

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.

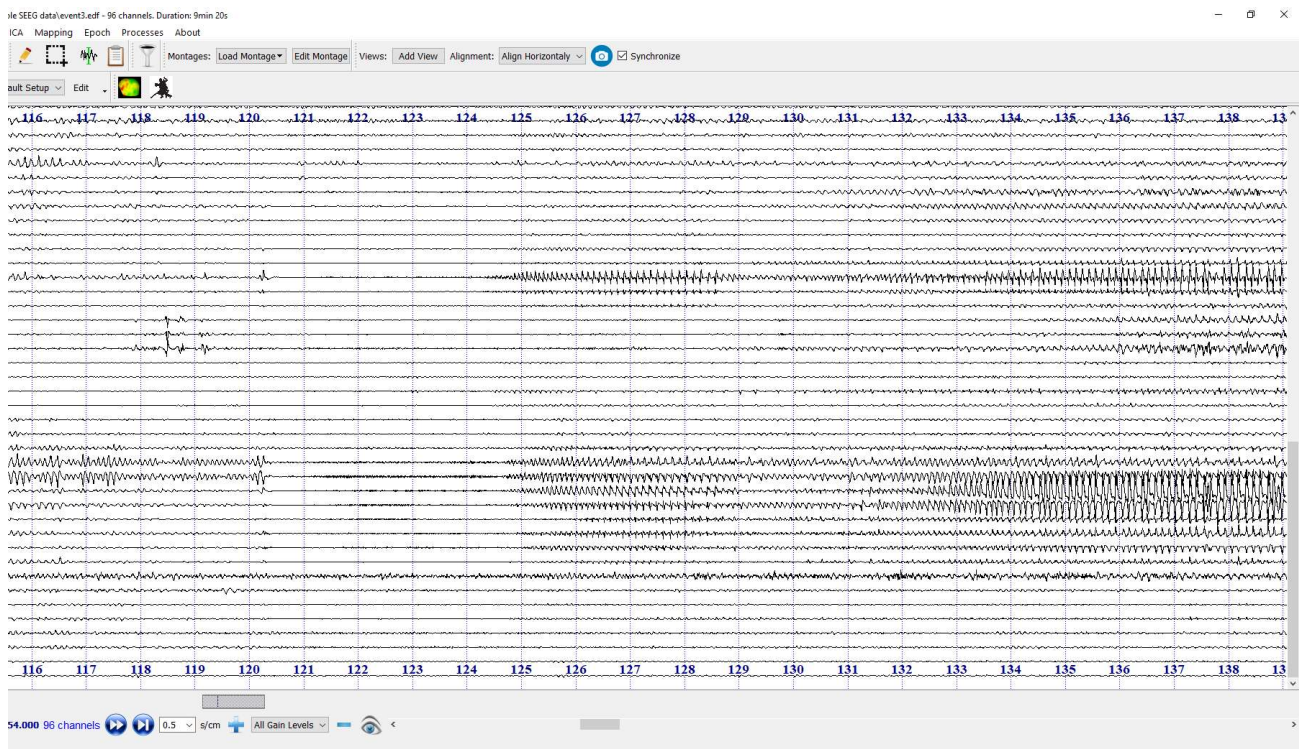
Prerequisites

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>.

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.

The screenshot displays the EPI-rank software interface, which is organized into eight numbered steps for localizing the Epileptogenic Zone (EZ) from SEEG data. The interface includes various input fields, buttons, and a plot area.

Step 1: Upload SEEG signal and electrode contact coordinates
Upload pruned SEEG a few minutes before the seizure initiation (15 mins). as .edf ; Upload the SEEG electrode MRI coordinates generated using GARDEL.
File upload

Step 2: Validate the channel details
Validate channels

Step 3: Set Parameters
☒ Filter power noise at 50Hz and 60 Hz
Theta low: 4 Hz, Alpha low: 8 Hz, Beta low: 13 Hz, Gamma low: 31 Hz
Theta high: 7 Hz, Alpha high: 12 Hz, Beta high: 30 Hz, Gamma high: 90 Hz

