

# RT-NET

Real-time noninvasive electrophysiology  
toolbox

USER MANUAL

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## Introduction and requirements

RT-NET is a MATLAB toolbox for real-time source estimation using high-density EEG (hdEEG). The toolbox can perform 2D and 3D source activity visualization and source-based neurofeedback experiments.

RT-NET requires MATLAB R2016b (MathWorks) or later versions.

The following additional packages are included in RT-NET:

- SPM12 <https://www.fil.ion.ucl.ac.uk/spm/software/spm12/>
- EEGLAB <https://sccn.ucsd.edu/eeglab/>
- Fieldtrip <http://www.fieldtriptoolbox.org/>
- OpenMeeg <http://openmeeg.github.io/>
- Brainstorm <https://neuroimage.usc.edu/brainstorm/>
- Lab Streaming Layer (LSL) <https://github.com/labstreaminglayer/>
- Psychtoolbox-3 <http://psychtoolbox.org/>
- ICLabel <https://sccn.ucsd.edu/wiki/ICLabel>

The LSL app, OpenMeeg, *LSL\_Demo\_1.2.exe* and *Psychtoolbox-3* (in the folder *External to install*) need to be installed before the first initialization of RT-NET.

ICLabel needs to be installed and compiled.

Actually, this version of RT-NET works in Windows platforms. To work in MacOS, LSL has to be re-compiled.

## Supported Hardware

RT-NET supports the following EEG systems:

- actiCHamp (Brain Products GmbH, Gilching, Germany)
  - 128 channels (ActiCAP)

- 64 channels (ActiCAP)
- Electrical Geodesics (Eugene, US)
  - 256 channels (HydroCel Geodesic Sensor Net)
  - 128 channels (HydroCel Geodesic Sensor Net)
  - 64 channels (HydroCel Geodesic Sensor Net)
- eego sports (ANT Neuro, Enschede, The Netherlands)
  - 128 channels (Waveguard)
- SynAmps (NeuroScan Corporation, El Paso, US)
  - 128 channels (quickCap)
  - 64 channels (quickCap)
- ActiveTwo (Biosemi, Amsterdam, The Netherlands)
  - 128 channels
  - 64 channels
- Mobile-XX (Cognionics Inc, San Diego, US)
  - 128 channels (Mobile-128)
  - 64 channels (Mobile-64)

### Preliminary steps

If the user is operating with one of the following systems, he/she has to acquire an EEG dataset. This process needs to be performed only before the first utilization of the following systems.

Each EEG recording has to be saved with the appropriate name in the .sfp format, as listed below.

- EGI (128 and 64 channels)
  - *'template\_128\_EGI'*
  - *'template\_64\_EGI'*
- ANT (128 channels)
  - *'template\_128\_ANT'*

- Neuroscan (128 and 64 channels)
  - *'template\_128\_neuroscan'*
  - *'template\_64\_neuroscan'*
- Biosemi (128 and 64 channels)
  - *'template\_128\_biosemi'*
  - *'template\_64\_biosemi'*

Then, the EEG acquisition file needs to be copied in the folder *RT\_NET\_dir\template\template\_eeg\name of the system'*. After, it is possible to start the experimental session.

## Launching the GUI

First, the user has to start MATLAB with administrator privileges. The GUI can be launched from MATLAB environment by opening the RT-NET folder and then typing in the command line:

```
>> run_RT_NET
```

This opens the user interface and allows to start a new analysis.

## Starting the analysis

At the beginning, the user has to start a new study selecting *File* → *New Study*.

## Study Overview

After, all the windows of RT-NET will be opened but only *Study Overview* tab (figure 2) will be activated. Here, the user can choose the output folder and which EEG sensor montage under consideration.

Finally, it is possible to visualize the path of the output folder and the name of the subject.

Now a new folder, called with subject's name, has been created in the selected directory.

At the end, *Head Segmentation* window will be activated.

