Localizing epileptogenic network from SEEG recordings using Epileptogenicity Ranking method

Epileptogenicity Rank (ER) is a modified method of EI for quantifying epileptogenicity of brain structures in epilepsy patients. ER was calculated as the normalized values of the product of spatio-temporal parameter and energy of the signal. The spatial parameter was added along with the existing temporal domain based index calculation (EI) (Bartolomei et al., 2008) to bring the new epileptogenicity rank (ER). We set the range of ER from 1 to 10, 'ER=1' being highly epileptogenic and normal brain ranked as 'ER=10'. ER classifies the seizure onset from the propagation using abrupt frequency change in the time domain and the spatial domain by the anatomical distance from the brain structure that initiated the seizure discharges.

The EZ localization was partially automated by converting the time-series data to the frequency spectrum and applied a threshold over the mean activity to detect the seizure onset. Page and Hinkely's algorithm was implemented for seizure onset detection (Hinkley, 1971; Page, 1954). ER needs two parameters to localize epileptogenic zone (EZ) 1) SEEG and 2) The 3D location of SEEG electrode contacts.

Prerequisites

1. **MATLAB Runtime R2021a** - Download and install the windows version of MATLAB Runtime R2021a (9.10). from: https://www.mathworks.com/products/compiler/matlab-runtime.html

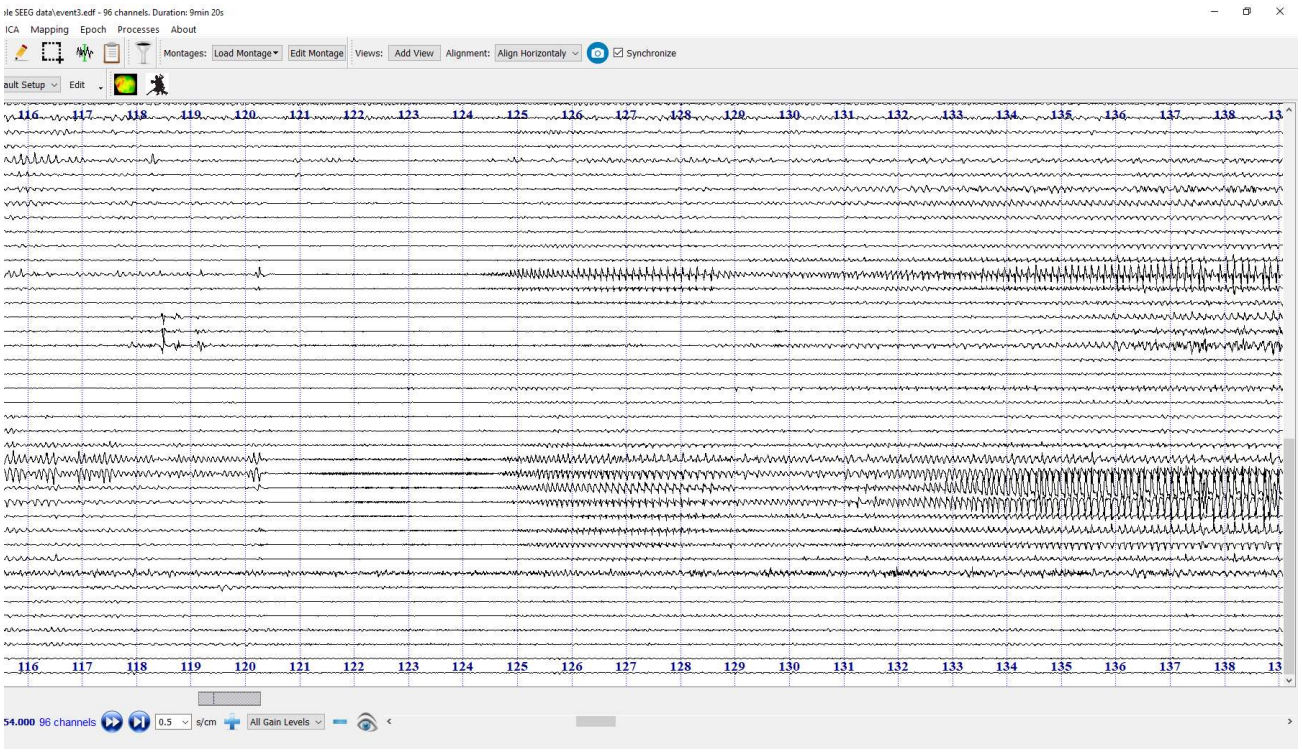
2. **Sample data -** Sample SEEG data and implantation images can be downloaded from publically available database of Brainstorm download. https://neuroimage.usc.edu/bst/download.php preprocessed data at: click here

