Non-rigid Registration of T1 MR Images Constrained with Fractional Anisotropic (FA) Maps

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Introduction

Conventional images, such as T_1 weighted (T1W) or T_2 weighted (T2W) MR images, provide basic contrast information between gray matter, white matter, and cerebro-spinal fluid. However, those images are limited because they provide little contrast between distinct white matter structures. Diffusion tensor imaging (DTI) is a complementary tool that provides information on the orientation and integrity of white matter fiber bundles. The co-registration of intra- or inter-subject DTI data in a standard coordinate space allows us to perform statistical analysis of DTI images, or compare data across subjects. Usually DTI data is registered indirectly through aligning the high resolution T_1 weighted MR images and then applying the obtained transformation to DTI data. This approach only uses the information of MR images to register DTI data and loses the significant micro-structural information about tissues. In this study, a non-rigid registration algorithm, which combines both T_1 weighted MR images and DTI information, is proposed.

Methods

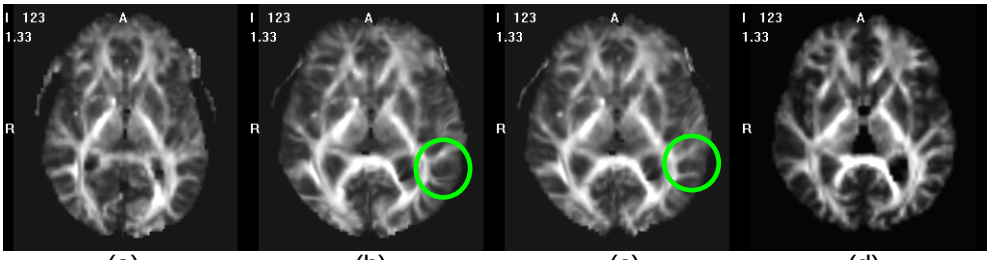
Fractional anisotropy (FA) measures the anisotropy of diffusion in tissues. For example, bright regions in a FA map indicate anisotropic structures in those regions (e.g., corpus callosum), and dark areas show more isotropic regions (e.g., gray matter). Hence, the FA map was incorporated into the non-rigid registration algorithm we proposed in the past, which we call ABA for adaptive bases algorithm [1]. This algorithm uses normalized mutual information as the similarity measure and models the deformation field that registers the two images as a linear combination of radial basis functions with finite support. To include the FA map into this algorithm, we compute the mutual information of not only T_1 weighted MR source and target images, but also the corresponding FA maps. Hence, the cost function becomes:

$$f_{\text{cost}} = -\frac{H(A_{T_1}) + H(B_{T_1})}{H(A_{T_1}, B_{T_1})} - \alpha \cdot \frac{H(A_{FA}) + H(B_{FA})}{H(A_{FA}, B_{FA})} \quad , \tag{1}$$

where $H()$ the Shannon entropy, A_{T1}, B_{T1}, A_{FA}, B_{FA} are the T1 weighted MR and FA source and target images, respectively. The parameter, α, which is 0.4 here, can be used to control the weight of the additional constraint term.

Results

We acquired T_1 MR images and DTI images from two subjects. Their corresponding FA maps were calculated and used in the proposed algorithm. Fig. 1 shows the registration results using only T1W images (Fig. 1(b)) and using both T1W and FA images (Fig. 1(c)). Without using FA maps, the gray matter regions in the FA map were distorted more than using both kinds of images. We also calculated and compared three similarity measurements: mean sum of squared differences, correlation coefficient, and normalized mutual information, for the FA volumes after rigid registration, non-rigid registration using only T1W images, and after the proposed method. The proposed method results in the highest similarity values for all the measurements, which indicates an accurate registration.



(a) (b) (c) (d)

Fig. 1. One axial slice from (a) the source FA image before registration, (b) the deformed FA image using only T_1 weighted MR image, (c) the deformed FA image using the proposed method, and (d) the target FA image.

Conclusions

We incorporate FA map as a constraint in the intensity-based non-rigid registration algorithm. A better FA map registration result allows the more accurate analysis of DTI images. In the future, we will incorporate tensor information in the ABA algorithm, similar to the work in [2][3].

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