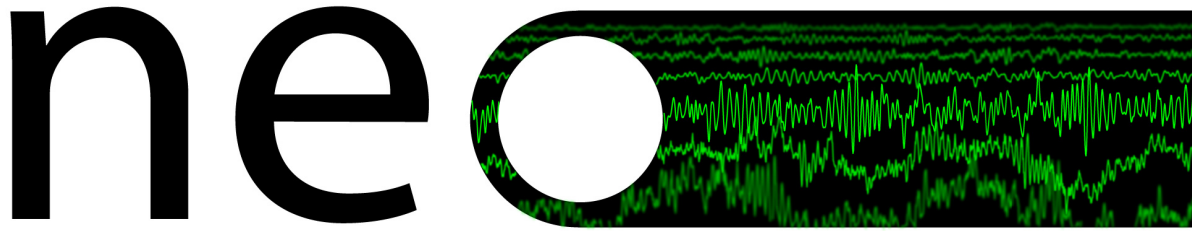

Neo Documentation

Release 0.4.1

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August 03, 2016

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Neo is a package for representing electrophysiology data in Python, together with support for reading a wide range of neurophysiology file formats, including Spike2, NeuroExplorer, AlphaOmega, Axon, Blackrock, Plexon, Tdt, and support for writing to a subset of these formats plus non-proprietary formats including HDF5.

The goal of Neo is to improve interoperability between Python tools for analyzing, visualizing and generating electrophysiology data (such as [OpenElectrophy](#), [NeuroTools](#), [G-node](#), [Helmholtz](#), [PyNN](#)) by providing a common, shared object model. In order to be as lightweight a dependency as possible, Neo is deliberately limited to representation of data, with no functions for data analysis or visualization.

Neo implements a hierarchical data model well adapted to intracellular and extracellular electrophysiology and EEG data with support for multi-electrodes (for example tetrodes). Neo's data objects build on the [quantities](#) package, which in turn builds on NumPy by adding support for physical dimensions. Thus Neo objects behave just like normal NumPy arrays, but with additional metadata, checks for dimensional consistency and automatic unit conversion.

A project with similar aims but for neuroimaging file formats is [NiBabel](#).

Download and Installation

Neo is a pure Python package, so it should be easy to get it running on any system.

1.1 Dependencies

- Python ≥ 2.6
- numpy $\geq 1.7.1$
- quantities $\geq 0.9.0$

For Debian/Ubuntu, you can install these using:

```
$ apt-get install python-numpy python-pip
$ pip install quantities
```

You may need to run these as root. For other operating systems, you can download installers from the links above.

Certain IO modules have additional dependencies. If these are not satisfied, Neo will still install but the IO module that uses them will fail on loading:

- scipy $\geq 0.12.0$ for NeoMatlabIO
- pytables ≥ 2.4 for Hdf5IO

For SciPy on Debian testing/Ubuntu, you can install these using:

```
$ apt-get install python-scipy python-tables
```

1.2 Installing from the Python Package Index

If you have pip installed:

```
$ pip install neo
```

This will automatically download and install the latest release (again you may need to have administrator privileges on the machine you are installing on).

To download and install manually, download:

<http://pypi.python.org/packages/source/n/neo/neo-0.4.1.tar.gz>

Then:

```
$ tar xzf neo-0.4.1.tar.gz
$ cd neo-0.4.1
$ python setup.py install
```

or:

```
$ python3 setup.py install
```

depending on which version of Python you are using.

1.3 Installing from source

To install the latest version of Neo from the Git repository:

```
$ git clone git://github.com/NeuralEnsemble/python-neo.git
$ cd python-neo
$ python setup.py install
```

1.4 Python 3 support

neo.core is fully compatible with Python 3, but only some of the IO modules support it, as shown in the table below:

Module	Python 2	Python 3
AlphaOmegaIO	Yes	No
AsciiSignalIO	Yes	Yes
AsciiSpikeTrainIO	Yes	Yes
AxonIO	Yes	Yes
BlackrockIO	Yes	No
BrainwareDamIO	Yes	Yes
BrainwareF32IO	Yes	Yes
BrainwareSrcIO	Yes	Yes
ElanIO	Yes	No
HDF5IO	Yes	No
KlustakwikIO	Yes	No
KwikIO	Yes	Yes
MicromedIO	Yes	No
NeoMatlabIO	Yes	Yes
NeuroExplorerIO	Yes	No
NeuroscopeIO	Yes	Yes
PickleIO	Yes	Yes
PlexonIO	Yes	No
PyNNIO	Yes	Yes
RawBinarySignalIO	Yes	Yes
Spike2IO	Yes	Yes
TdtIO	Yes	No
WinEdrIO	Yes	Yes
WinWcpIO	Yes	Yes

2.1 Introduction

Objects in Neo represent neural data and collections of data. Neo objects fall into three categories: data objects, container objects and grouping objects.

2.1.1 Data objects

These objects directly represent data as arrays of numerical values with associated metadata (units, sampling frequency, etc.).

AnalogSignal: A regular sampling of a continuous, analog signal.

AnalogSignalArray: A regular sampling of a multichannel continuous analog signal. This representation (as a 2D NumPy array) may be more efficient for subsequent analysis than the equivalent list of individual `AnalogSignal` objects.

Spike: One action potential characterized by its time and waveform.

SpikeTrain: A set of action potentials (spikes) emitted by the same unit in a period of time (with optional waveforms).

Event and EventArray: A time point representing an event in the data, or an array of such time points.

Epoch and EpochArray: An interval of time representing a period of time in the data, or an array of such intervals.

2.1.2 Container objects

There is a simple hierarchy of containers:

Segment: A container for heterogeneous discrete or continuous data sharing a common clock (time basis) but not necessarily the same sampling rate, start time or end time. A `Segment` can be considered as equivalent to a “trial”, “episode”, “run”, “recording”, etc., depending on the experimental context. May contain any of the data objects.

Block: The top-level container gathering all of the data, discrete and continuous, for a given recording session. Contains `Segment` and `RecordingChannelGroup` objects.

2.1.3 Grouping objects

These objects express the relationships between data items, such as which signals were recorded on which electrodes, which spike trains were obtained from which membrane potential signals, etc. They contain references to data objects that cut across the simple container hierarchy.

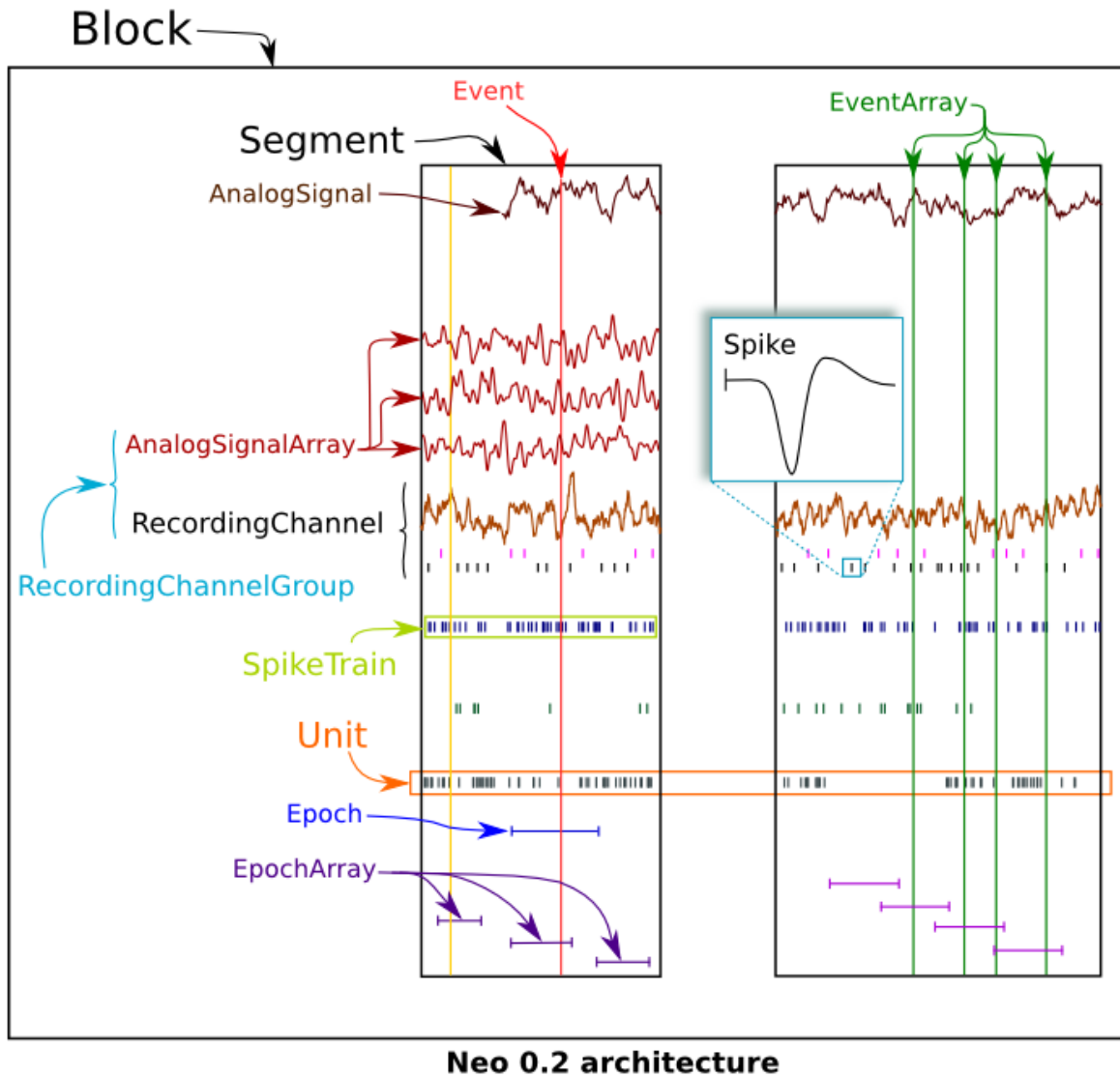
RecordingChannel: Links `AnalogSignal`, `SpikeTrain` objects that come from the same logical and/or physical channel inside a `Block`, possibly across several `Segment` objects.

RecordingChannelGroup:

A group for associated `RecordingChannel` objects. This has several possible uses:

- for linking several `AnalogSignalArray` objects across several `Segment` objects inside a `Block`.
- for multielectrode arrays, where spikes may be recorded on more than one recording channel, and so the `RecordingChannelGroup` can be used to associate each `Unit` with the group of recording channels from which it was calculated.
- for grouping several `RecordingChannel` objects. There are many use cases for this. For instance, for intracellular recording, it is common to record both membrane potentials and currents at the same time, so each `RecordingChannelGroup` may correspond to the particular property that is being recorded. For multielectrode arrays, `RecordingChannelGroup` is used to gather all `RecordingChannel` objects of the same array.

Unit: A `Unit` gathers all the `SpikeTrain` objects within a common `Block`, possibly across several `Segments`, that have been emitted by the same cell. A `Unit` is linked to `RecordingChannelGroup` objects from which it was detected. This replaces the `Neuron` class in the previous version of Neo (v0.1).



2.2 Relationships between objects

Container objects like `Block` or `Segment` are gateways to access other objects. For example, a `Block` can access a `Segment` with:

```
>>> bl = Block()
>>> bl.segments
# gives a list of segments
```

A `Segment` can access the `AnalogSignal` objects that it contains with:

```
>>> seg = Segment()
>>> seg.analogsignals
# gives a list a AnalogSignals
```

In the *Neo diagram* below, these *one to many* relationships are represented by cyan arrows. In general, an object can access its children with an attribute `childname+s` in lower case, e.g.

- `Block.segments`
- `Segments.analogsignals`
- `Segments.spiketrains`
- `Block.recordingchannelgroups`

These relationships are bi-directional, i.e. a child object can access its parent:

- `Segment.block`
- `AnalogSignal.segment`
- `SpikeTrains.segment`
- `RecordingChannelGroup.block`

Here is an example showing these relationships in use:

```
from neo.io import AxonIO
import urllib
url = "https://portal.g-node.org/neo/axon/File_axon_3.abf"
filename = './test.abf'
urllib.urlretrieve(url, filename)

r = AxonIO(filename=filename)
bl = r.read() # read the entire file > a Block
print(bl)
print(bl.segments) # child access
for seg in bl.segments:
    print(seg)
    print(seg.block) # parent access
```

On the *Neo diagram* you can also see a magenta line reflecting the *many-to-many* relationship between `RecordingChannel` and `RecordingChannelGroup`. This means that each group can contain multiple channels, and each channel can belong to multiple groups.

