In vivo MRI histology revisited: en route to hMRI toolbox 1.0

Presented During: Poster Session 3
Friday, June 27, 2025: 01:45 PM - 03:45 PM

Presented During: Poster Session 4
Saturday, June 28, 2025: 01:45 PM - 03:45 PM

Poster No:

1832

Submission Type:

Abstract Submission

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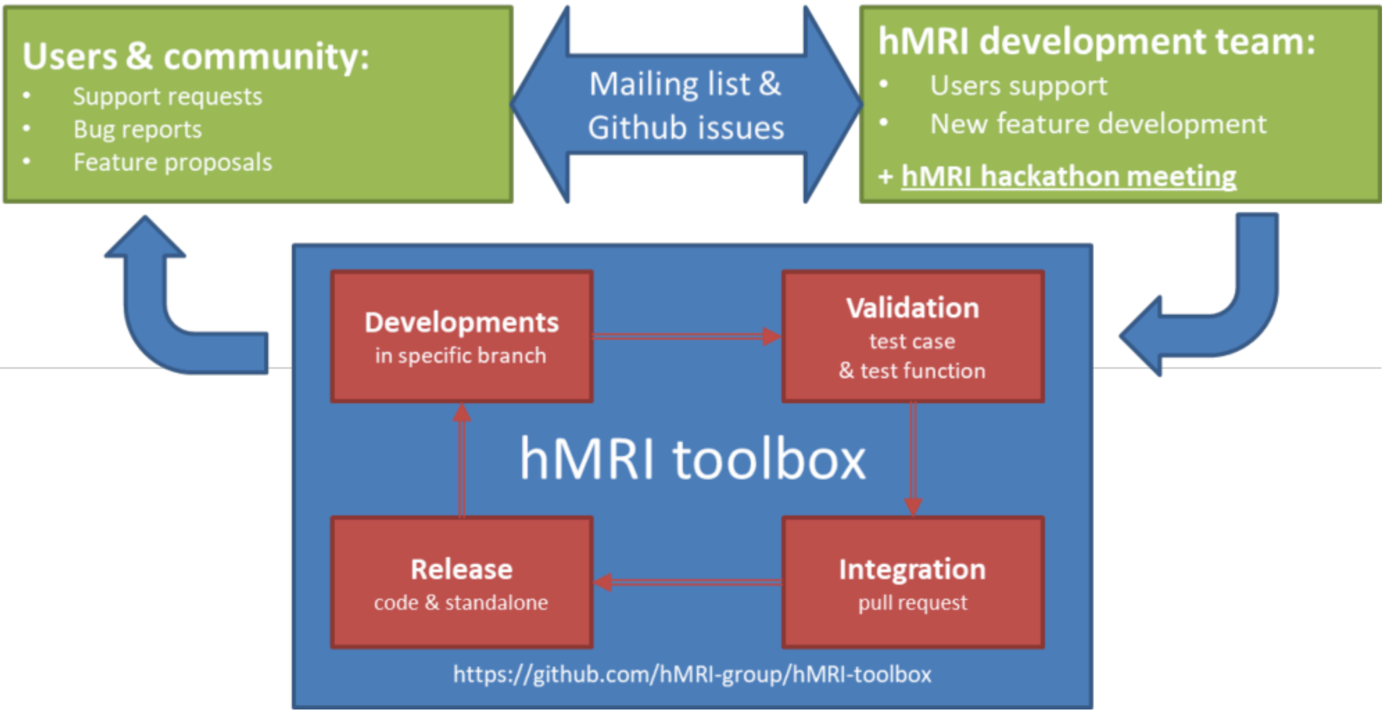
Introduction:

The hMRI toolbox is an internationally developed SPM-based framework for creation and statistical analysis of quantitative MRI maps sensitive to myelin and iron content (https://hmri.info; Tabelow et al. 2019, Draganski et al. 2011). The toolbox team uses Github to manage the collaborative software development workflow (Fig. 1) which includes: collecting user queries through issues and mailing list, organized coding and test development structured by pull requests, careful code review and testing of the new features before getting merged to the master branch. Since its initial release (v0.2) in 2018, the toolbox has acquired several new functionalities. A standalone version of the toolbox not requiring Matlab has also been released and included in the Neurodesk platform. Here we present these new features, which are part of the planned (for early 2025) major public release 1.0.



