

Automatic offline spike sorting using SpikeCluster

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Offline sorting?

- multi-electrode array
- signal quality
- manual sorting using Offline Sorter -- time-consuming
- customized codes -- which algorithm?
- isolation quality -- 'well-isolated' doesn't work nowadays

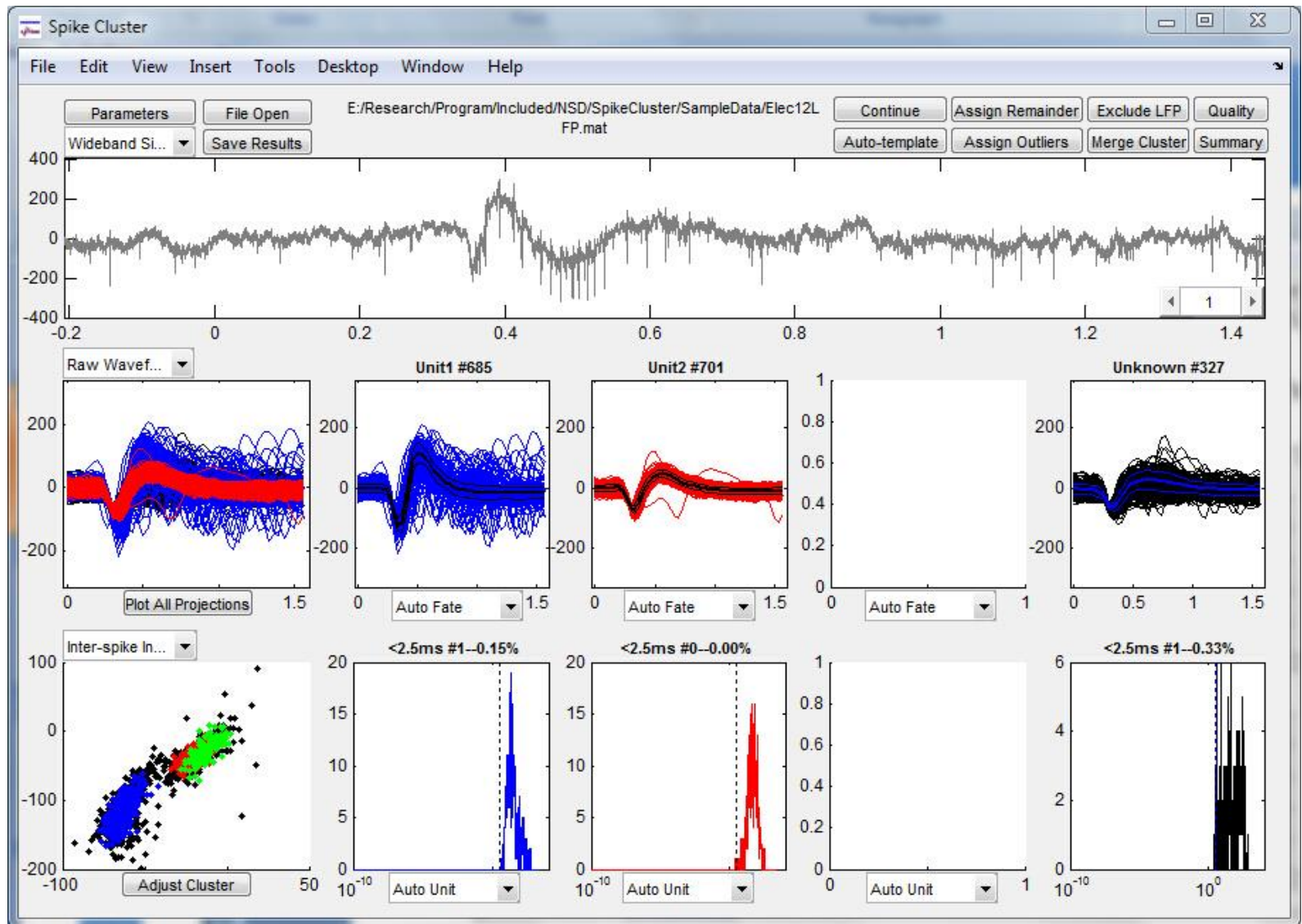
Offline sorting?