Step 4: Select 'er' calculation
☐ $er = \text{sum}(\text{Beta low} : \text{Gamma high})$ ☐ $er = \text{sum}(\text{Theta low} : \text{Gamma high})$
☒ $er = \text{sum}(\text{Beta low} : \text{Gamma high}) / \text{sum}(\text{Alpha low} : \text{Alpha high})$
☐ $er = \text{sum}(\text{Beta high} : \text{Gamma high}) / \text{sum}(\text{Beta low} : \text{Beta high})$

Step 5:
Slope: 15 (1 to 20) Threshold: 0.2
Time window: 1 in seconds, value valid from 0.4 to 1.0
er adaptation from: 1 to 100 in seconds.
Check detection

Step 6: Set Epileptogenicity Rank (ER)
Epileptogenicity Rank: 7 takes value between 1 and 10
View detection on SEEG

Step 7:
Detect **Clear** **Quit**

Step 8:
Save parameters **Load parameters** **Locate EZ in patient brain model**

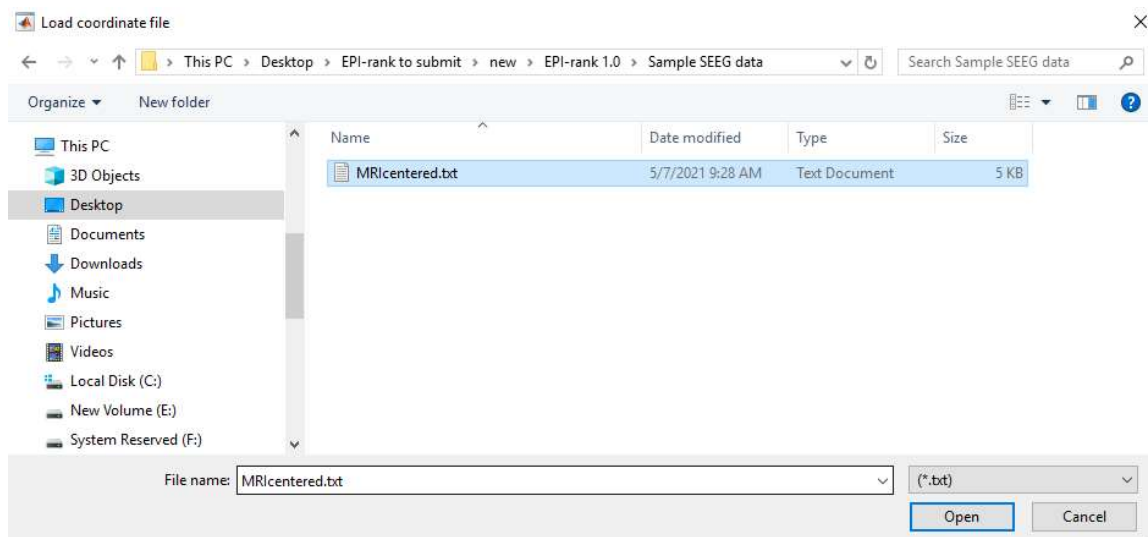
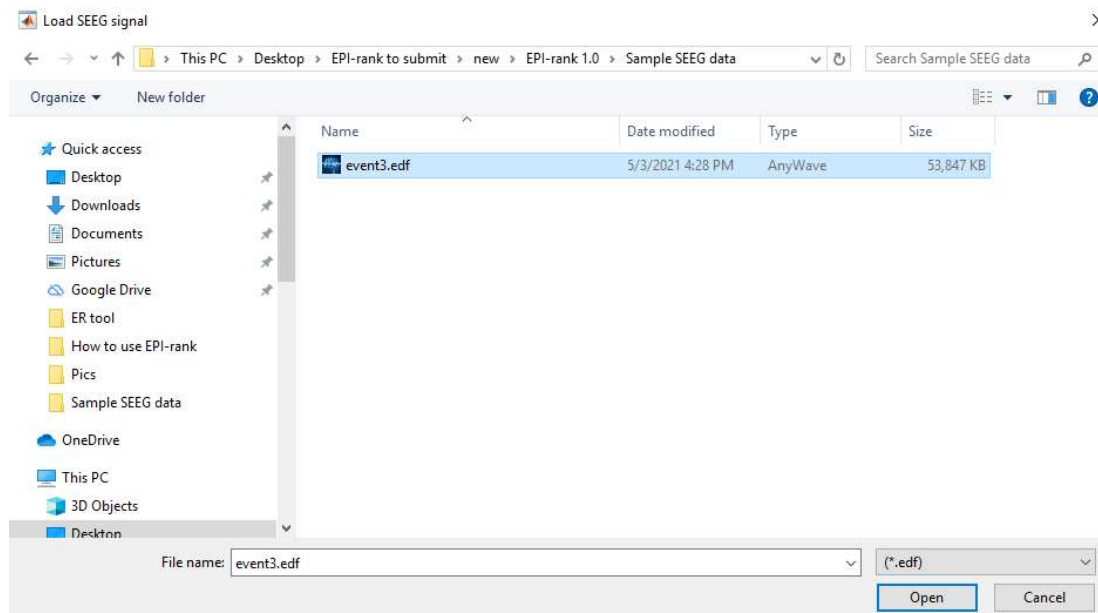
Energy Ratio plot
A line plot showing the Energy Ratio (ER) over time. The x-axis represents time from 0 to 1, and the y-axis represents the ER from 0 to 1. The plot is currently empty.