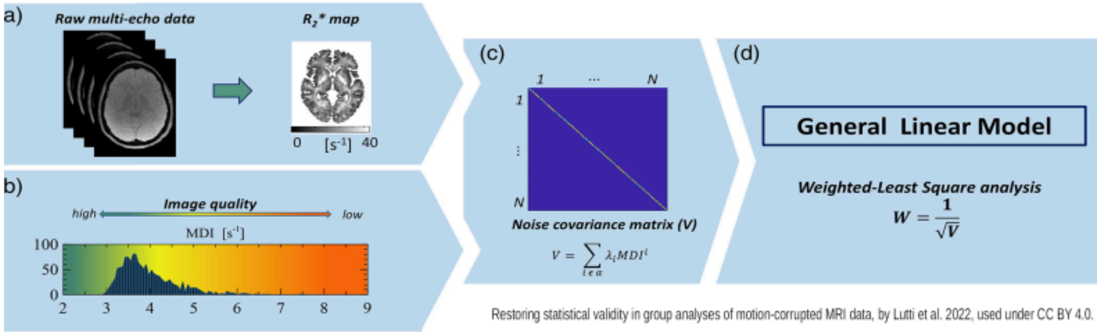
·FIGURE 1: hMRI toolbox software development flow

Methods:

The new features that we would like to highlight are:
1. Compilation of the toolbox and inclusion in Neurodesk (https://www.neurodesk.org/). The standalone version can be run directly without a Matlab license. It can either be used through the SPM batch GUI or through SPM batch jobs submitted directly on the command line.
2. Denoising module (Edwards et al., 2024). We have wrapped publicly available implementations of the state-of-the-art denoising methods (Bazin et al. 2019, Does et al. 2016, Veraart et al., 2019) within our toolbox through our own GUI, pre-processing modules and a Java-Matlab interface. Our implementation also possesses meta-data capabilities which outputs JSON sidecar files for further processing.
3. Error Maps (Mohammadi et al., 2022) give the voxelwise error of the quantitative maps for quality assurance, which can be turned on by the parameter hmri_def.errormaps in hmri defaults. An additional submodule ('Combine two successive hmri datasets') can also use these error maps as weights to robustly combine quantitative maps from two successive acquisitions.
4. Analysis of QUantitative Imaging data using a Quality Index (QUIQI) module for motion-robust group analysis (Lutti et al., 2022). The module implements a data-driven solution to account for subject specific motion, by assigning weights to each map based on an index of image quality, when performing group-level GLM estimations.

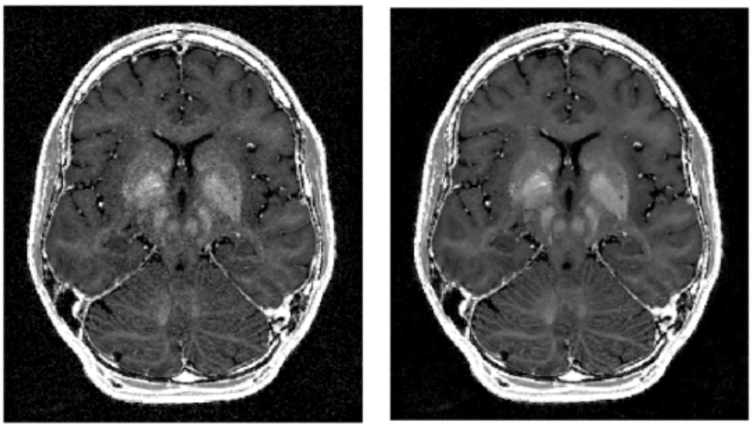
Results:

The results (Fig. 2) corresponding to the new features are:
1. The standalone version (also included in Neurodesk) increases the reach of the toolbox and contributes to cross platform efforts. The main functionalities can be used by installing the freely available "Matlab runtime environment" without any need for a Matlab license.
2. The built-in denoising module can be seamlessly configured and piped with other main processing steps through the SPM batch dependencies. LCPCA-denoising, originally written in Java, can now be invoked also within/from Matlab through an advanced custom developed Java-Matlab interface, which is a reflection of the cross-platform and advanced software initiatives of the toolbox.
3. Error maps enable evaluation of both local data quality variations and artifacts without requiring additional data. The resulting robust MPM parameters show reduced variability at the group level compared to the single-repeat or averaged counterparts.
4. The QUIQI module mitigates the effects of head motion on group comparison/regression statistical analysis.

