

Simultaneous Population Based Image Alignment for Template Free Spatial Normalisation of Brain Anatomy

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Abstract. Current approaches to spatial normalisation of brain images have made use of a target image to which each subject image is matched. However, in many cases the use of a single brain template, or a statistical one derived from multiple subjects of another population, does not adequately capture the structure present in a population of anatomies under investigation. In such cases this paper proposes that a better approach may be to seek a method of driving subjects in the group into registration with each other, rather than with an unrepresentative template. This paper explores the approach of extending registration concepts from multi-modality registration, specifically those deriving criteria from the joint probability distribution of image values, to the general case of describing the alignment of a population of images simultaneously. Geometric constraints forcing the convergence to an average geometric shape are discussed and results presented on synthetic images and clinical brain image data.

1 Introduction

Spatial normalisation of brain anatomy from different subjects [19,2,4,16,5,6] is an increasingly important step in automated brain image analysis [17,7], useful both in structural and functional data analysis. One important and challenging application of spatial normalisation, which is the focus of this work, is in computational morphometry of tissue loss in neurodegeneration [13]. In such studies, it is common to make use of a reference anatomy or shape, to which all subject anatomies are aligned in order to permit local mapping of shape difference across a population. However, in an aging population, a range of cumulative-random degenerative processes have acted on each anatomy, and a separate reference brain may have little in common with many subject anatomies being studied. The aim of this paper therefore is to explore an approach to spatially aligning structural MRI scans that is free from the use of a single reference shape (be it either a statistical combination of anatomies or a single example). Specifically, we explore a generic statistical approach to defining a measure of population alignment, by examining the joint probability distribution between all image values across a population. This is combined with geometric constraints to allow simultaneous spatial alignment of images of populations of randomly varying shapes.

2 Method

2.1 Why Population Focused Alignment?

In applying deformation morphometry to study brain shape, particularly in dementia and aging, there are two key problems posed by normal aging and abnormal neurodegenerative conditions:

Varying Patterns of Regional Tissue Contrast: The presence of local white matter tissue contrast changes due, for example, to local vascular disease, or other white matter changes, cannot easily be captured by a single target anatomy. It may possible to construct a statistical target from another population [15], which somehow captures the local presence of regional white matter lesions. However, the question then arises how to align the individuals from this reference population in order construct this statistical target? More importantly, this statistical reference target will be derived from a different population to that of the disease being studied, in terms of lesions occurrence, location and contrast, and may therefore still be far from optimal for the purposes of study alignment.

Extreme Geometric Differences: Accurate estimation of mappings between boundaries in a reference brain to a subject is more difficult for subjects with greater shape variations arising from structural degeneration, than for more normal subject brains, simply because of the greater difference in curvature and separation of anatomical boundaries. The use of a synthetic average of a population can provide some reduction in the overall distance for the registration process to 'cross', by providing a more representative starting shape. However the distance between an average and a highly diseased individual may still be significant, and it is often the case that such individuals that are shape 'outliers' are important to capturing the nature of the shape variation in a population.

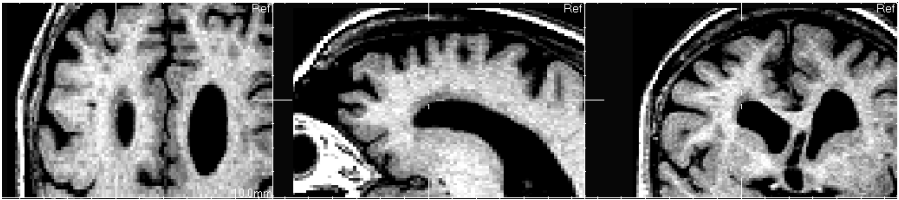


Fig. 1. Slices through a T1 weighted MR image of the brain of a cognitively normal 87 year old showing shape variations (in particular ventricular shape) and contrast variations (peri-ventricular white matter lesions, visible as a reduction in white matter intensity around the ventricles).

These two observations lead us to propose that a better solution may be one which attempts to simultaneously co-align subjects together in the population of interest, rather than with some other target shape. Such an approach may make