Four-dimensional cone beam computed tomography using prior image constrained compressed sensing (PICCS-4DCBCT): Clinical implementation and evaluation

Zhihua Qi

4D imaging is a key technique in developing advanced radiotherapy treatment methods to improve treatment outcome for lung cancer. 4D computed tomography (4DCT) has been successfully developed and integrated into radiation oncology practice over the past few years, however, it has the limitation of being available in the treatment planning stage only. To extend 4D imaging capability into treatment room and enable adaptive treatment of lung tumors, 4D cone beam CT (4DCBCT) using an on board imager (OBI) has been investigated in recent years.

Among available techniques, 4D cone beam CT using prior image constrained compressed sensing (PICCS-4DCBCT) is able to reconstruct high quality 4D images with the standard 1-minute data acquisition protocol. The aims of this work are the implementation and evaluation of PICCS-4DCBCT for clinical applications.

The clinical implementation of PICCS-4DCBCT involves image reconstruction and motion delineation. 4D images with both high SNR and high temporal resolution are reconstructed by the PICCS algorithm. After image reconstruction, motion can be delineated by applying deformable registration on the 4D images.

PICCS-4DCBCT is also evaluated for its clinical application, the extraction of tumor motion trajectory prior to the treatment delivery. It is first validated with phantom studies to provide motion trajectories with accuracy on the order of a single pixel size. Its performance is studied using a hybrid phantom on the effects of the data acquisition time and the number of phase bins. As irregular breathing motion causes uncertainty in motion quantification, the robustness of PICCS-4DCBCT to breathing irregularity is also investigated.

After PICCS-4DCBCT has been implemented to meet clinical requirement and evaluated under clinically relevant conditions, human subject studies are performed. The results demonstrate that tumor motion trajectories with both high temporal resolution and high accuracy can be extracted by a deformable registration algorithm from PICCS-4DCBCT images and can be used to triage clinical actions.