SanPy: A whole-cell electrophysiology analysis pipeline.

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All tables and recipes included here are available online in the SanPy documentation.

Supplemental Table 1. Definition of detection parameters.
See: https://cudmore.github.io/SanPy/methods/#detection-parameters

Supplemental Table 2. Analysis results for each detected AP.
See: https://cudmore.github.io/SanPy/methods/#analysis-output-full

Supplemental Recipe 1.
See: https://cudmore.github.io/SanPy/api/writing-a-file-loader/

Supplemental Recipe 2.
See: https://cudmore.github.io/SanPy/api/writing-new-analysis/

Supplemental Recipe 3.
See: https://cudmore.github.io/SanPy/api/writing-a-plugin/

Supplemental Figure 1. Analysis of runtime for AP detection

Supplemental Table 1. Definition of detection parameters.
See: https://cudmore.github.io/SanPy/methods/#detection-parameters

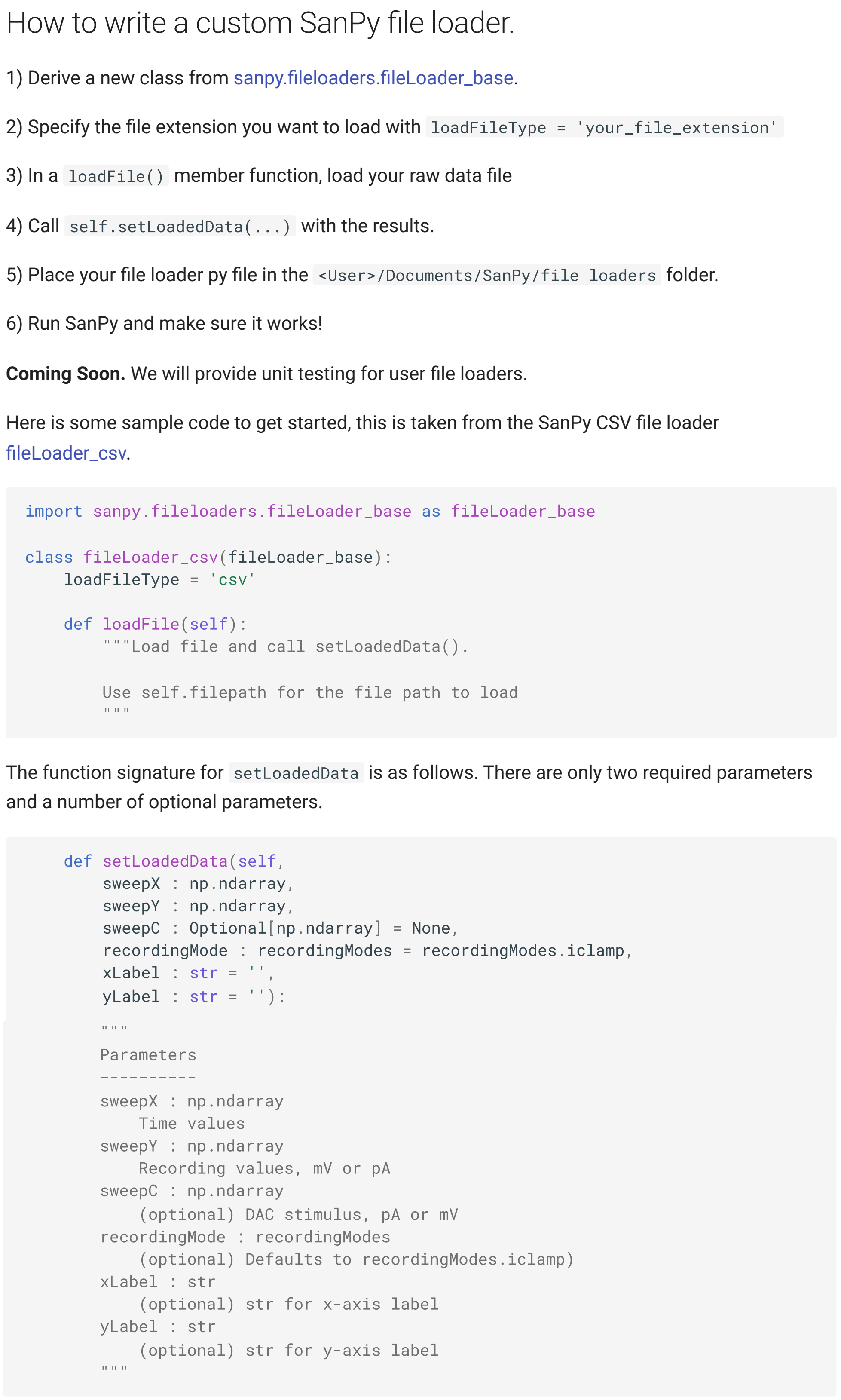
Parameter	Default Value	Units	Human Readable	Description
detectionName	default		Detection Preset Name	The name of detection preset
detectionType	dvdt		Detection Type	Detect using derivative (dvdt) or membrane potential (mV)
dvdtThreshold	20	dVdt	dV/dt Threshold	dV/dt threshold for a spike, will be backed up to dvdt_percentOfMax and have xxx error when this fails
mvThreshold	-20	mV	mV Threshold	mV threshold for spike AND minimum spike mV when detecting with dV/dt
startSeconds		s	Start(s)	Start seconds of analysis
stopSeconds		s	Stop(s)	Stop seconds of analysis
condition	“”	String	Condition	Condition
dvdt_percentOfMax	0.1	Percent	dV/dt Percent of max	For dV/dt detection, the final TOP is when dV/dt drops to this percent from dV/dt AP peak
