Improving the Accuracy of MR Image Segmentation through the use of Local Gradient Information

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Segmentation, i.e. separating an image into individual tissue regions, is a common task in medical image analysis. The results can be used directly in tissue volume estimation, for example to monitor the effects of atrophic processes [1], or as a component of more complex analysis techniques, for example to identify anatomical locations of activations in fMRI or cerebral blood flow measurements. Several fully automatic segmentation packages have been developed in recent years in order to both improve the repeatability and reduce the time required to perform such analyses on large cohorts of data, including SPM [2], FSL [3], and TINA [4], and are now widely used. In general terms, the more information we extract from the images in order to solve the segmentation problem the more accurate the results will be. This offers the possibility of improving the confidence limits on the conclusions drawn from any medical image analysis task utilising segmentation as a component, or equivalently retaining the same confidence limits whilst reducing the size of the subject group.

Accurate segmentation of MR images requires modelling of the partial volume effect, where multiple tissues are contained within a single voxel. In feature-space based approaches to image segmentation (e.g. [5]) this involves generating a model of the intensity distribution of the data that contains terms for both pure tissue and partial volume voxels, and then fitting this to the intensity histogram using for example the Expectation-Maximisation algorithm. However, problems can arise when the pure tissue distributions are poorly separated and obscure the partial volume distributions; in this scenario the intensity generation processes are ambiguous and so improved segmentation accuracy cannot be gained through simply increasing the sample size. Therefore, alternative methods for increasing the statistical power of the data must be investigated. One possible approach is to utilise spatial information, which is discarded in techniques based solely on image intensities. Since tissues typically form contiguous regions in medical images, significant amounts of information may be present in this form. Some researchers have investigated methods for recovering this information e.g. histograms built from local image phase [6] or Gaussian scale-space derivatives [7] have both been investigated in the context of image registration.

In previous work [4], we have described an EM-based Gaussian mixture model segmentation algorithm, based on a model including both pure tissue and partial volume terms. We have subsequently demonstrated extensions to both multi-dimensional [8] data, and to limited spatial information in the form of image gradients [9]. In the work presented here we provide a quantitative evaluation of the improvements in segmentation accuracy gained through the inclusion of local gradient information in the feature space.

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