In some cases, a one-to-many relationship is sufficient. Here is a simple example with tetrodes, in which each tetrode has its own group.:

```
from neo import *
bl = Block()

# creating individual channel
all_rc = [ ]
for i in range(16):
    rc = RecordingChannel(index=i, name='rc %d' % i)
    all_rc.append(rc)

# the four tetrodes
for i in range(4):
    rcg = RecordingChannelGroup(name='Tetrode %d' % i)
    for rc in all_rc[i*4:(i+1)*4]:
        rcg.recordingchannels.append(rc)
        rc.recordingchannelgroups.append(rcg)
    bl.recordingchannelgroups.append(rcg)

# now we load the data and associate it with the created channels
# ...
```

Now consider a more complex example: a 1x4 silicon probe, with a neuron on channels 0,1,2 and another neuron on channels 1,2,3. We create a group for each neuron to hold the *Unit* object associated with this spikesorting group. Each

group also contains the channels on which that neuron spiked. The relationship is many-to-many because channels 1 and 2 occur in multiple groups.:

```
from neo import *
bl = Block(name='probe data')

# create individual channels
all_rc = []
for i in range(4):
    rc = RecordingChannel(index=i, name='channel %d' % i)
    all_rc.append(rc)

# one group for each neuron
rcg0 = RecordingChannelGroup(name='Group 0', index=0)
for i in [0, 1, 2]:
    rcg1.recordingchannels.append(all_rc[i])
    rc[i].recordingchannelgroups.append(rcg0)
bl.recordingchannelgroups.append(rcg0)

rcg1 = RecordingChannelGroup(name='Group 1', index=1)
for i in [1, 2, 3]:
    rcg1.recordingchannels.append(all_rc[i])
    rc[i].recordingchannelgroups.append(rcg1)
bl.recordingchannelgroups.append(rcg1)

# now we add the spiketrain from Unit 0 to rcg0
# and add the spiketrain from Unit 1 to rcg1
# ...
```

Note that because neurons are sorted from groups of channels in this situation, it is natural that the `RecordingChannelGroup` contains the `Unit` object. That unit then contains its spiketrains.

There are some shortcuts for IO writers to automatically create this structure based on ‘channel_indexes’ entries in the annotations for each spiketrain.

See [Typical use cases](#) for more examples of how the different objects may be used.

2.3 Neo diagram

Object:

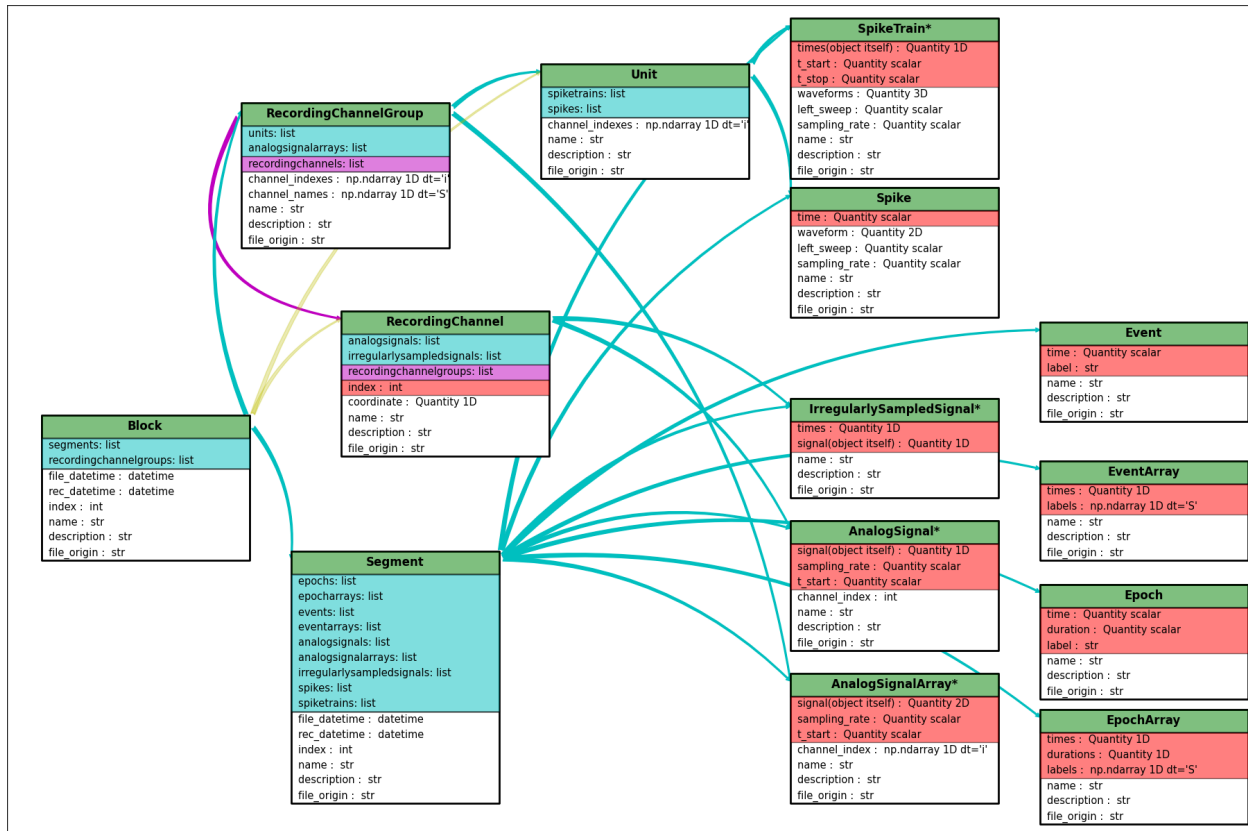
- With a star = inherits from `Quantity`

Attributes:

- In red = required
- In white = recommended

Relationship:

- In cyan = one to many
- In magenta = many to many
- In yellow = properties (deduced from other relationships)



[Click here for a better quality SVG diagram](#)

For more details, see the [API Reference](#).

2.4 Inheritance

Some Neo objects (`AnalogSignal`, `SpikeTrain`, `AnalogSignalArray`) inherit from `Quantity`, which in turn inherits from `NumPy ndarray`. This means that a Neo `AnalogSignal` actually is also a `Quantity` and an array, giving you access to all of the methods available for those objects.

For example, you can pass a `SpikeTrain` directly to the `numpy.histogram()` function, or an `AnalogSignal` directly to the `numpy.std()` function.

2.5 Initialization

Neo objects are initialized with “required”, “recommended”, and “additional” arguments.

- Required arguments **MUST** be provided at the time of initialization. They are used in the construction of the object.
- Recommended arguments may be provided at the time of initialization. They are accessible as Python attributes. They can also be set or modified after initialization.
- Additional arguments are defined by the user and are not part of the Neo object model. A primary goal of the Neo project is extensibility. These additional arguments are entries in an attribute of the object: a Python dict called `annotations`.

2.5.1 Example: SpikeTrain

`SpikeTrain` is a `Quantity`, which is a NumPy array containing values with physical dimensions. The spike times are a required attribute, because the dimensionality of the spike times determines the way in which the `Quantity` is constructed.

Here is how you initialize a `SpikeTrain` with required arguments:

```
>>> import neo
>>> st = neo.SpikeTrain([3, 4, 5], units='sec', t_stop=10.0)
>>> print(st)
[ 3.  4.  5.] s
```

You will see the spike times printed in a nice format including the units. Because `st` “is a” `Quantity` array with units of seconds, it absolutely must have this information at the time of initialization. You can specify the spike times with a keyword argument too:

```
>>> st = neo.SpikeTrain(times=[3, 4, 5], units='sec', t_stop=10.0)
```

The spike times could also be in a NumPy array.

If it is not specified, `t_start` is assumed to be zero, but another value can easily be specified:

```
>>> st = neo.SpikeTrain(times=[3, 4, 5], units='sec', t_start=1.0, t_stop=10.0)
>>> st.t_start
array(1.0) * s
```

Recommended attributes must be specified as keyword arguments, not positional arguments.

Finally, let’s consider “additional arguments”. These are the ones you define for your experiment:

```
>>> st = neo.SpikeTrain(times=[3, 4, 5], units='sec', t_stop=10.0, rat_name='Fred')
>>> print(st.annotations)
{'rat_name': 'Fred'}
```

Because `rat_name` is not part of the Neo object model, it is placed in the dict `annotations`. This dict can be modified as necessary by your code.

2.5.2 Annotations

As well as adding annotations as “additional” arguments when an object is constructed, objects may be annotated using the `annotate()` method possessed by all Neo core objects, e.g.:

```
>>> seg = Segment()
>>> seg.annotate(stimulus="step pulse", amplitude=10*nA)
>>> print(seg.annotations)
{'amplitude': array(10.0) * nA, 'stimulus': 'step pulse'}
```

Since annotations may be written to a file or database, there are some limitations on the data types of annotations: they must be “simple” types or containers (lists, dicts, NumPy arrays) of simple types, where the simple types are integer, float, complex, `Quantity`, string, date, time and datetime.

See `specific_annotations`

Typical use cases

3.1 Recording multiple trials from multiple channels

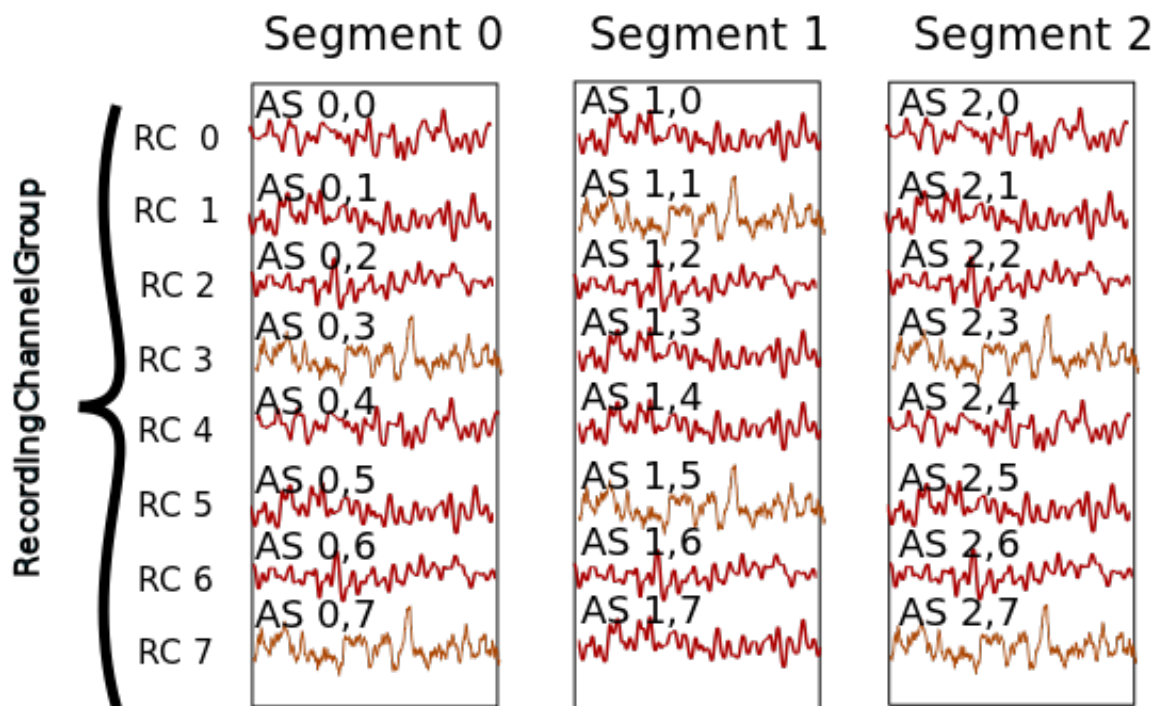
In this example we suppose that we have recorded from an 8-channel probe, and that we have recorded three trials/episodes. We therefore have a total of $8 \times 3 = 24$ signals, each represented by an `AnalogSignal` object.

Our entire dataset is contained in a `Block`, which in turn contains:

- 3 `Segment` objects, each representing data from a single trial,
- 1 `RecordingChannelGroup`, composed of 8 `RecordingChannel` objects.

RC = `RecordingChannel`

AS = `AnalogSignal`



`Segment` and `RecordingChannel` objects provide two different ways to access the data, corresponding respectively, in this scenario, to access by **time** and by **space**.

Note: segments do not always represent trials, they can be used for many purposes: segments could represent parallel recordings for different subjects, or different steps in a current clamp protocol.