- multi-electrode array
- signal quality
- manual sorting using Offline Sorter -- time-consuming
- customized codes -- which algorithm?
- isolation quality -- 'well-isolated' doesn't work nowadays

An integrated toolbox to

- 1) automatically sort action potentials,**
- 2) quantify the isolation quality.**

SpikeCluster



A similar GUI to WAVE_CLUS by Quiroga, R.Q.

But SpikeCluster has...

The image shows the 'Parameters' dialog box for SpikeCluster, a software used for spike sorting. The dialog is organized into several sections with blue vertical bars on the left indicating different stages of the process: Load, Filter, Detect, Align, Extract, Select, Cluster, and HMM.

Load Section:

- Electrodes to Analyze: 12
- Sampling Frequency (Hz): 30000

Filter Section:

- Cutoff Frequency (Hz): 250 — 7500
- Filter Direction: Forward Only
- High-pass Type: Butterworth
- High-pass Order: 4
- Low-pass Type: Butterworth
- Low-pass Order: 3

Detect Section:

- Waveform Indicator: Raw Voltage
- Std Estimation: Median absol...
- Adaptive Std Duration (S): Inf
- Threshold/Std (Neg-Pos): 5
- Crossing Polarity: Negative
- Spike Duration (ms): 1.6
- Refractory Period (ms): 2.5

Align Section:

- Reverse filter waveform: No
- Interpolation Method: Raw Wavef...
- Interp. Resolution (ms): 0.0333333
- Align by: Raw Wavef...
- Align at (ms): 0.33333

Extract Section:

- Num. Clustered Spikes: 5000
- Extraction Method: Wavelet Coe...
- Wavelet Type: Haar
- Wavelet Scales: 4

Select Section:

- Selection Criteria: KS Statistics...
- Account for Variance (%): 90
- Max. Num. of Coefficients: 10

Cluster Section:

- Outlier Removal: None
- Clustering Method: t-Distribution ...
- Number of Clusters: Auto
- Minimum Cluster Ratio (%): 1
- Auto-create Templates: Peak-Valley ...
- Autotemp SNR Threshold: 2
- Assign Remainers: Waveform, ...
- Assign Outliers: Segment Mat...

HMM Section:

- (This section is currently disabled, indicated by a greyed-out bar)

Quality Metrics Section:

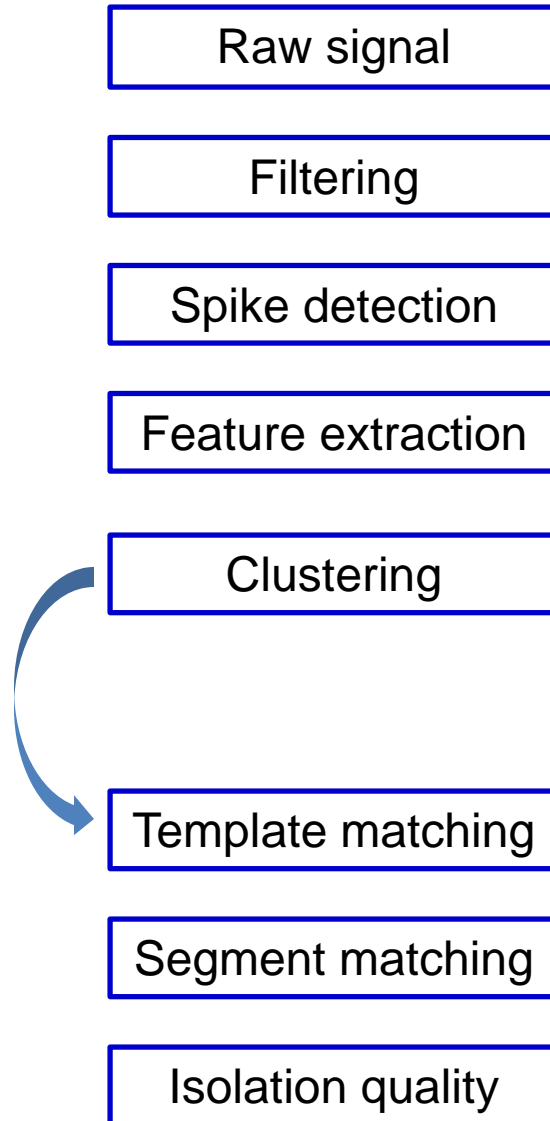
- ☒ Cluster SNR
- ☒ Joshua Isolation Score
- ☒ FNeg. Noise
- ☒ FPos. Noise
- ☒ SingleMultiUnit
- ☐ FNeg. Detection
- ☐ FPos. Refractory
- ☐ FNeg. Cluster
- ☐ FPos. Cluster
- ☐ FNeg. Censors
- ☒ L Ratio
- ☒ Isolation Distance
- ☒ Isolation Info.

