A method for detailed analysis of prostate motion demonstrated with a study of bladder filling effect

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Purpose: To test a method of registration for assessing the impact of the bladder volume change on prostate motion in the context of radiotherapy treatment planning for prostate cancer.

Methods and Materials: Using a 1.5T Sonata MRI machine, 5 healthy volunteers were scanned in the axial plane. Each subject was scanned twice; the first scan was considered that the subject had a full bladder. The subject was then instructed to void his bladder and was scanned again. The scans were done one after the other ensuring that the rectal volume difference should be kept to a minimum.

The two scans were first registered through a mutual information based registration algorithm to eliminate the differences in the imaging setup. In the individual images prostate surfaces were contoured, stacked and then three dimensionally reconstructed by a single observer.

Points were sampled on the 3D surface, which were used for the centre of mass (COM) calculations and in the Iterative Closest Point (ICP) algorithm [1]. In the COM method only the translation of the centre of the mass was taken as a rough measure of the prostate motion. The ICP method allows both translation and rotation to be measured. The ICP method involves the registration of the 3D reconstruction of the prostate contoured from the first scan to the 3D reconstruction of the prostate from the second scan, see Fig 1. The change in volume was calculated through the 3D reconstruction of the contours and was used as an indication of deformation.

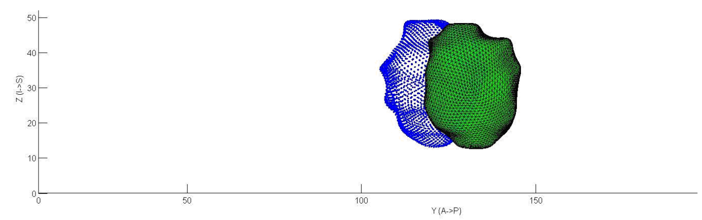

Fig 1: Full bladder and empty bladder prostate 3D reconstructions, in the global reference, after bony landmark registration.

Results: The centre of mass results showed mean displacements with one standard deviation (SD) of -0.21 ± 4.26mm (maximum of -7.38mm), -3.05 ±10.86mm (maximum of -15.55mm) and -4.51 ±5.44mm (maximum of -10.88mm) in the Lateral, Anterior-Posterior and Inferior-Superior directions (with the negatives indicate shifts along the Right, Anterior and Inferior directions, respectively). By comparison, translations of -0.58 ± 5.95mm (maximum of -8.60mm), -2.67 ±10.34mm (maximum of -16.31mm) and -4.56 ±5.90mm (maximum of -13.90mm) were found from the ICP method in the lateral, Anterior-Posterior and Inferior-Superior directions. The mean rotations with one SD associated with the ICP were -0.33 ± 3.97 degrees (maximum of 5.13^{o}), -0.32 ± 0.84 degrees (maximum of -1.32 ^{o}) and -0.24 ±1.23 degrees (maximum of -1.90 ^{o}) around the Lateral, Anterior-Posterior and the Inferior-Superior axes, respectively. The differences in prostate volume between the two scans were found to be negligible.

The COM results agree within the range of reported prostate motion in the literature [2] and show similar displacement on average to the ICP results in cases where minimal rotation was observed. When the rotation was relatively large, some noticeable discrepancies between COM and ICP were observed, as expected.

Discussion: Although there are previous studies on prostate motion, most of them have used the COM method which essentially uses only one point to describe the prostate motion. Fiducial markers have also been used to describe the motion but this is invasive for the patient. Our aim is to develop a more comprehensive and non-invasive way of describing the prostate motion. We believe that to better quantify the prostate motion and deformation, prostate surfaces need to be registered through not only translation but also rotation as accurate as possible. From this preliminary study the ICP method is proved to be an appropriate tool for this registration task. The transformation parameters found by ICP registration method provide a more complete description of the prostate motion in 3D. More subjects are needed to see if the rotation of the prostate detected through ICP can have significant impact in the radiotherapy treatment of the patients with prostate cancer.

Future work: This work is the first step to a detailed analysis of prostate motion and volume changes/deformation on patients based on bladder filling, rectal filling, breathing effects and if possible muscle contraction. In these cases the rectal and bladder volumes will be monitored through contouring and three-dimensional reconstruction.

1. Besl, P.J. and H.D. McKay, *A method for registration of 3-D shapes.* Pattern Analysis and Machine Intelligence, IEEE Transactions on, 1992. 14(2): p. 239-256.
2. Thomas E. Bryne, PH.D. *A Review of prostate motion with considerations for the treatment of prostate cancer*. Medical Dosimetry, Vol 30, No. 3, pp. 155-161, 2005.