Temporal (by segment)

In this case you want to go through your data in order, perhaps because you want to correlate the neural response with the stimulus that was delivered in each segment. In this example, we're averaging over the channels.

```
import numpy as np
from matplotlib import pyplot as plt

for seg in block.segments:
    print("Analyzing segment %d" % seg.index)

    siglist = seg.analogsignals
    avg = np.mean(siglist, axis=0)

    plt.figure()
    plt.plot(avg)
    plt.title("Peak response in segment %d: %f" % (seg.index, avg.max()))
```

Spatial (by channel)

In this case you want to go through your data by channel location and average over time. Perhaps you want to see which physical location produces the strongest response, and every stimulus was the same:

```
# We assume that our block has only 1 RecordingChannelGroup
rcg = block.recordingchannelgroups[0]:
for rc in rcg.recordingchannels:
    print("Analyzing channel %d: %s", (rc.index, rc.name))

    siglist = rc.analogsignals
    avg = np.mean(siglist, axis=0)

    plt.figure()
    plt.plot(avg)
    plt.title("Average response on channel %d: %s" % (rc.index, rc.name))
```

Note that `Block.list_recordingchannels` is a property that gives direct access to all `RecordingChannels`, so the two first lines:

```
rcg = block.recordingchannelgroups[0]:
for rc in rcg.recordingchannels:
```

could be written as:

```
for rc in block.list_recordingchannels:
```

Mixed example

Combining simultaneously the two approaches of descending the hierarchy temporally and spatially can be tricky. Here's an example. Let's say you saw something interesting on channel 5 on even numbered trials during the experiment and you want to follow up. What was the average response?

```
avg = np.mean([seg.analogsignals[5] for seg in block.segments[::2]], axis=1)
plt.plot(avg)
```

Here we have assumed that segment are temporally ordered in a `block.segments` and that signals are ordered by channel number in `seg.analogsignals`. It would be safer, however, to avoid assumptions by explicitly testing the `index` attribute of the `RecordingChannel` and `Segment` objects. One way to do this is to loop over the recording channels and access the segments through the signals (each `AnalogSignal` contains a reference to the `Segment` it is contained in).

```
siglist = []
rcg = block.recordingchannelgroups[0]:
for rc in rcg.recordingchannels:
    if rc.index == 5:
        for anasig in rc.analogsignals:
            if anasig.segment.index % 2 == 0:
                siglist.append(anasig)
avg = np.mean(siglist)
```

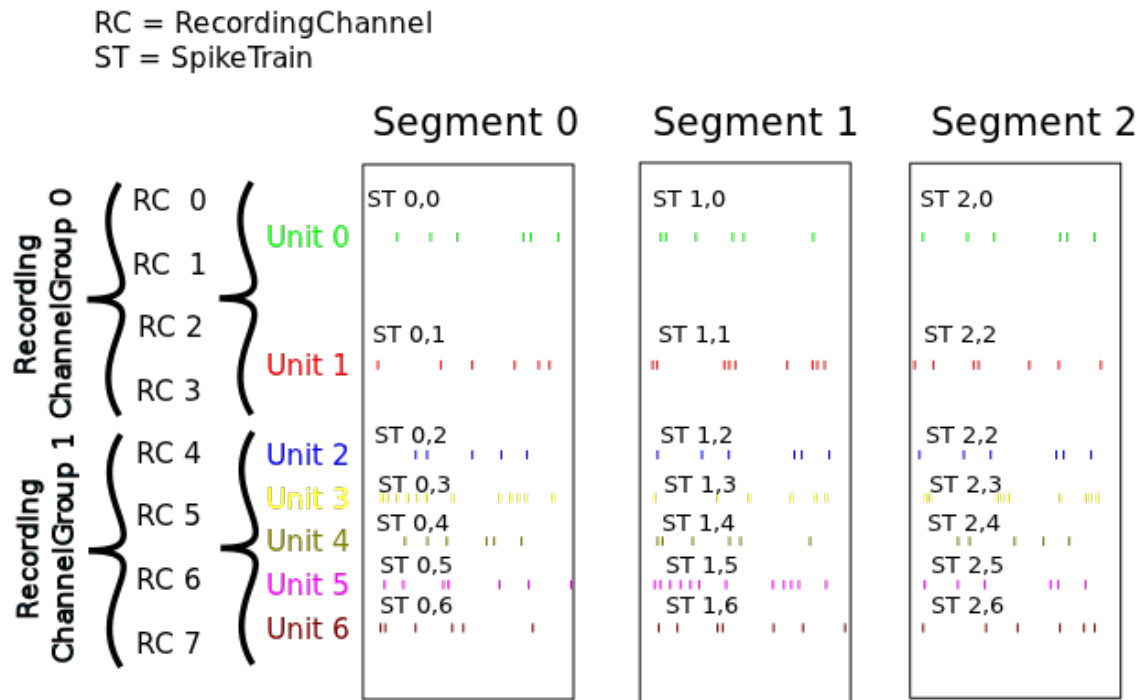
3.2 Recording spikes from multiple tetrodes

Here is a similar example in which we have recorded with two tetrodes and extracted spikes from the extra-cellular signals. The spike times are contained in `SpikeTrain` objects.

Again, our data set is contained in a `Block`, which contains:

- 3 `Segments` (one per trial).
- 2 `RecordingChannelGroups` (one per tetrode), which contain:
 - 4 `RecordingChannels` each
 - 2 `Unit` objects (= 2 neurons) for the first `RecordingChannelGroup`
 - 5 `Units` for the second `RecordingChannelGroup`.

In total we have $3 \times 7 = 21$ `SpikeTrains` in this `Block`.



There are three ways to access the SpikeTrain data:

- by Segment
- by RecordingChannel
- by Unit

By Segment

In this example, each Segment represents data from one trial, and we want a PSTH for each trial from all units combined:

```
for seg in block.segments:
    print("Analyzing segment %d" % seg.index)
    stlist = [st - st.t_start for st in seg.spiketrains]
    plt.figure()
    count, bins = np.histogram(stlist)
    plt.bar(bins[:-1], count, width=bins[1] - bins[0])
    plt.title("PSTH in segment %d" % seg.index)
```

By Unit

Now we can calculate the PSTH averaged over trials for each unit, using the `block.list_units` property:

```
for unit in block.list_units:
    stlist = [st - st.t_start for st in unit.spiketrains]
    plt.figure()
    count, bins = np.histogram(stlist)
    plt.bar(bins[:-1], count, width=bins[1] - bins[0])
    plt.title("PSTH of unit %s" % unit.name)
```

By RecordingChannelGroup

Here we calculate a PSTH averaged over trials by channel location, blending all units:

```
for rcg in block.recordingchannelgroups:
    stlist = []
    for unit in rcg.units:
        stlist.extend([st - st.t_start for st in unit.spiketrains])
    plt.figure()
    count, bins = np.histogram(stlist)
    plt.bar(bins[:-1], count, width=bins[1] - bins[0])
    plt.title("PSTH blend of tetrode %s" % rcg.name)
```

3.3 Spike sorting

Spike sorting is the process of detecting and classifying high-frequency deflections (“spikes”) on a group of physically nearby recording channels.

For example, let’s say you have defined a RecordingChannelGroup for a tetrode containing 4 separate channels. Here is an example showing (with fake data) how you could iterate over the contained signals and extract spike times. (Of course in reality you would use a more sophisticated algorithm.)

```
# generate some fake data
rcg = RecordingChannelGroup()
for n in range(4):
    rcg.recordingchannels.append(neo.RecordingChannel())
    rcg.recordingchannels[n].analogsignals.append(
        AnalogSignal([.1, -2.0, .1, -.1, -.1, -3.0, .1, .1],
            sampling_rate=1000*Hz, units='V'))

# extract spike trains from each channel
st_list = []
for n in range(len(rcg.recordingchannels[0].analogsignals)):
    sigarray = np.array(
        [rcg.recordingchannels[m].analogsignals[n] for m in range(4)])
    # use a simple threshold detector
    spike_mask = np.where(np.min(sigarray, axis=0) < -1.0 * pq.V)[0]

    # create a spike train
    anasig = rcg.recordingchannels[m].analogsignals[n]
    spike_times = anasig.times[spike_mask]
    st = neo.SpikeTrain(spike_times, t_start=anasig.t_start,
        anasig.t_stop)

    # remember the spike waveforms
    wf_list = []
    for spike_idx in np.nonzero(spike_mask)[0]:
        wf_list.append(sigarray[:, spike_idx-1:spike_idx+2])
    st.waveforms = np.array(wf_list)

    st_list.append(st)
```

At this point, we have a list of spiketrain objects. We could simply create a single Unit object, assign all spike trains to it, and then assign the Unit to the group on which we detected it.

```
u = Unit()
u.spiketrains = st_list
rcg.units.append(u)
```

Now the recording channel group (tetrode) contains a list of analogsignals, and a single Unit object containing all of the detected spiketrains from those signals.

Further processing could assign each of the detected spikes to an independent source, a putative single neuron. (This processing is outside the scope of Neo. There are many open-source toolboxes to do it, for instance our sister project OpenElectrophy.)

In that case we would create a separate Unit for each cluster, assign its spiketrains to it, and then store all the units in the original recording channel group.

4.1 Preamble

The Neo `io` module aims to provide an exhaustive way of loading and saving several widely used data formats in electrophysiology. The more these heterogeneous formats are supported, the easier it will be to manipulate them as Neo objects in a similar way. Therefore the IO set of classes propose a simple and flexible IO API that fits many format specifications. It is not only file-oriented, it can also read/write objects from a database.

`neo.io` can be seen as a *pure-Python* and open-source Neuroshare replacement.

At the moment, there are 3 families of IO modules:

1. for reading closed manufacturers' formats (Spike2, Plexon, AlphaOmega, BlackRock, Axon, ...)
2. for reading(/writing) formats from open source tools (KlustaKwik, Elan, WinEdr, WinWcp, PyNN, ...)
3. for reading/writing Neo structure in neutral formats (HDF5, .mat, ...) but with Neo structure inside (NeoHDF5, NeoMatlab, ...)

Combining **1** for reading and **3** for writing is a good example of use: converting your datasets to a more standard format when you want to share/collaborate.

4.2 Introduction

There is an intrinsic structure in the different Neo objects, that could be seen as a hierarchy with cross-links. See [Neo core](#). The highest level object is the `Block` object, which is the high level container able to encapsulate all the others.

A `Block` has therefore a list of `Segment` objects, that can, in some file formats, be accessed individually. Depending on the file format, i.e. if it is streamable or not, the whole `Block` may need to be loaded, but sometimes particular `Segment` objects can be accessed individually. Within a `Segment`, the same hierarchical organisation applies. A `Segment` embeds several objects, such as `SpikeTrain`, `AnalogSignal`, `AnalogSignalArray`, `EpochArray`, `EventArray` (basically, all the different Neo objects).

Depending on the file format, these objects can sometimes be loaded separately, without the need to load the whole file. If possible, a file IO therefore provides distinct methods allowing to load only particular objects that may be present in the file. The basic idea of each IO file format is to have, as much as possible, read/write methods for the individual encapsulated objects, and otherwise to provide a read/write method that will return the object at the highest level of hierarchy (by default, a `Block` or a `Segment`).

The `neo.io` API is a balance between full flexibility for the user (all `read_XXX()` methods are enabled) and simple, clean and understandable code for the developer (few `read_XXX()` methods are enabled). This means that not all IOs offer the full flexibility for partial reading of data files.

4.3 One format = one class

The basic syntax is as follows. If you want to load a file format that is implemented in a generic `MyFormatIO` class:

```
>>> from neo.io import MyFormatIO
>>> reader = MyFormatIO(filename = "myfile.dat")
```

you can replace `MyFormatIO` by any implemented class, see [List of implemented formats](#)

4.4 Modes

IO can be based on file, directory, database or fake This is describe in mode attribute of the IO class.

```
>>> from neo.io import MyFormatIO
>>> print MyFormatIO.mode
'file'
```

For *file* mode the *filename* keyword argument is necessary. For *directory* mode the *dirname* keyword argument is necessary.

Ex:

```
>>> reader = io.PlexonIO(filename='File_plexon_1.plx')
>>> reader = io.TdtIO(dirname='aep_05')
```

4.5 Supported objects/readable objects

To know what types of object are supported by a given IO interface:

```
>>> MyFormatIO.supported_objects
[Segment , AnalogSignal , SpikeTrain, Event, Spike]
```

Supported objects does not mean objects that you can read directly. For instance, many formats support `AnalogSignal` but don't allow them to be loaded directly, rather to access the `AnalogSignal` objects, you must read a `Segment`:

```
>>> seg = reader.read_segment()
>>> print(seg.analogsignals)
>>> print(seg.analogsignals[0])
```

To get a list of directly readable objects

```
>>> MyFormatIO.readable_objects
[Segment]
```

The first element of the previous list is the highest level for reading the file. This mean that the IO has a `read_segment()` method:

```
>>> seg = reader.read_segment()
>>> type(seg)
neo.core.Segment
```

All IOs have a `read()` method that returns a list of `Block` objects (representing the whole content of the file):


```
>>> bl = reader.read()
>>> print bl[0].segments[0]
neo.core.Segment
```

4.6 Lazy and cascade options

In some cases you may not want to load everything in memory because it could be too big. For this scenario, two options are available:

- `lazy=True/False`. With `lazy=True` all arrays will have a size of zero, but all the metadata will be loaded. `lazy_shape` attribute is added to all object that inheritate Quantities or `numpy.ndarray` (`AnalogSignal`, `AnalogSignalArray`, `SpikeTrain`) and to object that have array like attributes (`EpochArray`, `EventArray`) In that cases, `lazy_shape` is a tuple that have the same shape with `lazy=False`.
- `cascade=True/False`. With `cascade=False` only one object is read (and *one_to_many* and *many_to_many* relationship are not read).

