An Improved Method for Automatic Placement of Spatial Saturation Planes in MR Spectroscopy

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Introduction

Magnetic Resonance Spectroscopy (MRS) provides information that can be a boon for the non-invasive diagnosis of disease. However, the cuboidal excitation volumes used are not well adapted to the irregularly shaped tissues of interest (TOI) often desired for signal collection. In practice, there are two common approaches to address this problem: the cuboid can be shrunk so that it is contained entirely within the TOI, thereby reducing the total volume of the TOI sampled, or it can be chosen to completely encompass the TOI, introducing contamination in the acquisition volume.

The conformal voxel MRS (CV-MRS) technique[1,2] attempts to better “conform” the acquisition to the TOI by automatically placing a series of spatial saturation planes that annul unwanted signal from tissues at the periphery of a cuboid voxel encompassing the TOI. The original implementation used a constrained local optimization to place the saturation planes for arbitrary TOI geometries. Recently, a similar local optimization has been used to improve outer volume suppression in whole brain MRS studies[3]. However, the initial implementation of the method suffered from drawbacks which could limit its clinical applicability. These included the lack of a reliable, user-friendly, interface for defining the voxel and the extended time required to perform the optimization. To address these problems, a new algorithm for creating a conformal voxel has been implemented in an application with a graphical user interface for visualising and modifying the results.

Materials and Methods

Rather than optimize the location and orientation of the saturation planes, we follow a line of reasoning put forth previously[4], and optimize the shape of the conformal voxel directly. This is accomplished by first defining a triangulated surface to represent the TOI, then simplifying the surface until it has the desired number of faces. The position and location of each triangle defines the inner face of a spatial saturation slice. The first step, therefore, is to generate the initial surface. We begin with the TOI segmented from a set of anatomical images and construct the convex hull, *i.e.* the minimal convex surface enclosing the TOI. Next, using a surface simplification algorithm[5], all adjacent vertices of the surface are examined to find pairs which can be combined while causing the least modification of the surface's shape. This simplification of the surface continues until the user-defined number of faces remains.

We have implemented this algorithm by developing, in IDL[6], the application with a graphical user interface pictured in Figure 1. It runs on any platform using a freely available virtual machine. The user can load and display DICOM[7] format images to locate the TOI. The TOI may then be delineated using a number of tools: simple segmentation methods, drawing, or calling external programs such as a skull-stripping tool[8] to obtain whole brain coverage. With the TOI defined, the conformal voxel is then calculated without the need for any user interaction.

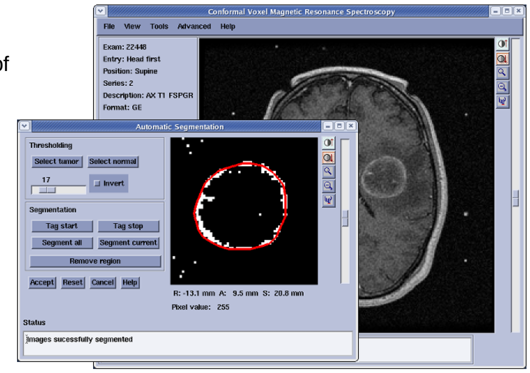

Figure 1: The main conformal voxel application and a tool for automatic segmentation

The results are then displayed, as in Figure 2, both as a two-dimensional overlay on the images and as a three-dimensional reconstruction. The user may view and modify the location of individual saturation planes while observing the effect on statistics such as the volume of the TOI, the fraction of the TOI contained within the voxel and the fraction of contamination. When the voxel is finalized, the location and orientation of the initial excitation volume and saturation planes are written into a file which may be read by pulse sequences implementing the conformal voxel technique.

Results and Discussion

A new conformal voxel algorithm has been implemented in an application with a user friendly interface. The new interface is platform independent and gives the ability to construct and modify a conformal voxel while viewing the results. Typically, the new algorithm can construct a conformal voxel of similar accuracy to that produced with previous methods in fractions of a second — orders of magnitude faster.

In the previous implementation, the location and orientation of the spatial saturation planes were treated as independent continuous variables for a local optimization of a cost function defined over the space of images. The optimization presented here is able to achieve dramatic improvements in calculation time because it replaces the previous cost function with one defined relative to the triangulated convex hull of the TOI. Further, by simplifying this triangulated surface, we have effectively traded the optimization of many continuous parameters for a much faster and more robust discrete optimization. Of course, if the TOI is not convex, then using the convex hull as a starting point will lead to contamination. However, as only convex surfaces can be represented by applying saturation pulses, this is already an implicit requirement of the CV-MRS method. In practice, however, this does not often lead to a large amount of contamination.

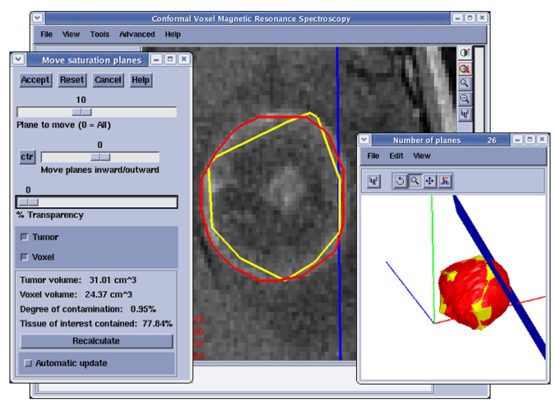

Figure 2: 2D and 3D display of resulting conformal voxel. The TOI is shown in red, conformal voxel in yellow and a particular saturation plane in blue.

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