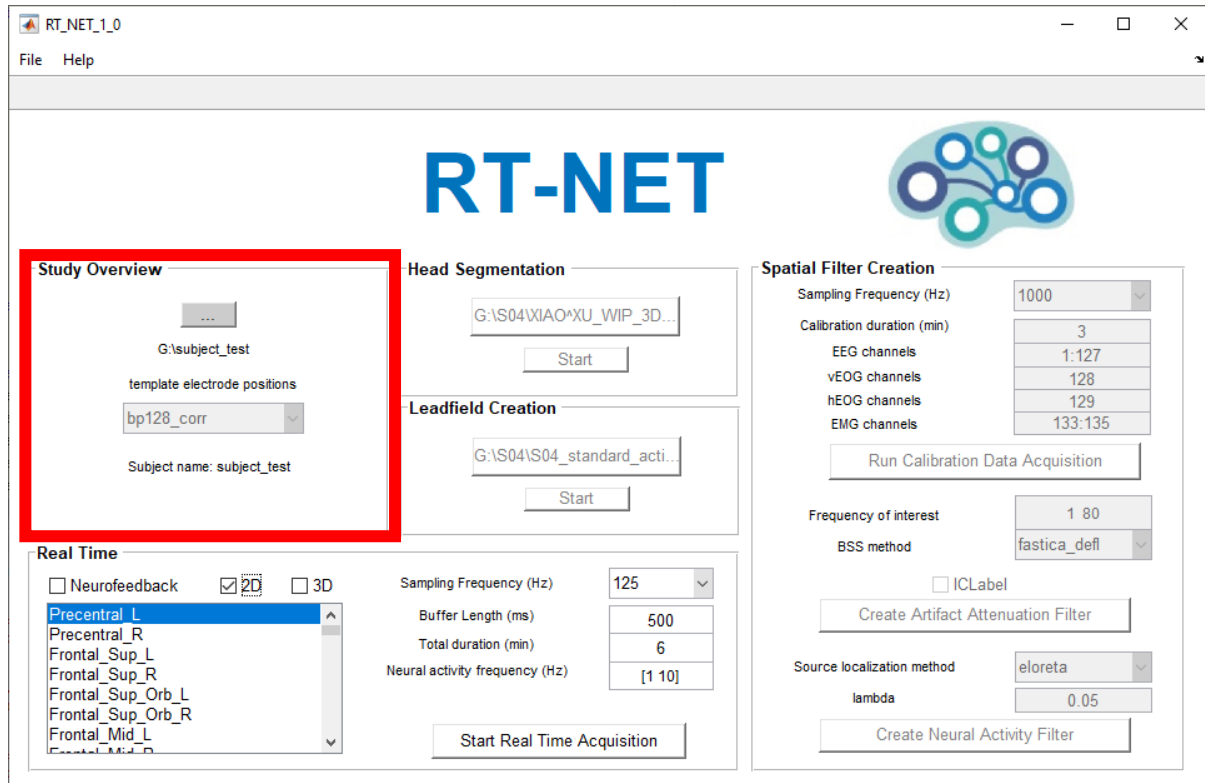


Figure 1

## Head Segmentation

In this tab (figure 3), the user can perform the segmentation of MR into 3 tissue classes.

The user needs to load a .nii file containing the anatomy of the subject's head. In absence of it, it is possible to load an anatomy template "Colin27" .nii file from the *RT\_NET\_dir\template\anatomy* folder in RT-NET directory.

Then, the segmented MR image will be automatically processed, and the results will be saved in the folder *RT\_NET\_dir\subject\_name\calibration\mr\_data* and *Leadfield Creation* window will be activated.

