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Analyzing fMRI and dMRI experiments with R

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Poster
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Introduction

The rapid progress of research in the neuroscience and neuroimaging fields has been accompanied by the development of many excellent analysis software tools. These are implemented in a variety of computer languages and programming environments, such as Matlab, IDL, Python, C/C++ and others. This variety has been developed over time through a combination of user preferences and the strengths/weaknesses of the computing environments. Here, we present a selection of tools dedicated to functional and diffusion MRI written in the R Statistical Language.

Functional Magnetic Resonance Imaging (fMRI) using R

There exist a number of packages that enable the analysis of function MRI data with the complete pipeline from data I/O, over preprocessing, modeling and inference. Results can be written to disk using standard imaging formats for easy interaction with other fMRI software pipelines (SPM, Brainvoyager, AFNI, ...).

I/O and Preprocessing

- I/O of imaging data in ANALYZE, NIfTI, DICOM, and AFNI files
  (**oro.nifti**, **oro.dicom**, **Rniftilib**, ...)
- Image Registration and Normalization (**RNiftyReg**)
- Non-adaptive Gaussian smoothing (**aws**, **SimpleITK**, **kernsm**, ...)

GLM modeling

- Create GLM design for fMRI experiments and estimate model parameters (**fmri**)
- Perform AR(1) correction to time series
- Create simulation data with realistic noise based on any GLM (**neuRosim**)

Inference using package fmri

- Gaussian filter and Random Field Theory
- Structural adaptive smoothing and Random Field Theory
- Structural adaptive segmentation
- False discovery rate (FDR)

More fMRI analysis

- Independent Component Analysis (ICA) also for resting state data (**AnalyzeFMRI**)
- Activated region fitting (ARF) with **arf3DS4**
- Bayesian Multilevel Model with **cudaBayesreg**

R: A language for statistical computing and graphics

- Open source, freely available
- Access to all kinds of statistical tools (linear/nonlinear regression, classical statistical tests, time-series analysis, classification, clustering, etc...)
- Extension by packages with new functionality
- Download at `http://cran.r-project.org`

R: A Language and Environment for Statistical Computing

R: The concept of packages

- Packages: Reliable, convenient, and documented access to a huge variety of techniques. Easy to install.
- Integrate code from low-level languages (C/C++, FORTRAN)
- A recent website (`http://crantastic.org`) provides the facilities to search for, review and tag CRAN packages.

Diffusion weighted Magnetic Resonance Imaging (dMRI) using R

The processing of diffusion MRI data with R is highly developed. It includes a large variety of models, like the diffusion tensor model, tensor mixture models, q-ball imaging using the orientation distribution function, modeling the square root of the ODF, and diffusion kurtosis imaging. Results can be written to disk using the standard imaging formats, or with publication-ready images. 3D interactive visualization is possible on the screen using OpenGL functionality.

I/O

- I/O of imaging data in ANALYZE, NIfTI, DICOM files
  (**dti**, **oro.nifti**, **oro.dicom**, **Rniftilib**, ...)
- Image Registration (**RNiftyReg**)
- Publication-ready images
- 3D interactive visualization (**dti**, **rgl**)

Data Models

- DTI model (**dti**, **dcemriS4**, **tractoR**)
- Q-ball imaging with **dti**
- Tensor mixture model (**dti**)
- Diffusion Propagator methods (**dti**)
- Diffusion Kurtosis Imaging (**dti**)

Smoothing dMRI data with package dti

- Structural adaptive smoothing DTI data
- Position orientation adaptive smoothing (POAS)
- Multi-shell POAS (msPOAS), see **Poster #1687-MoTue**

Fiber tracking

- Streamline FACT algorithm based on DTI or tensor mixture models (**dti**)
- Probabilistic fiber tracking using R interface to FSL (**tractoR**)

Conclusions

- R provides an excellent environment for all levels of analysis with fMRI and dMRI data, from basic image processing to advanced statistical techniques.
- A series of packages can assist user-guided data analysis as well as automated bulk analysis of imaging data.
- The user is free to create additional data structures or analysis routines using the programming environment in R—making it easily customized.
- It may be run in either interactive or batch-processing modes in order to scale with the application,
- R may be combined with other computing environments (e.g., Matlab or NIPY) to allow even greater flexibility.

Links and literature

- **Medical Imaging task view** at `http://cran.r-project.org/web/views/MedicalImaging.html` (with download links to all packages)
- Access to R via **the Comprehensive R Archive Network (CRAN)** at `http://cran.r-project.org/`
- Tabelow, K., Clayden, J.D., Lafaye de Micheaux, P., Polzehl, J., Schmid, V.J., Whitcher, B. (2011), 'Image analysis and statistical inference in neuroimaging with R', NeuroImage, **55(4)**, pp. 1686–1693.
- Tabelow, K., and Whitcher, B. eds. (2011), Special Volume of Journal of Statistical Software "MRI in R", vol. 44.

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