Evaluation of intensity-based deformable registration of multi-parametric MRI of the prostate

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Introduction and objective. Multi-parametric magnetic resonance imaging (mpMRI) has been shown to be a powerful tool in the detection, treatment, and prognosis of prostate cancer[1]. The preprocessing of MR images prior to any type of quantitative analysis is crucial to the quality, reproducibility, and reliability of the results. Co-registration of mpMRI data, in particular, plays an important role in combining the imaging data from each MR modality in order to more accurately assess the condition of prostatic tissue[2]. We aim to investigate the quality of co-registration obtainable by commonly used opensource toolkits.

Specific aims. In this study, we assess the performance of elastix[3], NiftyReg[4], and ANTs[5] for the registration of mpMRI of the prostate. We also examine the usefulness and validity of commonly used registration evaluation metrics.

Rationale and background. The aim of intensity-based deformable registration is to determine a transformation that relates one image to another. The ideal transformation is both biologically and mathematically sound (sooth and regular transformation) and provides the highest degree of alignment that can be achieved with the least amount of inference or loss of information. Despite the necessity for accurate co-registration of prostate mpMRI, it may still be performed manually, through the use of proprietary software that is not readily available, or neglected as a consideration altogether. Thus, the determination of a strategy for consistent alignment of prostate imaging could prove to be particularly useful.

Methods and materials.
Acquisition. Retrospective mpMRI data was obtained from the PROSTATEx2 Challenge through the Cancer Imaging Archive for a subset of 30 subjects. All images were acquired without the use of an endorectal coil.
Processing. Bias correction was performed on the entire dataset using N4 Bias Correction. All T2w and DW images were manually segmented by a single rater.
Registration. Co-registration of T2w and DW images was performed using three tools: elastix, NiftyReg, and ANTs, each carried out in 3D. The transformation consisted of a global transformation (rigid + affine), followed by a nonrigid b-spline deformation. Mutual information was selected as the similarity metric, and a standard gradient descent optimizer was used. An exploration of common parameter manipulations was carried out on each software toolkit, including strategies for multi-resolution, interpolation, sampling, smoothing, and control point grid resolution. Final evaluation of each toolkit was based upon registrations implemented with parameter choices shown to produce optimal registration quality.
Evaluation. Registration quality was assessed by two methods: a tissue overlap measure, the Dice coefficient, and a deformation field assessment using the determinant of the Jacobian.

Results. The median Dice values of the final registrations across subjects are 0.83 (std=0.13, min=0.22, max=0.90), 0.70 (std=0.14, min=0.24, max=0.90), and 0.88 (std=0.10, min=0.52, max=0.93) for elastix, NiftyReg, and ANTs, respectively. The average Jacobian determinant values are as follows: elastix (min=0.85, max=1.11), NiftyReg (min=0.38, max=0.45), and ANTs (min=0, max=1038.20).

Discussion and conclusion. Based on the Dice values alone, ANTs appears to generate the highest quality registrations, but the deformation field assessment shows that the degree of deformation is far greater than the generally acceptable range of 0 to 1. Visual inspection confirms the poor quality of the final ANTs registrations. These results demonstrate the differences in registration quality that may result from various implementations of the same registration approach. Furthermore, they are consistent with previous studies that emphasize that tissue overlap scores alone are insufficient for assessing nonrigidregistration quality. Registrations carried out with elastix are ultimately shown to outperform NiftyReg and ANTs for this particular task and dataset when both tissue overlap and deformation assessment values are taken into account.

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