Guidelines for Joint Analysis

Introduction

Codes published here are particularly scripted for the article Kapucu et al. (2015). Thus some changes would be required for analyzing some other data. In the mentioned study burst analysis tool from Kapucu et al. (2012) and spike sorting tool from Quiroga et al. (2004) are utilized.

Format of the analysis data is initially stored in *DataCell* format which was created by Fikret Emre Kapucu for our lab. This format is mainly designed for reading MEA data (in particular Multi Channel System's MCD recordings) and storing the required information (e.g. spike time points, spike waveforms, etc.) in different columns of one data cell.

1. Starting: Preparing the data for spike sorting (here Wave_clus (Quiroga et al., 2004))

Required Input:

- DataCell (first column: channel names, second column: number of spikes, third column: spike times in milliseconds and the sixth column: spike waveforms of all the detected spikes)

NOTE: If you don't use one of our codes to read your data in *DataCell* format, just prepare your data similar way. At least under the name *DataCell* which includes first, second, third and sixth columns (Fig.*1)*

	1	2	3	4	5	6
1	'120103_MP...	6	[4.5328e+03...	300.1000	1.2658e-05	6x64 double
2	'120103_MP...	3	[2.4409e+04...	300.1000	1.2495e-05	3x64 double
3	'120103_MP...	5	[1.9042e+04...	300.1000	1.2116e-05	5x64 double
4	'120103_MP...	7	[5.8979e+04...	300.1000	1.2400e-05	7x64 double
5	'120103_MP...	7	[2.5196e+04...	300.1000	1.3085e-05	7x64 double
6	'120103_MP...	4	[6.4685e+04...	300.1000	1.3049e-05	4x64 double
7	'120103_MP...	8	[2.3879e+04...	300.1000	1.4386e-05	8x64 double
8	'120103_MP...	5	[2.5884e+04...	300.1000	1.2816e-05	5x64 double
9	'120103_MP...	6	[5.9414e+04...	300.1000	1.3107e-05	6x64 double
10	'120103_MP...	6	[1.1672e+05...	300.1000	1.2643e-05	6x64 double
11	'120103_MP...	2	[2.7193e+05...	300.1000	1.3178e-05	2x64 double
12	'120103_MP...	3	[1.3488e+05...	300.1000	1.2656e-05	3x64 double
13	'120103_MP...	6	[4.8247e+03...	300.1000	1.2354e-05	6x64 double
14	'120103_MP...	1	2.2574e+05	300.1000	1.3094e-05	1x64 double
15	'120103_MP...	2	[4.5142e+04...	300.1000	1.2829e-05	2x64 double
16	'120103_MP...	5	[5.5612e+04...	300.1000	1.3489e-05	5x64 double

Fig.1 An example DataCell. First column shows the data name with channel information, second column shows the number of spikes in the corresponding channel, third column has the spike times in milliseconds and the sixth column has the spike waveforms.

Run *DataCellSpikeSorter.m*

Output:

- *spikes: spike waveforms*
- *index: spike time points in milliseconds*
- *channels: information on channels where each spike appear*

 **Save** *spikes* and *index* together with a desired filename

2. Spike Sorting:

Spikes are assigned for clusters in this section. As final output we have the identity of the cluster in numbers (e.g. 1, 2, etc.) for each spike.

Required Input:

File which includes:

- *spikes: spike waveforms*
- *index: spike time points in milliseconds*

 **Load** your saved *spikes* and *index as ASCII spike times in* Wave_clus and **manage spike sorting**

for more info:
http://www2.le.ac.uk/departments/engineering/research/bioengineering/neuroengineering-lab/spike-sorting

 **Save Clusters**

This will save a file which includes *cluster_class* matrix. It saves the output as filename of your input data with adding *"times_"* in front of it.

Output:

- *cluster_class:* first column shows the identity of the clusters for each spike sorted and the second column is the spike times in milliseconds. Cluster IDs are in numbers i.e. "1, 2, 3, etc." and "0" corresponds for unclustered spikes.

NOTE: If you don't use Wave_clus for spike sorting be sure that your sorted spikes are saved as same format and with the name *cluster_class.*

3. Burst Detection (here CMA method (Kapucu et al., 2012))

Burst detection is done for each channel stored in *DataCell* and in the final output burst information (i.e. number of bursts, average burst duration and average number of spikes in the corresponding channel) information on type of spikes (whether burst or individual spikes) are stored.

First enter which lines (i.e. which channels) of the DataCell you are interested. If you don't want to exclude any channels enter as it is below:

When you are excluding channels be sure that it will not conflict with other tasks in joint analysis. Actually, excluding channels option added for some other analysis to the code so we strongly advise to include all the lines in your data.

 **Enter** *CellsInterested =1 : size(DataCell,1);*

Required Input:

- *DataCell*

Output:

- *CellsInterested*

Then calculate inter spike interval matrix which includes the required information for burst detection such as ISI intervals, ISI histograms, skewness of histograms, etc.

 **Run** *[ISIcell] = InterSpikeInformation (CellsInterested, DataCell);*

Required Input:

- *DataCell*
- *CellsInterested*

Output:

- *ISIcell*

Run the burst analysis tool next.

 **Run** *[CMABurstInfo,TypeOfSpikeCell] = BurstsAndClusters_BurstPlotterNoRounding(DataCell,ISIcell,CellsInterested);*

Required Input:

- *DataCell*
- *CellsInterested*
- *ISIcell*

Output:

- *CMABurstInfo : burst information (i.e. number of bursts, average burst duration and average number of spikes in the corresponding channel)*
- TypeOfSpikeCell : information on type of spikes (whether burst or individual spikes)

4. Joint Analysis

After detecting bursts and assigning spike types for each spike waveform, spike type compositions of bursts can be revealed. The number of each spike type is given with the information of their participation to bursts or individual spikes.

Run *ClustersAndBursts.m*

Required Input:

- *CellsInterested*
- *cluster_class*
- *TypeOfSpikeCell*

Output:

- *BurstSp: Spike type participations to bursts for each spike type calculated for each channel*
- SeparateSp: *Individual spikes for each spike type calculated for each channel*

Required Codes:

```
DataCellSpikeSorter.m
Wave_clus or any other spike sorting tool
InterSpikeInformation.m
BurstsAndClusters_BurstPlotterNoRounding.m
BurstDetectNoRounding.m
ClustersAndBursts.m
```

References:

Kapucu FE, Mäkinen ME-L, Tanskanen JMA, Ylä-Outinen L, Narkilahti S, Hyttinen JAK. Joint analysis of extracellular spike waveforms and neuronal network bursts. J Neu Meth 2015, http://dx.doi.org/10.1016/j.jneumeth.2015.11.022.

Kapucu FE, Tanskanen JMA, Mikkonen JE, Ylä-Outinen L, Narkilahti S, Hyttinen JAK. Burst analysis tool for developing neuronal networks exhibiting highly varying action potential dynamics. Front Comput Neurosci 2012;6:38, http://dx.doi.org/10.3389/fncom.2012.00038.

Quiroga RQ, Nadasdy Z, Ben-Shaul Y. Unsupervised spike detection and sorting with wavelets and superparamagnetic clustering. Neural Comput 2004;16(8):1661-87, http://dx.doi.org/10.1162/089976604774201631.