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Non-linear registration of intra-subject ex-vivo and in-vivo brain acquisitions

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Abstract

In the past, we have introduced a pair-wise registration method called CVS that optimizes the alignment of inter-subject volumetric MRI acquisitions. We established, both quantitatively and qualitatively, that our technique accurately and robustly aligns both cortical and noncortical regions of the brain anatomy imaged by uni-modal MRI. We implemented a cross-contrast intensity procedure that would complement the original sum of squares (SSD)-based registration component of this framework making it suitable for registering intra-subject multi-modal acquisitions, such as ex-vivo and in-vivo images of the same anatomy. Registering these two modalities is a challenging problem given the differences between the intensities exhibited by the ex-vivo and in-vivo scans, together with the large scale deformations induced in the ex-vivo hemisphere during the autopsy process, as well as the fact that we are registering a single hemisphere image to one with an entire head.

Methods

Combined volumetric and surface-based registration (CVS) [1]

- pair-wise registration method that optimizes the alignment of both cortical and subcortical structures in volumetric MRI acquisitions
- three main registration steps
  1. surface-based registration to computes correspondences between the input surfaces
  2. translation of the cortical correspondences into a sparse displacement field in Euclidean space and the diffusion of such solution into the volume using the Navier operator of elasticity
  3. intensity-based volumetric registration to refine the alignment in subcortical regions

In the original algorithm , the last registration step implicitly assumes that the input images are of the same modality. In order to relax that assumption and accommodate multi-modal data sets, such as the ex-vivo and in-vivo acquisitions, we propose to replace the final step of CVS with a **mutual information-based non-linear registration step** [2, 3].

Data sets

We had access to data sets from four subjects. Three with single ex-vivo hemispheres and one with two ex-vivo hemispheres.

In-vivo MRI scans:

- acquired on a 1.5T Vision system (Siemens, Erlangen Germany). T1-weighted magnetization-prepared rapid gradient echo (MP-RAGE) scans were obtained according to the following protocol: two sagittal acquisitions, FOV = 224, Matrix = 256x256, Resolution = 1x1x1.25 mm, TR = 9.7 ms, TE = 4 ms, Flip angle = 10o, TI = 20 ms, TD = 200 ms. Two acquisitions were averaged together to increase the contrast-to-noise ratio

Ex-vivo MRI scans:

- acquired using a T2*-weighted Multi Echo Flash protocol due to the reduced T1 contrast observed post-mortem.

Results

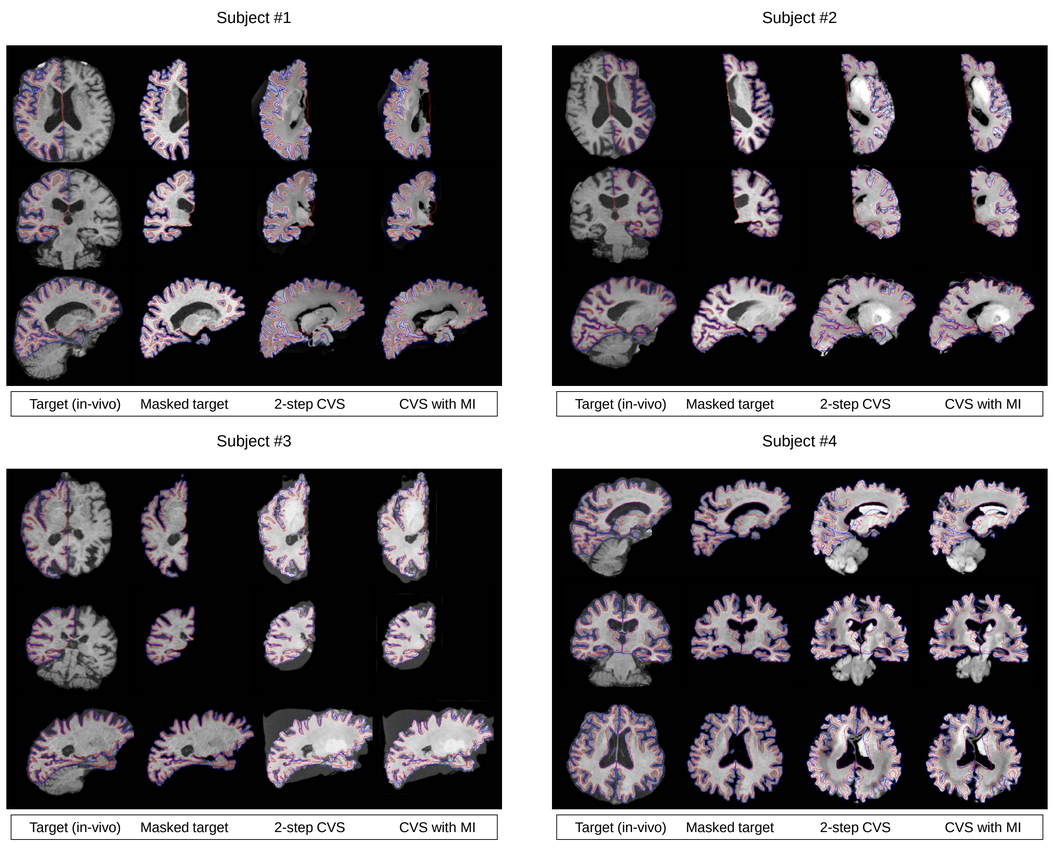

Figure 1: Results of the surface-driven elastic morph (2-step CVS) and full CVS with mutual information-based volumetric morph between an ex-vivo hemispheres and in-vivo scans of four subjects. Surfaces are extracted from the in-vivo data (pial surface in blue and gray/white surface in red).

Conclusions

We proposed a registration framework for multi-modal ex-vivo to in-vivo registration that accurately aligns both cortical and subcortical regions of the imaged anatomy. This registration is critical for relating the ultra-high resolution images available ex-vivo to in-vivo scans of the same subject, a necessary step for direct validation of high-resolution in-vivo labeling based on ex-vivo data, or for relating histological properties to in-vivo scans. As manual segmentation labels do not yet exist for our ex-vivo data sets, at present, our evaluation is qualitative. In the future, we aim to carry out rigorous validation experiments to promote our algorithm.

Bibliography

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