By default (if they are not specified), `lazy=False` and `cascade=True`, i.e. all data is loaded.

Example cascade:

```
>>> seg = reader.read_segment( cascade=True)
>>> print(len(seg.analogsignals)) # this is N
>>> seg = reader.read_segment(cascade=False)
>>> print(len(seg.analogsignals)) # this is zero
```

Example lazy:

```
>>> seg = reader.read_segment(lazy=False)
>>> print(seg.analogsignals[0].shape) # this is N
>>> seg = reader.read_segment(lazy=True)
>>> print(seg.analogsignals[0].shape) # this is zero, the AnalogSignal is empty
>>> print(seg.analogsignals[0].lazy_shape) # this is N
```

Some IOs support advanced forms of lazy loading, cascading or both (these features are currently limited to the HDF5 IO, which supports both forms).

- For lazy loading, these IOs have a `load_lazy_object()` method that takes a single parameter: a data object previously loaded by the same IO in lazy mode. It returns the fully loaded object, without links to container objects (`Segment` etc.). Continuing the lazy example above:

```
>>> lazy_sig = seg.analogsignals[0] # Empty signal
>>> full_sig = reader.load_lazy_object(lazy_sig)
>>> print(lazy_sig.lazy_shape, full_sig.shape) # Identical
>>> print(lazy_sig.segment) # Has the link to the object "seg"
>>> print(full_sig.segment) # Does not have the link: None
```

- For lazy cascading, IOs have a `load_lazy_cascade()` method. This method is not called directly when interacting with the IO, but its presence can be used to check if an IO supports lazy cascading. To use lazy cascading, the `cascade` parameter is set to `'lazy'`:

```
>>> block = reader.read(cascade='lazy')
```

You do not have to do anything else, lazy cascading is now active for the object you just loaded. You can interact with the object in the same way as if it was loaded with `cascade=True`. However, only the objects that are actually accessed are loaded as soon as they are needed:

```
>>> print(block.recordingchannelgroups[0].name) # The first RecordingChannelGroup is loaded
>>> print(block.segments[0].analogsignals[1]) # The first Segment and its second AnalogSignal a
```

Once an object has been loaded with lazy cascading, it stays in memory:

```
>>> print(block.segments[0].analogsignals[0]) # The first Segment is already in memory, its fir
```

4.7 Logging

neo uses the standard python logging module for logging. All *neo.io* classes have logging set up by default, although not all classes produce log messages. The logger name is the same as the full qualified class name, e.g. `neo.io.hdf5io.NeoHdf5IO`. By default, only log messages that are critically important for users are displayed, so users should not disable log messages unless they are sure they know what they are doing. However, if you wish to disable the messages, you can do so:

```
>>> import logging
>>>
>>> logger = logging.getLogger('neo')
>>> logger.setLevel(100)
```

Some io classes provide additional information that might be interesting to advanced users. To enable these messages, do the following:

```
>>> import logging
>>>
>>> logger = logging.getLogger('neo')
>>> logger.setLevel(logging.INFO)
```

It is also possible to log to a file in addition to the terminal:

```
>>> import logging
>>>
>>> logger = logging.getLogger('neo')
>>> handler = logging.FileHandler('filename.log')
>>> logger.addHandler(handler)
```

To only log to the terminal:

```
>>> import logging
>>> from neo import logging_handler
>>>
>>> logger = logging.getLogger('neo')
>>> handler = logging.FileHandler('filename.log')
>>> logger.addHandler(handler)
>>>
>>> logging_handler.setLevel(100)
```

This can also be done for individual IO classes:

```
>>> import logging
>>>
>>> logger = logging.getLogger('neo.io.hdf5io.NeoHdf5IO')
>>> handler = logging.FileHandler('filename.log')
>>> logger.addHandler(handler)
```

Individual IO classes can have their loggers disabled as well:

```
>>> import logging
>>>
>>> logger = logging.getLogger('neo.io.hdf5io.NeoHdf5IO')
>>> logger.setLevel(100)
```

And more detailed logging messages can be enabled for individual IO classes:

```
>>> import logging
>>>
>>> logger = logging.getLogger('neo.io.hdf5io.NeoHdf5IO')
>>> logger.setLevel(logging.INFO)
```

The default handler, which is used to print logs to the command line, is stored in `neo.logging_handler`. This example changes how the log text is displayed:

```
>>> import logging
>>> from neo import logging_handler
>>>
>>> formatter = logging.Formatter('%(asctime)s - %(name)s - %(levelname)s - %(message)s')
>>> logging_handler.setFormatter(formatter)
```

For more complex logging, please see the documentation for the `logging` module.

Note: If you wish to implement more advanced logging as describe in the documentation for the `logging` module or elsewhere on the internet, please do so before calling any `neo` functions or initializing any `neo` classes.

This is because the default handler is created when `neo` is imported, but it is not attached to the `neo` logger until a class that uses logging is initialized or a function that uses logging is called. Further, the handler is only attached if there are no handlers already attached to the root logger or the `neo` logger, so adding your own logger will override the default one. Additional functions and/or classes may get logging during bugfix releases, so code relying on particular modules not having logging may break at any time without warning.

4.8 Details of API

The `neo.io` API is designed to be simple and intuitive:

- each file format has an IO class (for example for Spike2 files you have a `Spike2IO` class).
- each IO class inherits from the `BaseIO` class.
- each IO class can read or write directly one or several Neo objects (for example `Segment`, `Block`, ...): see the `readable_objects` and `writable_objects` attributes of the IO class.
- each IO class supports part of the `neo.core` hierarchy, though not necessarily all of it (see `supported_objects`).
- each IO class has a `read()` method that returns a list of `Block` objects. If the IO only supports `Segment` reading, the list will contain one block with all segments from the file.
- each IO class that supports writing has a `write()` method that takes as a parameter a list of blocks, a single block or a single segment, depending on the IO's `writable_objects`.
- each IO is able to do a *lazy* load: all metadata (e.g. `sampling_rate`) are read, but not the actual numerical data. `lazy_shape` attribute is added to provide information on real size.
- each IO is able to do a *cascade* load: if `True` (default) all child objects are loaded, otherwise only the top level object is loaded.

- each IO is able to save and load all required attributes (metadata) of the objects it supports.
- each IO can freely add user-defined or manufacturer-defined metadata to the `annotations` attribute of an object.

4.9 List of implemented formats

`neo.io` provides classes for reading and/or writing electrophysiological data files.

Note that if the package dependency is not satisfied for one io, it does not raise an error but a warning.

`neo.io.iolist` provides a list of succesfully imported io classes.

Classes:

class `neo.io.AlphaOmegaIO` (*filename=None*)

Class for reading data from Alpha Omega .map files (experimental)

This class is an experimental reader with important limitations. See the source code for details of the limitations. The code of this reader is of alpha quality and received very limited testing.

Usage:

```
>>> from neo import io
>>> r = io.AlphaOmegaIO( filename = 'File_AlphaOmega_1.map')
>>> blk = r.read_block(lazy = False, cascade = True)
>>> print blk.segments[0].analogsignals
```

class `neo.io.AsciiSignalIO` (*filename=None*)

Class for reading signal in generic ascii format. Columns represents signal. They share all the same sampling rate. The sampling rate is externally known or the first columns could hold the time vector.

Usage:

```
>>> from neo import io
>>> r = io.AsciiSignalIO(filename='File_asciisignal_2.txt')
>>> seg = r.read_segment(lazy=False, cascade=True)
>>> print seg.analogsignals
[<AnalogSignal(array([ 39.0625      ,  0.          ,  0.          , ..., -26.85546875 ...
```

class `neo.io.AsciiSpikeTrainIO` (*filename=None*)

Classe for reading/writing SpikeTrain in a text file. Each Spiketrain is a line.

Usage:

```
>>> from neo import io
>>> r = io.AsciiSpikeTrainIO( filename = 'File_ascii_spiketrain_1.txt')
>>> seg = r.read_segment(lazy = False, cascade = True,)
>>> print seg.spiketrains
[<SpikeTrain(array([ 3.89981604,  4.73258781,  0.608428 ,  4.60246277,  1.23805797,
...

```

class `neo.io.AxonIO` (*filename=None*)

Class for reading abf (axon binary file) file.

Usage:

```
>>> from neo import io
>>> r = io.AxonIO(filename='File_axon_1.abf')
>>> bl = r.read_block(lazy=False, cascade=True)
>>> print bl.segments
```

```
[<neo.core.segment.Segment object at 0x105516fd0>]
>>> print bl.segments[0].analogsignals
[<AnalogSignal(array([2.18811035, 2.19726562, 2.21252441, ...,
1.33056641, 1.3458252, 1.3671875]), dtype=float32) * pA,
[0.0 s, 191.2832 s], sampling rate: 10000.0 Hz)>]
>>> print bl.segments[0].eventarrays
[]
```

class neo.io.**BlackrockIO** (*filename*)

class neo.io.**BrainVisionIO** (*filename=None*)

Class for reading/writing data from BrainVision product (brainAmp, brain analyser...)

Usage:

```
>>> from neo import io
>>> r = io.BrainVisionIO( filename = 'File_brainvision_1.eeg')
>>> seg = r.read_segment(lazy = False, cascade = True,)
```

class neo.io.**BrainwareDamIO** (*filename=None*)

Class for reading Brainware raw data files with the extension ‘.dam’.

The read_block method returns the first Block of the file. It will automatically close the file after reading. The read method is the same as read_block.

Note:

The file format does not contain a sampling rate. The sampling rate is set to 1 Hz, but this is arbitrary. If you have a corresponding .src or .f32 file, you can get the sampling rate from that. It may also be possible to infer it from the attributes, such as “sweep length”, if present.

Usage:

```
>>> from neo.io.brainwaredamio import BrainwareDamIO
>>> damfile = BrainwareDamIO(filename='multi_500ms_multitrep_ch1.dam')
>>> blk1 = damfile.read()
>>> blk2 = damfile.read_block()
>>> print blk1.segments
>>> print blk1.segments[0].analogsignals
>>> print blk1.units
>>> print blk1.units[0].name
>>> print blk2
>>> print blk2[0].segments
```

class neo.io.**BrainwareF32IO** (*filename=None*)

Class for reading Brainware Spike ReCord files with the extension ‘.f32’

The read_block method returns the first Block of the file. It will automatically close the file after reading. The read method is the same as read_block.

The read_all_blocks method automatically reads all Blocks. It will automatically close the file after reading.

The read_next_block method will return one Block each time it is called. It will automatically close the file and reset to the first Block after reading the last block. Call the close method to close the file and reset this method back to the first Block.

The isopen property tells whether the file is currently open and reading or closed.

Note 1: There is always only one RecordingChannelGroup. BrainWare stores the equivalent of RecordingChannelGroups in separate files.

Usage:

```
>>> from neo.io.brainwaref32io import BrainwareF32IO
>>> f32file = BrainwareF32IO(filename='multi_500ms_multitrep_ch1.f32')
>>> blk1 = f32file.read()
>>> blk2 = f32file.read_block()
>>> print blk1.segments
>>> print blk1.segments[0].spiketrains
>>> print blk1.units
>>> print blk1.units[0].name
>>> print blk2
>>> print blk2[0].segments
```

class neo.io.**BrainwareSrcIO** (*filename=None*)

Class for reading Brainware Spike ReCord files with the extension '.src'

The read_block method returns the first Block of the file. It will automatically close the file after reading. The read method is the same as read_block.

The read_all_blocks method automatically reads all Blocks. It will automatically close the file after reading.

The read_next_block method will return one Block each time it is called. It will automatically close the file and reset to the first Block after reading the last block. Call the close method to close the file and reset this method back to the first Block.

The _isopen property tells whether the file is currently open and reading or closed.

Note 1: The first Unit in each RecordingChannelGroup is always UnassignedSpikes, which has a SpikeTrain for each Segment containing all the spikes not assigned to any Unit in that Segment.

Note 2: The first Segment in each Block is always Comments, which stores all comments as an EventArray object.

Note 3: The parameters from the BrainWare table for each condition are stored in the Segment annotations. If there are multiple repetitions of a condition, each repetition is stored as a separate Segment.

Note 4: There is always only one RecordingChannelGroup. BrainWare stores the equivalent of RecordingChannelGroups in separate files.

