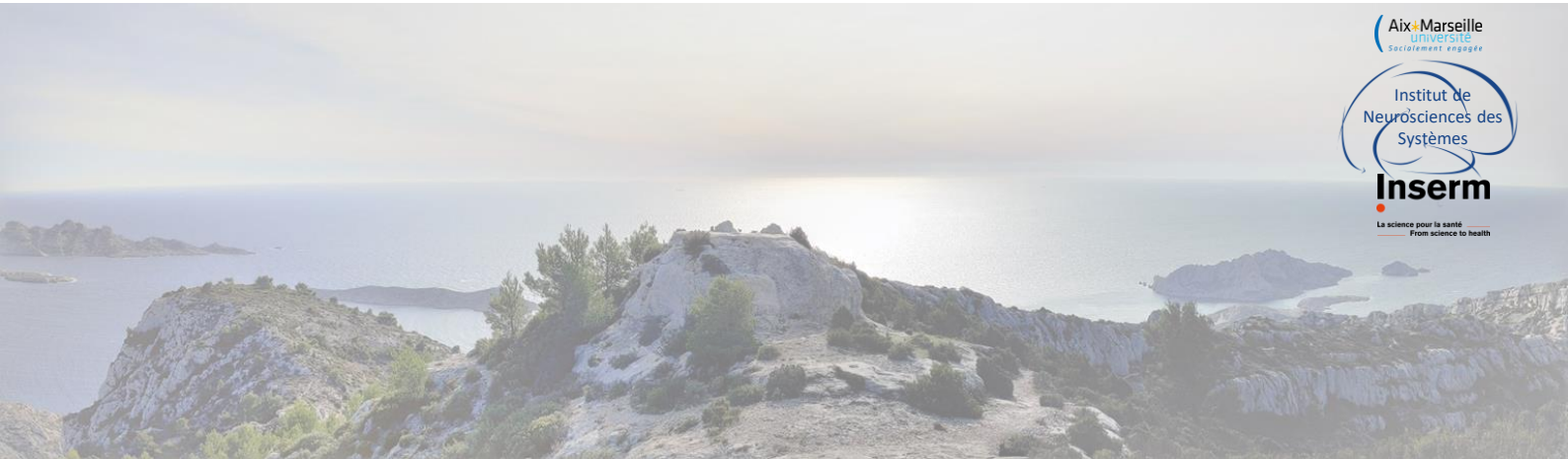
BrainHack
Open collaboration in neuroscience
Marseille

Tools for data science & data analysis:
Fieldtrip

Manuel Mercier

Aix*Marseille université
Socialement engagée
Institut de Neurosciences des Systèmes
Inserm
La science pour la santé
From science to health



Fieldtrip toolbox: a bit of history

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Research Article

FieldTrip: Open Source Software for Advanced Analysis of MEG, EEG, and Invasive Electrophysiological Data