onlyPeaksAbove_mV		mV	Accept Peaks Above (mV)	Only accept APs with peaks above this value (mV)
onlyPeaksBelow_mV		mV	Accept Peaks Below (mV)	Only accept APs below this value (mV)
doBackupSpikeVm	False	Boolean	Backup Vm Spikes	If true, APs detected with just mV will be backed up until Vm falls to xxx
refractory_ms	170	ms	Minimum AP interval (ms)	APs with interval (wrt previous AP) less than this will be removed
peakWindow_ms	100	ms	Peak Window (ms)	Window after TOP (ms) to search for AP peak (mV)
dvdtPreWindow_ms	10	ms	dV/dt Pre Window (ms)	Window (ms) to search before each TOP for real threshold crossing
dvdtPostWindow_ms	20	ms	dV/dt Post Window (ms)	Window (ms) to search after each AP peak for minimum in dv/dt
mdp_ms	250	ms	Pre AP MDP window (ms)	Window (ms) before an AP to look for MDP
avgWindow_ms	5	ms	MDP averaging window (ms)	Window (ms) to calculate MDP (mV) as a mean rather than mV at single point for MDP
lowEddRate_warning	8	EDD slope	EDD slope warning	Generate warning when EED slope is lower than this value.
halfHeights	[10, 20, 50, 80, 90]		AP Durations (%)	AP Durations as percent of AP height (AP Peak (mV) - TOP (mV))
halfWidthWindow_ms	200	ms	Half Width Window (ms)	Window (ms) after TOP to look for AP Durations
medianFilter	0	points	Median Filter Points	Number of points in median filter, must be odd, 0 for no filter
SavitzkyGolay_pnts	5	points	SavitzkyGolay Points	Number of points in Savitzky-Golay filter, must be odd, 0 for no filter
SavitzkyGolay_poly	2		SavitzkyGolay Poly Deg	The degree of the polynomial for Savitzky-Golay filter
verbose	FALSE	Boolean	Verbose	Verbose Detection Reporting

Supplemental Table 2. Analysis results for each detected AP.
See: https://cudmore.github.io/SanPy/methods/#analysis-output-full

