Classification of epilepsy ictal with Bayes inference Model

Goal:  As the non-invasively obtained signals are the most prevalent methods utilized in epileptic signal recording, to get focal and informative epilepsy features is the main aim of detecting different patterns of the ictal. Thus, our focus is using Bayes inference method to classify the ictal[2,3] recorded by MEA to especially extracted the higher frequency oscillations (HFOs [4]>70Hz) parts as the biomarkers for surveillance of the seizures and analysis for the effect of drugs in the future.[5,6]

Methods: Bayes inference model [10,11,12,13,15,16,18,19,20]combined with Hamilton Markov[1, 14] sampling is utilized as the updating of dynamic information of the MEA signal, with the prior knowledge of the different ictal patterns decomposed by empirical mode decomposition(EMD) with intrinsic mode functions(IMF)[3], after computing the entropy, instantaneous energy and frequencies, it is classified based on likely free method. To further study the ictal/interictal, HFO parts are extracted with filter threshold as 80Hz(ripples) and 250Hz(fast ripples) separately and with more than 9 spikes detected in bins of duration at least 10ms.

Results: As MEA data is convenient for analysis on both time and frequency domain, spikes can be detected on different bands and specific time bins. First and last spike of one ictal (manually labeled), featured as narrow spikes (more biased duration and narrower) and broad spikes(more centric with longer duration and broader gap).[6,7,8,14] Most signals are oscillated in the gamma band, giving out HFOs. Featured with their duration, frequency, asymmetry and etc., they are classified with linear regression method tested with ANOVA (p = 2.53e-6). (Asymmetry and duration are interpreted with higher correlation according to the test, and the asymmetry accounts the heaviest positive weight 1.0311, while gap and 3sigma of accounts the trivial weights 1.6852e-5, which can be deleted.) Another coarser model include some descriptive stats of the ictal itself, including standard deviation and mean. (p = 0.0511) Finally, with the components IMF numbered as 8,7,8,7,7, the prediction based on Hamilton Markov Process[1,2,5] is done with 50 iterations for each chain and 100 steps for leap frog. In addition to the instantaneous energy and frequencies plotted on time and frequency domains separately, five inburst Markov chain are also evaluated with sensitivity, sensitivity, precision, miss rate, false discovery rate and accuracy as well. (The first prediction is accurate with high specificity and false discovery rate and low miss rate while low sensitivity and precision, second accuracy is low with low sensitivity, sensitivity, false discovery rate and high miss rate while only precision is high; The third ictal is also with low accuracy prediction, due to low sensitivity, sensitivity, false discovery rate and high miss rate while high precision, similar to the second ictal; the 4th ictal is with high accuracy of high sensitivity, false discovery rate and low miss rate while sensitivity and precision are low; the last ictal is similar to the 4th ictal, highly accurate with high specificity, false discovery rate and low miss rate while low in sensitivity and precision. )

Conclusion: As multichannel MEA signals are recorded from patients annotating different ictal times, the linear regression method gives coarse classification models with interpretable factors(asymmetry and duration are most significant factors.). However, with the request of more focal signals for interpreting the effect of drugs or analysis with syndrome clinically, the Bayes Inference Hamilton Markov Chain are more suitable as the analysis of dynamic properties, including instantaneous energies and frequencies. Although current features for the HMC is only based on IMFs, those extracted HFO parts (ripple and fast ripple parts) is also considered as important since their AC value are fixed around 0.8 (fast ripples) and lower than 0.4(ripple) which is easy to be detected when seizure is outburst. Further more, it can be important in analysis on direction of the ictal spreading although we did not do such analysis here. It is obvious that those peaks and HFO are mainly close in one smaller interval according to the phase polar graph which manifests the oscillation with some specific phase angle, compared to normal signal on the whole domain. To add angle as factor or prior knowledge can possibly raise the classification accuracy as well. (More models[11] and statistical tests[5,9,17] see supplementary materials.)

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More detail about experimental data:

1. 64 channels MEA
2. Sample rate: 2000 Hz, 600s, 1200000 sample points
3. Multi-channels(12,13,14,22) for baseline correction, normalization and global mean analysis while 12th channel is utilized for single channel analysis of the ictal. (5 manually annotated: a. 55s – 80s, b. 167s- 183s, c. 216s-343s, d. 383s-410s, e: 547s-573s.)
4. Spike detection:

Single spikes: amplitude over 10mV

Trains: more than 5 spikes in 100s

Bursts: more than 30 ictal in 500s

1. Onset: 2nd bin
2. Label of spikes: broad, broad, broad, narrow, broad, narrow, broad, broad, broad, broad

Labels of ictal: interictal, ictal, ictal, interictal, interictal

1. Linear regression model: Type~ asymmetry + duration + Asymmetry /distance+ Q3\_distance(gap)+ Q3\_Distance/sigma
2. Specific bands(coupled windows):

delta = [0.5, 3]; 2, 3

theta = [4, 7]; 5,6,7

alpha = [8, 12]; 9,10,11,12

mu = [7.5, 12.5]; 9,10,11,12,13

SMR = [12.5, 15.5]; 14,15,16

beta = [16, 31]; 17-31

gamma = [32, 100]; 33-100

HF = 70; 71-2000

ripple = [80, 250]; 81-250

fastripple= 251; 252-2000

Code and more results:

<https://github.com/LilyHeAsamiko/Biophysics/tree/master/EUprojectCnf>