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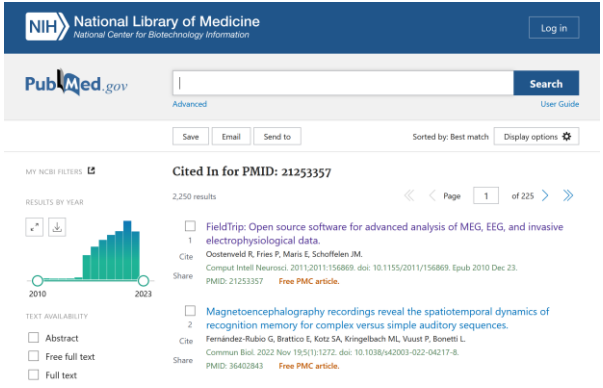
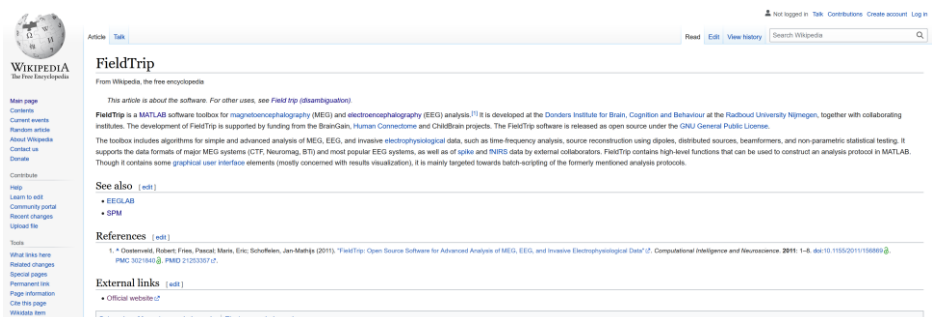
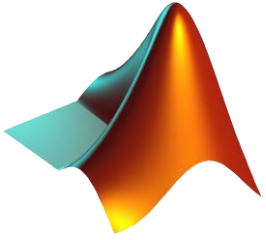
This paper describes FieldTrip, an open source software package that we developed for the analysis of MEG, EEG, and other electrophysiological data. The software is implemented as a MATLAB toolbox and includes a complete set of consistent and user-friendly high-level functions that allow experimental neuroscientists to analyze experimental data. It includes algorithms for simple and advanced analysis, such as time-frequency analysis using multitapers, source reconstruction using dipoles, distributed sources and beamformers, connectivity analysis, and nonparametric statistical permutation tests at the channel and source level. The implementation as toolbox allows the user to perform elaborate and structured analyses of large data sets using the MATLAB command line and batch scripting. Furthermore, users and developers can easily extend the functionality and implement new algorithms. The modular design facilitates the reuse in other software packages.





Fieldtrip toolbox: the philosophy

- mostly code (well written)
- No GUI (almost)
- Function based
- Structure organized



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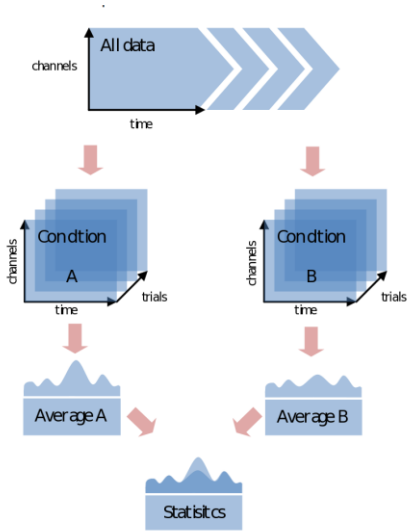


Fieldtrip toolbox: pipeline examples

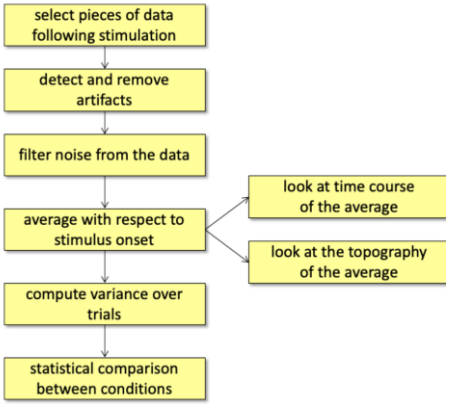
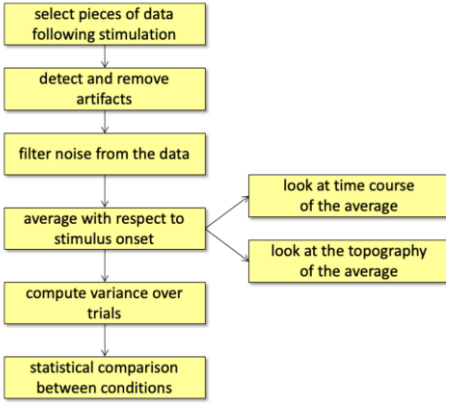


Figure: Analysis protocol for Event-Related Potentials (ERPs).