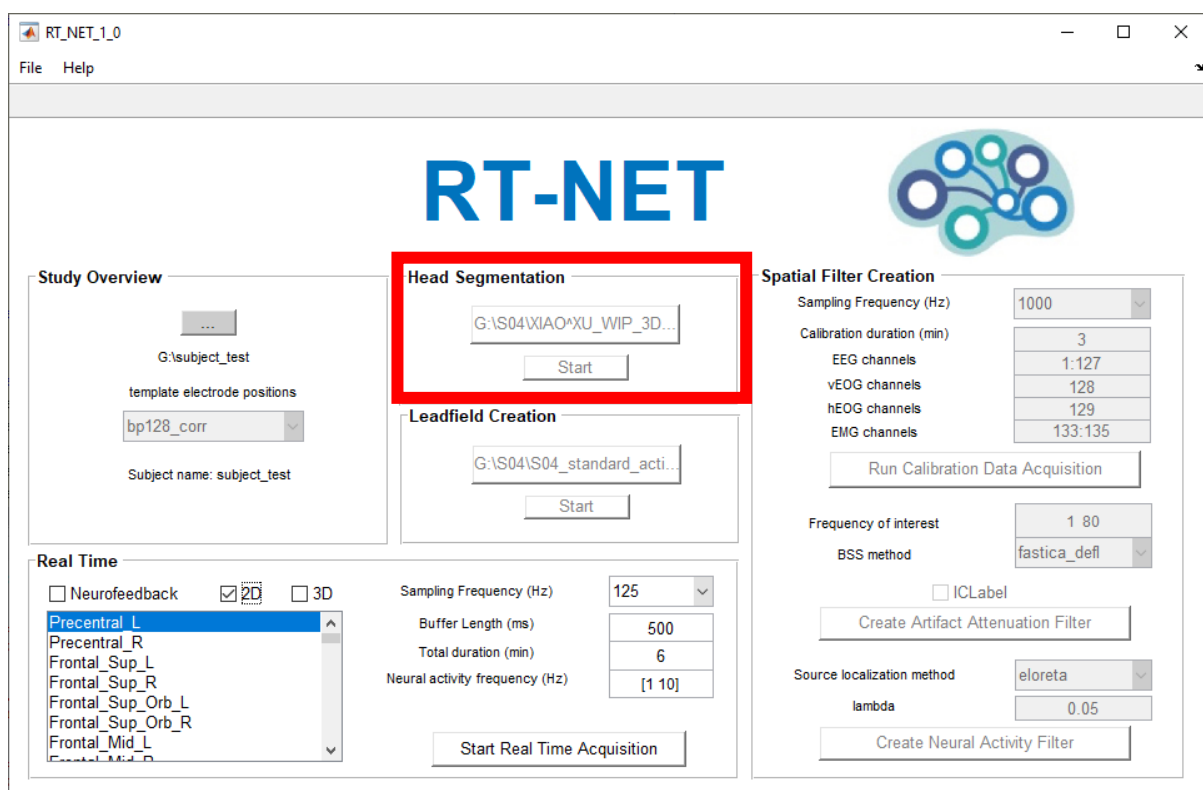


Figure 2



## Leadfield Creation

In *Leadfield Creation* tab (figure 4), RT-NET performs the creation of a leadfield matrix that links brain activity sources and electric potentials to be defined at electrode level.

The user needs to load a .sfp or .elc file containing the electrode positions acquired over the subject's scalp. Finally, it is possible to run this module and to activate *Spatial Filter Creation*. The results will be saved in the folder *RT\_NET\_dir\subject\_name\calibration\mr\_data*.

