BrainAreaR:

A tool for electrophysiological analysis and functional pattern detection

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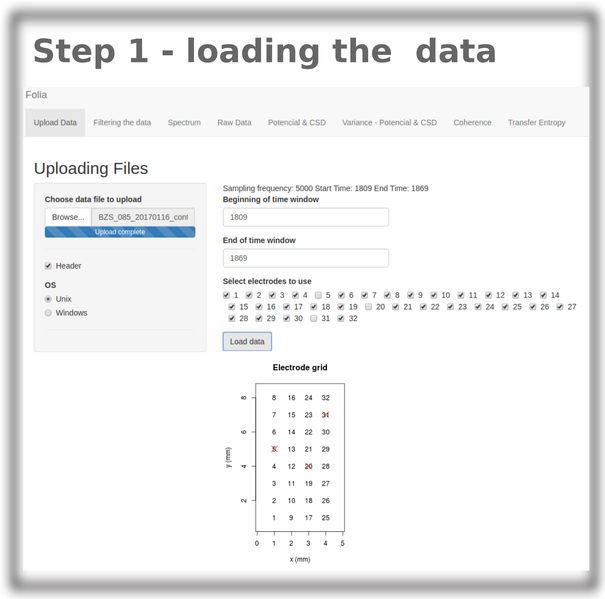
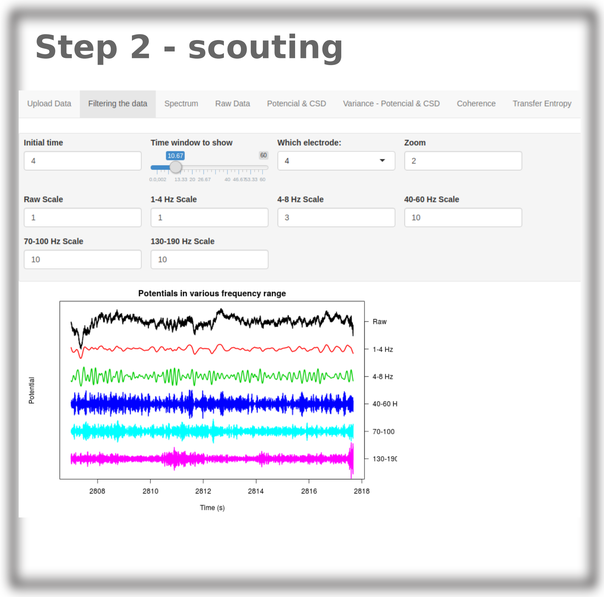
The recent development in multielectrode array technology enables recording of potential with a high spatio-temporal resolution and to use more sophisticated experimental setups. There is a parallelly emerging need for more complex quantities describing the activity and spatial interaction of neuron population and visualization.We aim to target this demand by the BrainAreaR, a software with graphical user interface developed in R. Besides generating images of simple quantities as raw and filtered data, power and frequency spectrum, kernel source density distribution map and coherence is also calculated. One of the main features is the coherence-clustering which can be used for identifying functionally cohesive neuron population. This might be of special interest for those interested in changes of population level interactions under various paradigms. An application of this software is demonstrated on data from freely moving rat recorded by a 4x8 channel foli based multielectrode with 1 mm interelectrode distance. The result of the coherence clustering is a map that shows strong similarity to the underlying anatomical cortical area map (more on F. Fedor's poster).