Name	type	Description
analysisDate	str	Date of analysis in yyyymmdd ISO 8601 format.
analysisTime	str	Time of analysis in hh:mm:ss 24 hours format.
modDate	str	Modification date if AP is modified after detection.
modTime	str	Modification time if AP is modified after detection.
analysisVersion	str	Analysis version when analysis was run. See sanpy.analysisVersion
interfaceVersion	str	Interface version string when analysis was run. See sanpy.interfaceVersion
file	str	Name of raw data file analyzed
detectionType		Type of detection, either vm or dvdt. See enum sanpy.bDetection.detectionTypes
cellType	str	User specified cell type
sex	str	User specified sex
condition	str	User specified condition
sweep	int	Sweep number of analyzed sweep. Zero based.
epoch	int	Stimulus epoch number the spike occurred in. Zero based.
epochLevel	float	Epoch level (DAC) stimulus during the AP threshold.
sweepSpikeNumber	int	AP number within the sweep. Zero based.
spikeNumber	int	AP number across all sweeps. Zero based.
include	bool	Boolean indication include or not. Can be set by user/programmatically after analysis.
userType	int	Integer indication user type. Can be set by user/programmatically after analysis.
errors	list	List of dictionary to hold detection errors for this AP
dvdtThreshold	float	AP Threshold in derivative dv/dt
mvThreshold	float	AP Threshold in primary recording mV
medianFilter	int	Median filter to generate filtered vm and dvdt. Value 0 indicates no filter.
halfHeights	list	List of int to specify half-heights like [10, 20, 50, 80, 90].
thresholdPnt	int	AP threshold point
thresholdSec	float	AP threshold seconds
thresholdVal	float	Value of Vm at AP threshold point.
thresholdVal_dvdt	float	Value of dvdt at AP threshold point.
dacCommand	float	Value of DAC command at AP threshold point.
peakPnt	int	AP peak point.
peakSec	float	AP peak seconds.
peakVal	float	Value of Vm at AP peak point.
peakHeight	float	Difference between peakVal minus thresholdVal.
timeToPeak_ms	float	Time to peak (ms) after TOP.
preMinPnt	int	Minimum before an AP taken from predefined window.
preMinVal	float	Minimum before an AP taken from predefined window.
preLinearFitPnt0	int	Point where pre linear fit starts. Used for EDD Rate

preLinearFitPnt1	int	Point where pre linear fit stops. Used for EDD Rate
earlyDiastolicDuration_ms	float	Time (ms) between start/stop of EDD.
preLinearFitVal0	float	
preLinearFitVal1	float	
earlyDiastolicDurationRate	float	Early diastolic duration rate, the slope of the linear fit between start/stop of EDD.
lateDiastolicDuration	float	Depreciated
preSpike_dvdt_max_pnt	int	Point corresponding to peak in dv/dt before an AP.
preSpike_dvdt_max_val	float	Value of Vm at peak of dv/dt before an AP.
preSpike_dvdt_max_val2	float	Value of dv/dt at peak of dv/dt before an AP.
postSpike_dvdt_min_pnt	int	Point corresponding to min in dv/dt after an AP.
postSpike_dvdt_min_val	float	Value of Vm at minimum of dv/dt after an AP.
postSpike_dvdt_min_val2	float	Value of dv/dt at minimum of dv/dt after an AP.
isi_pnts	int	Inter-Spike-Interval (points) with respect to previous AP.
isi_ms	float	Inter-Spike-Interval (ms) with respect to previous AP.
spikeFreq_hz	float	AP frequency with respect to previous AP.
cycleLength_pnts	int	Points between APs with respect to previous AP.
cycleLength_ms	int	Time (ms) between APs with respect to previous AP.
diastolicDuration_ms	float	Time (ms) between minimum before AP (preMinPnt) and AP time (thresholdPnt).
widths_10	int	Width (ms) at half-height 10 %.
widths_20	int	Width (ms) at half-height 20 %.
widths_50	int	Width (ms) at half-height 50 %.
widths_80	int	Width (ms) at half-height 80 %.
widths_90	int	Width (ms) at half-height 90 %.

Supplemental Recipe 1.
See: https://cudmore.github.io/SanPy/api/writing-a-file-loader/



How to write a custom SanPy file loader.

1) Derive a new class from sanpy.fileloaders.fileLoader_base.

2) Specify the file extension you want to load with `loadFileType = 'your_file_extension'`

3) In a `loadFile()` member function, load your raw data file

4) Call `self.setLoadedData(...)` with the results.