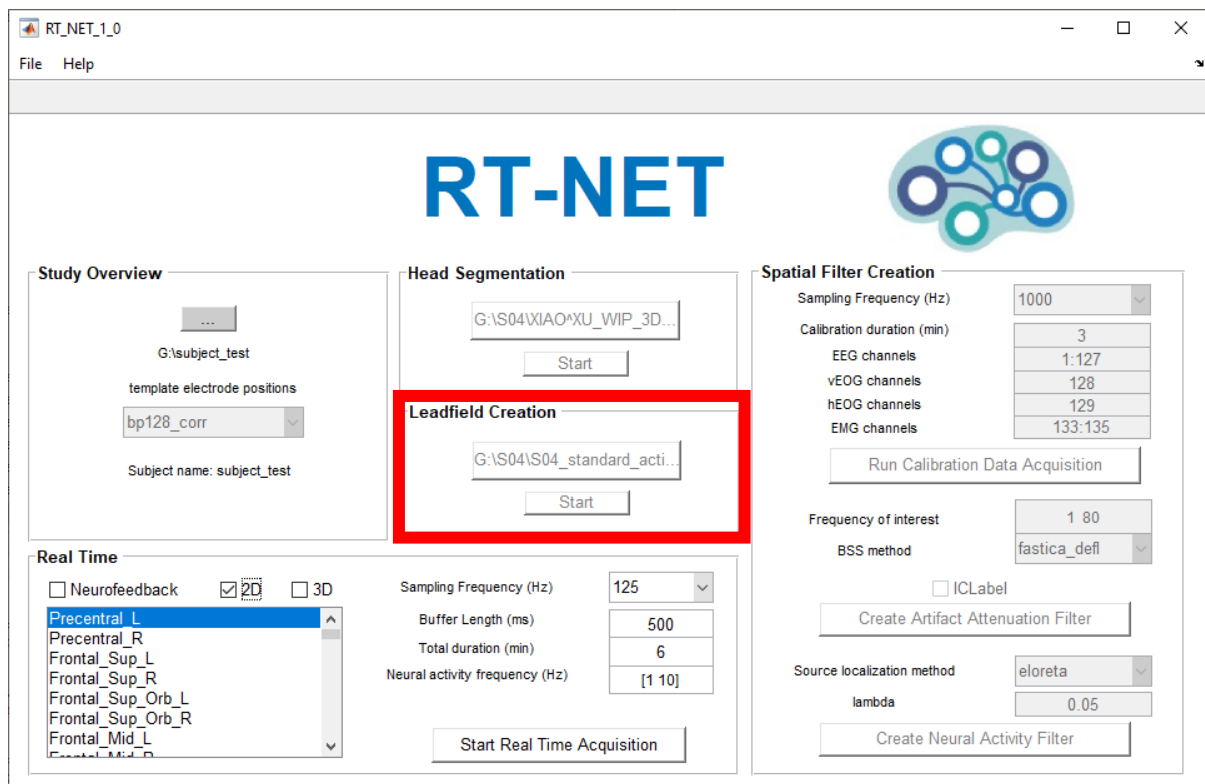


Figure 3

## Spatial Filter Creation

In this window (figure 5), the user needs to select several parameters:

- The sampling frequency (in Hz) of acquisition between the ones that are specified in the popup menu
- The duration of the calibration acquisition (in minutes and it cannot be empty)
- The EEG channels (it cannot be empty)
- The vertical EOG channels (it cannot be empty)
- The horizontal EOG channels (it cannot be empty)
- The EMG channels (it cannot be empty)
- The type of blind source separation method (fastica deflation, fastica symmetric, jade, Infomax)
- The possibility to use ICLabel for automated independent components recognition. If not selected, a technique developed by the authors will be applied

Once all the parameters are selected, it is possible to start the acquisition of the calibration recording while the subject will fixate a cross on the screen (figure 5).

After, it is possible the Artifact Attenuation filter creation by pressing the relative button.

The user can choose, from the popup menu, among several source localization methods:

- eLORETA (there is the possibility to choose the regularization parameter)
- sLORETA
- LCMV
- MNE
- wMNE

After the selection, it is possible to create the neural activation filter.

Only when all these steps are performed, the *Real Time* window will be activated.

The acquired signal and the artefact filter will be saved in *RT\_NET\_dir\subject\_name\calibration\eeg\_signal*, whereas the neural activity filter will be saved in *RT\_NET\_dir\subject\_name\calibration\eeg\_source*.