3. **SEEG electrode location and naming using GARDEL –** GARDEL is a computational tool for automatic segmentation and labeling of SEEG electrode contacts (Medina Villalon et al., 2018). We

used GARDEL for 1) to coregister and localize SEEG electrodes in post-op MRI and 2) to export 3d coordinates of SEEG electrode contacts and brain model.

GARDEL can be downloaded from: https://meg.univ-amu.fr/wiki/GARDEL:presentation

4. **Data preprocessing -** AnyWave : multi-platform software for visualizing and processing EEG/SEEG/MEG/XMG data (Colombet et al., 2015). We used AnyWave for preprocessing and excluding the channels other than SEEG / bad channels. The preprocessed data exported in EDF format. Later this file was imported in EPI-rank. Seizure 3 in the sample dataset will look like the below plot.

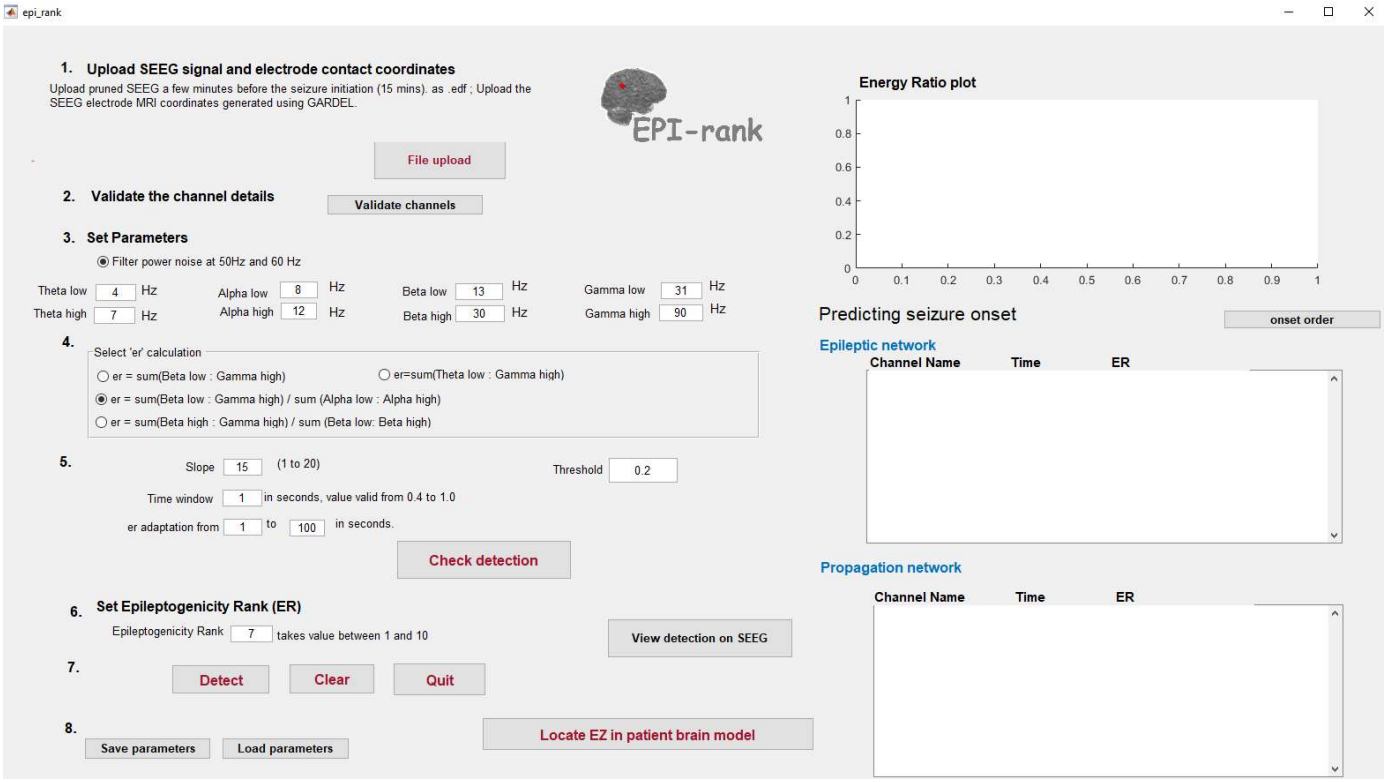


AnyWave can be downloaded from : https://meg.univ-amu.fr/wiki/AnyWave

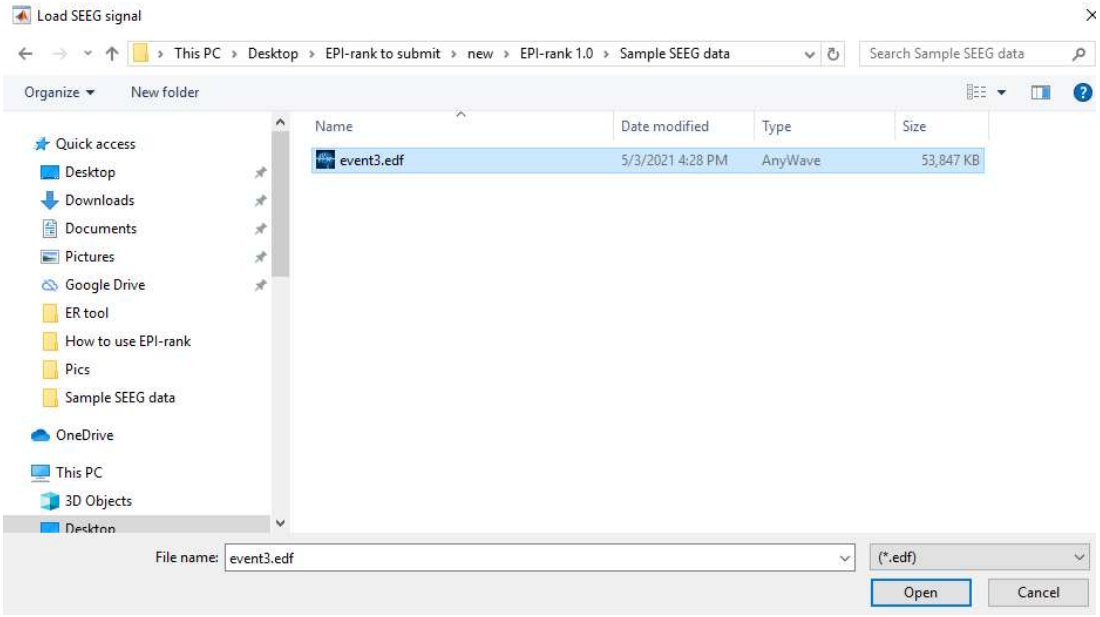
EPI-rank interface

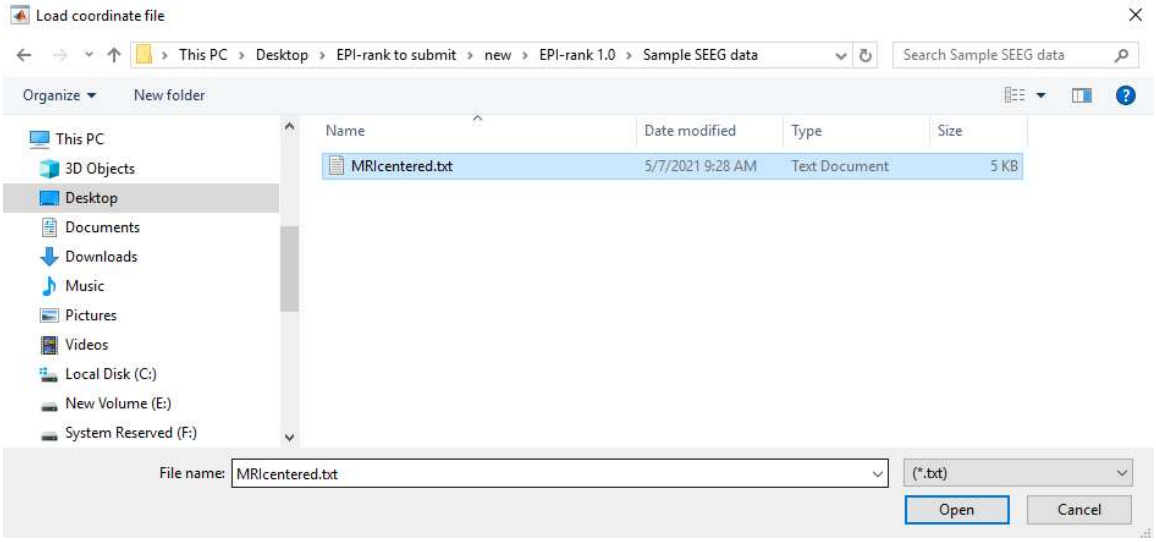