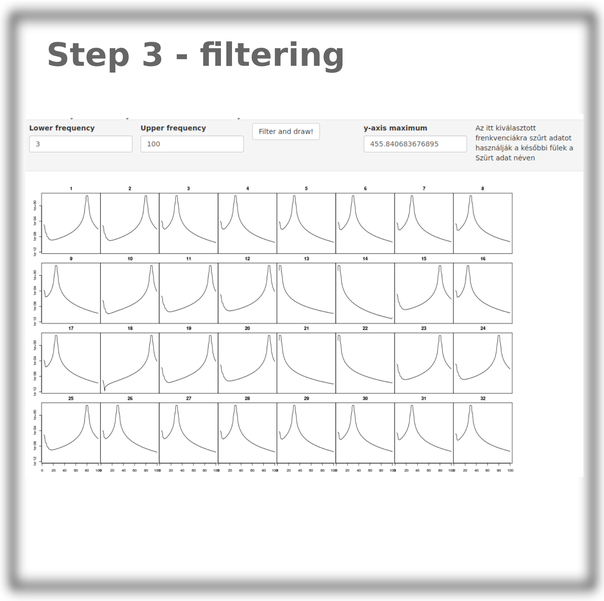


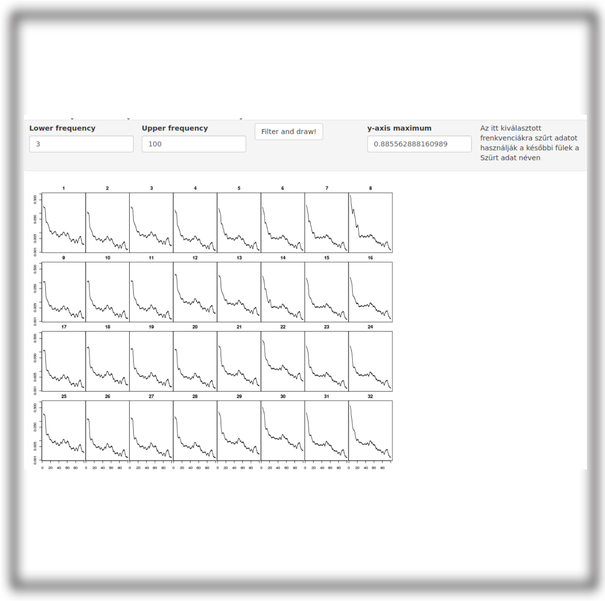
Running BrainArear

Step 1 - loading the data
After selecting the data file, the sampling frequency and the time range of the recording will be detected, an option to load only part of the data is available as well. Certain channels might be discarded from the further analysis, which can be useful in case of damaged electrodes, which will be marked by red crosses on the electrode distribution map.

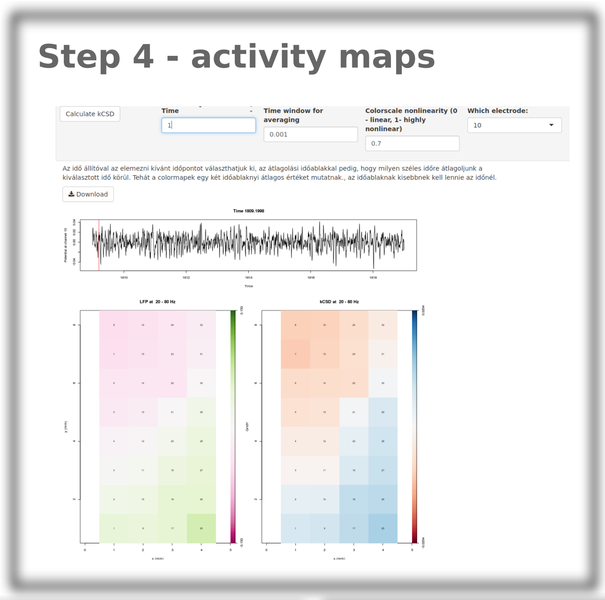
Step 2 - scouting
A simple view of the raw filtered data is provided for a certain time window and channel on the second tab. 5 frequency bands are shown and amplitude scaling is provided. This figure is intended to help the filtering of the data.

Step 3 - filtering
A frequency range of interest can be selected on the next panel and the spectral density related to each channel will appear on seperate figures.
The peaks of different frequences in case of the simulated are clearly visible. In case of the experimental data the frequency spectrum of an awake animal shows the typical drop of intensity at higher frequencies, on some channels a cpeak at th 40-60 Hz regime can be observed.