Buttons:

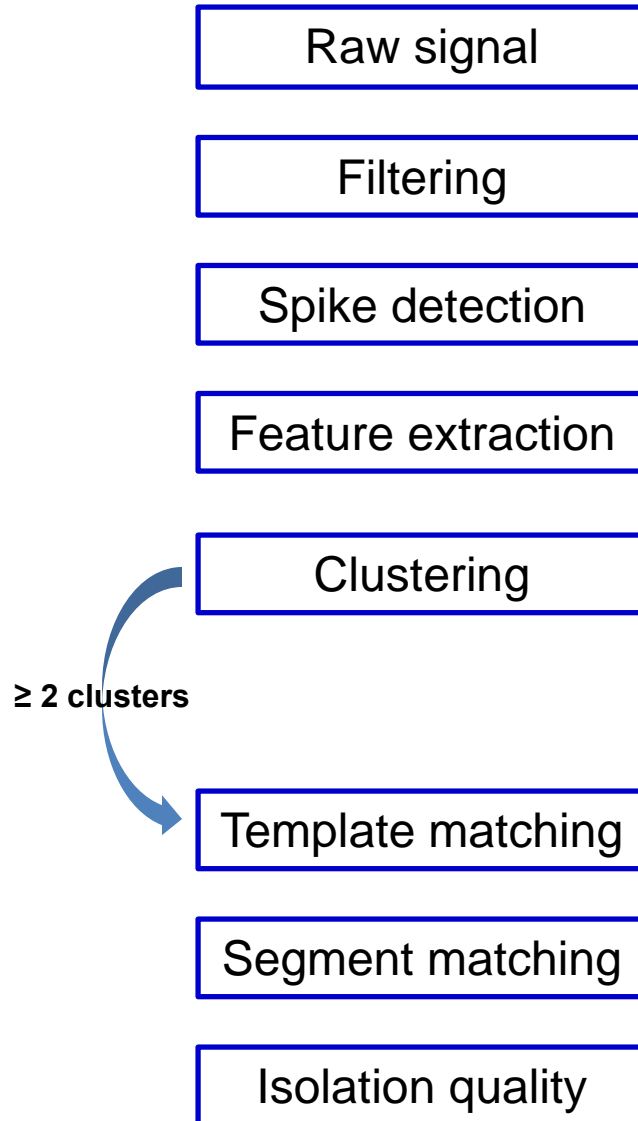
- OK
- Filter Visualization
- Restore to Default
- Save as Default
- Cancel

