USF Scope

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1 New Features in Version 1.9.6

- "Save Surrogates" on the bandpass dialog. See Section 4.5.8 [Save Surrogates], page 8.
- "Left Ticks" on the Options menu. See Section 4.7 [Left Ticks], page 8.
- Bug fix: bandpass threshold in Log and Thr mode has been corrected.

2 Overview

Typically, before the files generated by a spike sorter system can be analyzed they must be read, displayed, annotated, selected, and saved. This document describes the program `Scope`[1], a spike train analysis utility program to visualize the times of action potentials in simultaneously monitored neurons, other event timing pulse codes, and associated analog signal. The program can scan, edit, select and save sections of the files generated by a spike "sorting" system for subsequent analyses.

The program provides traditional representations such as firing rate histograms and rectified and filtered ("integrated") records, and has tools to add time marker "codes" and delete or select sections of the data for subsequent analysis (e.g., results from a particular stimulus protocol).

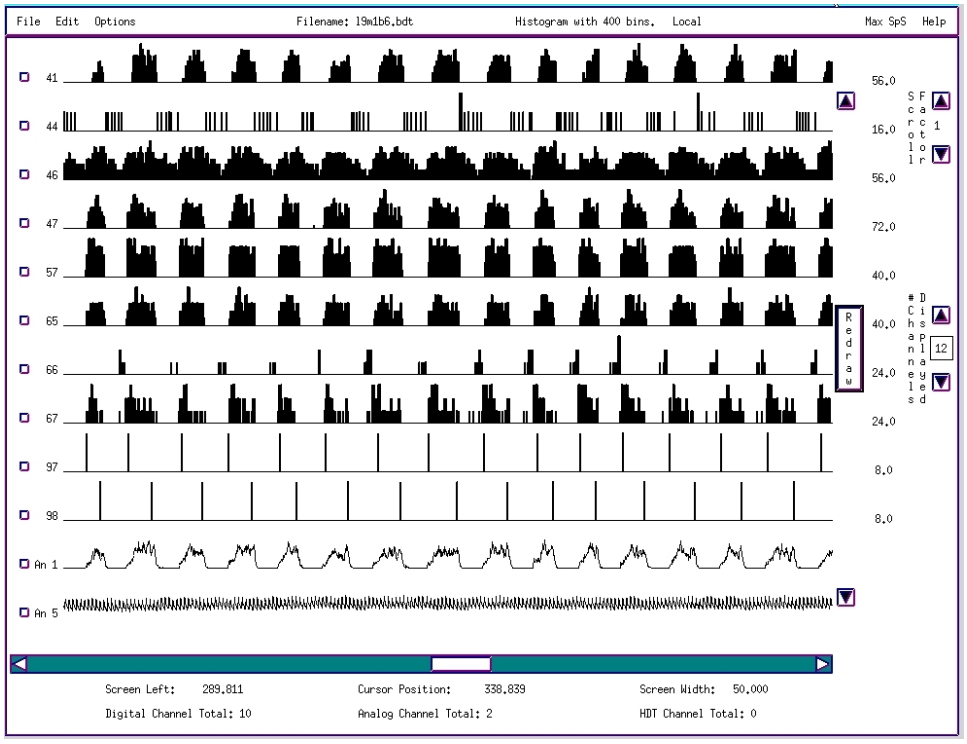

Figure 2.1: a representative snapshot with histograms of action potential firing rates of eight simultaneously monitored neurons. Timing pulse codes marking the onset of inspiration and expiration derived from analog trace 1 showing integrated phrenic activity are also included. Analog trace 2 shows arterial blood pressure.

[1] The initial version of this program was named `Xscope` (Lindsey et al., 1992). The program was developed in laboratory of B. G. Lindsey at the University of South Florida by Jim Miller, Peter R. Barnhill and others using the K&R C language, X-windows and Motif. The latest version was modified and enhanced as described in this document by Russell O'Connor in 2006-2007. Development of the program was supported by NIH grants NS19814 and NS46062 as part of the NSF/NIH Collaborative Research in Computational Neuroscience Program.

2.1 Features

- Accurate display of both spike train occurrence times and associated signals recorded in multiple formats with varying time resolutions.
- Accurate synchronization and display of original analog channel recordings and spike sorter output files.
- Support for multiple time resolutions of spike train data to allow for the continued increase in sampling speeds of data acquisition systems.
- The ability to "slide" or "jump" to different locations in the file.
- The ability to insert new codes by mouse click, automatically at regular intervals, or to indicate cycle phase transitions in analog signals (e.g., onset of a respiratory phase or cardiac cycle).
- The ability to delete or select and write channels and/or time slices to separate files.
- Simple search routines to find a particular event on a channel by time or event count.
- The ability to display an event count for each channel of spike train data.
- Display a simple firing rate histogram for the spike train data with a choice of single channel or global scaling.
- Display an integrated or moving average representation of spike train firing rate data.
- Display bandpass filtered spike trains and analog signals with tests of significance for signals in the band.