Predicting seizure onset
onset order

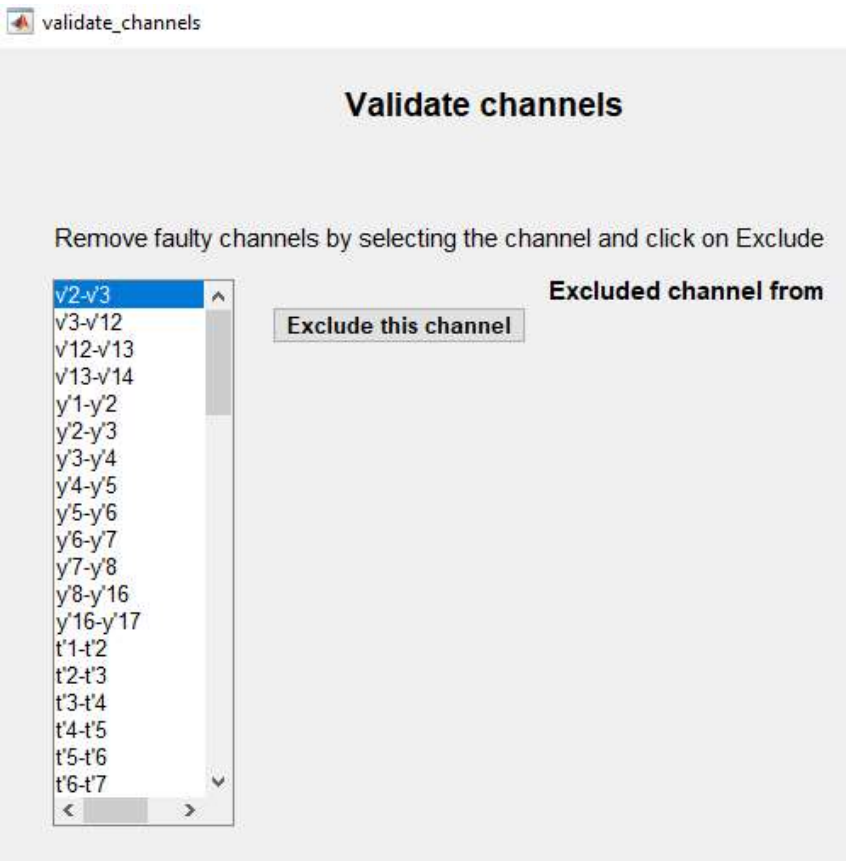
Epileptic network
Channel Name Time ER

Propagation network
Channel Name Time ER

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.

3. Set Parameters

☒ Filter power noise at 50Hz and 60 Hz

Theta low

4

Hz

Alpha low

8

Hz

Beta low

13

Hz

Gamma low

31

Hz

Theta high

7

Hz

Alpha high

12

Hz

Beta high

30

Hz

Gamma high

90

Hz

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

4. Select 'er' calculation

☐ $er = \text{sum}(\text{Beta low} : \text{Gamma high})$ ☐ $er = \text{sum}(\text{Theta low} : \text{Gamma high})$

☒ $er = \text{sum}(\text{Beta low} : \text{Gamma high}) / \text{sum}(\text{Alpha low} : \text{Alpha high})$

☐ $er = \text{sum}(\text{Beta high} : \text{Gamma high}) / \text{sum}(\text{Beta low} : \text{Beta high})$

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.