Fieldtrip toolbox: pipeline examples and functions



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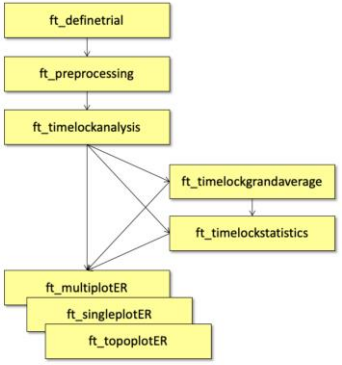


Figure: An example analysis protocol for Event-Related Potentials (ERPs) using the FieldTrip functions.

Fieldtrip toolbox: pipeline examples and functions

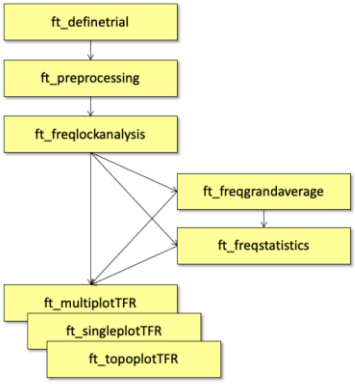


Figure: An example analysis protocol of (time-)frequency analysis in FieldTrip.

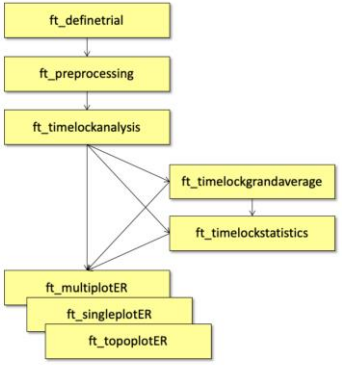


Figure: An example analysis protocol for Event-Related Potentials (ERPs) using the FieldTrip functions.

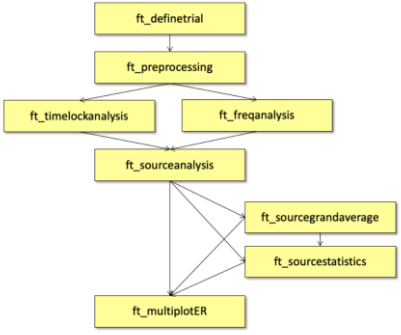


Figure: An example analysis protocol of the source analysis using beamforming in FieldTrip.