Aims to automate spike sorting and qualification

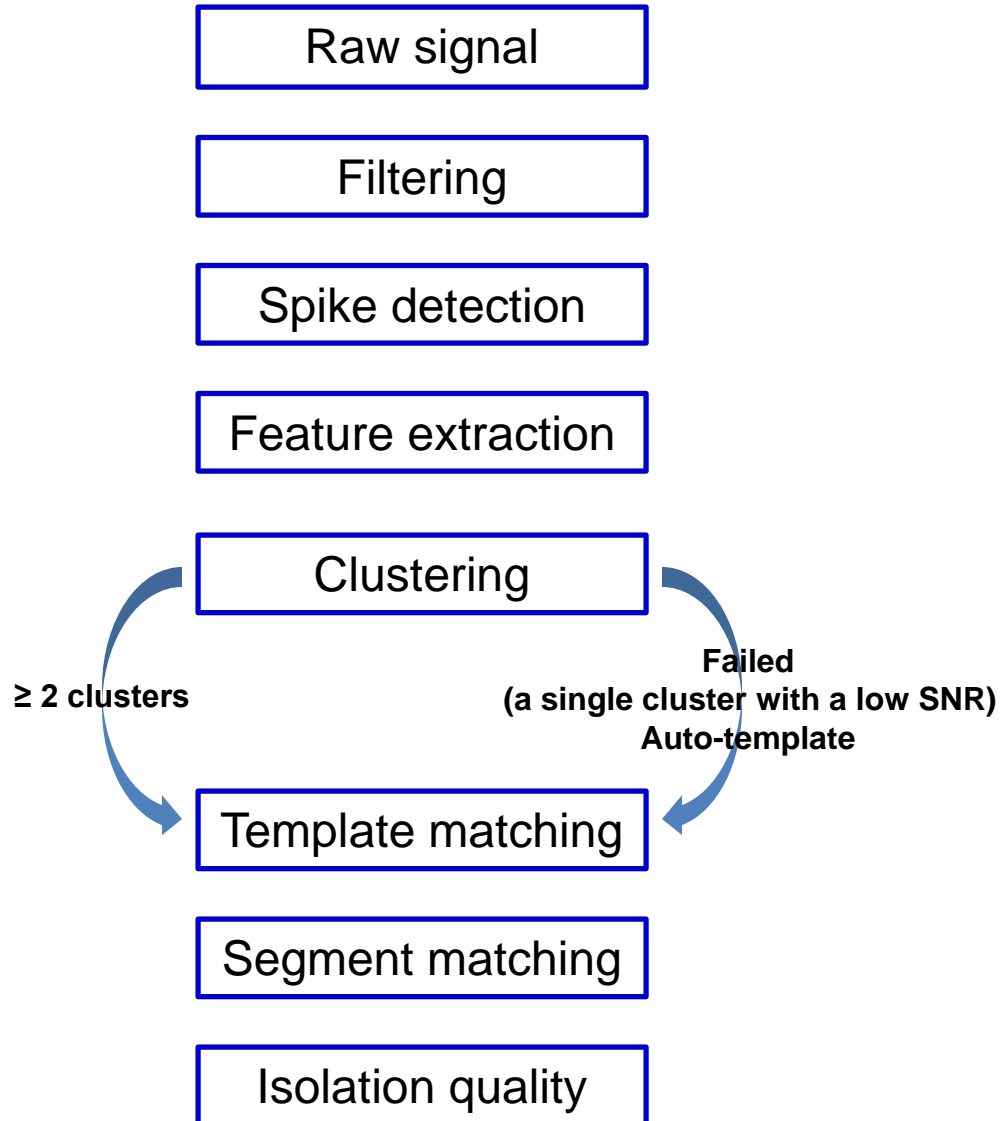
Overall scheme of SpikeCluster



Overall scheme of SpikeCluster

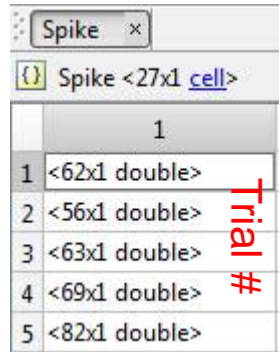


Overall scheme of SpikeCluster



Time for demos

Data format for online spikes (*.mat)

