An Integrated Volume Approach Enhances the Accuracy of Functional Voxel Classifications

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Introduction:

A common practice for functional Magnetic Resonance Imaging (fMRI) is to collect an anatomy volume image at an in-plane resolution of 256x256 with N slices through the brain. Subsequently, temporal sequences are collected at significantly lower in-plane resolutions, say 64x64 while retaining the same N slices through the brain. The reduced in-plane resolution allows a more rapid cycle frequency, a factor of 8 in this example. This compromise of spatial resolution is balanced by the enhanced transient data associated with the control and stimulation time dynamics of the fMRI study. The anatomy (and functional) image sets are aligned to a detailed segmented atlas, See Figures 1-2. Each subject functional pixel is mapped to a specific location within the atlas. During the fMRI analysis each functional pixel deemed statistically significant is summed into the specific brain region based on the atlas registration. Consequently, it is imperative to reliably classify these voxels with the appropriate material or regions of the brain. In the current classification methodology a functional voxel in subject space is classified based on the centroid of that voxel within the atlas space. In this paper we classify the functional pixel based on the integrated volume of the atlas space voxels occupying the single functional voxel space.

Method:

Let [S] = global coordinates of the Subject voxels obtained from a functional MR study. Let [A] = global coordinates of the segmented Atlas. Subject coordinates can be aligned to atlas data coordinates via [A] = [T] [S], where [T] is a 4*4 homogeneous coordinate transformation matrix. This linear transformation matrix can account for rotation, translation, skew, and perspective distortion in all 3 orthogonal coordinate directions. On applying the transformation matrix [T], the disparity in the image resolution of the functional MR data (ex: 64x64xN) and the segmented atlas data (512x512x10N) results in multiple atlas voxels occupying a single subject functional voxel, in this example 640 atlas voxels occupy the space of a single subject functional voxel. Consequently, to classify the functional voxel solely on its centroid location within the atlas can be misleading. As an alternative, we march through all atlas voxels within each subject voxel and assign to that subject voxel, the atlas material that occurs with the greatest frequency within the functional voxel. This process is repeated for all subject voxels.

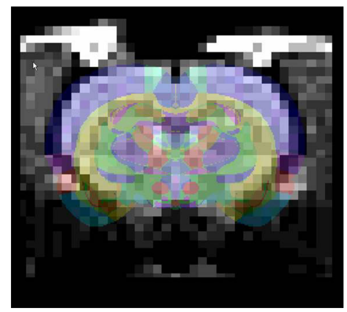

Figure 1 fMRI data registered to a segmented rat brain atlas.

Results:

The algorithm described was implemented and a typical mapped slice obtained from a 512*512*73 resolution rat atlas [1][2] and a 64*64*12 type functional MR dataset with the cerebrum and the amygdaloid complex as Regions Of Interest (ROI) are shown in Figures 4-6. For this dataset more than 700 functional pixels would have changed their classification between the centroid and majority volume strategies.

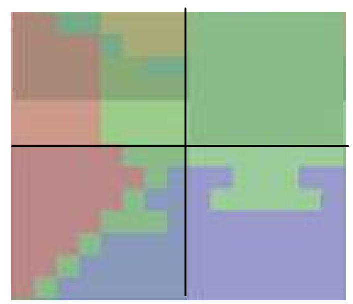

Figure 2 Magnified 2x2 region of a fMRI dataset registered to a higher resolution brain atlas.

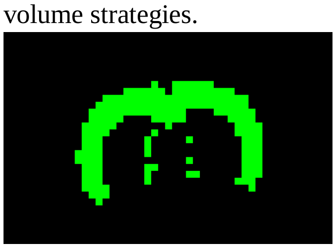

Figure 3 Subject voxels classified based on atlas material located at the centroid of MRI subject voxel.

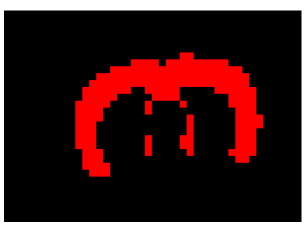

Figure 4 Improved algorithm based on material with greatest frequency of occurrence within subject voxel.

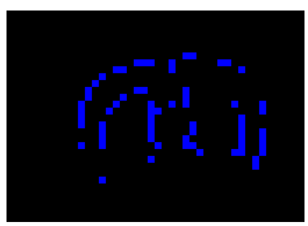

Figure 5 XOR operation on Figures 5 and 6 to contrast the two methods. Note that a significant number of pixels have been reclassified.

Conclusions and Future work:

The majority volume approach describes the function pixel location more accurately. It captures the biology of the tissue and the underlying MR physics more accurately. The described procedure is most noticeable for delineating smaller ROI functional activations.

References:

1. Swanson, L.W. Brain Maps: Structure of the Rat Brain. New York, Elsevier, Second Edition, 1999.
2. P.P. Kulkarni, J.M. Sullivan, Jr., H.R. Ghadyani, W. Huang, Z. Wu, and J.A. King, "Automatic Segmentation of a Rat Brain Atlas via a Multiple-Material, Marching-Cube Strategy", Proc. 11th Intl. Soc. Mag. Reson. Med., No. 4512, (2003).