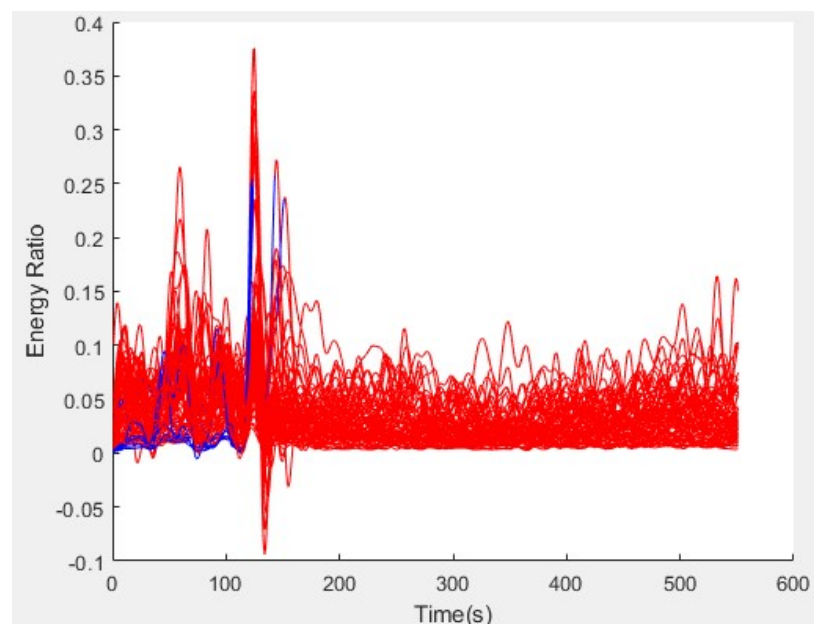
5.

Slope (1 to 20) Threshold

Time window in seconds, value valid from 0.4 to 1.0

er adaptation from to in seconds.

[Check detection](#)



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.

6. Set Epileptogenicity Rank (ER)

Epileptogenicity Rank takes value between 1 and 10

7.