Usage:

```
>>> from neo.io.brainwaresrcio import BrainwareSrcIO
>>> srcfile = BrainwareSrcIO(filename='multi_500ms_multitrep_ch1.src')
>>> blk1 = srcfile.read()
>>> blk2 = srcfile.read_block()
>>> blks = srcfile.read_all_blocks()
>>> print blk1.segments
>>> print blk1.segments[0].spiketrains
>>> print blk1.units
>>> print blk1.units[0].name
>>> print blk2
>>> print blk2[0].segments
>>> print blks
>>> print blks[0].segments
```

class neo.io.**ElanIO** (*filename=None*)

Classe for reading/writing data from Elan.

Usage:

```
>>> from neo import io
>>> r = io.ElanIO( filename = 'File_elan_1.eeg')
>>> seg = r.read_segment(lazy = False, cascade = True,)
```

```
>>> print seg.analogsignals
[<AnalogSignal(array([ 89.21203613,  88.83666992,  87.21008301, ...,  64.56298828,
 67.94128418,  68.44177246], dtype=float32) * pA, [0.0 s, 101.5808 s], sampling rate: 1000.0 Hz)>]
>>> print seg.spiketrains
[]
>>> print seg.eventarrays
[]
```

class neo.io.ElphyIO(filename=None)

Class for reading from and writing to an Elphy file.

It enables reading: - Block - Segment - RecordingChannel - RecordingChannelGroup - EventArray - SpikeTrain

Usage:

```
>>> from neo import io
>>> r = io.ElphyIO(filename='ElphyExample.DAT')
>>> seg = r.read_block(lazy=False, cascade=True)
>>> print(seg.analogsignals)
>>> print(seg.spiketrains)
>>> print(seg.eventarrays)
>>> print(anasig._data_description)
>>> anasig = r.read_analogsignal(lazy=False, cascade=False)
```

```
>>> bl = Block()
>>> # creating segments, their contents and append to bl
>>> r.write_block( bl )
```

class neo.io.KlustaKwikIO(filename, sampling_rate=30000.0)

Reading and writing from KlustaKwik-format files.

class neo.io.MicromedIO(filename=None)

Class for reading data from micromed (.trc).

Usage:

```
>>> from neo import io
>>> r = io.MicromedIO(filename='File_micromed_1.TRC')
>>> seg = r.read_segment(lazy=False, cascade=True)
>>> print seg.analogsignals
[<AnalogSignal(array([ -1.77246094e+02, -2.24707031e+02, -2.66015625e+02,
...]) * pA, [0.0 s, 101.5808 s], sampling rate: 1000.0 Hz)>]
```

class neo.io.NeoHdf5IO(filename=None, array_dtype=<type 'numpy.float64'>, **kwargs)

The IO Manager is the core I/O class for HDF5 / NEO. It handles the connection with the HDF5 file, and uses PyTables for data operations. Use this class to get (load), insert or delete NEO objects to HDF5 file.

dtype: The data type to use when creating the underlying PyTable EArrays storing the data. If None, the data type of the runtime data arrays will be used. Defaults to *np.float64* to keep old behavior.

class neo.io.NeoMatlabIO(filename=None)

Class for reading/writing Neo objects in MATLAB format (.mat) versions 5 to 7.2.

This module is a bridge for MATLAB users who want to adopt the Neo object representation. The nomenclature is the same but using Matlab structs and cell arrays. With this module MATLAB users can use neo.io to read a format and convert it to .mat.

Rules of conversion:

- Neo classes are converted to MATLAB structs. e.g., a Block is a struct with attributes “name”, “file_datetime”, ...
- Neo one_to_many relationships are cellarrays in MATLAB. e.g., `seg.analogsignals[2]` in Python Neo will be `seg.analogsignals{3}` in MATLAB.
- Quantity attributes are represented by 2 fields in MATLAB. e.g., `anasig.t_start = 1.5 * s` in Python will be `anasig.t_start = 1.5` and `anasig.t_start_unit = 's'` in MATLAB.
- classes that inherit from Quantity (AnalogSignal, SpikeTrain, ...) in Python will have 2 fields (array and units) in the MATLAB struct. e.g.: `AnalogSignal([1., 2., 3.], 'V')` in Python will be `anasig.array = [1. 2. 3]` and `anasig.units = 'V'` in MATLAB.

1 - Scenario 1: create data in MATLAB and read them in Python

This MATLAB code generates a block:

```
block = struct();
block.segments = { };
block.name = 'my block with matlab';
for s = 1:3
    seg = struct();
    seg.name = strcat('segment ', num2str(s));
    seg.analogsignals = { };
    for a = 1:5
        anasig = struct();
        anasig.signal = rand(100,1);
        anasig.signal_units = 'mV';
        anasig.t_start = 0;
        anasig.t_start_units = 's';
        anasig.sampling_rate = 100;
        anasig.sampling_rate_units = 'Hz';
        seg.analogsignals{a} = anasig;
    end
    seg.spiketrains = { };
    for t = 1:7
        sptr = struct();
        sptr.times = rand(30,1)*10;
        sptr.times_units = 'ms';
        sptr.t_start = 0;
        sptr.t_start_units = 'ms';
        sptr.t_stop = 10;
        sptr.t_stop_units = 'ms';
        seg.spiketrains{t} = sptr;
    end

    block.segments{s} = seg;
end
save 'myblock.mat' block -V7
```

This code reads it in Python:

```
import neo
r = neo.io.NeoMatlabIO(filename='myblock.mat')
bl = r.read_block()
print bl.segments[1].analogsignals[2]
print bl.segments[1].spiketrains[4]
```

2 - Scenario 2: create data in Python and read them in MATLAB

This Python code generates the same block as in the previous scenario:

```
import neo
import quantities as pq
from scipy import rand

bl = neo.Block(name='my block with neo')
for s in range(3):
    seg = neo.Segment(name='segment' + str(s))
    bl.segments.append(seg)
    for a in range(5):
        anasig = neo.AnalogSignal(rand(100), units='mV', t_start=0*pq.s, sampling_rate=100*pq.s)
        seg.analogsignals.append(anasig)
    for t in range(7):
        sptr = neo.SpikeTrain(rand(30), units='ms', t_start=0*pq.ms, t_stop=10*pq.ms)
        seg.spiketrains.append(sptr)
```

```
w = neo.io.NeoMatlabIO(filename='myblock.mat') w.write_block(bl)
```

This MATLAB code reads it:

```
load 'myblock.mat'
block.name
block.segments{2}.analogsignals{3}.signal
block.segments{2}.analogsignals{3}.signal_units
block.segments{2}.analogsignals{3}.t_start
block.segments{2}.analogsignals{3}.t_start_units
```

3 - Scenario 3: conversion

This Python code converts a Spike2 file to MATLAB:

```
from neo import Block
from neo.io import Spike2IO, NeoMatlabIO

r = Spike2IO(filename='myspike2file.smr')
w = NeoMatlabIO(filename='convertedfile.mat')
seg = r.read_segment()
bl = Block(name='a block')
bl.segments.append(seg)
w.write_block(bl)
```

```
class neo.io.NeuroExplorerIO(filename=None)
```

Class for reading nex file.

Usage:

```
>>> from neo import io
>>> r = io.NeuroExplorerIO(filename='File_neuroexplorer_1.nex')
>>> seg = r.read_segment(lazy=False, cascade=True)
>>> print seg.analogsignals
[<AnalogSignal(array([ 39.0625      ,  0.          ,  0.          , ..., -26.85546875, ...
>>> print seg.spiketrains
[<SpikeTrain(array([ 2.29499992e-02,  6.79249987e-02,  1.13399997e-01, ...
>>> print seg.eventarrays
[<EventArray: @21.1967754364 s, @21.2993755341 s, @21.350725174 s, @21.5048999786 s, ...
>>> print seg.epocharrays
[<neo.core.epocharray.EpochArray object at 0x10561ba90>, <neo.core.epocharray.EpochArray object at 0x10561ba90>]
```

```
class neo.io.NeuroScopeIO(filename=None)
```

`neo.io.NeuroshareIO`
alias of `NeuroshareIO`

class `neo.io.PickleIO` (*filename=None*, ***kargs*)

class `neo.io.PlexonIO` (*filename=None*)
Class for reading plx file.

Usage:

```
>>> from neo import io
>>> r = io.PlexonIO(filename='File_plexon_1.plx')
>>> seg = r.read_segment(lazy=False, cascade=True)
>>> print seg.analogsignals
[]
>>> print seg.spiketrains
[<SpikeTrain(array([ 2.75000000e-02,  5.68250000e-02,  8.52500000e-02, ...,
...
>>> print seg.eventarrays
[]
```

class `neo.io.PyNNNumpyIO` (*filename=None*, ***kargs*)
Reads/writes data from/to PyNN NumpyBinaryFile format

class `neo.io.PyNNTextIO` (*filename=None*, ***kargs*)
Reads/writes data from/to PyNN StandardTextFile format

class `neo.io.RawBinarySignalIO` (*filename=None*)
Class for reading/writing data in a raw binary interleaved compact file.

Usage:

```
>>> from neo import io
>>> r = io.RawBinarySignalIO( filename = 'File_ascii_signal_2.txt')
>>> seg = r.read_segment(lazy = False, cascade = True,)
>>> print seg.analogsignals
...
```

class `neo.io.StimfitIO` (*filename=None*)
Class for converting a stfio Recording to a neo object. Provides a standardized representation of the data as defined by the neo project; this is useful to explore the data with an increasing number of electrophysiology software tools that rely on the neo standard.

Example usage:

```
>>> import neo
>>> neo_obj = neo.io.StimfitIO("file.abf")
or
>>> import stfio
>>> stfio_obj = stfio.read("file.abf")
>>> neo_obj = neo.io.StimfitIO(stfio_obj)
```

class `neo.io.TdtIO` (*dirname=None*)
Class for reading data from from Tucker Davis TTank format.

Usage:

```
>>> from neo import io
>>> r = io.TdtIO(dirname='aep_05')
>>> bl = r.read_block(lazy=False, cascade=True)
>>> print bl.segments
[<neo.core.segment.Segment object at 0x1060a4d10>]
```

```
>>> print bl.segments[0].analogsignals
[<AnalogSignal(array([ 2.18811035,  2.19726562,  2.21252441, ...,  1.33056641,
        1.3458252 ,  1.3671875 ]), dtype=float32) * pA, [0.0 s, 191.2832 s], sampling rate: 1
>>> print bl.segments[0].eventarrays
[]
```

class neo.io.**KwikIO** (*filename*, *dataset=0*)
Class for “reading” experimental data from a .kwik file.

Generates a Segment with a AnalogSignal

class neo.io.**WinEdrIO** (*filename=None*)
Class for reading data from WinEDR.

Usage:

```
>>> from neo import io
>>> r = io.WinEdrIO(filename='File_WinEDR_1.EDR')
>>> seg = r.read_segment(lazy=False, cascade=True,)
>>> print seg.analogsignals
[<AnalogSignal(array([ 89.21203613,  88.83666992,  87.21008301, ...,  64.56298828,
        67.94128418,  68.44177246]), dtype=float32) * pA, [0.0 s, 101.5808 s], sampling rate:
```

class neo.io.**WinWcpIO** (*filename=None*)
Class for reading from a WinWCP file.

Usage:

```
>>> from neo import io
>>> r = io.WinWcpIO( filename = 'File_winwcp_1.wcp')
>>> bl = r.read_block(lazy = False, cascade = True,)
>>> print bl.segments
[<neo.core.segment.Segment object at 0x1057bd350>, <neo.core.segment.Segment object at 0x105
...
>>> print bl.segments[0].analogsignals
[<AnalogSignal(array([-2438.73388672, -2428.96801758, -2425.61083984, ..., -2695.39453125,
...
...])
```

4.10 If you want to develop your own IO

See [IO developers’ guide](#) for information on how to implement of a new IO.