Fieldtrip toolbox: pipeline examples

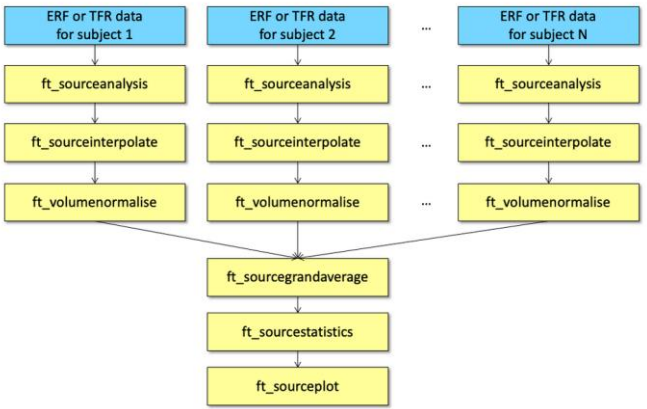
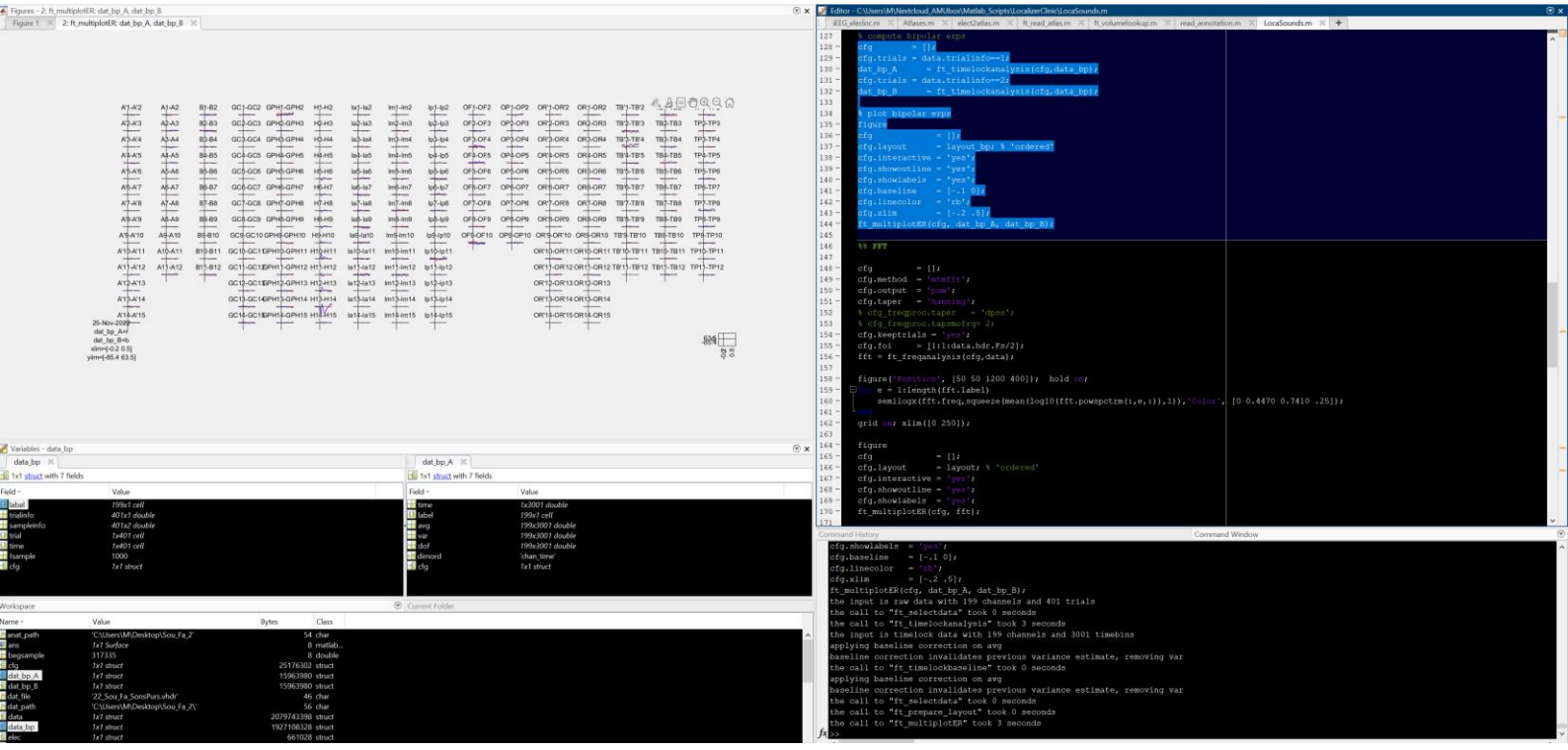
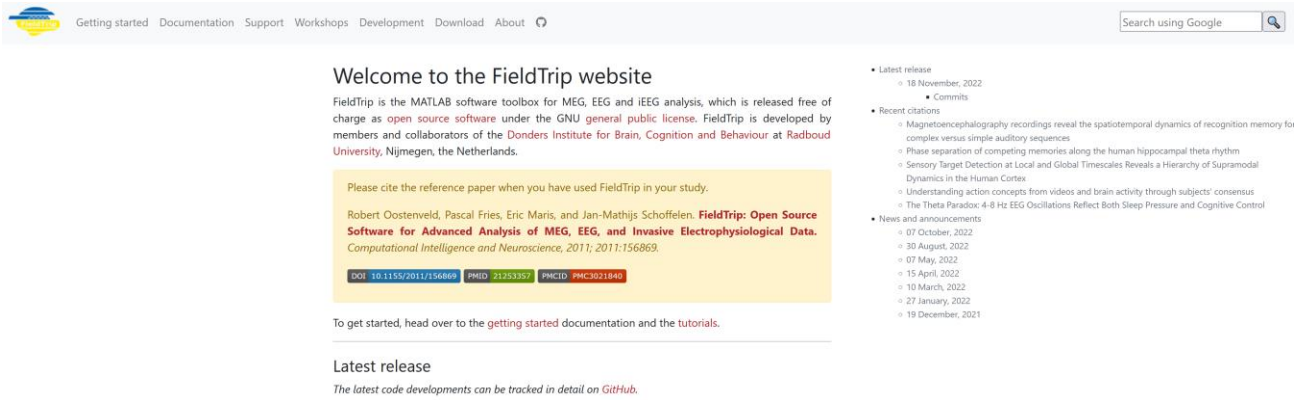