After downloading the EPI-rank from [https://github.com/Brain-Mapping/EPI-rank.](https://github.com/Brain-Mapping/EPI-rank)

On a windows machine/computer, unzip, then double click on “epi_rank.exe”. This open up the tool interface. EPI-rank tool interface has eight steps/sub-menus to localize EZ from SEEG.

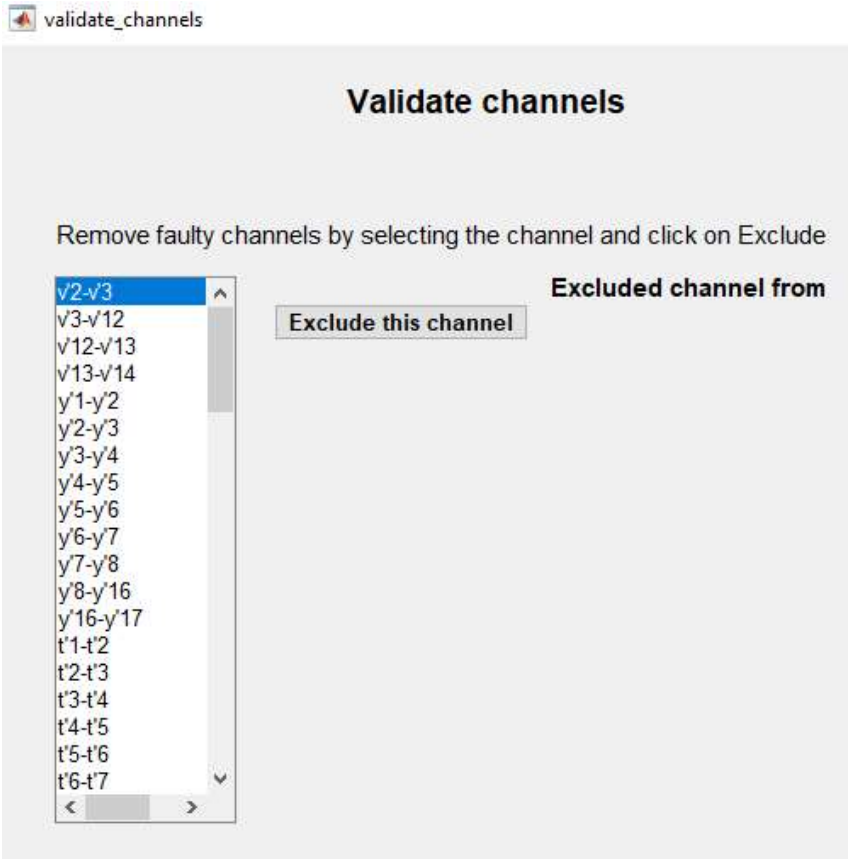


Step 1: Click on “File upload” button to upload SEEG (data should be in “.edf”) and electrode location file (“MRIcentered.txt” generated using GARDEL). See how to use the GARDEL: https://meg.univ-amu.fr/wiki/GARDEL:presentation