5) Place your file loader py file in the `<User>/Documents/SanPy/file loaders` folder.

6) Run SanPy and make sure it works!

Coming Soon. We will provide unit testing for user file loaders.

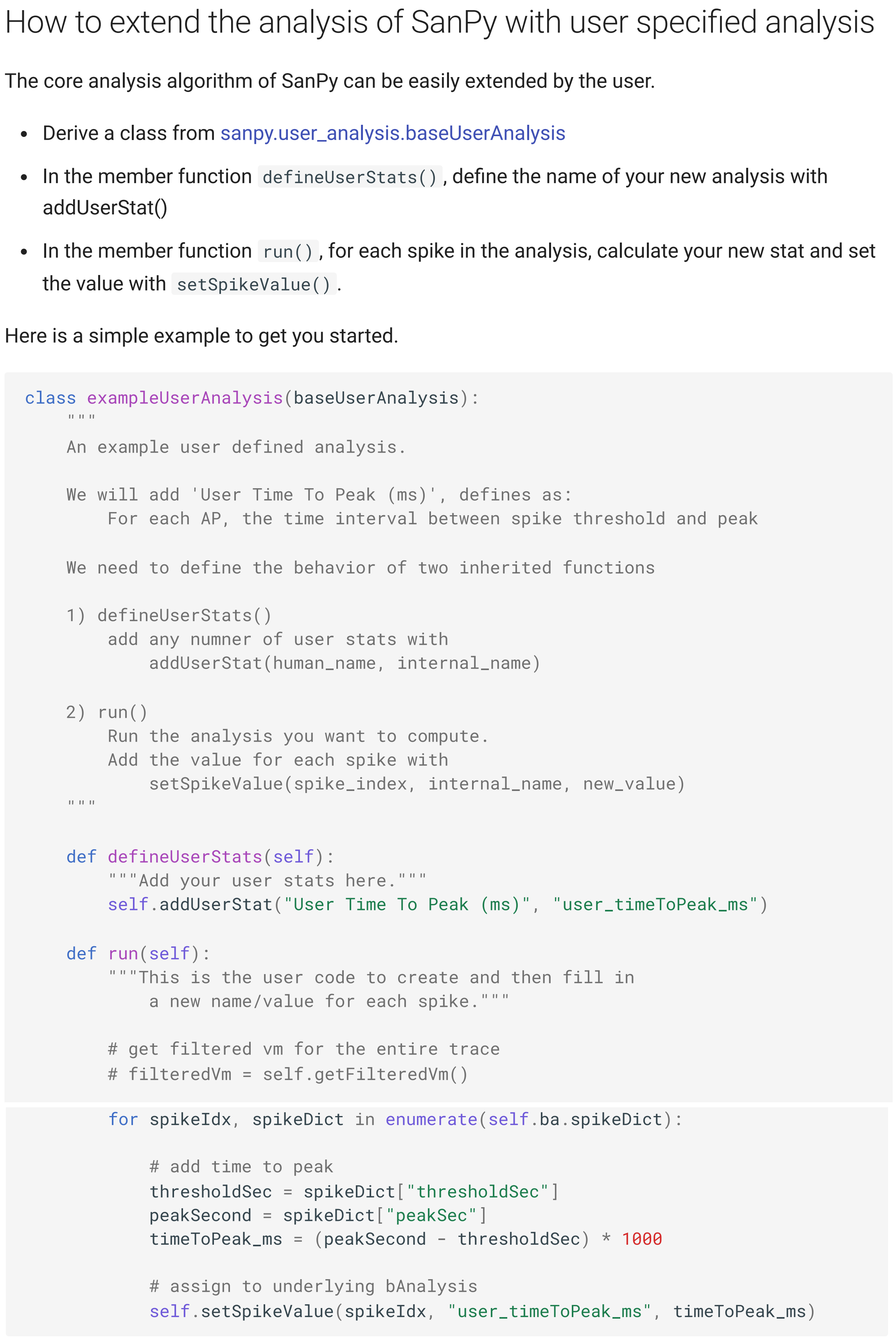
Here is some sample code to get started, this is taken from the SanPy CSV file loader fileLoader_csv.

```
import sanpy.fileloaders.fileLoader_base as fileLoader_base

class fileLoader_csv(fileLoader_base):
    loadFileType = 'csv'

    def loadFile(self):
        """Load file and call setLoadedData().

        Use self.filepath for the file path to load
        """
```

