Increasing registration accuracy by sub-volume based mutual information registration

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Purpose: In order to take full advantage of the many imaging modalities available today such as CT, MRI, PET etc., accurate image registration is essential. Mutual information (MI) registration is a commonly used and robust method as it is based on the complete image information instead of fiducial markers or anatomical landmarks. However, MI registration is often dominated by the patient external contour and bony structures. This is problematic in cases when an organ of interest does not have a fixed position in relation to bony anatomy; a typical example is the prostate. To be able to ensure proper registration with the prostate in focus it is necessary to restrict the registration volume to include the prostate with a small margin, i.e. a sub-volume based registration (SVR). In the present study, the accuracy and precision for sub-volume based MI registrations in the prostate area was investigated and compared to full-volume registrations (FVR).

Material: A MATLAB® software was constructed that enabled rigid registration of 3D-image datasets using a normalized MI metric and a stochastic optimizer that proved very robust. Image interpolation was performed tri-linearly. 10 prostate cancer patients were included in the study, and were imaged once with CT prior to treatment and 4 times during the treatment period using a T2 weighted 3D SPACE sequence (voxel size 1.2 x 1.2 x 2.7 mm). The prostate gland was delineated on all studies under supervision of an experienced physician and the centre of mass (CoM) was calculated. MI registrations were performed using the complete images and based on the prostate sub-volume. The quality of the registration was quantified through the deviations of CoM between registered images.

Results: SVR showed a significant improvement in centre of mass coincidence compared to FVR. Typical deviations after FVR were ~10 mm and after SVR these errors were reduced to ~1 mm in MR-MR registrations. CT-MR SVR showed very erratic behaviour of large uncertainty. A comparison between full-volume MR-MR registration, sub-volume based MR-MR registration and sub-volume based MR-CT registration can be seen in figure 1.
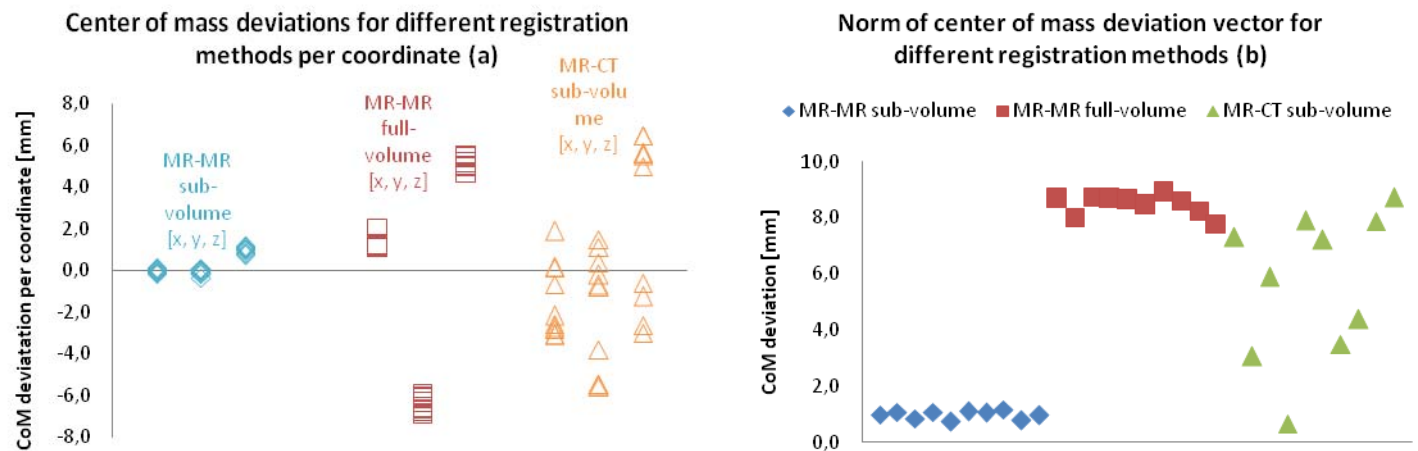

Fig 1: Registrations were repeated 10 times for each setting using the same image sets in order to quantify accuracy and precision. MR-MR sub-volume registration showed high accuracy and precision, in contrast to MR-CT sub-volume registration. (a) shows the CoM deviations per coordinate and (b) shows the norm of the center of mass deviation vector.

Conclusion: Sub-volume based MR-MR MI registration of the prostate is possible using just a small margin around the prostate gland, due to the relatively high information content in MR depiction of soft tissue. This is not the case in CT-MR registration, where registrations are less precise and severely erratic, which is to be expected since there is a very small amount of structural information available in the prostate area of the CT image. MR-MR SVR showed high precision and accuracy, where MR-MR FVR displayed high precision but poor accuracy with respect to the prostate CoM. These results are of high importance in treatment planning for radiotherapy, multi-modality diagnostics as well as treatment follow-up where the organ of interest can move relatively freely within the patient. Both with SVR and FVR, the registration error between CT and MR can introduce errors in the order of cm, which can have severe consequences if used as basis for radiotherapy treatment planning.