Practical 5: Information theory

Get the Matlab files from http://www.biological-networks.org/t/cneurosci/practical5.zip

Detecting a seizure from EEG data using entropy

A seizure (ictus) is a sudden surge of electrical activity in the brain that usually affects how a person feels or acts for a short time (http://www.epilepsy.com). Epilepsy is a seizure disorder raising repeated seizures. A diagnosis of seizures is investigating electroencephalogram (EEG) recording of patients. However, interpreting EEG requires specialized neurologists (neurophysiologists) and their interpretation could be subject. Here, we try to use entropy of EEG recordings to increase objectivity of judgement.

Our data set contains EEG recordings of a patient suffering from medically intractable focal epilepsy. The data were recorded during an invasive pre-surgical epilepsy with 256 Hz sampling rate.

For an "ictal" block, containing data with epileptic seizures and at least 50 min pre-ictal data, the six contacts of all implanted grid, strip and depth electrodes were selected by visual inspection of the raw data by a certified epileptologist. Three contacts were chosen from the seizure onset zone, i.e. from areas involved early in ictal activity (focal electrodes, 1-3). The remaining three electrode contacts were selected as not involved or involved latest during seizure spread (focal electrodes, 4-6). *pat001_1.jpg* and *pat001_2.jpg* show those areas. The ictal periods ware determined based on identification of typical seizure patterns preceding clinically manifest seizures in intracranial recordings by visual inspection of experienced epileptologists.

	EEG seizure onset (sample)	EEG seizure end (sample)
010403ba_0007	91100	96090

InFokus1	InFokus2	InFokus3	OutFokus1	OutFokus2	OutFokus3
G_A4	IH4	IH3	G_D2	IHA1	IH1

There are many ways of estimating entropy of EEG signals. Here, we introduced a simplest one: entropy of signal amplitude distribution. The function *entropy.m* estimates, first, a histogram of signals and, then, calculate the entropy of the histogram. You may check details from the developer's web site (http://www.cs.rug.nl/~rudy/matlab/doc/entropy.html).
You may use those built-in Matlab functions or given scripts (entropy.m and histogram.m) in order to analyze. This is a simple flow of the program.

load ascii data (using *load* command)
estimate entropy with moving window (using *indexing* technique and *entropy.m* script)
visualize EEG traces in a single figure (using *subplot* and *plot* command)
visualize entropy of EEG traces in a single figure

1) What are signs of a seizure in EEG?

2) Can we detect it using the entropy? What are signs of a seizure in the entropy? Why does the entropy show them?

3) Change a window size (100, 500, 1000, 2000, 5000). How the entropy estimation changes?

4) Can you say that this method is free from a false-alarm? (Change the sample range to the range that does not have a seizure, and run the program again. If this is not enough, how will you check?)

Model of neural response to stimuli (sensorymotor cortex)

For localized tactile stimulation by a pin, only a small amount of receptors and therefore only a small region of the somatosensory cortex will be activated. This small activated module can be represented through two neuron populations: an inhibitory population and an excitatory population. The results of the model can then be compared to experimentally measured activity (e.g. in the rat) depending on stimulus duration and amplitude.

In the model, the mean membrane potential of excitatory neurons is given by u and the mean membrane potential for inhibitory neurons by v. The coupling between both populations is equal (exc. -> inh. connection strength is the same as inh. -> exc.). There is also coupling within each population (exc. -> exc. and inh.->inh.) which can be adjusted.

The differential equations for changing both membrane potentials are:

$$du = -u - w \cdot f(v) + w_{ffx} \cdot s + h$$

$$\tau \; dv = -v + w \cdot f(u)$$

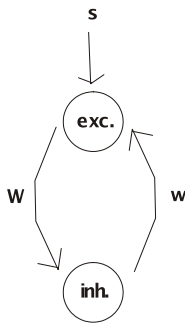

Figure 1: (A) Model of sensory stimulation. (B)

(u: mean membrane potential of the excitatory neurons; v: mean membrane potential of the inhibitory neurons; w: coupling strength between populations, coupling strength within populations not shown; w_{ffx}: coupling strength of the stimulus; s: stimulus; h: additive constant; f(x): activation function; τ: time constant)

The activation function, a sigmoid function, is non-linear. This causes non-linear dynamics of the population activities. The additive constant corresponds to the resting potential of the excitatory

neurons. The time constant τ determines the speed of the potential change of the inhibitory population relative to the excitatory population ($\tau := \tau_{inhibitory} / \tau_{excitatory}$). A delayed activation of the inhibitory populatoin is necessary to get a suppression. The stimulus s corresponds to the amplitude of the stimulus weighted by the coupling strength w_{ffx} .

Run the script *one_module*. It will show a plot of the stimulus and the resulting population activities and a second plot with the phase space of the simulation. The phase is the current state of the system given by the value of *u* and *v*. Each state can be represented by a point in (in this case two-dimensional) phase space. Over time, the system will visit different states and this change is shown as a trajectory in the second plot.

1) Why is the activity of the excitatory population lower for the second stimulus? What happens if the second stimulus is presented earlier or later?

2) What happens if only one stimulus is presented for a long time (100 ms)?

3) Change the amplitude of the stimulus. Does the peak excitatory population activity depend linearly or non-linearly on the stimulus amplitude?

4) Adjusting the model parameters, is it possible to get a longer fluctuation of the population activity (say beyond 400 ms)?