Detect

Clear

Quit

Predicting seizure onset

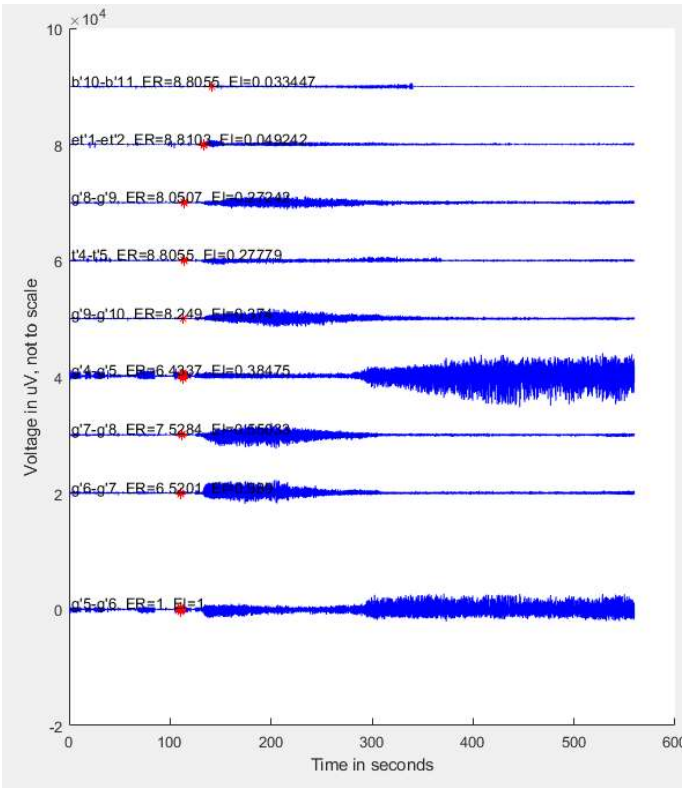
onset order

Epileptic network

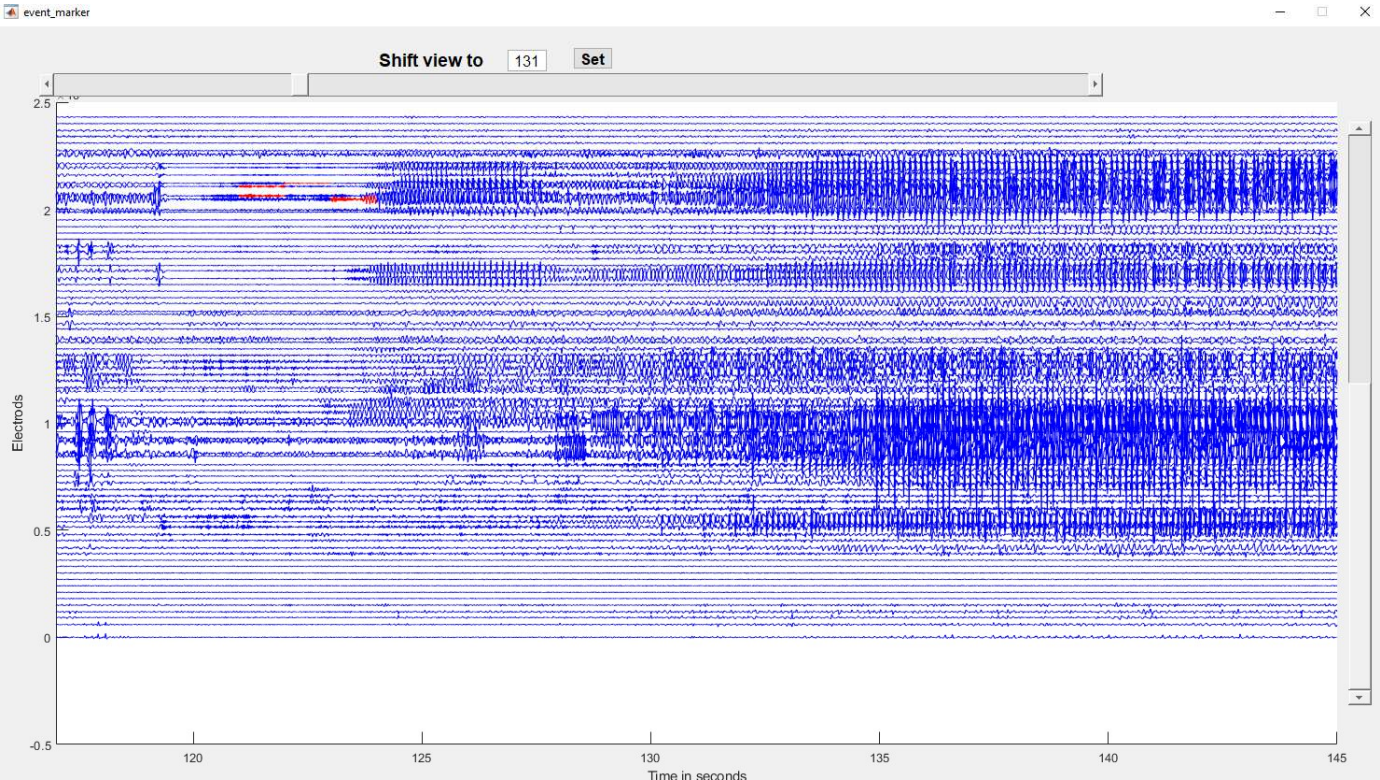
Channel Name	Time	ER
g'5-g'6	16:29:52 (121)	1
g'6-g'7	16:29:52 (121)	6.5201
g'7-g'8	16:29:53 (122)	7.5284
g'4-g'5	16:29:54 (123)	6.4337

Propagation network

Channel Name	Time	ER
g'9-g'10	16:29:54 (123)	8.249
t'4-t'5	16:29:55 (124)	8.8055
g'8-g'9	16:29:55 (124)	8.0507
et'1-et'2	16:30:14 (143)	8.8103
b'10-b'11	16:30:22 (151)	8.8055



Clicking on “view detection on SEEG” will open,



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.

