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Study of Motion in a 4D-CT Using Deformable Registration

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ABSTRACT BODY:
Purpose/Objective: To compare individual voxels trajectories obtained from a 4D-CT with deformable registration between end-inhalation and end-exhalation stages.

Materials/Methods: 4D-CT acquisitions allow to have internal organ and tumor deformation and movement information during respiration but can include some residual motion artifacts. Breath-hold scans acquired at a predetermined level of the breathing cycle have the advantage of being quasi-motion artifact free but do not give movement and deformation information. Deformable registration methods estimate voxels correspondences between two or several acquisitions. Here, the goal is to study if acquisitions of 2 extrema breathing stages are sufficient to build a 4D-CT over the whole free breathing cycle. We considered the end-exhalation (EEX) and end-inhalation (EIN) acquisitions of the 4D-CT as breath-hold images. Deformation fields estimation between these 2 images was done in two different ways. One way was to compute deformable registration between each pair of intermediate successive scans of the 4D-CT. The final deformation field was obtained by composing these deformations. The other way was to apply deformable registration between the two extrema stages of the free breathing cycle. We named the difference between these two deformation fields target difference vector field. 4D-CT were composed of 10 3D-CT at different stages over the free breathing cycle (4 intermediate stages for inhalation, 4 intermediate stages for exhalation). We studied if there were significant differences between a straight line trajectory (displacements computed only between EIN and EEX stages) and a detailed trajectory (displacements through successive stages of 4D-CT). Evaluation was conducted separately for inhalation and exhalation voxels trajectories. Trajectories comparisons were done in two steps. Firstly, we evaluated vector norms of the target difference vector field. Secondly, at each intermediate stage, for each voxel, we computed the distance from intermediate voxel position of the detailed trajectory to the straight line trajectory (point to line distance). The evaluation was done for different anatomical regions of the patient : thorax, lung, soft and rigid tissues and tumor.

Results: Demons dense deformable registration was applied. We evaluated 11 vectorfields (9 between intermediate stages, 1 EEX-EIN, 1 EIN-EEX) and 2 composed vectorfields (EEX-EIN, EIN-EEX). Mean(standard deviation) of displacements between EEX and EIN were : 7.5mm(3.5mm) for lung, 12.1mm(2.2mm) for tumor. Mean(stdev) of vector norms of target difference vector field was 3.7mm(2.2mm) for exhalation and 3.8mm(3.5mm) for inhalation. Table shows mean(stdev) of distances and maximum distances between detailed and straight trajectories. Means of maximum distances were significantly different (t-test, p=0.03) between inspiration and exhalation. Distances means were greater for inhalation than for exhalation but it was not statistically different (p=0.17).

Conclusions: Preliminary results showed small differences (<2mm) between straight and detailed trajectories. It suggests that construction of the whole free breathing cycle may be feasible with 2 extrema stages. We plan to compare real breath-hold acquisitions with extrema stages of the 4D-CT. Works are ongoing for hysteresis evaluation between voxels pathways during inhalation and exhalation. Consequences on the PTV dose coverage will be also evaluated.

Distance in mm straight - detailed trajectory	Exhalation		Inhalation	
	Mean(stdev)	mean(stdev) of Max	Mean(stdev)	mean(stdev) of Max
Thorax	1.1(0.5)	1.6(0.8)	1.5(1.0)	2.6(2.6)

Lung	1.2(0.5)	1.8(0.7)	1.6(0.9)	2.8(2.7)
Soft & rigid tissues	1.0(0.6)	1.6(0.9)	1.4(1.00)	2.6(2.6)
Tumor	1.6(0.6)	2.2(0.8)	1.9(0.5)	2.8(0.9)

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