Confounds in Image Registration

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Introduction

Many of the analysis methods applied to neuroimaging are dependent upon correct co-registration of datasets, either to different examinations of the same subject (from other modalities or other time points), to other subjects, or to a population-based atlas. In many of these approaches, the direction in which the registration is applied (i.e. image A registered to image B, or vice-versa) may vary depending upon the topic of interest. However, we show here how care must be taken when performing registration, even affine registration, due to the risk of inverse inconsistency (registration performed A -> B is not equivalent to that performed B -> A).

Theory

Very recent theoretical work utilizing a novel registration framework termed Locally Orderless Registration (LOR) has shown that popular density estimation schemes such as mutual information (MI) and normalized mutual information (NMI) exhibit inverse inconsistency [1]. To approximate the probability distributions used within MI and NMI, discrete histograms are often employed, which are in turn estimated by methods such as Parzen Window (PW) [2] and Generalized Partial Volume (GPV) [3,4]. By referral to the LOR framework in [1], it is clear that the GPV approach is inversely inconsistent whilst that of the PW is symmetric. To demonstrate this, simulated registrations constrained to a pure translation were applied to T1-weighted structural MR images, and the impact of the choice of histogram estimation method upon the inverse inconsistency was assessed.

Results

When employed in the constrained example of a pure translation, the inverse inconsistency exhibited with the GPV approach was 0.5 voxels (Figure 1). That is, coregistration of image A -> image B, or M(A,B), differed in the location of the determined optimum from that of the inverse coregistration (image B -> image A, M(B,A)) by 0.5 voxels. In addition, the inverse inconsistency in GPV increased with W, the size of the partial volume window employed (Figure 2). The effect also increased with the curvature of the features in the associated images (data not shown). As seen from Figure 2, the only way to remove the asymmetry when using GPV would be to employ nearest neighbour interpolation. However this would prohibit the use of fast gradient-based registration schemes.

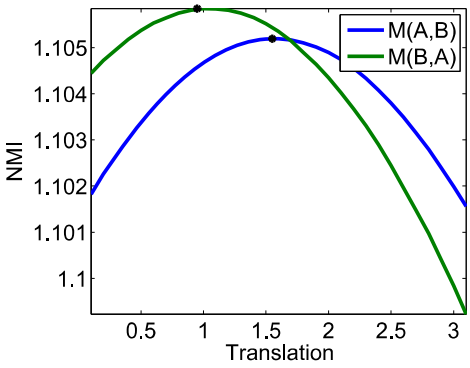

Figure 1 The inverse inconsistency for translation in one direction

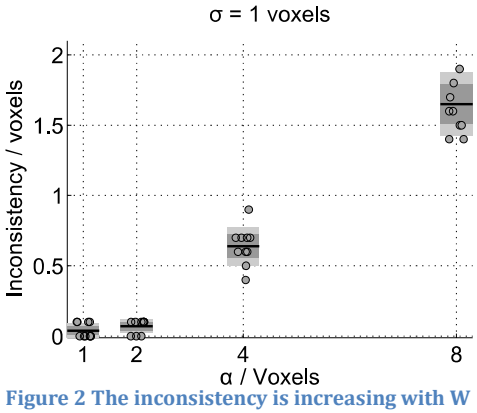

Figure 2 The inconsistency is increasing with W

Conclusion

Inverse inconsistency in affine image registration has been shown to cause a difference of up to 0.5 voxels. In many applications, especially where surface extraction is employed, such differences may have a significant impact upon analytical results, e.g. volume estimation. For example, for a hippocampus of 3000 voxels of which 800 are surface voxels, a mis-registration of 0.5 voxels could produce as much as (0.5x800)/3000=13.3 % volume error. It is suspected that the impact upon non-rigid registration will be locally even more pronounced. In such cases, choice of a different interpolation scheme such as nearest neighbor may be more optimal if the GPV approach is used. Otherwise a PW approach, which has been shown to be symmetrical, should be chosen. In general, care must be taken when performing co-registration in order to minimize subsequent confounds due purely to the direction of registration chosen.

References

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