

Multi-modal MR spectroscopic image processing in 3D Slicer: the SIVIC-Slicer module

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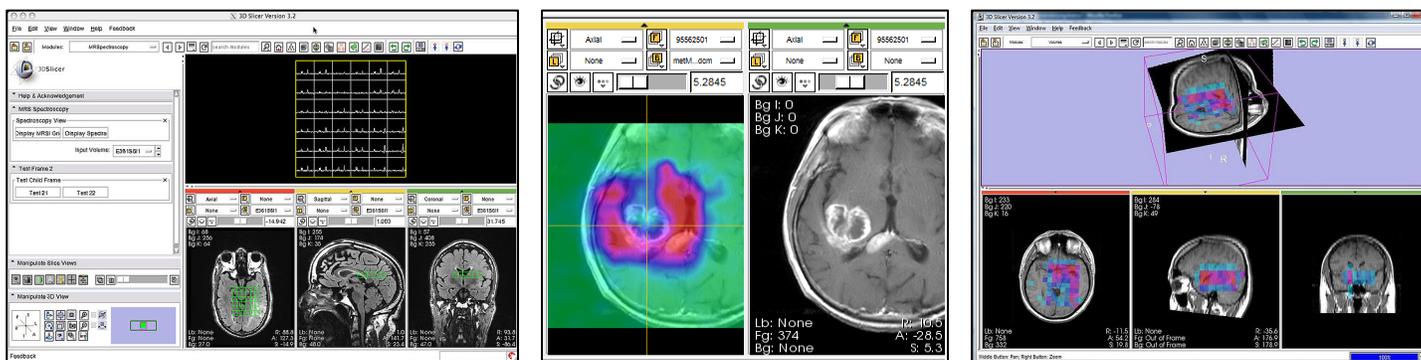
Background: MR spectroscopic images are typically acquired together with standard MR images to obtain the necessary spatial context at high resolution. In addition to morphological T1- and T2-weighted MRI, other modalities such as diffusion tensor imaging, perfusion, fMRI, or targeted biomarkers are also increasingly used in clinical protocols. While the use of such multi-modal imaging sequences has advantages in tissue characterization and the general understanding of the patho-physiologic process, it also increases the requirements for the processing and analysis of the image information. Here, it would be desirable to handle tasks such as spatial registration, gray value calibration, or tissue segmentation jointly across modalities, within one workflow and using one interactive image processing platform. Unfortunately, the most popular implementations of standard signal processing routines for the handling of MR spectroscopic images (e.g., LCModel, jMRUI, or MR scanner-specific tools) are closed source stand-alone applications specializing in MRS data analysis only. As a consequence, it remains difficult to integrate such tools into multi-modal image processing protocols – hindering a simple, joint visualization of relevant image features across modalities as well as the development and dissemination of novel MRS signal processing and analysis routines.

We address this problem by implementing the “Spectroscopic Imaging Visualization and Computing” (SIVIC) framework as a module for inter-active use and display of MRS data in the multi-modal image visualization and analysis platform “3D Slicer”, a free and open source software package. We also extend the open source SIVIC framework with MRS quantification routines to provide the means for a basic, self-contained processing of MR spectroscopic in this module.

Methods: The “SIVIC-Slicer module” provides a plug-in for SIVIC functionality in 3D Slicer. The SIVIC framework is designed for multi-center and multi-scanner MRS data handling and processing. It is an open source C++ framework with BSD-style license, extending VTK with reading, writing, algorithms and visualization classes for building MR spectroscopy data analysis workflows. SIVIC supports reading MR spectroscopic data from vendor-specific formats (GE P-file, GE postage stamp, GE sdbm, DICOM MRS, Varian FID, FDF, Siemens) and writing them to standard DICOM (DICOM MRS, DICOM SC). It also provides functionality for processing and interactively visualizing DICOM MRSI data. SIVIC is available as a stand-alone processing tool, and as an “OsiriX” plug-in. The SIVIC framework is currently in a beta/prototype state available from <http://sivic.sourceforge.net/>.

We implemented the SIVIC-Slicer interface as a so-called “module” within the 3D Slicer GUI. Slicer is a BSD licensed, cross-platform C++ image analysis framework. It provides a graphical user interface, but can also be used in batch processing for large imaging studies. Its modular framework provides methods for the inter-active visualization of volumetric images (with the ability to display arbitrarily oriented image slices, build surface models from image labels, and high performance volume rendering), for the generation of polygonal meshes, for manual editing and inter-active measuring, for fusing and co-registering multi-modal image data using rigid and non-rigid algorithms, for the automatic image segmentation (in particular for structures of the brain), for the display of 4D data sets, and the analysis and visualization of diffusion tensor image data. So far, it does not provide support for MRS data processing and analysis. The 3D Slicer is available as a stable release (Version 3.6) from <http://www.slicer.org/>.

The novel SIVIC plug-in to Slicer is a prototype enabling functionality of the SIVIC framework to be accessed from within 3D Slicer, facilitating the integration of MRS data with other imaging modalities. It uses the SIVIC data structures for reading and writing MRS data, the workflow, and the display of both individual spectra and the localization of the 3D voxel grid jointly with morphological images (Figure, left). We extended the SIVIC framework by new MRS signal processing functionalities to be used in the module and implemented both a non-parametric signal decomposition via HSVD (Hankel singular value decomposition) for removing peaks in predefined spectral ranges (e.g., water, lipid), and an AMARES-like, non-linear least squares fitting of Voigt-type template models in the time domain for quantification (Figure, center). In the module, the resulting metabolic maps are registered with other imaging data directly in Slicer for 3D visualization and rendering like standard images (Figure, right).



The figures illustrate functionality of the “SIVIC-Slicer module” prototype: MRSI data formats are automatically recognized and read, spectroscopic images are registered and visualized as overlays over morphological images in the Slicer GUI (left). The module outputs metabolic maps (center) to be rendered as standard label maps in 3D Slicer (right).

Discussion/Conclusions: The “SIVIC-Slicer module” provides the means for using Slicer functionalities, such as multi-modal image registration and segmentation modules, to process MRS data jointly with other information from multi-modal imaging protocols. Providing this basic functionality in an open-source framework will allow users to implement, contribute and publically disseminate their own task-specific MRS processing routines in a simple and straightforward fashion. We expect this to ease the exchange, testing and general availability of algorithms developed at the interface of MRI and MRS data analysis – such as, for example, spatial fitting and quantification of overlapping spectral resonances, tissue-specific calibration of MRS signals, multi-parametric tissue classification using image and spectroscopic features, image-guided definition of morphology-matched voxels, and MRSI-based tumor modeling.

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