Image Analysis and Statistical Inference in Neuroimaging with R

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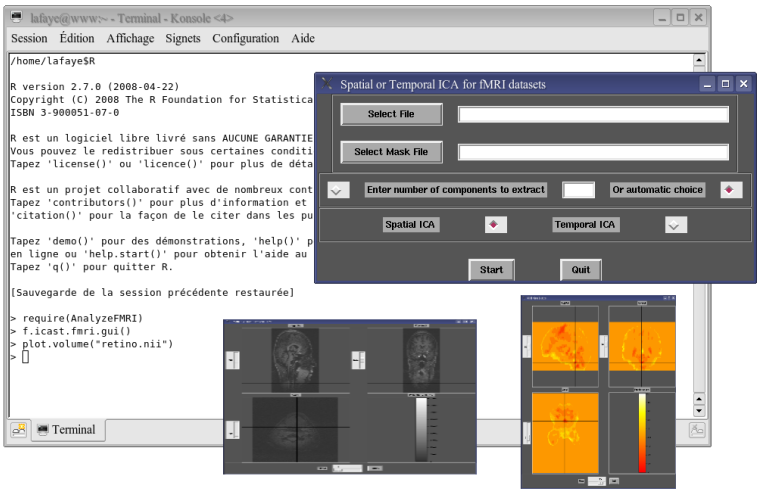
Introduction: The rapid progress of research in the neuroscience and neuroimaging fields has been accompanied by the development of many excellent analysis software tools. These are implemented in a variety of computer languages and programming environments, such as Matlab, IDL, Python, C/C++ and others. This variety has been developed over time through a combination of user preferences and the strengths/weaknesses of the computing environments.

R is a free software environment for statistical computing and graphics [1]. It compiles and runs on almost every UNIX platform, Windows, and Mac OS. Access to R is provided via the Comprehensive R Archive Network (CRAN) [2]. R provides a wide variety of statistical (linear and nonlinear regression modelling, classical statistical tests, time-series analysis, classification, clustering, etc...) and graphical techniques, and is highly extensible. As of October 2009, the CRAN package repository features over 2000 separate packages contributed by R users. A recent website (`http://crantastic.org`) provides the facilities to search for, review and tag CRAN packages. Several mailing lists are maintained in order to provide updates and access to literally thousands of R users. This is in addition to a complete set of open-access manuals about the R language.

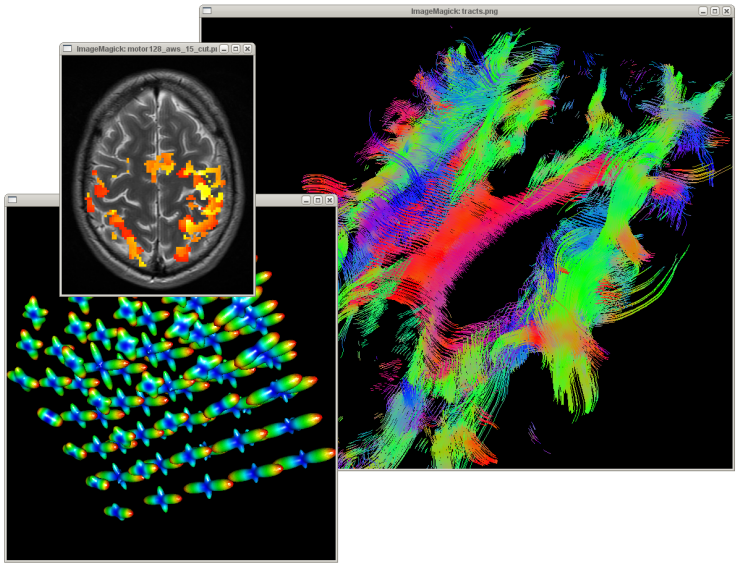
Methods: Over time a number of packages specific to medical imaging, and in particular neuroimaging, have been developed. They are collected in the Medical Imaging task view [3] and address the following application areas:

- Data Formats: `AnalyzeFMRI`, `DICOM`, `Rniftilib` and `tractor.base` provide interfaces between R and common data formats, including DICOM, Analyze and NIfTI.
- Magnetic Resonance Imaging: `AnalyzeFMRI` (e.g., spatial/temporal ICA for fMRI data), `dcemri` (e.g., quantitative analysis of Dynamic Contrast-Enhanced MRI), `dti` (e.g., structural adaptive smoothing for DTI data), `fmri` (e.g., structural adaptive smoothing for fMRI data including signal detection with random field theory) and the TractoR project, of which the `tractor.base` package is part (e.g., DTI-based tract shape analysis and segmentation).
- Imaging: `adimpro` (2D black-and-white and color general image processing tools) and `AnalyzeFMRI` (2D interactive tool for the visualization of 3D functional and/or anatomical brain images).

Results:



Snapshot of `AnalyzeFMRI` at work.



Results from the `fmri` and `dti` package

Conclusions: R provides an excellent environment for all levels of analysis with neuroimaging data, from basic image processing to advanced statistical techniques via the current list of contributed packages in the Medical Imaging task view [3]. These packages can assist user-guided data analysis for fMRI, DCE-MRI and DWI data 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, and may be combined with other computing environments (e.g., Matlab or NIPY) to allow even greater flexibility.

Bibliography:

[1] R Development Core Team (2008). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0.
[2] `http://cran.r-project.org`.
[3] `http://cran.r-project.org/web/views/MedicalImaging.html`.