Figure: An example analysis protocol of source reconstruction for multiple subjects in FieldTrip.

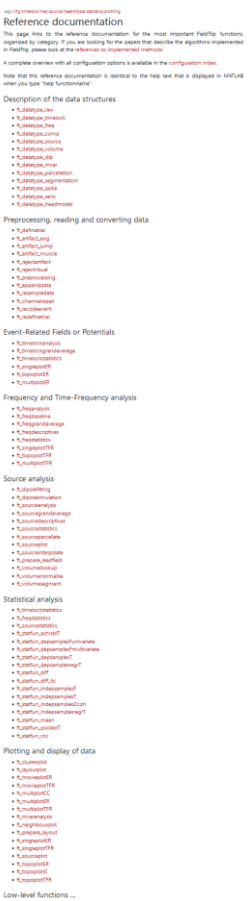
Fieldtrip toolbox: code example



Fieldtrip toolbox: the website



Fieldtrip toolbox: functions



ftp://ftp.fieldtrip.org/pub/fieldtrip/doc/datatypes.html

Reference documentation

This page links to the reference documentation for the most important FieldTrip functions, organized by category. If you are looking for the papers that describe the algorithms implemented in FieldTrip, please look at the references to implemented methods.

A complete overview with all configuration options is available in the configuration index.

Note that this reference documentation is identical to the help text that is displayed in MATLAB when you type "help functionname".

Description of the data structures

- ft_datatype_raw
- ft_datatype_timelock
- ft_datatype_freq
- ft_datatype_comp
- ft_datatype_source
- ft_datatype_volume
- ft_datatype_dip
- ft_datatype_mvar
- ft_datatype_parcellation
- ft_datatype_segmentation
- ft_datatype_spike
- ft_datatype_sens
- ft_datatype_headmodel

Preprocessing, reading and converting data

- ft_definetrial
- ft_artifact_ecg
- ft_artifact_jump
- ft_artifact_muscle
- ft_rejectartifact
- ft_rejectvisual
- ft_preprocessing
- ft_appenddata
- ft_resampledata
- ft_channelrepair
- ft_recodeevent
- ft_redefinetrial

Event-Related Fields or Potentials

- ft_timelockanalysis
- ft_timelockgrandaverage
- ft_timelockstatistics
- ft_singleplotER
- ft_topoplotER
- ft_multiplotER

Frequency and Time-Frequency analysis

- ft_freqanalysis
- ft_freqbaseline
- ft_freqgrandaverage
- ft_freqdescriptives
- ft_freqstatistics
- ft_singleplotTFR
- ft_topoplotTFR
- ft_multiplotTFR

Source analysis

- ft_dipolefitting
- ft_dipolesimulation
- ft_sourceanalysis
- ft_sourcegrandaverage
- ft_sourcedescriptives
- ft_sourcestatistics
- ft_sourceparcellate
- ft_sourceplot
- ft_sourceinterpolate
- ft_prepare_leadfield
- ft_volumelookup
- ft_volumenormalise
- ft_volumesegment

