# SIVIC: An Extensible Open-Source DICOM MR Spectroscopy Software Framework and Application Suite

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Introduction: Despite the existence of the DICOM MR Spectroscopy standard [1], it is currently not widely adopted and there is considerable variability in the way MR spectroscopy data sets are encoded. This results in a lack of interoperability between imaging devices, PACS, and MRS processing and visualization software packages. This is particularly problematic for multi-center collaborations, which often require complicated workflows and file format conversions to analyze spectroscopic data from multiple vendors. We describe here the SIVIC (Spectroscopic Imaging, Visualization and Computing) [https://launchpad.net/sivic] package, which is an open-source cross-platform, DICOM MR Spectroscopy software platform and application suite designed to streamline the integration of MRS data with MRI studies. SIVIC provides tools for reading DICOM and non-DICOM MRS data, an extensible algorithm layer to support development of reconstruction, post-processing and quantification methodologies, as well as display tools for visualizing MRS data. SIVIC also supports plug-ins developed for OsiriX [2] and Slicer [3] to provide MRS support within these existing widely used software tools.

Implementation: The SIVIC framework is implemented in C++ (with Python and Tcl bindings), extending and leveraging the VTK [4] and DCMTK [5] packages and is supported on Linux, Solaris, OsX and Windows platforms. The SIVIC framework libraries are publically available and can be used to develop MRS processing pipelines, or extended to support new MRS methodologies. SIVIC encourages contributions and participation from the spectroscopy community.
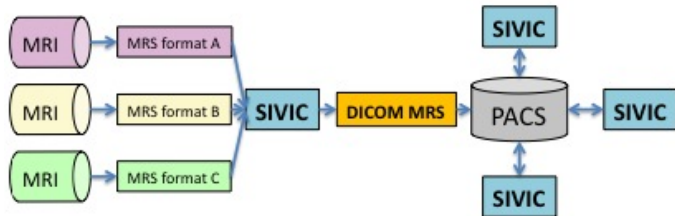
Figure 1. SIVIC converts MRS data acquired in a heterogeneous multi-center environment to the DICOM MRS standard for transmission with other imaging data to PACS. PACS clients that support SIVIC, e.g. OsiriX, can retrieve DICOM MRS data for analysis and visualization with other DICOM data using a single software package.

Discussion: We have applied SIVIC to data from patients with brain tumors and have found that it is extremely valuable for evaluating the spatial variations in metabolism associated with disease progression and response to therapy. The software framework and applications were able to streamline MRS workflows, by supporting conversion of non-DICOM MRS data to the DICOM MRS standard. Once MRS data was encoded to the DICOM standard, it was integrated with other DICOM imaging data and DICOM infrastructures (PACS) were utilized for communicating, discovering and storing data (Fig 1). SIVIC can also be applied to visualization and fitting of dynamic imaging data. Figure 2 shows the visualization interface from the standalone SIVIC application. Display of acquisition grid, sat bands, volume localization and overlays are supported in 2D and 3D modes. Processing panels provide interactive GUI access and graphical feedback for execution of reconstruction, post-processing and quantification pipelines. SIVIC's implementation of the DICOM MRS standard together with its standalone display applications enable the free flow and interoperability of MRS data and DICOM applications using a single tool set, permitting scientists to focus on the underlying MRS science rather than the logistics of handling MRS data.
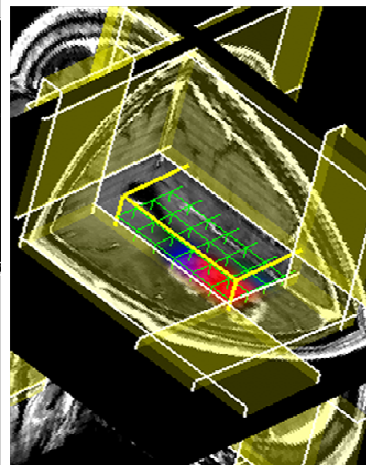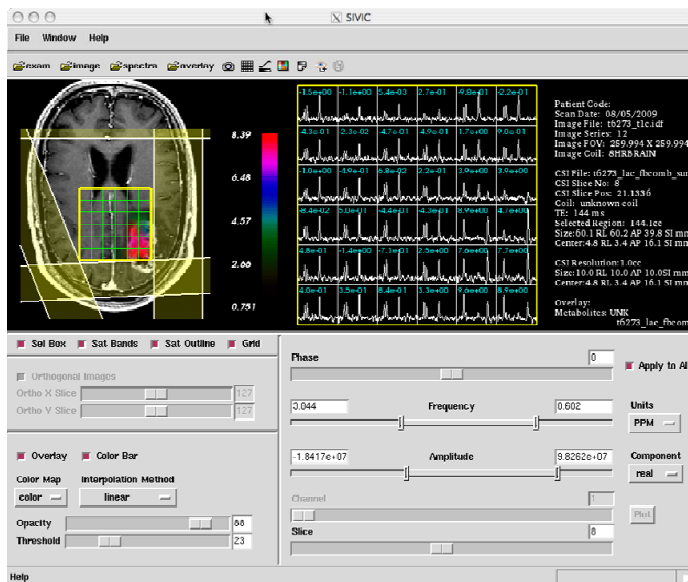
Figure 2. SIVIC standalone application and OsiriX Plug-in showing the 2D and 3D (inset) visualization panel that supports rendering of acquisition grid (green), sat bands (pale yellow), volume selection (yellow), color metabolite overlays, and supports multi-coil and time point data, all referenced spatially to anatomical data. Data can be written to DICOM MRS, DICOM Secondary Capture, or other common image formats (e.g. JPEG). Interactive data reconstruction, processing and quantification are supported through the processing panel (not shown).

References 1. ftp://medical.nema.org/medical/dicom/2008/08_03pu.pdf, 2. http://www.osirix-viewer.com/, 3. http://www.slicer.org/, 4. http://www.vtk.org 5. http://dicom.offis.de/dcmtk **We gratefully acknowledge support for this work from**: NIH P01 CA118816 and NIH RO1CA127612.