3 The Edit Menu

3.1 Add a code

3.1.1 Manual

Add a new code by mouse click.

3.1.2 Periodic

Add a new code at regular intervals.

3.1.3 Offset

Add a new code that repeats existing code, but with each event offset.

3.2 Set Filters

Allows user to “mark” sections of the data with the mouse for “passing” to another file or deleting from the file to be written out. In auto mode a particular event code is used to define the beginning of blocks to be selected. In either mode markB code 21 and markE code 22 can be added to the beginning and end of each selected block respectively. Some programs need such identifiers.

3.3 Write

Writes out the selected stuff and/or the file without the ’deleted’ stuff. Any line can be deleted at write by clicking the box to the left of each line.

4 The Options Menu

4.1 Scale

Set the time span displayed in seconds.

4.2 Tally

Display the number of events with each id.

4.3 Histogram

Display rate histograms for each row of events.

4.4 Integrate

Display leaky integration of events in each row.

4.5 Bandpass

Display bandpass filtered events or analog data in each row.

A sampled signal is generated from the spike-time data as follows:

First, a sampling frequency is chosen that is four times the upper limit of the pass band. Then, the value of each sample at this frequency is calculated as the number of spikes that occurred during that sample interval.

This signal is generated to cover the displayed portion of the signal plus 10% (to avoid edge effects) plus as much more as is necessary so that the number of samples has no factor larger than 7 (so the FFT will be quick).

Then the FFT of the signal is calculated, the frequency bins outside the passband are set to zero, and the inverse FFT is calculated. The result is what is displayed when the Display Format is set to "Norm".

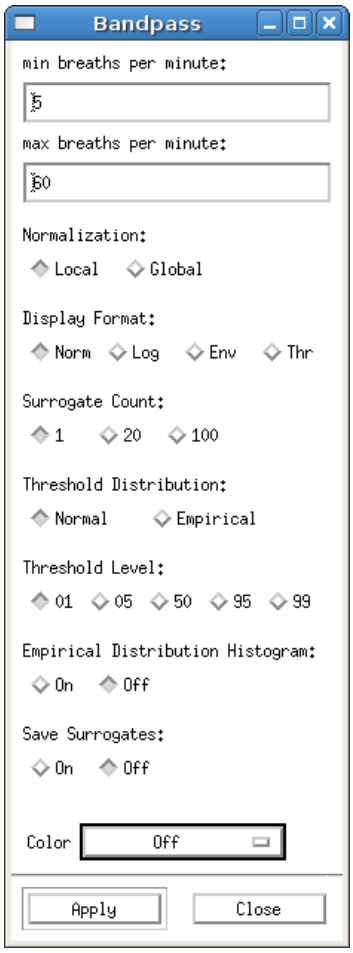

Figure 4.1: The bandpass filter dialog.

4.5.1 Breaths per minute

The pass band is specified in breaths per minute because the filter is traditionally used on respiratory data.

4.5.2 Normalization

- Local Normalization: each trace is scaled so that the largest displayed amplitude of that trace just fits in the available space.
- Global Normalization: each trace is scaled so that the largest displayed amplitude of the trace with the largest amplitude just fits in the available space, and the rest use the same scale.

Normalization does not apply to the threshold display.

4.5.3 Display Format

- Norm: filtered data is displayed.
- Log: the log of the envelope of the filtered data is displayed. This is one value per cycle of the filtered signal. The zero of this display is the threshold level.
- Env: the envelope of the filtered data is displayed. This is one value per cycle of the filtered signal.
- Thr: the display is either full scale or zero depending on whether the envelope is above or below the threshold. This is the same threshold used in the Log display.

4.5.4 Surrogate Count

This option selects the number of surrogate spike trains used in calculating the threshold level. Even if the firing rate of the spike train has no content in the pass band, the spike train itself will have some content in the pass band due to the random component of the spike times. We estimate this minimal level of content to use as a threshold by generating surrogate spike trains from the firing rate of the original spike train with the pass band filtered out, and then filtering the surrogate spike trains with the normal bandpass filter, and then using the distribution of the envelope values (one per cycle) to set the threshold. If one surrogate doesn't generate enough envelope values, the user can choose 20 or 100.