Statistical analysis

- ft_timelockstatistics
- ft_freqstatistics
- ft_sourcestatistics
- ft_statfun_actvsblT
- ft_statfun_depsamplesFunivariate
- ft_statfun_depsamplesFmultivariate
- ft_statfun_depsamplesT
- ft_statfun_depsamplesregrT
- ft_statfun_diff
- ft_statfun_diff_itc
- ft_statfun_indepsamplesF
- ft_statfun_indepsamplesT
- ft_statfun_indepsamplesZcoh
- ft_statfun_indepsamplesregrT
- ft_statfun_mean
- ft_statfun_pooledT
- ft_statfun_roc

Plotting and display of data

- ft_clusterplot
- ft_layoutplot
- ft_movieplotER
- ft_movieplotTFR
- ft_multiplotCC
- ft_multiplotER
- ft_multiplotTFR
- ft_mvaranalysis
- ft_neighbourplot
- ft_prepare_layout
- ft_singleplotER
- ft_singleplotTFR
- ft_sourceplot
- ft_topoplotER
- ft_topoplotIC
- ft_topoplotTFR

Low-level functions ...

Fieldtrip toolbox: docs & tutos

Documentation

The tutorials will help you to get started by providing examples that you can copy-and-paste into MATLAB. The introduction tutorial provides a short introduction in the the ideas behind the FieldTrip toolbox. The Walkthrough will give you a more thorough overview of the conceptual ideas behind MEG and EEG analysis and how the toolbox is used.

The frequently asked questions section provides a lot of practical information. Furthermore, the example MATLAB scripts contain pieces of documentation that are often not so elaborate as the tutorials, but that go in more detail into specific aspects of the data, code or analysis.

In the reference documentation you find an overview of all main functions in FieldTrip and the configuration index has a list of their configuration options.

Sometimes we prepare dedicated course material for workshops, which is also shared on this website, together with video recordings of lectures.

If you are very eager to get started with your specific data, please proceed to the user documentation section on importing your own data.

- Walkthrough
- Tutorial documentation
- Frequently asked questions
- Example MATLAB scripts
- Reference documentation and configuration index
- Video lectures
- References to implemented methods
- Review and teaching material
- Template models and data
- Realtime BCI

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Overview of all tutorials

The tutorials contain background on the different analysis methods and include code that you can copy-and-paste in MATLAB to walk through the different analysis options. The frequently asked questions and example scripts are other forms of documentation.

Some of these tutorials are also used during the "Advanced EEG/MEG analysis" toolkit course that is presented at the Centre for Cognitive Neuroimaging of the Donders Institute for Brain, Cognition and Behaviour each year. Furthermore, we use these tutorials during the various workshops.

For information on what types of datasets we have here on FieldTrip, and which datasets are used in which tutorials see this overview of the datasets used in the tutorials.

When adding or contributing to the tutorials please consider the documentation guidelines.

Introduction to FieldTrip and MATLAB

- Introduction to the FieldTrip toolbox
- Creating a clean analysis pipeline
- Making a memory efficient analysis pipeline
- Speeding up your analysis with distributed computing

Reading and preprocessing data

- Preprocessing - Reading continuous EEG and MEG data
- Preprocessing - Trigger based trial selection
- Introduction on dealing with artifacts
- Visual artifact rejection
- Automatic artifact rejection

Sensor-level analyses

- Event-related fields and MEG planar gradient
- Preprocessing of EEG data and computing ERPs
- Preprocessing and event-related activity in combined MEG/EEG data
- Time-frequency analysis using Hanning window, multitapers and wavelets
- Time-frequency analysis of combined MEG/EEG data
- Sensor-level ERF, TFR and connectivity analyses
- Extracting the brain state and events from continuous sleep EEG

