A segmentation methodology that accounts for the MR physics of the RF pulse sequence.

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Introduction :

Digital Atlas based, Region of Interest (ROI) segmentation for functional Magnetic Resonance Imaging (fMRI) and subsequent statistical data analysis of the ROI's is the standard means of analyzing fMRI data. Digital Atlas resolution is typically higher than the fMRI data resolution due to the tradeoff between the desired spatial and temporal resolutions. Following registration the problem is one of classifying each fMRI dataset voxel with a single material index from the atlas. See Fig. 1. Traditionally, a functional voxel is classified based on the centroid of that voxel within the atlas space. An improved classification strategy was based on the integrated volume of all the atlas space voxels within the single functional voxel space [1],[2]. In this paper, we present a method to classify the functional voxel based on a pulse sequence specific weighing scheme, which accounts for the transmit RF pulse truncation effects, thereby describing the biology of the tissue better.

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 the coordinate transformation matrix. On applying the transformation matrix [T], the disparity in the image resolution of the functional MR data (ex: 64x64x12) and the segmented atlas data (512x512x300) results in multiple atlas voxels occupying a single subject functional voxel, in this example 1600 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 that lie within the neighborhood (computed range of the RF pulse along 3 dimensions) of each subject voxel, assigning each with a normalized weighting function. The weighting is pulse sequence specific incorporating RF pulse truncation effects, which is a measure of the contribution to the subject's signal intensity from that space [3]. The weighting function profile for a simple pulse sequence is shown in Figs. 2, 3. The weighting function follows a 2D Sinc profile in X-Y directions and filtered square function for appropriate bandwidth in Z-direction. The Z-direction profile is obtained by considering the truncation effects of Sinc transmit pulse using hamming window. Finally the subject voxel is classified with the atlas material that returns the largest cumulative weight.

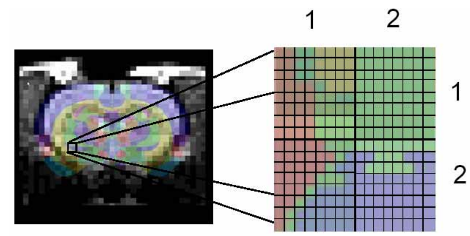

Figure 1: lower resolution subject data registered to higher resolution atlas. For instance subject pixel [1,1] encloses 64 atlas pixels containing 3 different color coded materials.

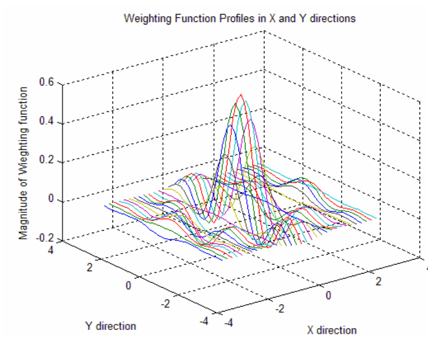

Figure 2 : Weighting function in the X-Y direction

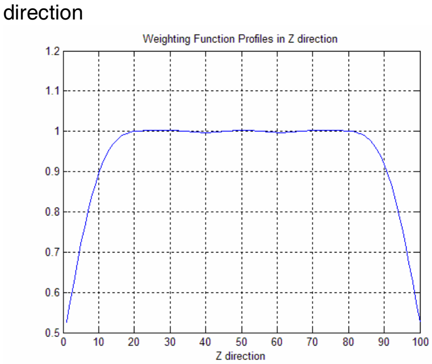

Figure 3 : Weighting function in the Z direction

Results :

The described algorithm was implemented and an axial cross-section mapped slice from a 512*512*300 resolution rat atlas [1] and a 64*64*12 resolution fMRI dataset is shown in Fig. 4. The white pixels mark those regions which were classified differently from the centroid based approach, which is shown in Fig. 5. Different colors indicate different materials. Fig. 6 shows the classification scheme [2], with the highest frequency of atlas voxels occurrence approach.

Figure 4 : Subject voxels classified using the proposed atlas voxel weighted frequency method.

Figure 5 : Subject voxels classified based on the centroid of MRI subject voxel.

Figure 6 : Subject voxels classified using the highest frequency of occurrence method.

Conclusions :

The enhanced, weighted material classification scheme describes the functional pixel in greater detail as it accounts for both the biology of the tissue and the MR physics of particular subject voxel selection by means of the pulse sequence specific weighting function. This study further contrasts the issues involved in reliable atlas based segmentation studies by comparing three different classification schemes.

References :

[1] Swanson, L.W. Brain Maps: Structure of the Rat Brain. New York, Elsevier, Second Edition, 1999. [2] M. Murugavel, J.M. Sullivan, Jr., P.K. Kulkarni, "An Integrated Volume Approach Enhances the Accuracy of Functional Voxel Classifications", Proc. 13th Intl. Soc. Mag. Reson. Med., No 1565, Miami, FL, (2005). [3] Handbook of MRI Pulse Sequences, Matt A. Bernstein, Kevin F. King, Xiaohong Joe Zhou, Academic Press 2004.