STI Suite: a Software Package for Quantitative Susceptibility Imaging

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AUDIENCE: Researchers interested in Quantitative Susceptibility Mapping (QSM) and Susceptibility Tensor Imaging (STI).

INTRODUCTION: Quantitative susceptibility mapping (QSM) and susceptibility tensor imaging (STI) are two recently developed imaging methods for quantifying tissue's magnetic property. Magnetic susceptibility offers a new contrast for high-resolution anatomical imaging; it further provides important information on tissue's chemical composition, especially myelin and iron, and white matter microstructures of the brain. However, processing QSM and STI still requires advanced technical expertise. The growing application and wider acceptance of this new technique has generated a need for a comprehensive software package that can easily perform all these analysis. Here, we have developed such a tool named "**STI Suite**". In this Matlab-based software package, we have implemented the essential algorithms for phase processing, QSM, STI, and related analysis tools. STI Suite is freely available at http://people.duke.edu/~cl160/ for non-commercial academic use.

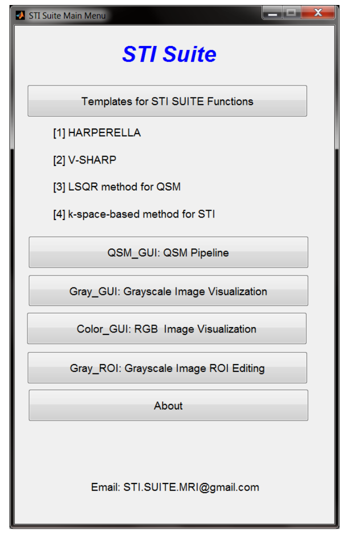

Fig. 1. Main STI Suite user interface.

METHODS: STI Suite contains both Matlab command-line functions and graphical user interfaces (GUIs) for phase processing, QSM, STI, and related visualization and ROI analysis tools.

<u>The main command-line functions include:</u>

1) Integrated phase unwrapping and <u>ha</u>rmonic background <u>p</u>has<u>e</u> <u>re</u>moval using <u>La</u>placian (HARPERELLA) (function: **HARPERELLA_v1**). This function uses a Laplacian-based method to achieve 3D phase unwrapping and background phase removal in a single step. [1].
2) Laplacian-based phase unwrapping (function: **LaplacianPhaseUnwrap_v1**). This method uses a Laplacian-based approach to achieve efficient 3D phase unwrapping [2].
3) SHARP background phase removal using a varying spherical kernel (V-SHARP) (function: **V_SHARP_v1**). This method is modified version of the SHARP method by Schweser et al (NeuroImage 2011), and uses a varying spherical kernel to remove the background phase and preserve the contrast near the boundary of the brain. [2, 3].
4) QSM using LSQR method (function: **QSM_LSQR_v1**). This function calculates the apparent magnetic susceptibility from the background-removed phase using the Matlab LSQR linear solver. [2].
5) STI using a k-spaced-based method: (function: **STI_Parfor_v1**). This function calculates the susceptibility tensor in the k-space using multi-orientation background-removed phase. It allows parallel computing using multi-core CPU. [4-7].

<u>The graphical user interfaces include:</u>

6) The main GUI, **STISuite** (Fig. 1): This GUI allows access to templates of the above functions, related GUIs and documentation.
7) **QSM_GUI, Gray_GUI, Color_GUI and Gray_ROI**: These GUIs provide the graphical interfaces for QSM, visualization of grayscale images, visualization of RGB images, and the ROI-editing tools. The advantages of these GUIs are their direct access to Matlab workspace, and their easy modification using Matlab guide to incorporate new features and functionalities.

RESULTS AND DISUSSION: Fig. 2 shows the representative phase processing, QSM, and STI using STI Suite. The phase unwrapping in HARPERELLA used the Laplacian-based approach, which is very robust. The resulting phase maps (Fig. 2 B, and Fig. 3 middle column) is free of erroneous phase wraps. As a result, high quality QSM can be obtained without spatial constrains using the LSQR method. This is an advantage, since the structural boundaries and contrast in magnitude, phase and susceptibility are not identical (e.g. cerebellar nuclei in Fig. 3), due to the blooming artifacts in magnitude and the nonlocal property of phase. While the QSM maps derived in STI Suite is similar to those using other methods [1,3], the Laplacian-based phase processing and the LSQR method offer additional advantages for handling large dataset (e.g. 1024x512x512), where traditional path-based phase unwrapping and QSM with spatial constraints would take too long to complete.

To conclude, STI Suite provides efficient and robust methods, and convenient user interfaces for routine application of QSM and STI.

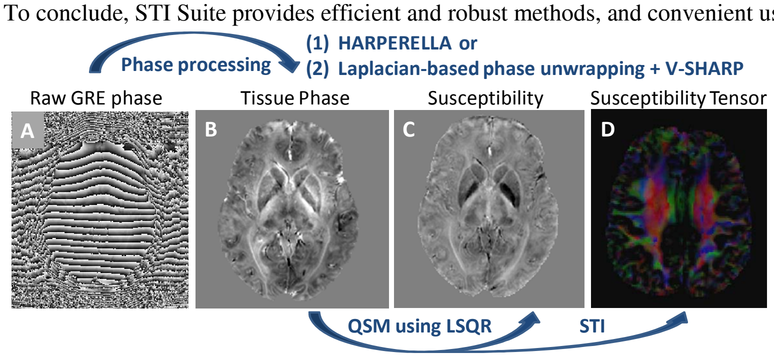

Fig. 2. Representative raw gradient echo (GRE) signal phase (A), HARPERELLA processed phase (B), susceptibility (C) and susceptibility tensor (D) using the STI Suite.

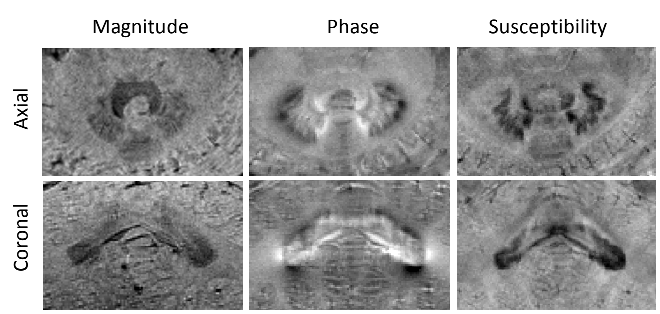

Fig. 3. Representative gradient echo magnitude, phase and magnetic susceptibility of cerebellar nuclei.

REFERENCES:

[1] Li, et al. Integrated phase unwrapping and background phase removal using Laplacian for quantitative susceptibility mapping. NMR Biomed, (In press). [2] Li et al., NeuroImage. 2011; 55:1645. [3] Wu et al. MRM 2012; 67:137. [4] Liu. MRM 2010;63:1471-7. [5] Liu et al. NeuroImage. 2012;59:1290. [6] Li et al, NeuroImage. 2012; 59:2088. [7] Li and Liu, Comparison of magnetic susceptibility tensor and diffusion tensor of the brain. J. Neurosci. Neuroeng. (In press).