Source reconstruction

- Construct a headmodel for MEG source analysis
- Construct a BEM headmodel for EEG source analysis
- Construct a FEM headmodel for EEG source analysis
- Construct a sourcemodel for MEG or EEG source analysis
- Localizing electrodes using a 3D-scanner
- Localizing oscillatory sources in MEG data using a beamformer
- Beamforming oscillatory responses in combined MEG/EEG data
- Localizing visual gamma and cortico-muscular coherence
- Source reconstruction of event-related fields using minimum-norm estimation
- Dipole fitting of combined MEG/EEG data
- Computation of virtual MEG channels in source-space
- Virtual channel analysis of epilepsy MEG data

Analysis of intracranial data

- Analysis of human ECoG and sEEG recordings
- Analysis of monkey ECoG recordings
- Channel and source analysis of mouse EEG
- Preprocessing and analysis of spike-train data
- Preprocessing and analysis of spike and LFP data

Analysis of TMS-EEG data

- Dealing with TMS-EEG datasets

Analysis of fNIRS data

- Preprocessing and averaging of single-channel NIRS data
- Preprocessing and averaging of multi-channel NIRS data

Connectivity analysis

- Analysis of corticomuscular coherence
- Analysis of sensor- and source-level connectivity
- Extended analysis of sensor- and source-level connectivity
- Whole brain connectivity and network analysis
- Whole brain connectivity and network analysis (2) - EEG