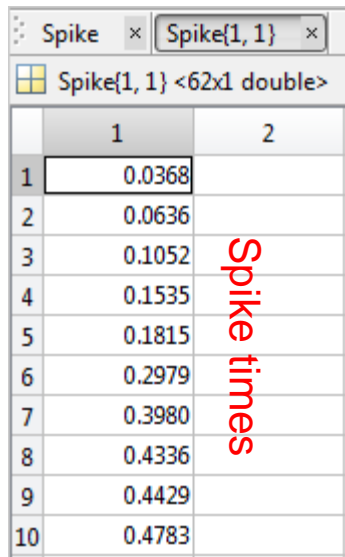


Spike ×

Spike <27x1 cell>

	1
1	<62x1 double>
2	<56x1 double>
3	<63x1 double>
4	<69x1 double>
5	<82x1 double>

Trial #



Spike × Spike{1,1} ×

Spike{1,1} <62x1 double>

	1	2
1	0.0368	
2	0.0636	
3	0.1052	
4	0.1535	
5	0.1815	
6	0.2979	
7	0.3980	
8	0.4336	
9	0.4429	
10	0.4783	

Spike times

Data format for online spikes (*.mat)

Spike x

Spike <27x1 cell>

	1
1	<62x1 double>
2	<56x1 double>
3	<63x1 double>
4	<69x1 double>
5	<82x1 double>

Trial #

Waveform x

Waveform <27x1 cell>

	1
1	<62x48 single>
2	<56x48 single>
3	<63x48 single>
4	<69x48 single>
5	<82x48 single>

Trial #

Spike x Spike{1, 1} x

Spike{1, 1} <62x1 double>

	1	2
1	0.0368	
2	0.0636	
3	0.1052	
4	0.1535	
5	0.1815	
6	0.2979	
7	0.3980	
8	0.4336	
9	0.4429	
10	0.4783	

Spike times

Waveform x Waveform{1, 1} x

Waveform{1, 1} <62x48 single>

	1	2	
1	-3.5994	0.6929	
2	-4.8965	-3.6488	
3	16.6380	12.9574	
4	0.5093	-0.6713	
5	-13.4670	-9.9565	
6	-17.7466	-9.0644	
7	-17.5532	-10.0999	
8	-8.8918	-8.2720	
9	-2.9978	3.2478	
10	2.5089	-0.6256	

waveforms

Data format for online spikes (*.mat)

Spike x

Spike <27x1 cell>

	1
1	<62x1 double>
2	<56x1 double>
3	<63x1 double>
4	<69x1 double>
5	<82x1 double>

Trial #

Waveform x

Waveform <27x1 cell>

	1
1	<62x48 single>
2	<56x48 single>
3	<63x48 single>
4	<69x48 single>
5	<82x48 single>

Trial #

Unit x

Unit <27x1 cell>

	1
1	<62x1 uint8>
2	<56x1 uint8>
3	<63x1 uint8>
4	<69x1 uint8>
5	<82x1 uint8>

Trial #

Spike x Spike{1, 1} x

Spike{1, 1} <62x1 double>

	1	2
1	0.0368	
2	0.0636	
3	0.1052	
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Spike times

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7	-17.5532	-10.0999
8	-8.8918	-8.2720
9	-2.9978	3.2478
10	2.5089	-0.6256

waveforms

Unit x Unit{1, 1} x

Unit{1, 1} <62x1 uint8>

	1	2
1	2	
2	1	
3	2	
4	3	
5	2	
6	2	
7	2	
8	2	
9	1	
10	2	

unit #

Data format for online spikes (*.mat)

Spike x

Spike <27x1 cell>

	1
1	<62x1 double>
2	<56x1 double>
3	<63x1 double>
4	<69x1 double>
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Trial #

Waveform x

Waveform <27x1 cell>

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1	<62x48 single>
2	<56x48 single>
3	<63x48 single>
4	<69x48 single>
5	<82x48 single>

Trial #

Unit x

Unit <27x1 cell>

	1
1	<62x1 uint8>
2	<56x1 uint8>
3	<63x1 uint8>
4	<69x1 uint8>
5	<82x1 uint8>

Trial #

ExpMonitor x

ExpMonitor <1x1 struct>

Field
StartT
EndT
LFPStartT
LFPEndT

Spike x Spike{1, 1} x

Spike{1, 1} <62x1 double>

	1	2
1	0.0368	
2	0.0636	
3	0.1052	
4	0.1535	
5	0.1815	
6	0.2979	
7	0.3980	
8	0.4336	
9	0.4429	
10	0.4783	

