Demons Registration of CT Volume and CBCT Projections for Adaptive Radiotherapy: Avoiding CBCT Reconstruction - DTU Orbit (28/12/2018)

Purpose/Objective: In adaptive radiotherapy, the dose plan is adapted throughout the fractionation schedule to accommodate for anatomical changes. This can be achieved by deformable image registration of the planning PET-CT scan with segmented tumor and organs to daily cone beam CT (CBCT) scans. CBCT scans, are typically reconstructed using the filtered back-projection algorithm, which introduces significant artefacts, causing deteriorated image quality and registration results. We study the feasibility of performing demons registration without tomographic reconstruction of the CBCT projections.

Materials and Methods: We demonstrate demons registration [1,2] of a CT volume and CBCT projections of the same subject. For simplicity, instead of measured projections, we used synthetic projections of the CT deformed by a known deformation. A volume from [3] was used. The iterative registration is performed by repeating steps 1-4: 1. Simulate CBCT projections of deformed planning CT. 2. Back-project difference between simulated and measured projections. 3. Perform demons update based on back-projected difference. 4. Apply deformation to the planning CT. We used an additive demons update schemes with adaptive fluidity (smoothing kernel width). For forward/back-projection, the separable footprints algorithm with trapezoid functions was applied. The similarity between the simulated and measured projections was measured as the SSD.

Results: The figure shows a slice of; the CT volume (reference), the CT deformed by the known deformation (target), the relative Euclidean error of the true and estimated deformation fields, and the CT volume registered to the projections of the deformed CT. Interestingly, the deformation was accurately estimated from only 24 projections. The MSE between the target and registered image was 1.4·10^{-3} HU^2. The mean absolute difference between the Jacobian determinant of the true and estimated deformation field was 4.0·10^{-4}. Time consumption was 11 min. using 8 2.3 GHz AMD Opteron cores.

Conclusions: In this feasibility study, using a known deformation and synthetic noise-less projection data, it was possible to estimate the deformation with good accuracy. For real projection data it might be necessary to use the mutual information similarity measure. Using few projections, daily dose burden could be decreased, or photon fluence for each projection increased. Time consumption was low compared to the alternative scheme of iterative reconstruction followed by registration, but can be reduced by further code parallelisation.

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