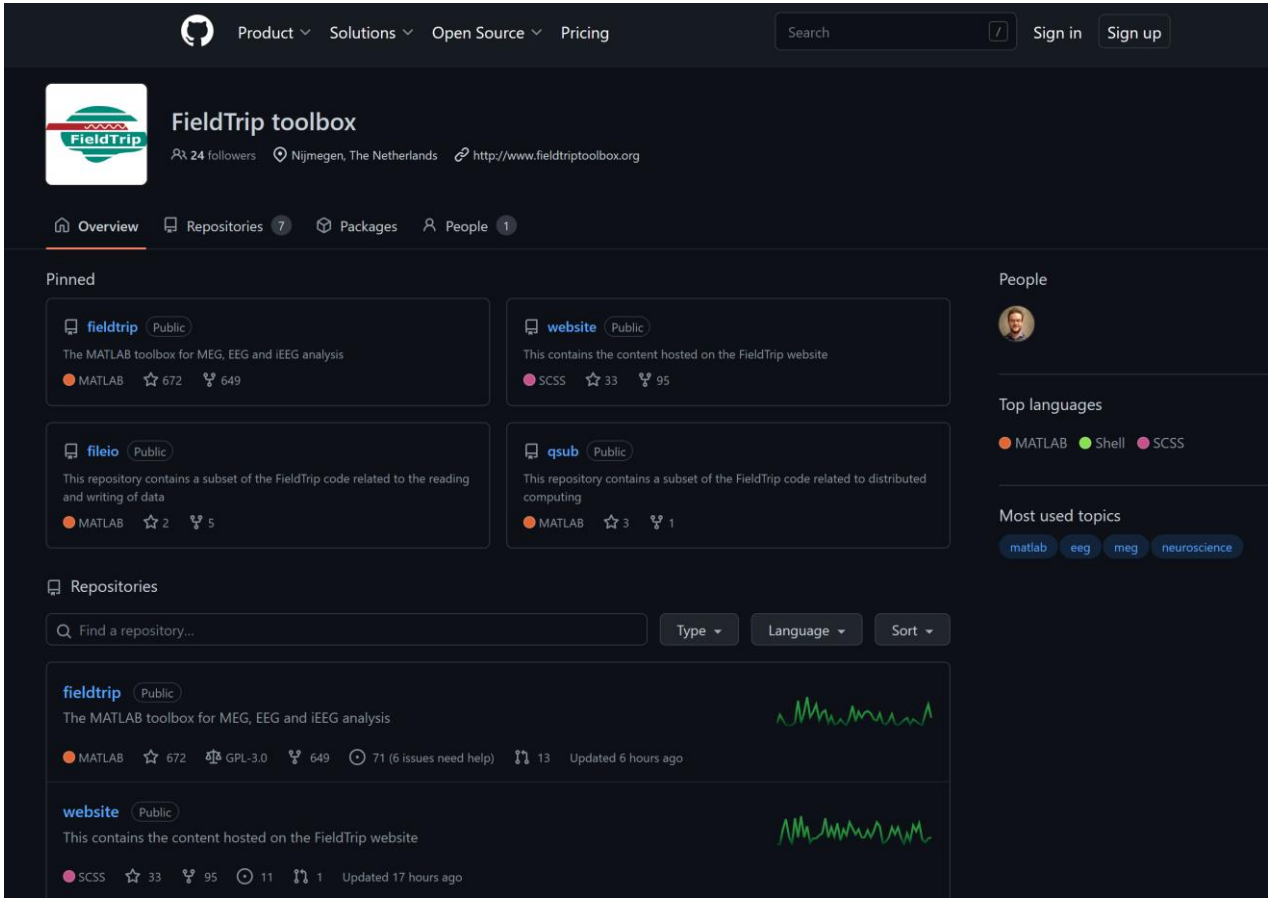
Statistical analysis

- Parametric and non-parametric statistics on event-related fields
- Cluster-based permutation tests on event-related fields
- Cluster-based permutation tests on time-frequency data
- Statistical analysis and multiple comparison correction for combined MEG/EEG data
- Multivariate analysis of MEG/EEG data (based on the MVPA light toolbox)

Plotting and visualization

- Specifying the channel layout for plotting
- Plotting data at the channel and source level

Fieldtrip toolbox: the git developpment



Fieldtrip toolbox: comparison with other toolboxes

		EEGLAB	*FieldTrip*	*Brainstorm*	*SPM*	*MNE-python*
Toolbox link		https://eeglab.org	https://www.fieldtriptoolbox.org/	https://neuroimage.usc.edu/brainstorm/	https://www.fil.ion.ucl.ac.uk/spm/	https://mne.tools
Environment		MATLAB	MATLAB	MATLAB	MATLAB	Python
Recommended programming level		Beginners to advanced	Intermediate to advanced	Beginners to advanced	Beginners to advanced	Intermediate to advanced
Interface		GUI and scripting	Scripting	GUI and scripting	GUI and scripting	Scripting
Supported modalities		EEG, eye tracking, MoBI	MEG, EEG, iEEG, fNIRS, Multiunit, motion capture, eye tracking, (f)MRI	MEG, EEG, iEEG, fNIRS, Multiunit, motion capture, eye tracking, MRI	(f)MRI, PET, EEG, and MEG	MEG, EEG, iEEG, fNIRS
BIDS support		bids-matlab-tools (Delorme et al., 2021)	data2bids (github.com/fieldtrip/fieldtrip/blob/release/data2bids.m)	BIDS tools (neuroimage.usc.edu/brainstorm/ExportBids)	en.wikibooks.org/wiki/SPM/BIDS	MNE-BIDS (Appelhoff et al., 2019)
Online community and support		✔	✔	✔	✔	✔
Strengths		- Advanced ICA integration	- High flexibility	- No progamming skills required	- Dynamic Causal Modeling (DCM)	- High flexibility
		- Mobile brain imaging (MoBI)	- Frequency and time-frequency analysis	- Advanced visualization & user interface	- Advanced statistics (native GLM support)	- Machine-learning (scikit-learn)
		- Advanced statistics incldluing GLM support	- Non-parametric statistics	- Automatic data organization	- Bayesian source analysis framework	- Source estimation
		- Numerous extensions	- Sophisticated forward models	- Interoperates with multiple MATLAB, Python packages	- Support for fMRI, PET, VBM as well	- Freesurfer integration
References	Seminal paper	Delorme and Makeig (2004), Delorme et al. (2011)	Oostenveld et al. (2011)	Tadel et al. (2011)	Friston et al. (1994); Litvak et al. (2011)	Gramfort et al. (2013), (2014)

Niso et al., 2022