Examples

5.1 Introduction

A set of examples in `neo/examples/` illustrates the use of neo classes.

```
# -*- coding: utf-8 -*-
"""
This is an example for reading files with neo.io
"""

import urllib

import neo

# Plexon files
distantfile = 'https://portal.g-node.org/neo/plexon/File_plexon_3.plx'
localfile = './File_plexon_3.plx'
urllib.urlretrieve(distantfile, localfile)

# create a reader
reader = neo.io.PlexonIO(filename='File_plexon_3.plx')
# read the blocks
blks = reader.read(cascade=True, lazy=False)
print blks
# acces to segments
for blk in blks:
    for seg in blk.segments:
        print seg
        for asig in seg.analogsignals:
            print asig
        for st in seg.spiketrains:
            print st

# CED Spike2 files
distantfile = 'https://portal.g-node.org/neo/spike2/File_spike2_1.smr'
localfile = './File_spike2_1.smr'
urllib.urlretrieve(distantfile, localfile)

# create a reader
reader = neo.io.Spike2IO(filename='File_spike2_1.smr')
# read the block
```

```
bl = reader.read(cascade=True, lazy=False)[0]
print bl
# acces to segments
for seg in bl.segments:
    print seg
    for asig in seg.analogsignals:
        print asig
    for st in seg.spiketrains:
        print st
```

```
# -*- coding: utf-8 -*-
"""
This is an example for plotting neo object with matplotlib.
"""

import urllib

import numpy as np
import quantities as pq
from matplotlib import pyplot

import neo

url = 'https://portal.g-node.org/neo/'
distantfile = url + 'neuroexplorer/File_neuroexplorer_2.nex'
localfile = 'File_neuroexplorer_2.nex'
urllib.urlretrieve(distantfile, localfile)

reader = neo.io.NeuroExplorerIO(filename='File_neuroexplorer_2.nex')
bl = reader.read(cascade=True, lazy=False)[0]
for seg in bl.segments:
    fig = pyplot.figure()
    ax1 = fig.add_subplot(2, 1, 1)
    ax2 = fig.add_subplot(2, 1, 2)
    ax1.set_title(seg.file_origin)
    mint = 0 * pq.s
    maxt = np.inf * pq.s
    for i, asig in enumerate(seg.analogsignals):
        times = asig.times.rescale('s').magnitude
        asig = asig.rescale('mV').magnitude
        ax1.plot(times, asig)

    trains = [st.rescale('s').magnitude for st in seg.spiketrains]
    colors = pyplot.cm.jet(np.linspace(0, 1, len(seg.spiketrains)))
    ax2.eventplot(trains, colors=colors)

pyplot.show()
```

API Reference

`neo.core` provides classes for storing common electrophysiological data types. Some of these classes contain raw data, such as spike trains or analog signals, while others are containers to organize other classes (including both data classes and other container classes).

Classes from `neo.io` return nested data structures containing one or more class from this module.

Classes:

class `neo.core.Block` (*name=None, description=None, file_origin=None, file_datetime=None, rec_datetime=None, index=None, **annotations*)

Main container for data.

Main container gathering all the data, whether discrete or continuous, for a given recording session.

A block is not necessarily temporally homogeneous, in contrast to `Segment`.

Usage:

```
>>> from neo.core import (Block, Segment, RecordingChannelGroup,
...                       AnalogSignalArray)
>>> from quantities import nA, kHz
>>> import numpy as np
>>>
>>> # create a Block with 3 Segment and 2 RecordingChannelGroup objects
... blk = Block()
>>> for ind in range(3):
...     seg = Segment(name='segment %d' % ind, index=ind)
...     blk.segments.append(seg)
...
>>> for ind in range(2):
...     rcg = RecordingChannelGroup(name='Array probe %d' % ind,
...                                  channel_indexes=np.arange(64))
...     blk.recordingchannelgroups.append(rcg)
...
>>> # Populate the Block with AnalogSignalArray objects
... for seg in blk.segments:
...     for rcg in blk.recordingchannelgroups:
...         a = AnalogSignalArray(np.random.randn(10000, 64)*nA,
...                                     sampling_rate=10*kHz)
...         rcg.analogsignalarrays.append(a)
...         seg.analogsignalarrays.append(a)
```

Required attributes/properties: None

Recommended attributes/properties:

name (str) A label for the dataset.

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

file_datetime (datetime) The creation date and time of the original data file.

rec_datetime (datetime) The date and time of the original recording.

index (int) You can use this to define an ordering of your Block. It is not used by Neo in any way.

Properties available on this object:

list_units descends through hierarchy and returns a list of *Unit* objects existing in the block. This shortcut exists because a common analysis case is analyzing all neurons that you recorded in a session.

list_recordingchannels descends through hierarchy and returns a list of *RecordingChannel* objects existing in the block.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

Container of: *Segment* *RecordingChannelGroup*

```
class neo.core.Segment (name=None, description=None, file_origin=None, file_datetime=None,
                        rec_datetime=None, index=None, **annotations)
```

A container for data sharing a common time basis.

A *Segment* is a heterogeneous container for discrete or continuous data sharing a common clock (time basis) but not necessarily the same sampling rate, start or end time.

Usage::

```
>>> from neo.core import Segment, SpikeTrain, AnalogSignal
>>> from quantities import Hz, s
>>>
>>> seg = Segment(index=5)
>>>
>>> train0 = SpikeTrain(times=[.01, 3.3, 9.3], units='sec', t_stop=10)
>>> seg.spiketrains.append(train0)
>>>
>>> train1 = SpikeTrain(times=[100.01, 103.3, 109.3], units='sec',
...                       t_stop=110)
>>> seg.spiketrains.append(train1)
>>>
>>> sig0 = AnalogSignal(signal=[.01, 3.3, 9.3], units='uV',
...                       sampling_rate=1*Hz)
>>> seg.analogsignals.append(sig0)
>>>
>>> sig1 = AnalogSignal(signal=[100.01, 103.3, 109.3], units='nA',
...                       sampling_period=.1*s)
>>> seg.analogsignals.append(sig1)
```

Required attributes/properties: None

Recommended attributes/properties:

name (str) A label for the dataset.

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

file_datetime (datetime) The creation date and time of the original data file.

rec_datetime (datetime) The date and time of the original recording

index (int) You can use this to define a temporal ordering of your Segment. For instance you could use this for trial numbers.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

Properties available on this object:

all_data (list) A list of all child objects in the *Segment*.

Container of: *Epoch EpochArray Event EventArray AnalogSignal AnalogSignalArray IrregularlySampledSignal Spike SpikeTrain*

```
class neo.core.RecordingChannelGroup(channel_names=None, channel_indexes=None,
                                     name=None, description=None, file_origin=None,
                                     **annotations)
```

A container for multiple data channels.

This container have several purpose:

- Grouping all *AnalogSignalArray* inside a *Block* across *Segment*
- Grouping *RecordingChannel* inside a *Block*. This case is *many to many* relation. It mean that a *RecordingChannel* can belong to several group. A typical use case is tetrode (4 X *RecordingChannel* inside a *RecordingChannelGroup*).
- Container of *Unit*. A neuron discharge (*Unit*) can be seen by several electrodes (4 in tetrode case).

Usage 1 multi *Segment* recording with 2 electrode array:

```
>>> from neo.core import (Block, Segment, RecordingChannelGroup,
...                       AnalogSignalArray)
>>> from quantities import nA, kHz
>>> import numpy as np
>>>
>>> # create a Block with 3 Segment and 2 RecordingChannelGroup objects
... blk = Block()
>>> for ind in range(3):
...     seg = Segment(name='segment %d' % ind, index=ind)
...     blk.segments.append(seg)
...
>>> for ind in range(2):
...     rcg = RecordingChannelGroup(name='Array probe %d' % ind,
...                                 channel_indexes=np.arange(64))
...     blk.recordingchannelgroups.append(rcg)
...
>>> # Populate the Block with AnalogSignalArray objects
... for seg in blk.segments:
...     for rcg in blk.recordingchannelgroups:
...         a = AnalogSignalArray(np.random.randn(10000, 64)*nA,
...                                 sampling_rate=10*kHz)
...         rcg.analogsignalarrays.append(a)
...         seg.analogsignalarrays.append(a)
```

Usage 2 grouping channel:

```

>>> from neo.core import (Block, RecordingChannelGroup,
...                       RecordingChannel)
>>> import numpy as np
>>>
>>> # Create a Block
... blk = Block()
>>>
>>> # Create a new RecordingChannelGroup and add it to the Block
... rcg = RecordingChannelGroup(channel_names=np.array(['ch0',
...                                                    'ch1',
...                                                    'ch2']))
>>> rcg.channel_indexes = np.array([0, 1, 2])
>>> blk.recordingchannelgroups.append(rcg)
>>>
>>> # Create 3 RecordingChannel objects and add them to the Block
... for ind in range(3):
...     chan = RecordingChannel(index=ind)
...     rcg.recordingchannels.append(chan) # <- many to many
...                                     # relationship
...     chan.recordingchannelgroups.append(rcg) # <- many to many
...                                     # relationship

```

Usage 3 dealing with *Unit* objects:

```

>>> from neo.core import Block, RecordingChannelGroup, Unit
>>>
>>> # Create a Block
... blk = Block()
>>>
>>> # Create a new RecordingChannelGroup and add it to the Block
... rcg = RecordingChannelGroup(name='octotrode A')
>>> blk.recordingchannelgroups.append(rcg)
>>>
>>> # create several Unit objects and add them to the
>>> # RecordingChannelGroup
... for ind in range(5):
...     unit = Unit(name = 'unit %d' % ind, description=
...                 'after a long and hard spike sorting')
...     rcg.units.append(unit)

```

Required attributes/properties: None

Recommended attributes/properties:

name (str) A label for the dataset.

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

channel_names (numpy.array 1D dtype='S') Names for each *RecordingChannel*.

channel_indexes (numpy.array 1D dtype='i') Index of each *RecordingChannel*.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

Container of: *RecordingChannel* *AnalogSignalArray* *Unit*

```
class neo.core.RecordingChannel (index=0, coordinate=None, name=None, description=None,
                                file_origin=None, **annotations)
```

A container for recordings coming from a single data channel.

A *RecordingChannel* is a container for *AnalogSignal* and *IrregularlySampledSignal* objects that come from the same logical and/or physical channel inside a `:class: 'Block`.

Note that a *RecordingChannel* can belong to several *RecordingChannelGroup* objects.

Usage one *Block* with 3 *Segment* objects, 16 *RecordingChannel* objects, and 48 *AnalogSignal* objects:

```
>>> from neo.core import (Block, Segment, RecordingChannelGroup,
...                       RecordingChannel, AnalogSignal)
>>> from quantities import mA, Hz
>>> import numpy as np
>>>
>>> # Create a Block
... blk = Block()
>>>
>>> # Create a new RecordingChannelGroup and add it to the Block
... rcg = RecordingChannelGroup(name='all channels')
>>> blk.recordingchannelgroups.append(rcg)
>>>
>>> # Create 3 Segment and 16 RecordingChannel objects and add them to
... # the Block
... for ind in range(3):
...     seg = Segment(name='segment %d' % ind, index=ind)
...     blk.segments.append(seg)
...
>>> for ind in range(16):
...     chan = RecordingChannel(index=ind)
...     rcg.recordingchannels.append(chan) # <- many to many
...                                         # relationship
...     chan.recordingchannelgroups.append(rcg) # <- many to many
...                                             # relationship
...
>>> # Populate the Block with AnalogSignal objects
... for seg in blk.segments:
...     for chan in rcg.recordingchannels:
...         sig = AnalogSignal(np.random.rand(100000)*mA,
...                                   sampling_rate=20*Hz)
...         seg.analogsignals.append(sig)
...         chan.analogsignals.append(sig)
```

Required attributes/properties:

index (int) You can use this to order *RecordingChannel* objects in an way you want.

Recommended attributes/properties:

name (str) A label for the dataset.

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

coordinate (quantity array 1D (x, y, z)) Coordinates of the channel in the brain.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

Container of: `AnalogSignal` `IrregularlySampledSignal`

class `neo.core.Unit` (`name=None`, `description=None`, `file_origin=None`, `channel_indexes=None`, ****annotations**)

A container of `Spike` and `SpikeTrain` objects from a unit.

A `Unit` regroups all the `SpikeTrain` and `Spike` objects that were emitted by a single spike source during a `Block`. A spike source is often a single neuron but doesn't have to be. The spikes may come from different `Segment` objects within the `Block`, so this object is not contained in the usual `Block/Segment/SpikeTrain` hierarchy.

A `Unit` is linked to `RecordingChannelGroup` objects from which it was detected. With tetrodes, for instance, multiple channels may record the same `Unit`.

Usage:

```
>>> from neo.core import Unit, SpikeTrain
>>>
>>> unit = Unit(name='pyramidal neuron')
>>>
>>> train0 = SpikeTrain(times=[.01, 3.3, 9.3], units='sec', t_stop=10)
>>> unit.spiketrains.append(train0)
>>>
>>> train1 = SpikeTrain(times=[100.01, 103.3, 109.3], units='sec',
...                       t_stop=110)
>>> unit.spiketrains.append(train1)
```

Required attributes/properties: None

Recommended attributes/properties:

name (str) A label for the dataset.

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

channel_index (numpy array 1D dtype='i') You can use this to order `Unit` objects in an way you want. It can have any number of elements. `AnalogSignal` and `AnalogSignalArray` objects can be given indexes as well so related objects can be linked together.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

Container of: `SpikeTrain` `Spike`

class `neo.core.AnalogSignal` (`signal`, `units=None`, `dtype=None`, `copy=True`, `t_start=array(0.0)` * `s`, `sampling_rate=None`, `sampling_period=None`, `name=None`, `file_origin=None`, `description=None`, `channel_index=None`, ****annotations**)

A continuous analog signal.

A representation of a continuous, analog signal acquired at time `t_start` at a certain sampling rate.

Inherits from `quantities.Quantity`, which in turn inherits from `numpy.ndarray`.