4.5.5 Threshold Distribution

- Normal: with this setting, the threshold is based on the mean and standard deviation of the log of the envelope values of the filtered surrogate spike trains (since the envelope value cannot be less that zero, the log of the value gives a more nearly normal distribution).
- Empirical: with this setting, the threshold is based on quantiles of the actual envelope values of filtered surrogate spike trains

4.5.6 Threshold Level

- 01: the threshold is set to 2.3263 standard deviations below the mean, or the .01 quantile (1st percentile). This setting is appropriate to give high confidence that there is no content in the pass band.
- 05: the threshold is set to 1.6449 standard deviations below the mean, or the .05 quantile (5th percentile).

- 50: the threshold is set to the mean, or the .5 quantile (50th percentile).
- 95: the threshold is set to 1.6449 standard deviations above the mean, or the .95 quantile (95th percentile).
- 99: the threshold is set to 2.3263 standard deviations above the mean, or the .99 quantile (99th percentile). This setting is appropriate to give high confidence that there is content in the pass band.

4.5.7 Empirical Distribution Histogram

If this option is set to "On", a histogram of the envelope values of the filtered surrogate spike trains will be displayed. This feature only works in "Log" or "Thr" Display Format. Also, it requires the applications "gv" and either "octave" or Matlab® to be installed on the system. (The programs "gv" and "octave" are not part of this package, but are available free of charge on most Linux systems.) Matlab® will not be used unless the environment variable USE_MATLAB is set, which can be done by invoking scope as

```
USE_MATLAB=1 scope
```

4.5.8 Save Surrogates

If this option is set to "On", the surrogate spike trains that are generated by a bandpass in Log or Env Display Format (see Section 4.5.3 [Display Format], page 7) are written to files named "control_NNN.edt" in the current directory. There is one file for each displayed digital channel – NNN is the channel id. The first channel in the control_NNN.edt file is the original channel, and the rest are the surrogates. Only the displayed portion plus a little extra is saved to the control_NNN.edt file. The saved portion is the portion on which the filtering was done. If you open a control_NNN.edt file in `scope` and apply the same bandpass filter (but with global normalization (see Section 4.5.2 [Normalization], page 7)) as the one that generated the file, you can see the relative effect of the filter on the original trace and the surrogates. In order to reproduce the original results, you must set the Left Time (see Section 4.7 [Left Ticks], page 8 and the Scale (see Section 4.1 [Scale], page 5) to the same values that they had when the filter was run that generated the file.

4.5.9 Color

Unless this option is set to "Off", the bandpass values to be plotted will be displayed encoded into colors, rather than plotted as a line or bar graph. A variety of different color encodings is offered. The appropriate spectrum is displayed in the selection box when a color option is chosen, serving as a key for the display.

4.6 Find..

Find the nth occurrence of an event code. After being found, it will be the left most of that event displayed.

4.7 Left Ticks

Display and set the "Screen Left" position in ticks. This is done in units of ticks (.5 ms for .bdt files, .1 ms for .edt files), because that is how it is stored internally. This allows you to determine or set it exactly. This is useful, for example, if you save the bandpass

surrogates and you want to open them in another `scope` and compare the bandpass results (see Section 4.5.8 [Save Surrogates], page 8).

5 The Slider

To scroll through time click on left or right arrow heads. Each click moves a few pixels. The arrows will repeat if held down, for a relatively smooth scroll. To move to a different place in the file, drag the slider. Clicking in the slider track will move a screen at at time.

6 File Structure

`Scope` reads and writes analog and spike data from three file types: .adt, .bdt, and .edt. All three are ASCII files with the id (and maybe analog value) in the first column, and the time in the second column.

6.1 .adt Files

Each line is I2,I8 where I2 is the spike (or other event) code and I8 is clock counts in 0.5 msec. resolution.

6.2 .bdt Files

Each line is I5,I8 where I5 is the event code and I8 is clock counts in 0.5 msec. resolution. If I5 is > 1000, then the I5 contains both the voltage and channel identifier. The right 12 bits are the voltage in 2's complement. The left 4 bits are the "analog channel number". This format was initially developed for use on a PDP11.

6.3 .edt Files

Each line is I5,I10 where I5 is the event code and I8 is clock counts in 0.1 msec. resolution. If I5 is > 1000, then the I5 contains both the voltage and channel identifier. The right 12 bits are the voltage in 2's complement. The left 4 bits are the "analog channel number". This format was initially developed for use on a PDP11.

7 References

Lindsey, B. G., Hernandez, Y. M., Morris, K. F., Shannon, R., and Gerstein, G. L. Dynamic reconfiguration of brain stem neural assemblies: Respiratory phase-dependent synchrony versus modulation of firing rates. **Journal of Neurophysiology** 67: 923-930, 1992.