The function signature for `setLoadedData` is as follows. There are only two required parameters and a number of optional parameters.

```
    def setLoadedData(self,
        sweepX : np.ndarray,
        sweepY : np.ndarray,
        sweepC : Optional[np.ndarray] = None,
        recordingMode : recordingModes = recordingModes.iclamp,
        xLabel : str = '',
        yLabel : str = ''):

        """
        Parameters
        ----------
        sweepX : np.ndarray
            Time values
        sweepY : np.ndarray
            Recording values, mV or pA
        sweepC : np.ndarray
            (optional) DAC stimulus, pA or mV
        recordingMode : recordingModes
            (optional) Defaults to recordingModes.iclamp)
        xLabel : str
            (optional) str for x-axis label
        yLabel : str
            (optional) str for y-axis label
        """
```

Supplemental Recipe 2.
See: https://cudmore.github.io/SanPy/api/writing-new-analysis/



How to extend the analysis of SanPy with user specified analysis

The core analysis algorithm of SanPy can be easily extended by the user.

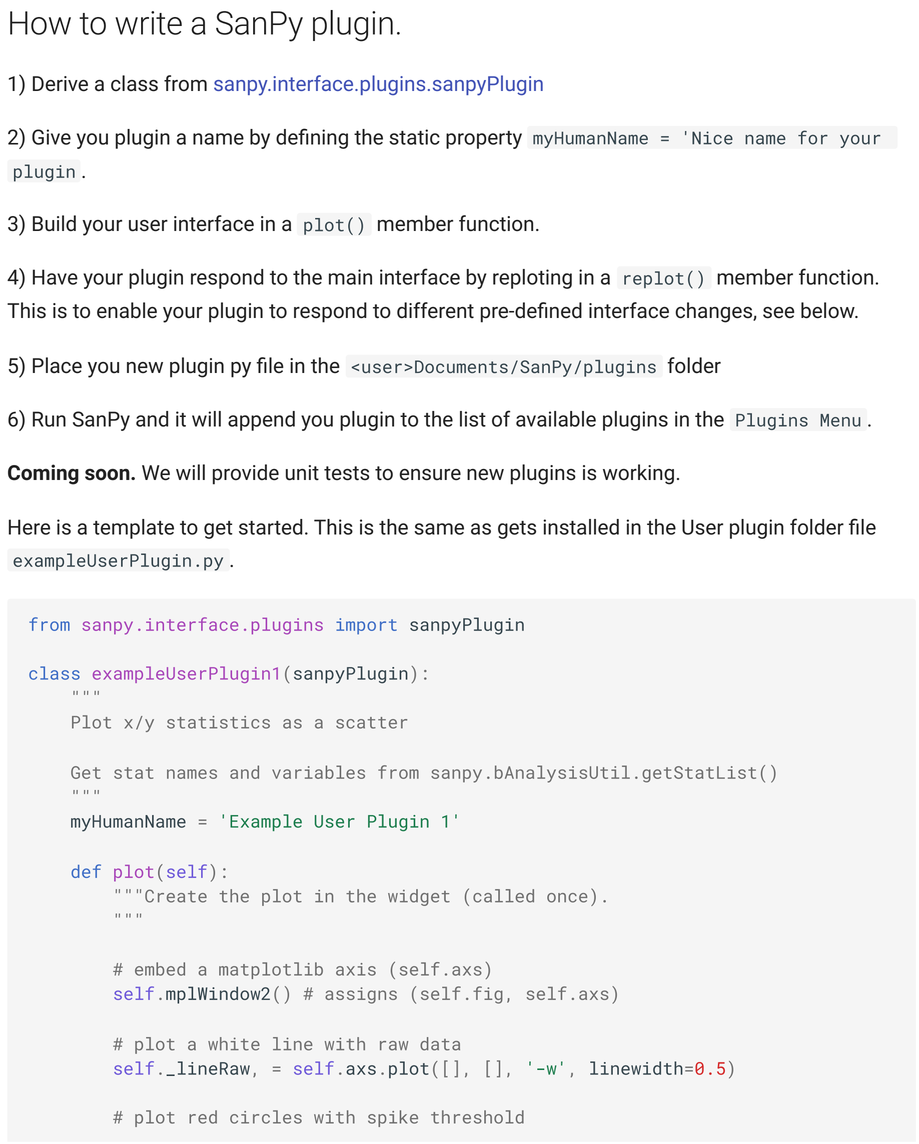
- Derive a class from sanpy.user_analysis.baseUserAnalysis
- In the member function `defineUserStats()`, define the name of your new analysis with addUserStat()
- In the member function `run()`, for each spike in the analysis, calculate your new stat and set the value with `setSpikeValue()`.