Usage:

```
>>> from neo.core import AnalogSignal
>>> from quantities import kHz, ms, nA, s, uV
>>> import numpy as np
```

```

>>>
>>> sig0 = AnalogSignal([1, 2, 3], sampling_rate=0.42*kHz,
...                      units='mV')
>>> sig1 = AnalogSignal([4, 5, 6]*nA, sampling_period=42*ms)
>>> sig2 = AnalogSignal(np.array([1.0, 2.0, 3.0]), t_start=42*ms,
...                      sampling_rate=0.42*kHz, units=uV)
>>> sig3 = AnalogSignal([1], units='V', day='Monday',
...                      sampling_period=1*s)
>>>
>>> sig3
<AnalogSignal(array([1]) * V, [0.0 s, 1.0 s], sampling rate: 1.0 1/s)>
>>> sig3.annotations['day']
'Monday'
>>> sig3[0]
array(1) * V
>>> sig3[:,2]
<AnalogSignal(array([1]) * V, [0.0 s, 2.0 s], sampling rate: 0.5 1/s)>

```

Required attributes/properties:

signal (quantity array 1D, numpy array 1D, or list) The data itself.

units (quantity units) Required if the signal is a list or NumPy array, not if it is a `Quantity`

sampling_rate or **sampling_period**: (quantity scalar) Number of samples per unit time or interval between two samples. If both are specified, they are checked for consistency.

Recommended attributes/properties:

name (str) A label for the dataset.

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

t_start (quantity scalar) Time when signal begins. Default: 0.0 seconds

channel_index (int) You can use this to order `AnalogSignal` objects in an way you want. `AnalogSignalArray` and `Unit` objects can be given indexes as well so related objects can be linked together.

Optional attributes/properties:

dtype (numpy dtype or str) Override the dtype of the signal array.

copy (bool) True by default.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

Properties available on this object:

sampling_rate (quantity scalar) Number of samples per unit time. ($1/\text{sampling_period}$)

sampling_period (quantity scalar) Interval between two samples. ($1/\text{sampling_rate}$)

duration (quantity scalar) Signal duration, read-only. ($\text{size} * \text{sampling_period}$)

t_stop (quantity scalar) Time when signal ends, read-only. ($\text{t_start} + \text{duration}$)

times (quantity 1D) The time points of each sample of the signal, read-only. ($\text{t_start} + \text{arange}(\text{shape})/\text{sampling_rate}$)

Slicing: *AnalogSignal* objects can be sliced. When this occurs, a new *AnalogSignal* (actually a view) is returned, with the same metadata, except that `sampling_period` is changed if the step size is greater than 1, and `t_start` is changed if the start index is greater than 0. Getting a single item returns a *Quantity* scalar.

Operations available on this object: `== != + * /`

```
class neo.core.AnalogSignalArray (signal, units=None, dtype=None, copy=True, t_start=array(0.0)
                                   * s, sampling_rate=None, sampling_period=None, name=None,
                                   file_origin=None, description=None, channel_index=None,
                                   **annotations)
```

Several continuous analog signals

A representation of several continuous, analog signals that have the same duration, sampling rate and start time. Basically, it is a 2D array like *AnalogSignal*: dim 0 is time, dim 1 is channel index

Inherits from `quantities.Quantity`, which in turn inherits from `numpy.ndarray`.

Usage:

```
>>> from neo.core import AnalogSignalArray
>>> import quantities as pq
>>>
>>> sigarr = AnalogSignalArray([[1, 2, 3], [4, 5, 6]], units='V',
...                             sampling_rate=1*pq.Hz)
>>>
>>> sigarr
<AnalogSignalArray(array([[1, 2, 3],
                           [4, 5, 6]]) * mV, [0.0 s, 2.0 s], sampling rate: 1.0 Hz)>
>>> sigarr[:,1]
<AnalogSignal(array([2, 5]) * V, [0.0 s, 2.0 s],
               sampling rate: 1.0 Hz)>
>>> sigarr[1, 1]
array(5) * V
```

Required attributes/properties:

signal (quantity array 2D, numpy array 2D, or list (data, channel)) The data itself.

units (quantity units) Required if the signal is a list or NumPy array, not if it is a *Quantity*

t_start (quantity scalar) Time when signal begins

sampling_rate or **sampling_period**: (quantity scalar) Number of samples per unit time or interval between two samples. If both are specified, they are checked for consistency.

Recommended attributes/properties:

name (str) A label for the dataset.

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

channel_index (numpy array 1D dtype='i') You can use this to order the columns of the signal in any way you want. It should have the same number of elements as the signal has columns. *AnalogSignal* and *Unit* objects can be given indexes as well so related objects can be linked together.

Optional attributes/properties:

dtype (numpy dtype or str) Override the dtype of the signal array.

copy (bool) True by default.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

Properties available on this object:

sampling_rate (quantity scalar) Number of samples per unit time. ($1/\text{sampling_period}$)

sampling_period (quantity scalar) Interval between two samples. ($1/\text{quantity scalar}$)

duration (Quantity) Signal duration, read-only. ($\text{size} * \text{sampling_period}$)

t_stop (quantity scalar) Time when signal ends, read-only. ($\text{t_start} + \text{duration}$)

times (quantity 1D) The time points of each sample of the signal, read-only. ($\text{t_start} + \text{arange}(\text{shape}[0]) / \text{attr: 'sampling_rate'}$)

channel_indexes (numpy array 1D dtype='i') The same as `channel_index`, read-only.

Slicing: `AnalogSignalArray` objects can be sliced. When taking a single row (dimension 1, e.g. `[:, 0]`), a `AnalogSignal` is returned. When taking a single element, a `Quantity` is returned. Otherwise a `AnalogSignalArray` (actually a view) is returned, with the same metadata, except that `t_start` is changed if the start index along dimension 1 is greater than 1. Getting a single item returns a `Quantity` scalar.

Operations available on this object: `== != + * /`

```
class neo.core.IrregularlySampledSignal(times, signal, units=None, time_units=None,
                                         dtype=None, copy=True, name=None, description=None, file_origin=None, **annotations)
```

An analog signal with samples taken at arbitrary time points.

A representation of a continuous, analog signal acquired at time `t_start` with a varying sampling interval.

Usage:

```
>>> from neo.core import IrregularlySampledSignal
>>> from quantities import s, nA
>>>
>>> irsig0 = IrregularlySampledSignal([0.0, 1.23, 6.78], [1, 2, 3],
...                                     units='mV', time_units='ms')
>>> irsig1 = IrregularlySampledSignal([0.01, 0.03, 0.12]*s,
...                                     [4, 5, 6]*nA)
```

Required attributes/properties:

times (quantity array 1D, numpy array 1D, or list) The data itself.

signal (quantity array 1D, numpy array 1D, or list) The time of each data point. Must have the same size as `times`.

units (quantity units) Required if the signal is a list or NumPy array, not if it is a `Quantity`.

time_units (quantity units) Required if `times` is a list or NumPy array, not if it is a `Quantity`.

Recommended attributes/properties:

name (str) A label for the dataset

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

Optional attributes/properties:

dtype (numpy dtype or str) Override the dtype of the signal array. (times are always floats).

copy (bool) True by default.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

Properties available on this object:

sampling_intervals (quantity array 1D) Interval between each adjacent pair of samples.
(times[1:] - times[:-1])

duration (quantity scalar) Signal duration, read-only. (times[-1] - times[0])

t_start (quantity scalar) Time when signal begins, read-only. (times[0])

t_stop (quantity scalar) Time when signal ends, read-only. (times[-1])

Slicing: *IrregularlySampledSignal* objects can be sliced. When this occurs, a new *IrregularlySampledSignal* (actually a view) is returned, with the same metadata, except that times is also sliced in the same way.

Operations available on this object: == != + * /

class neo.core.**Event** (time, label, name=None, description=None, file_origin=None, **annotations)

An event occurring at a particular point in time.

Useful for managing trigger, stimulus, comment, etc.

Usage:

```
>>> from neo.core import Event
>>> from quantities import s
>>>
>>> evt = Event(50*s, label='trigger')
>>>
>>> evt.time
array(50.0) * s
>>> evt.label
'trigger'
```

Required attributes/properties:

time (quantity scalar) The time of the event.

label (str) Name or label for the event.

Recommended attributes/properties:

name (str) A label for the dataset.

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

class neo.core.**EventArray** (times=None, labels=None, name=None, description=None, file_origin=None, **annotations)

Array of events. Introduced for performance reasons.

An *EventArray* is preferred to a list of *Event* objects.

Usage:


```

>>> from neo.core import EventArray
>>> from quantities import s
>>> import numpy as np
>>>
>>> evtarr = EventArray(np.arange(0, 30, 10)*s,
...                     labels=np.array(['trig0', 'trig1', 'trig2'],
...                                     dtype='S'))
>>>
>>> evtarr.times
array([ 0., 10., 20.] * s
>>> evtarr.labels
array(['trig0', 'trig1', 'trig2'],
      dtype='<S5')

```

Required attributes/properties:

times (quantity array 1D) The time of the events.

labels (numpy.array 1D dtype='S') Names or labels for the events.

Recommended attributes/properties:

name (str) A label for the dataset.

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

class `neo.core.Epoch` (*time, duration, label, name=None, description=None, file_origin=None, **annotations*)

A period of time with a start point and duration.

Similar to *Event* but with a duration. Useful for describing a period, the state of a subject, etc.

Usage:

```

>>> from neo.core import Epoch
>>> from quantities import s, ms
>>>
>>> epc = Epoch(time=50*s, duration=200*ms, label='button pressed')
>>>
>>> epc.time
array(50.0) * s
>>> epc.duration
array(200.0) * ms
>>> epc.label
'button pressed'

```

Required attributes/properties:

time (quantity scalar) The start of the time period.

duration (quantity scalar) The length of the time period.

label (str) A name or label for the time period.

Recommended attributes/properties:

name (str) A label for the dataset.

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

class `neo.core.EpochArray` (*times=None, durations=None, labels=None, name=None, description=None, file_origin=None, **annotations*)

Array of epochs. Introduced for performance reason.

An *EpochArray* is preferred to a list of *Epoch* objects.

Usage:

```
>>> from neo.core import EpochArray
>>> from quantities import s, ms
>>> import numpy as np
>>>
>>> epcarr = EpochArray(times=np.arange(0, 30, 10)*s,
...                     durations=[10, 5, 7]*ms,
...                     labels=np.array(['btn0', 'btn1', 'btn2'],
...                                     dtype='S'))
>>>
>>> epcarr.times
array([ 0., 10., 20.] * s
>>> epcarr.durations
array([ 10.,  5.,  7.] * ms
>>> epcarr.labels
array(['btn0', 'btn1', 'btn2'],
      dtype='|S4')
```

Required attributes/properties:

times (quantity array 1D) The starts of the time periods.

durations (quantity array 1D) The length of the time period.

labels (numpy.array 1D dtype='S') Names or labels for the time periods.

Recommended attributes/properties:

name (str) A label for the dataset,

description (str) Text description,

file_origin (str) Filesystem path or URL of the original data file.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations,

class `neo.core.Spike` (*time=array(0.0) * s, waveform=None, sampling_rate=None, left_sweep=None, name=None, description=None, file_origin=None, **annotations*)

A single spike.

Object to represent one spike emitted by a *Unit* and represented by its time occurrence and optional waveform.

Usage::

```
>>> from quantities import s
>>> spk = Spike(3*s)
>>> spk.time
array(3.0) * s
```

Required attributes/properties:

time (quantity) The time of the spike.

Recommended attributes/properties:

name (str) A label for the dataset.

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

waveforms (quantity array 2D (channel_index, time)) The waveform of the spike.

sampling_rate (quantity scalar) Number of samples per unit time for the waveform.

left_sweep (quantity scalar) Time from the beginning of the waveform to the trigger time of the spike.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

Properties available on this object:

sampling_period (quantity scalar) Interval between two samples. ($1/\text{sampling_rate}$)

duration (quantity scalar) Duration of waveform, read-only. ($\text{waveform.shape}[1] * \text{sampling_period}$)

right_sweep (quantity scalar) Time from the trigger time of the spike to the end of the waveform, read-only. ($\text{left_sweep} + \text{duration}$)

```
class neo.core.SpikeTrain(times, t_stop, units=None, dtype=<type 'float'>, copy=True, sampling_rate=array(1.0) * Hz, t_start=array(0.0) * s, waveforms=None, left_sweep=None, name=None, file_origin=None, description=None, **annotations)
```

SpikeTrain is a Quantity array of spike times.

It is an ensemble of action potentials (spikes) emitted by the same unit in a period of time.