Spike times

Waveform x Waveform{1, 1}

Waveform{1, 1} <62x48 single>

	1	2
1	-3.5994	0.6929
2	-4.8965	-3.6488
3	16.6380	12.9574
4	0.5093	-0.6713
5	-13.4670	-9.9565
6	-17.7466	-9.0644
7	-17.5532	-10.0999
8	-8.8918	-8.2720
9	-2.9978	3.2478
10	2.5089	-0.6256

waveforms

Unit x Unit{1, 1} x

Unit{1, 1} <62x1 uint8>

	1	2
1	2	
2	1	
3	2	
4	3	
5	2	
6	2	
7	2	
8	2	
9	1	
10	2	

unit #

ExpMonitor.StartT x

ExpMonitor.StartT <27x1 double>

	1	2
1	-0.2072	
2	-0.1972	
3	-0.2172	
4	-0.2171	
5	-0.2073	
6	-0.1772	
7	-0.1872	
8	-0.1970	
9	-0.1871	
10	-0.2072	

Trial #

Data format for online spikes (*.mat)

Spike

Spike <27x1 cell>

	1
1	<62x1 double>
2	<56x1 double>
3	<63x1 double>
4	<69x1 double>
5	<82x1 double>

Trial #

Waveform

Waveform <27x1 cell>

	1
1	<62x48 single>
2	<56x48 single>
3	<63x48 single>
4	<69x48 single>
5	<82x48 single>

Trial #

Unit

Unit <27x1 cell>

	1
1	<62x1 uint8>
2	<56x1 uint8>
3	<63x1 uint8>
4	<69x1 uint8>
5	<82x1 uint8>

Trial #

ExpMonitor

ExpMonitor <1x1 struct>

Field
StartT
EndT
LFPStartT
LFPEndT

SpikeBasic

SpikeBasic <1x1 struct>

Field
WaveformFs

Spike

Spike{1, 1}

Spike{1, 1} <62x1 double>

	1	2
1	0.0368	
2	0.0636	
3	0.1052	
4	0.1535	
5	0.1815	
6	0.2979	
7	0.3980	
8	0.4336	
9	0.4429	
10	0.4783	

Spike times

Waveform

Waveform{1, 1}

Waveform{1, 1} <62x48 single>

	1	2
1	-3.5994	0.6929
2	-4.8965	-3.6488
3	16.6380	12.9574
4	0.5093	-0.6713
5	-13.4670	-9.9565
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7	-17.5532	-10.0999
8	-8.8918	-8.2720
9	-2.9978	3.2478
10	2.5089	-0.6256