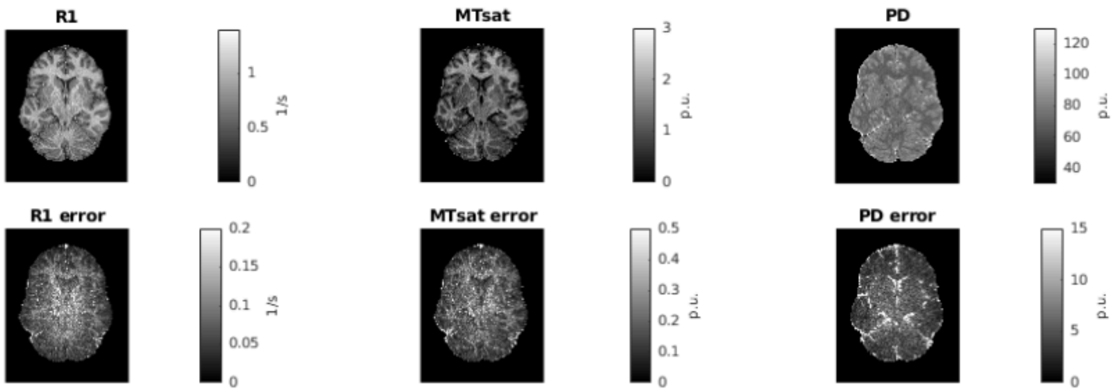


Restoring statistical validity in group analyses of motion-corrupted MRI data, by Lutti et al. 2022, used under CC BY 4.0.

QUIQI integrates correction of motion degradation into the analysis of MRI data. For the current application, analysis data are quantitative maps of the MRI parameter R2* (a). QUIQI requires a value of the MDI for each data set of the analysis. Here, we show the distribution of the MDI values across the images used for analysis (N = 1,432) (b). With QUIQI, basis functions are computed from powers of the MDI and inserted into REML (Friston et al., 2002) for the computation of the noise covariance matrix V (c). The set of powers of the MDI, α, is pre-defined by the user. From V, weights are computed that are used in the general linear model for data analysis (d)



R2s output: the left figure obtained from PDw, T1w, MTw of toolbox demo data (Callaghan et al. 2019) and the right from demo data which is first denoised in the built-in denoising module with the options 'LCPCA-denoising', 'window size=4', 'std_cutOff'= 1.05.



The error maps module (Mohammadi et al. 2022) associates an error estimate to each quantitative map voxel that can be used to evaluate data quality. Error maps created from demo dataset (Callaghan et al. 2019) using example error map configuration file.

·FIGURE 2: QUIQI, Denoising module and Error maps example results

Conclusions:

The new developments demonstrate the toolbox's dedication to cross platform efforts (inclusion of the compiled-standalone toolbox in Neurodesk), advanced software techniques (custom developed Java-Matlab interface and user focused GUI developments) and high quality image processing modules offering built-in denoising, error quantification, and motion mitigation. The hMRI toolbox 1.0 is prepared and developed as a self-sufficient, easily configurable, cross platform and well-documented software, which will further support developments in MRI-based in vivo histology.

Modeling and Analysis Methods:

Other Methods

Neuroinformatics and Data Sharing:

Informatics Other [1]

Novel Imaging Acquisition Methods:

Anatomical MRI

Multi-Modal Imaging [2]
Imaging Methods Other

Keywords:

MRI
MRI PHYSICS
Open-Source Code
Open-Source Software
STRUCTURAL MRI
Other - Quantitative MRI

[1|2]Indicates the priority used for review

Abstract Information

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Not applicable

Please indicate which methods were used in your research:

Other, Please specify - software development
Structural MRI

For human MRI, what field strength scanner do you use?

3.0T

7T

Which processing packages did you use for your study?

SPM

Provide references using APA citation style.

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