of that predicted by the fiducial positions, 61% of the cases were successful in both X-ray views with the new algorithm, thus allowing the 3D position of the target to be derived without needing implanted fiducial markers. In 83% of the cases, target tracking was successful in at least one of the X-ray views. This compares with 45% and 64% success rates, for both and at least one view respectively, for the previous version of the XLT algorithm. In the successful two-view cases, the mean distance between the target position derived by XLT and that predicted by fiducials was 1.61 mm.

Conclusions: The new XLT algorithm is capable of accurate tumor localization in a large percentage of patients without implanted fiducial markers.