waveforms

Unit

Unit{1, 1}

Unit{1, 1} <62x1 uint8>

	1	2
1	2	
2	1	
3	2	
4	3	
5	2	
6	2	
7	2	
8	2	
9	1	
10	2	

unit #

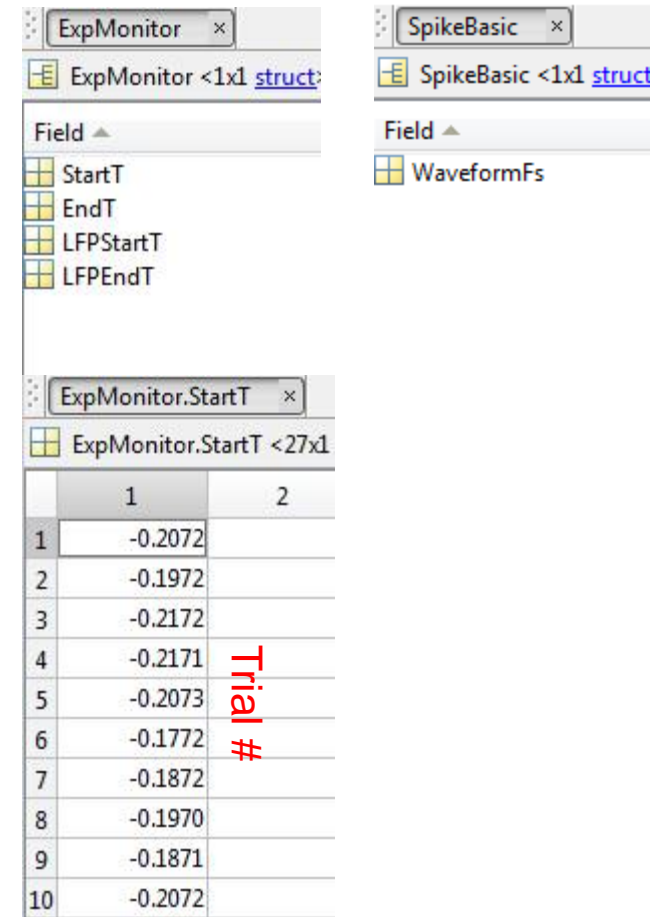
ExpMonitor.StartT

ExpMonitor.StartT <27x1 double>

	1	2
1	-0.2072	
2	-0.1972	
3	-0.2172	
4	-0.2171	
5	-0.2073	
6	-0.1772	
7	-0.1872	
8	-0.1970	
9	-0.1871	
10	-0.2072	

Trial #

Data format for unfiltered LFP (*.mat)



The image shows two MATLAB variable browser windows. The left window, titled 'ExpMonitor', displays a 1x1 structure with fields: StartT, EndT, LFPStartT, and LFPEndT. The right window, titled 'SpikeBasic', displays a 1x1 structure with a field: WaveformFs. Below the 'ExpMonitor' window, a zoomed-in view of the 'ExpMonitor.StartT' variable is shown as a 27x1 array. The first 10 rows of this array are displayed in a table format, with a red vertical label 'Trial #' next to the trial numbers 1 through 10.

	1	2
1	-0.2072	
2	-0.1972	
3	-0.2172	
4	-0.2171	
5	-0.2073	
6	-0.1772	
7	-0.1872	
8	-0.1970	
9	-0.1871	
10	-0.2072	

Data format for unfiltered LFP (*.mat)

LFP	
LFP <27x1 cell>	
	1
1	<49601x1 int16>
2	<48401x1 int16>
3	<46312x1 int16>
4	<52004x1 int16>
5	<57981x1 int16>

Trial #

ExpMonitor	
ExpMonitor <1x1 struct>	
Field	
StartT	
EndT	
LFPStartT	
LFPEndT	

ExpMonitor.StartT		
ExpMonitor.StartT <27x1		
	1	2
1	-0.2072	
2	-0.1972	
3	-0.2172	
4	-0.2171	
5	-0.2073	
6	-0.1772	
7	-0.1872	
8	-0.1970	
9	-0.1871	
10	-0.2072	

Trial #

SpikeBasic	
SpikeBasic <1x1 struct>	
Field	
WaveformFs	

Automated analysis

- individual *.mat file -- open the mat file directly
- batch mat files -- open *Batch.m directly

```
% Edit file paths here *****
FilePath = {
    'E:\Research\Program\Included\NSD\SpikeCluster\SampleData\Elec12LFP.mat';
    'E:\Research\Program\Included\NSD\SpikeCluster\SampleData\Elec12LFP.mat';
};
```

- batch all channels in multiple files -- open *FileBatch.m directly

```
% Edit file paths & electrodes here *****
FilePath = {
    'E:\Research\Program\Included\NSD\SpikeCluster\SampleData.sss';
    'E:\Research\Program\Included\NSD\SpikeCluster\SampleData.sss';
};
ElecNum = {
    [12 12];
    [12 12];
};
```

- called as a function

```
% Edit file paths here *****
ArgIn.FileType = 3;
ArgIn.FilePath = {
    'E:\Research\Program\Included\NSD\SpikeCluster\SampleData\Elec12Waveform.mat';
    'E:\Research\Program\Included\NSD\SpikeCluster\SampleData\Elec12Waveform.mat';
};
SpikeCluster(ArgIn);
```