Here is a simple example to get you started.

```python
class exampleUserAnalysis(baseUserAnalysis):
    """
    An example user defined analysis.

    We will add 'User Time To Peak (ms)', defines as:
        For each AP, the time interval between spike threshold and peak

    We need to define the behavior of two inherited functions

    1) defineUserStats()
        add any numner of user stats with
            addUserStat(human_name, internal_name)

    2) run()
        Run the analysis you want to compute.
        Add the value for each spike with
            setSpikeValue(spike_index, internal_name, new_value)
    """

    def defineUserStats(self):
        """Add your user stats here."""
        self.addUserStat("User Time To Peak (ms)", "user_timeToPeak_ms")

    def run(self):
        """This is the user code to create and then fill in
            a new name/value for each spike."""

        # get filtered vm for the entire trace
        # filteredVm = self.getFilteredVm()

        for spikeIdx, spikeDict in enumerate(self.ba.spikeDict):

            # add time to peak
            thresholdSec = spikeDict["thresholdSec"]
            peakSecond = spikeDict["peakSec"]
            timeToPeak_ms = (peakSecond - thresholdSec) * 1000

            # assign to underlying bAnalysis
            self.setSpikeValue(spikeIdx, "user_timeToPeak_ms", timeToPeak_ms)
```

Supplemental Recipe 3.

See: https://cudmore.github.io/SanPy/api/writing-a-plugin/



How to write a SanPy plugin.

1) Derive a class from sanpy.interface.plugins.sanpyPlugin

2) Give you plugin a name by defining the static property `myHumanName = 'Nice name for your plugin`.

3) Build your user interface in a `plot()` member function.

4) Have your plugin respond to the main interface by reploting in a `replot()` member function. This is to enable your plugin to respond to different pre-defined interface changes, see below.

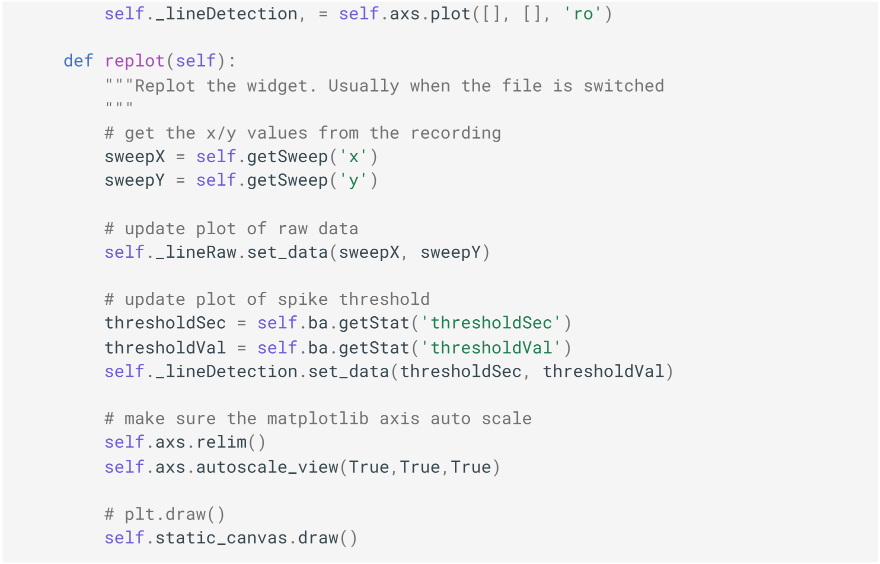
5) Place you new plugin py file in the `<user>Documents/SanPy/plugins` folder

6) Run SanPy and it will append you plugin to the list of available plugins in the `Plugins Menu`.