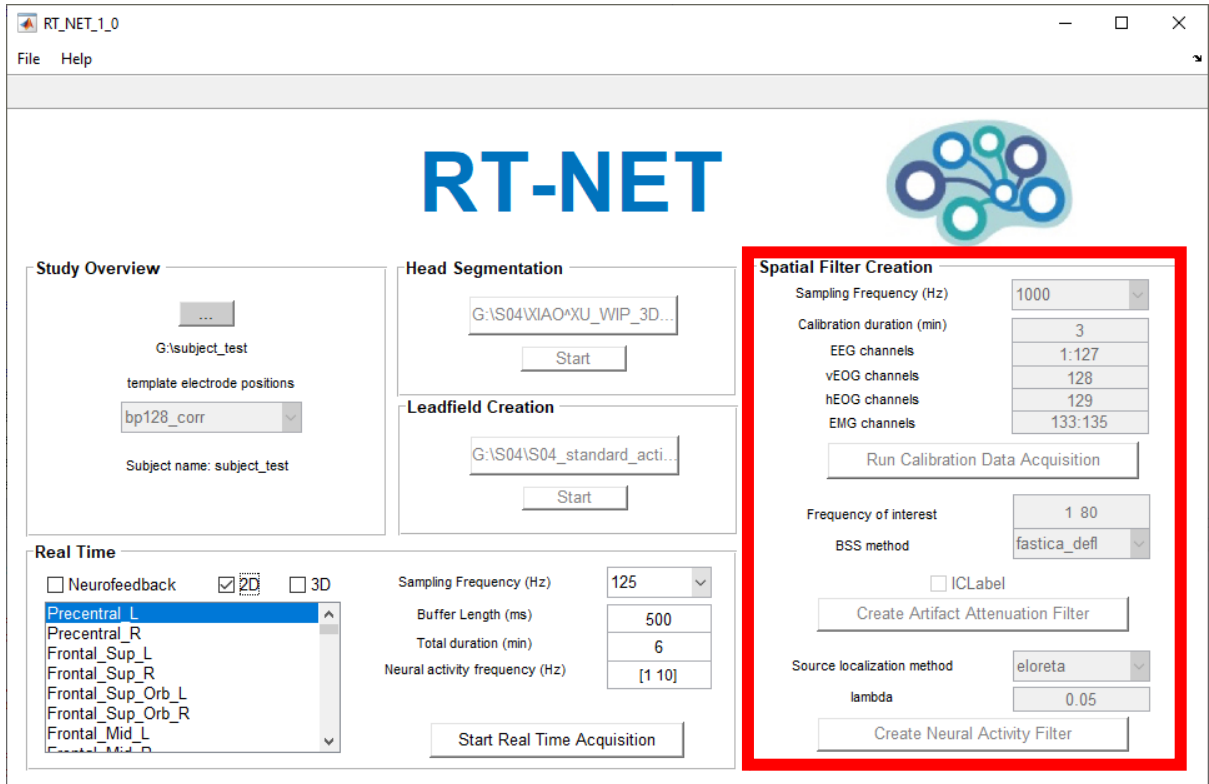


Figure 4

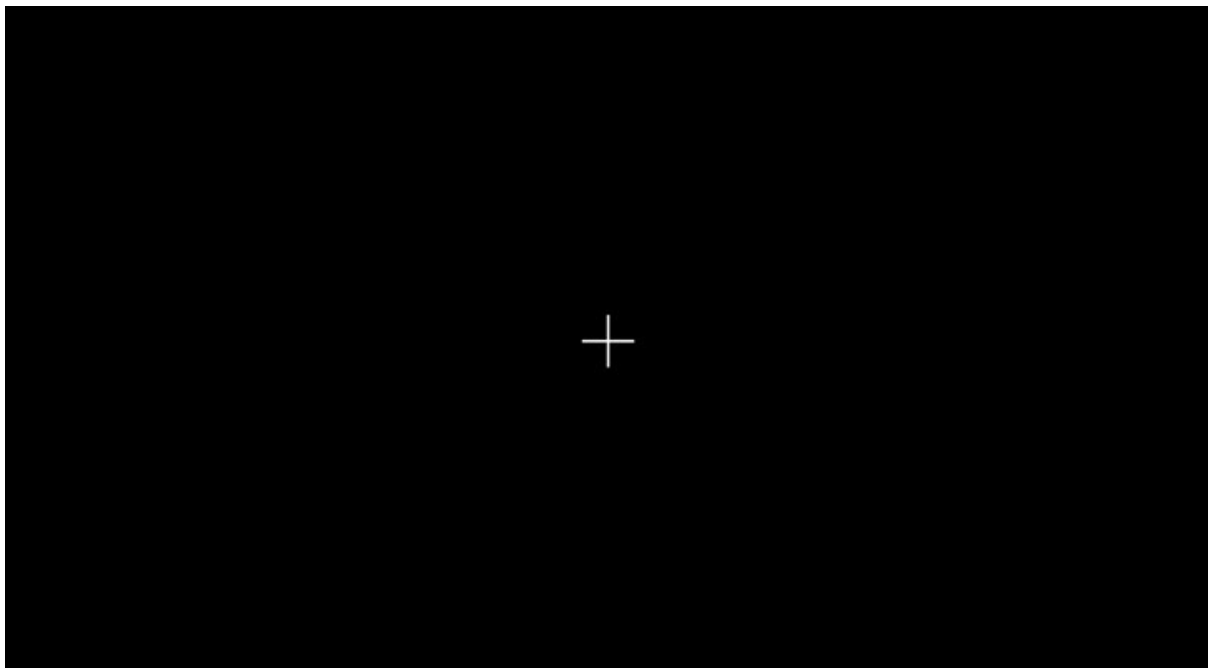


Figure 5

## Real Time

In this window (figure 6), the user can perform real-time experiments.

The choice of the experiment is among

- **Neurofeedback** in one or two brain areas to select in the list (figure 7);
  - The list is loaded from a template file located in the software folder *RT\_NET\_dir\template\seeds* under the name *seed\_RT\_NET*;
- Real-time visualization of time-courses related to neural activity in one or more brain areas (**2D**) (figure 8);
- **3D** Real-time visualization on a 3D freely rotatable cortical surface (figure 9).

Moreover, the user has to select:

- The sampling frequency (in Hz) of acquisition between the ones that are specified in the popup menu;
- Buffer data duration (in milliseconds and it cannot be empty);
- The duration of the calibration acquisition (in minutes it cannot be empty);
- The block acquisition duration (in seconds) for the alternance task/rest (not for 2D visualization).

Once all the parameters are selected, it is possible to start the real-time experiment.

When the experiment is concluded, in the subject folder the user can find all the acquired real-time signals under the folder *subject\_name\real\_time*.