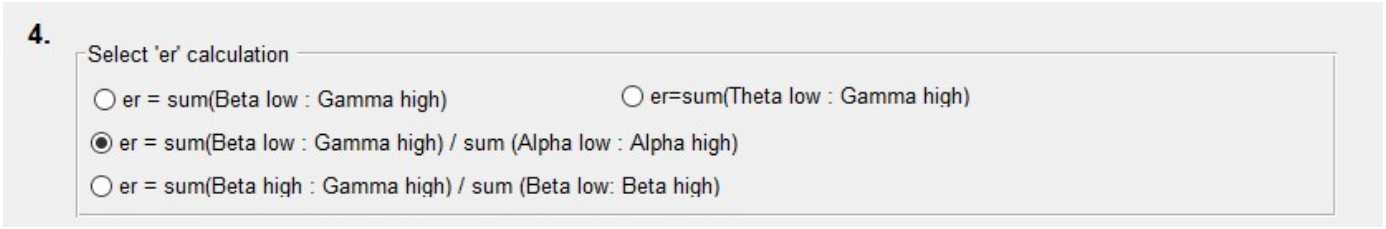


Step2: On successful loading of SEEG and electrode location, a window/pop-up will appear “validate channels”. The SEEG channels were automatically converted to bipolar montage in this step. Using the “exclude this channel button” the user can exclude artifact channels from the calculation.

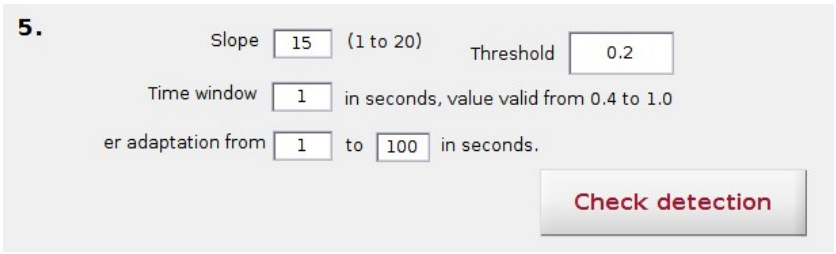


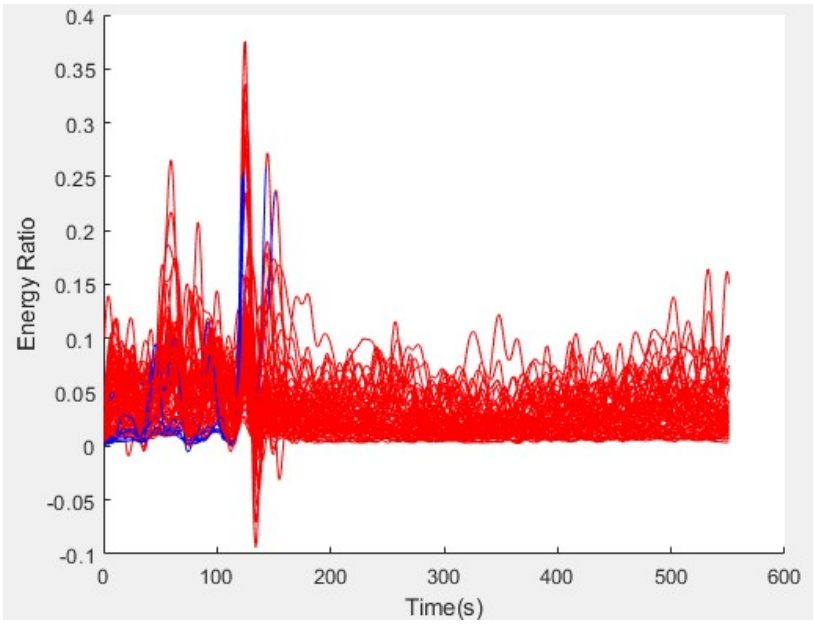
Step 3: This step removes the powerline noise from all SEEG channels. We can also set values for various EEG bands in this step. By clicking on “View SEEG”, the user can visualize the signal in bipolar montage.

Step 4: The user can select an equation for the calculation of energy ratio in this step.