Coming soon. We will provide unit tests to ensure new plugins is working.

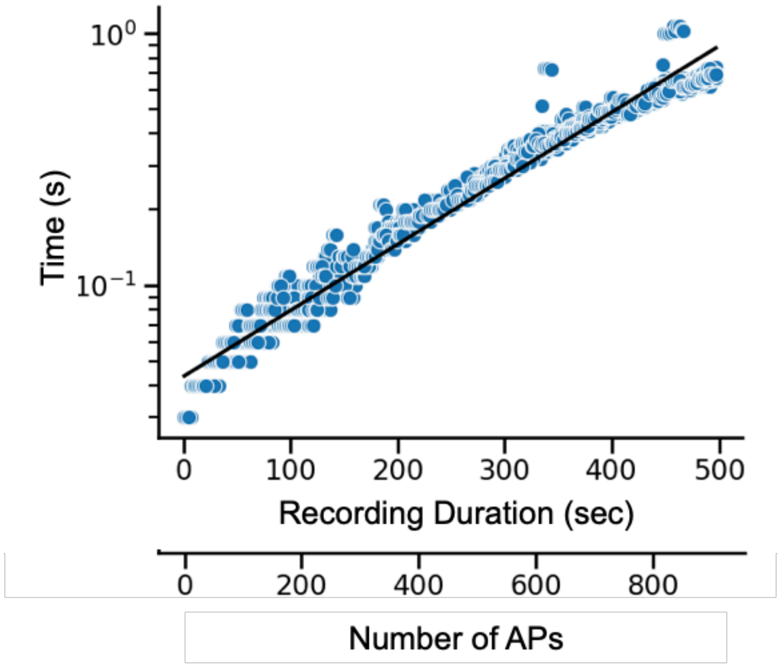
Here is a template to get started. This is the same as gets installed in the User plugin folder file `exampleUserPlugin.py`.

```
from sanpy.interface.plugins import sanpyPlugin

class exampleUserPlugin1(sanpyPlugin):
    """
    Plot x/y statistics as a scatter

    Get stat names and variables from sanpy.bAnalysisUtil.getStatList()
    """
    myHumanName = 'Example User Plugin 1'

    def plot(self):
        """Create the plot in the widget (called once).
        """

        # embed a matplotlib axis (self.axs)
        self.mplWindow2() # assigns (self.fig, self.axs)

        # plot a white line with raw data
        self._lineRaw, = self.axs.plot([], [], '-w', linewidth=0.5)

        # plot red circles with spike threshold
```



```
        self._lineDetection, = self.axs.plot([], [], 'ro')

    def replot(self):
        """Replot the widget. Usually when the file is switched
        """
        # get the x/y values from the recording
        sweepX = self.getSweep('x')
        sweepY = self.getSweep('y')

        # update plot of raw data
        self._lineRaw.set_data(sweepX, sweepY)

        # update plot of spike threshold
        thresholdSec = self.ba.getStat('thresholdSec')
        thresholdVal = self.ba.getStat('thresholdVal')
        self._lineDetection.set_data(thresholdSec, thresholdVal)

        # make sure the matplotlib axis auto scale
        self.axs.relim()
        self.axs.autoscale_view(True,True,True)

        # plt.draw()
        self.static_canvas.draw()
```

Supplemental Figure 1. Analysis of runtime for AP detection



Supplemental Figure 1. Analysis of runtime for AP detection. Plot of the time to execute AP detection versus the recording duration analyzed and corresponding number of APs detected. Each symbol (circle) represents one run of the detection algorithm for a given recording duration and number of APs. Y-axis is a log scale. Exponential fit is show as a line (black).