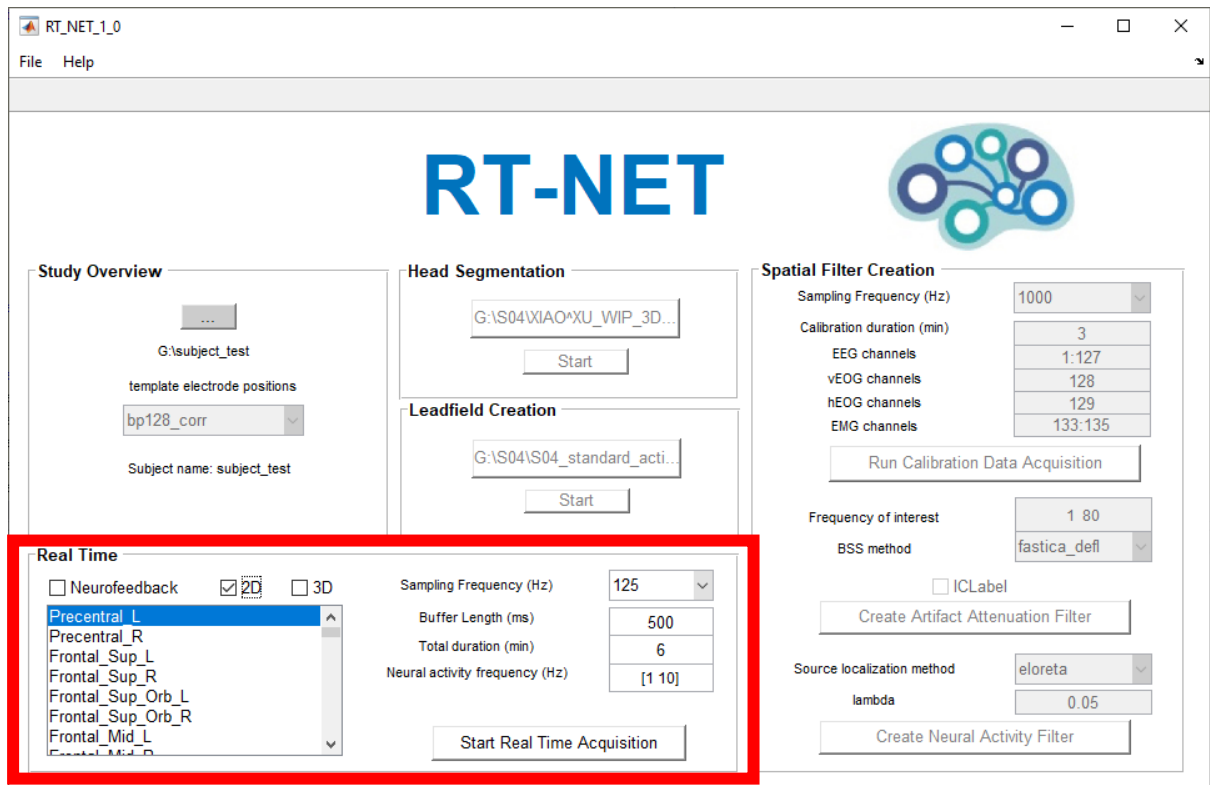


Figure 6

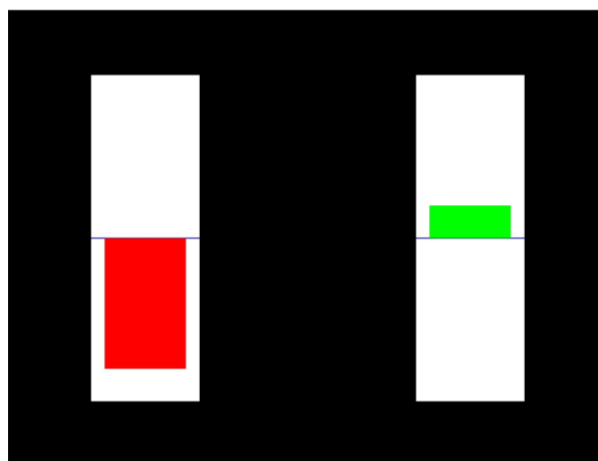


Figure 7

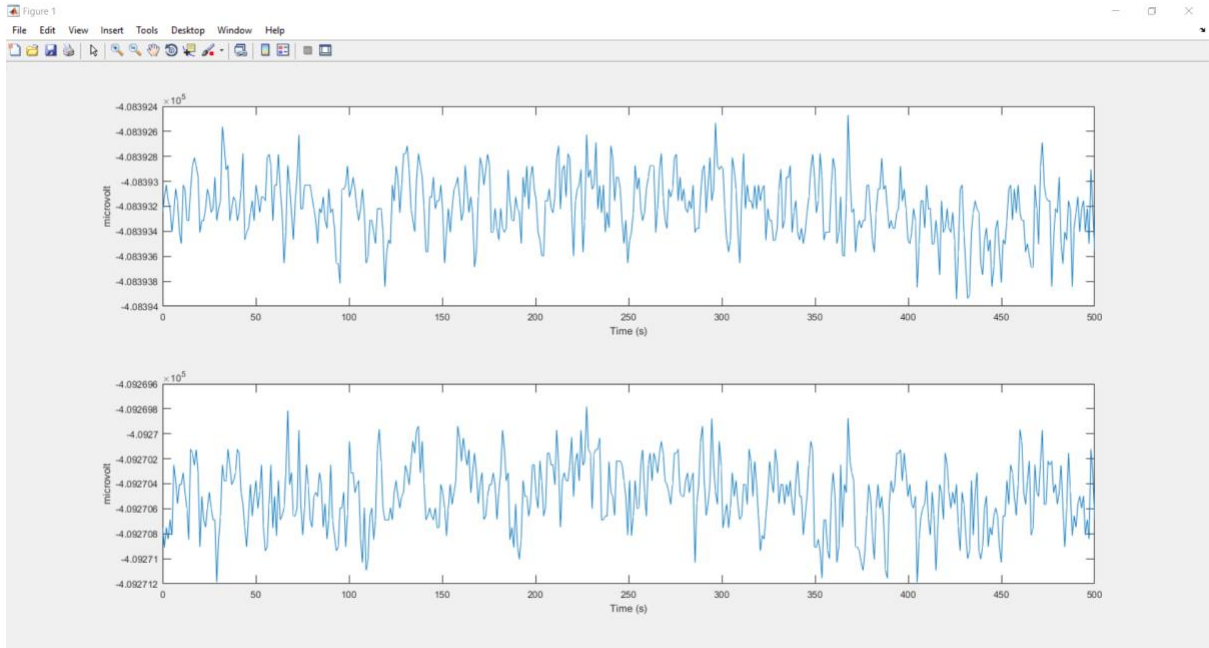


Figure 8

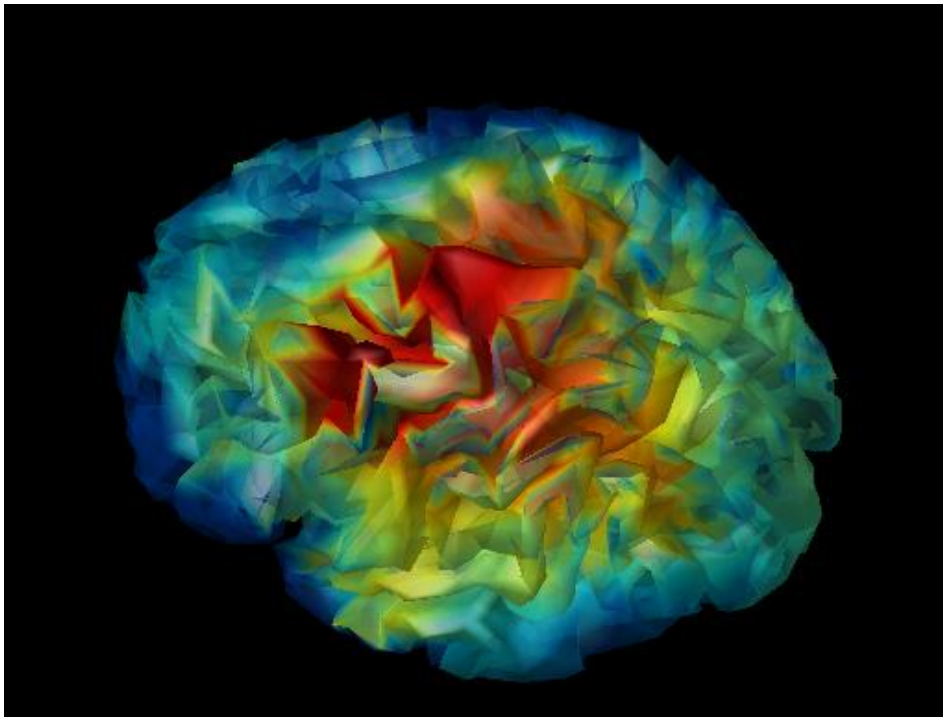


Figure 9

## Additional information

RT-NET software, together with the user manual, is freely available for download at <https://www.nitrc.org/projects/rtnet/> and <https://github.com/robertoguarnieri/rtnet>

For further information on RT-NET GUI and on the automated pipelines, it is possible to refer to the following manuscripts:

- Guarnieri, R., Marino, M., Barban, F., Ganzetti, M., Mantini, D. (2018).  
Online EEG artifact removal for BCI applications by adaptive spatial filtering.  
*Journal of Neural Engineering*, 15(5), 056009.  
<https://doi.org/10.1088/1741-2552/aacfd>
- Guarnieri, R., Zhao, M., Taberna, G.A., Ganzetti, M., Swinnen S.P., Mantini, D (2019).  
RT-NET: real-time reconstruction of neural activity using high-density EEG.  
Under revision