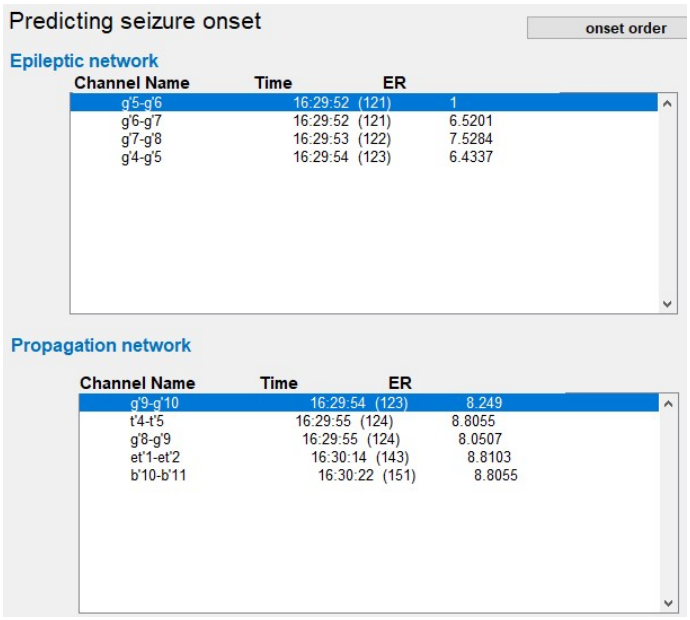


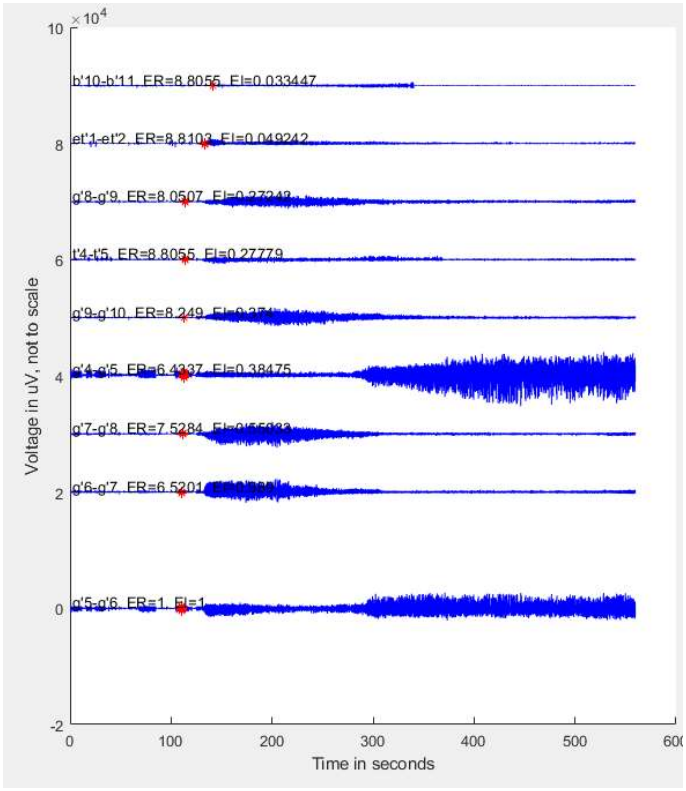
Step 5: Parameters including “time window”, “slope of energy ratio” and “energy ratio adaptation period” can be set in this step. er adaptation period usually set as an absolute period 1-2 minutes before the approximate seizure onset. Once all parameter set, then click on “Check detection” button that will compute the energy spectrum plot and each trace represents the energy spectrum of an SEEG. The interictal to ictal transition were colored in blue and red.





Step 6 and 7: In this step, the user can set the threshold for epileptogenicity rank. Localize the EZ by clicking the “Detect” button. This will compute ER for all SEEG contacts and differentiate the seizure onset and from the propagation. Follow to that click on “Localize EZ in patient brain model” button to view the EZ localized in patient brain model. The user needs to load “mesh_irm_centered_GARDEL.mat” file generated during SEEG electrode localization.





Step 8: The respective buttons save the parameters used for EZ localization by individual SEEGs.

Step9: Reset the application by clicking “Clear” button and close the application using “Quit” button.