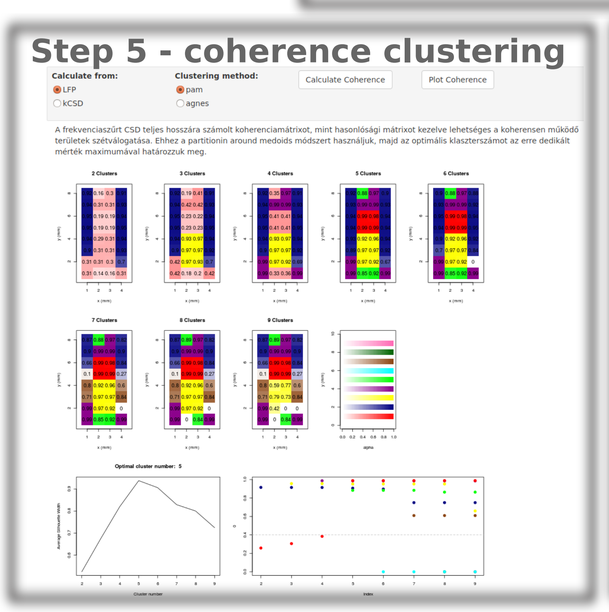


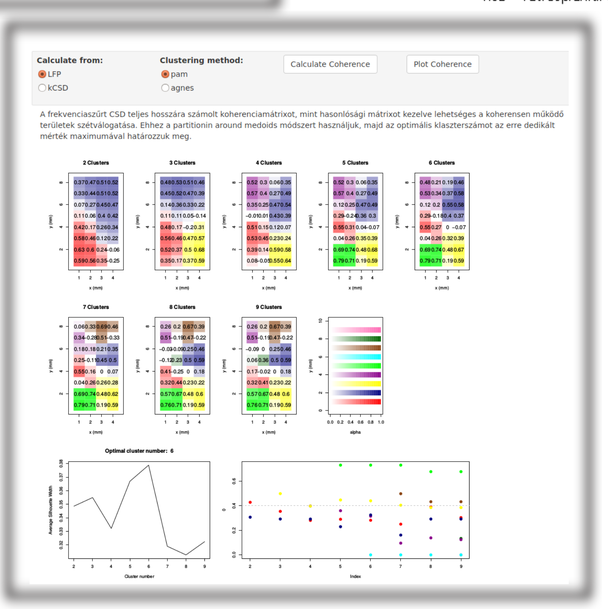


Step 4 - activity maps
A colorcoded spatial distribution of the potential and kCSD values, as this latter is a more direct measure of the underlying neural mechanisms [Potworowski, Jan, et al. "Kernel current source density method." Neural computation 24.2 (2012): 541-575.] at a certain timestep is displayedon the next tab. By selecting arbitrary instants in time or downloading a short video along time might helps in observing spatial pattern formation and propagation.



Step 5 - coherence clustering
In this case coherence [https://en.wikipedia.org/wiki/Coherence_(signal_processing)] can be interpreted as a measure, which informs about how much populations are co-working. Between two time series a value close to 1 means very similar patterns with a certain delay in time, a value close to 0 means negligible relationship. For the purpose of estimating relationships between populations, it is possible tovselect either the extracellular potentials or the kCSD values.. Calculating the coherence between all the kCSD values related to the population of neurons close to the certain electrodes resulted in a table informing about the similarities between the functional behavior of the neuron populations. By applying the partitioning around medoids clustering algorithm [Kaufman, Leonard, and Peter J. Rousseeuw. Finding groups in data: an introduction to cluster analysis. Vol. 344. John Wiley & Sons, 2009.] we aimed to identify the functionally cooperating brain areas. The reasonable number of clusters were selected by the average silhouette width measure. Global and local maxima values were considered as meaningful for indicating the number of optimal clusters with an expectation to be greater than 0.4. The resulted map of functionalb rain areas might be used for estimating the anatomical brain areas and show changes in electrophysiological behavior due to various brain states or drugs.
Validating the method on the simulated data it is visible, that the channels group according to their frequencies and the silhouette width measure finds the optimal number of clusters.
In case of the experimmental data, based on the recordings of an awake animal 6 clusters were found to be optimal, which could be identified with the V1, V2, S1, M, MPta and LtA corteces.

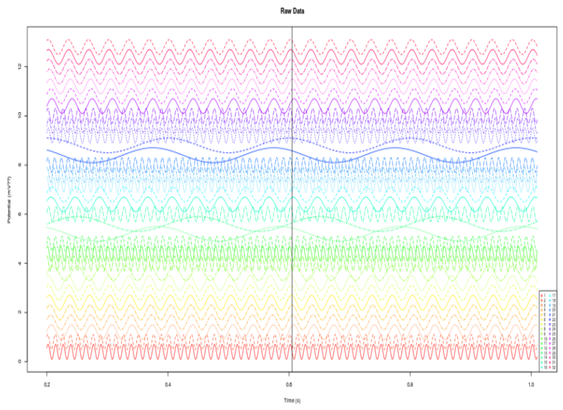




How to get BrainAreaR?

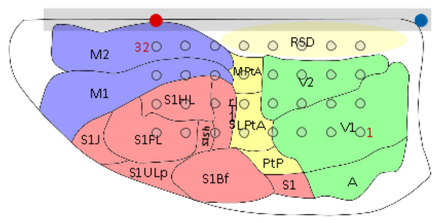
Checkout/download the git repository from:
https://bitbucket.org/csdori/brainarear
Currently it is a for 4x8 electrode arrangements with a 1mm interelectrode distance. The channel order must be given as in the example file. In order to be able to run the scripts R and RStudio must be installed as well as certain libraries.

Simulated data
The 32 channel simulated data was constructed of 5 sinusoidal of frequencies 5, 25, 30, 80, 90 Hz and between the channel containing the same frequency data a phase shift was applied.



Experimental data
EEG recording was made on 36 channels (32 for the electrode, 1 for the events and 3 for the accelerometers) at 20 kHz sampling rate using AmpliRec (Amplipex Ltd.) program. The electrode were placed directly onto the brain surface. The 25th contact was positioned 0.5 mm lateral, in line with the Bregma and the longitudinal axis of the assembly was parallel to the mid-sagittal line. For more details about the methods see F. Fedor's poster.

M1 – Primary motor cortex
M2 – Secondary motor cortex
S1J – Primary somatosensory cortex, jaw region
S1FL – Primary somatosensory cortex, forelimb region
S1ULp – Primary somatosensory cortex, upper lip region
S1Sh – Primary somatosensory cortex, shoulder region
S1Tr – Primary somatosensory cortex, trunk region
S1Bf – Primary somatosensory cortex, barrel field
S1 – Primary somatosensory cortex
MPtA – medial parietal association cortex
LPtA – lateral parietal association cortex
PtP – Parietal cortex, posterior area
V2 – secondary visual cortex
V1 – primary visual cortex
A – auditory areas
RSD – retrosplenial dysgranular cortex



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F. Fedor's poster

D. Cserpáns poster