Usage:

```
>>> from neo.core import SpikeTrain
>>> from quantities import s
>>>
>>> train = SpikeTrain([3, 4, 5]*s, t_stop=10.0)
>>> train2 = train[1:3]
>>>
>>> train.t_start
array(0.0) * s
>>> train.t_stop
array(10.0) * s
>>> train
<SpikeTrain(array([ 3.,  4.,  5.]) * s, [0.0 s, 10.0 s])>
>>> train2
<SpikeTrain(array([ 4.,  5.]) * s, [0.0 s, 10.0 s])>
```

Required attributes/properties:

times (quantity array 1D, numpy array 1D, or list) The times of each spike.

units (quantity units) Required if *times* is a list or ndarray, not if it is a Quantity.

t_stop (quantity scalar, numpy scalar, or float) Time at which *SpikeTrain* ended. This will be converted to the same units as *times*. This argument is required because it specifies

the period of time over which spikes could have occurred. Note that `t_start` is highly recommended for the same reason.

Note: If `times` contains values outside of the range `[t_start, t_stop]`, an Exception is raised.

Recommended attributes/properties:

name (str) A label for the dataset.

description (str) Text description.

file_origin (str) Filesystem path or URL of the original data file.

t_start (quantity scalar, numpy scalar, or float) Time at which *SpikeTrain* began. This will be converted to the same units as `times`. Default: 0.0 seconds.

waveforms (quantity array 3D (spike, channel_index, time)) The waveforms of each spike.

sampling_rate (quantity scalar) Number of samples per unit time for the waveforms.

left_sweep (quantity array 1D) Time from the beginning of the waveform to the trigger time of the spike.

sort (bool) If True, the spike train will be sorted by time.

Optional attributes/properties:

dtype (numpy dtype or str) Override the dtype of the signal array.

copy (bool) Whether to copy the times array. True by default. Must be True when you request a change of units or dtype.

Note: Any other additional arguments are assumed to be user-specific metadata and stored in annotations.

Properties available on this object:

sampling_period (quantity scalar) Interval between two samples. ($1/\text{sampling_rate}$)

duration (quantity scalar) Duration over which spikes can occur, read-only. ($t_{\text{stop}} - t_{\text{start}}$)

spike_duration (quantity scalar) Duration of a waveform, read-only. ($\text{waveform.shape}[2] * \text{sampling_period}$)

right_sweep (quantity scalar) Time from the trigger times of the spikes to the end of the waveforms, read-only. ($\text{left_sweep} + \text{spike_duration}$)

times (*SpikeTrain*) Returns the *SpikeTrain* without modification or copying.

Slicing: *SpikeTrain* objects can be sliced. When this occurs, a new *SpikeTrain* (actually a view) is returned, with the same metadata, except that `waveforms` is also sliced in the same way (along dimension 0). Note that `t_start` and `t_stop` are not changed automatically, although you can still manually change them.

Release notes

7.1 What's new in version 0.4.1?

- relaxed conflict-checking on merge, to restore compatibility with Neo 0.3. More rigorous conflict checking can be enabled as an option.

7.2 What's new in version 0.4.0?

- added StimfitIO
- added KwikIO
- significant improvements to AxonIO, BlackrockIO, BrainwareSrcIO, NeuroshareIO, PlexonIO, Spike2IO, TdtIO,
- many test suite improvements
- Container base class

7.3 What's new in version 0.3.3?

- fix a bug in PlexonIO where some EventArrays only load 1 element.
- fix a bug in BrainwareSrcIo for segments with no spikes.

7.4 What's new in version 0.3.2?

- cleanup of io test code, with additional helper functions and methods
- added BrainwareDamIo
- added BrainwareF32Io
- added BrainwareSrcIo

7.5 What's new in version 0.3.1?

- lazy/cascading improvement
- `load_lazy_object()` in `neo.io` added
- added `NeuroscopeIO`

7.6 What's new in version 0.3.0?

- various bug fixes in `neo.io`
- added `ElphyIO`
- `SpikeTrain` performance improved
- An IO class now can return a list of `Block` (see `read_all_blocks` in IOs)
- python3 compatibility improved

7.7 What's new in version 0.2.1?

- assorted bug fixes
- added `time_slice()` method to the `SpikeTrain` and `AnalogSignalArray` classes.
- improvements to annotation data type handling
- added `PickleIO`, allowing saving Neo objects in the Python pickle format.
- added `ElphyIO` (see <http://www.unic.cnrs-gif.fr/software.html>)
- added `BrainVisionIO` (see <http://www.brainvision.com/>)
- improvements to `PlexonIO`
- added `merge()` method to the `Block` and `Segment` classes
- development was mostly moved to GitHub, although the issue tracker is still at neuralensemble.org/neo

7.8 What's new in version 0.2?

New features compared to neo 0.1:

- new schema more consistent.
- new objects: `RecordingChannelGroup`, `EventArray`, `AnalogSignalArray`, `EpochArray`
- `Neuron` is now `Unit`
- use the `quantities` module for everything that can have units.
- Some objects directly inherit from `Quantity`: `SpikeTrain`, `AnalogSignal`, `AnalogSignalArray`, instead of having an attribute for data.
- Attributes are classified in 3 categories: necessary, recommended, free.
- lazy and cascade keywords are added to all IOs

- Python 3 support
- better tests

Developers' guide

These instructions are for developing on a Unix-like platform, e.g. Linux or Mac OS X, with the bash shell. If you develop on Windows, please get in touch.

8.1 Mailing lists

General discussion of Neo development takes place in the [NeuralEnsemble Google group](#).

Discussion of issues specific to a particular ticket in the issue tracker should take place on the tracker.

8.2 Using the issue tracker

If you find a bug in Neo, please create a new ticket on the [issue tracker](#), setting the type to “defect”. Choose a name that is as specific as possible to the problem you’ve found, and in the description give as much information as you think is necessary to recreate the problem. The best way to do this is to create the shortest possible Python script that demonstrates the problem, and attach the file to the ticket.

If you have an idea for an improvement to Neo, create a ticket with type “enhancement”. If you already have an implementation of the idea, create a patch (see below) and attach it to the ticket.

To keep track of changes to the code and to tickets, you can register for a GitHub account and then set to watch the repository at [GitHub Repository](#) (see <https://help.github.com/articles/watching-repositories/>).

8.3 Requirements

- [Python](#) 2.6, 2.7, or 3.3
- [numpy](#) \geq 1.3.0
- [quantities](#) \geq 0.9.0
- if using Python 2.6, [unittest2](#) \geq 0.5.1
- [Setuptools](#) \geq 0.7
- [nose](#) \geq 0.11.1 (for running tests)
- [Sphinx](#) \geq 0.6.4 (for building documentation)
- (optional) [tox](#) \geq 0.9 (makes it easier to test with multiple Python versions)

- (optional) `coverage` ≥ 2.85 (for measuring test coverage)
- (optional) `scipy` ≥ 0.8 (for Matlab IO)
- (optional) `pytables` ≥ 2.2 (for HDF5 IO)

8.4 Getting the source code

We use the Git version control system. The best way to contribute is through [GitHub](#). You will first need a GitHub account, and you should then fork the repository at [GitHub Repository](#) (see <http://help.github.com/fork-a-repo/>).

To get a local copy of the repository:

```
$ cd /some/directory
$ git clone git@github.com:<username>/python-neo.git
```

Now you need to make sure that the `neo` package is on your `PYTHONPATH`. You can do this either by installing Neo:

```
$ cd python-neo
$ python setup.py install
$ python3 setup.py install
```

(if you do this, you will have to re-run `setup.py install` any time you make changes to the code) *or* by creating symbolic links from somewhere on your `PYTHONPATH`, for example:

```
$ ln -s python-neo/neo
$ export PYTHONPATH=/some/directory:${PYTHONPATH}
```

An alternate solution is to install Neo with the *develop* option, this avoids reinstalling when there are changes in the code:

```
$ sudo python setup.py develop
```

To update to the latest version from the repository:

```
$ git pull
```

8.5 Running the test suite

Before you make any changes, run the test suite to make sure all the tests pass on your system:

```
$ cd neo/test
```

With Python 2.7 or 3.3:

```
$ python -m unittest discover
$ python3 -m unittest discover
```

If you have `nose` installed:

```
$ nosetests
```

At the end, if you see “OK”, then all the tests passed (or were skipped because certain dependencies are not installed), otherwise it will report on tests that failed or produced errors.

To run tests from an individual file:

```
$ python test_analogsignal.py
$ python3 test_analogsignal.py
```

8.6 Writing tests

You should try to write automated tests for any new code that you add. If you have found a bug and want to fix it, first write a test that isolates the bug (and that therefore fails with the existing codebase). Then apply your fix and check that the test now passes.

To see how well the tests cover the code base, run:

```
$ nosetests --with-coverage --cover-package=neo --cover-erase
```

8.7 Working on the documentation

All modules, classes, functions, and methods (including private and subclassed builtin methods) should have docstrings. Please see [PEP257](#) for a description of docstring conventions.

Module docstrings should explain briefly what functions or classes are present. Detailed descriptions can be left for the docstrings of the respective functions or classes. Private functions do not need to be explained here.

Class docstrings should include an explanation of the purpose of the class and, when applicable, how it relates to standard neuroscientific data. They should also include at least one example, which should be written so it can be run as-is from a clean newly-started Python interactive session (that means all imports should be included). Finally, they should include a list of all arguments, attributes, and properties, with explanations. Properties that return data calculated from other data should explain what calculation is done. A list of methods is not needed, since documentation will be generated from the method docstrings.

Method and function docstrings should include an explanation for what the method or function does. If this may not be clear, one or more examples may be included. Examples that are only a few lines do not need to include imports or setup, but more complicated examples should have them.

Examples can be tested easily using the iPython `%doctest_mode` magic. This will strip `>>>` and `...` from the beginning of each line of the example, so the example can be copied and pasted as-is.

The documentation is written in [reStructuredText](#), using the [Sphinx](#) documentation system. Any mention of another neo module, class, attribute, method, or function should be properly marked up so automatic links can be generated. The same goes for quantities or numpy.

To build the documentation:

```
$ cd python-neo/doc
$ make html
```

Then open *some/directory/neo_trunk/doc/build/html/index.html* in your browser.

8.8 Committing your changes

Once you are happy with your changes, **run the test suite again to check that you have not introduced any new bugs**. It is also recommended to check your code with a code checking program, such as [pyflakes](#) or [flake8](#). Then you can commit them to your local repository:

```
$ git commit -m 'informative commit message'
```

If this is your first commit to the project, please add your name and affiliation/employer to `doc/source/authors.rst`

You can then push your changes to your online repository on GitHub:

```
$ git push
```

Once you think your changes are ready to be included in the main Neo repository, open a pull request on GitHub (see <https://help.github.com/articles/using-pull-requests>).

8.9 Python 3

Neo core should work with both recent versions of Python 2 (versions 2.6 and 2.7) and Python 3 (version 3.3). Neo IO modules should ideally work with both Python 2 and 3, but certain modules may only work with one or the other (see [Download and Installation](#)).

So far, we have managed to write code that works with both Python 2 and 3. Mainly this involves avoiding the `print` statement (use `logging.info` instead), and putting `from __future__ import division` at the beginning of any file that uses division.

If in doubt, [Porting to Python 3](#) by Lennart Regebro is an excellent resource.

The most important thing to remember is to run tests with at least one version of Python 2 and at least one version of Python 3. There is generally no problem in having multiple versions of Python installed on your computer at once: e.g., on Ubuntu Python 2 is available as *python* and Python 3 as *python3*, while on Arch Linux Python 2 is *python2* and Python 3 *python*. See [PEP394](#) for more on this.

8.10 Coding standards and style

All code should conform as much as possible to [PEP 8](#), and should run with Python 2.6, 2.7, and 3.3.

You can use the [pep8](#) program to check the code for PEP 8 conformity. You can also use [flake8](#), which combines [pep8](#) and [pyflakes](#).

However, the [pep8](#) and [flake8](#) programs does not check for all PEP 8 issues. In particular, they does not check that the `import` statements are in the correct order.

Also, please do not use *from xyz import **. This is slow, can lead to conflicts, and makes it difficult for code analysis software.

8.11 Making a release

Add a section in `/doc/src/whatisnew.rst` for the release.

First check that the version string (in `neo/version.py`, `setup.py`, `doc/conf.py` and `doc/install.rst`) is correct.

To build a source package:

```
$ python setup.py sdist
```

To upload the package to [PyPI](#) (currently Samuel Garcia and Andrew Davison have the necessary permissions to do this):

```
$ python setup.py sdist upload
$ python setup.py upload_docs --upload-dir=doc/build/html
```

Finally, tag the release in the Git repository and push it:

```
$ git tag <version>
$ git push --tags origin
```

8.12 If you want to develop your own IO module

See *IO developers' guide* for implementation of a new IO.

IO developers' guide

9.1 Guidelines for IO implementation

Receipe to develop an IO module for a new data format:

1. Fully understand the object model. See [Neo core](#). If in doubt ask the [mailing list](#).
2. Fully understand `neo.io.exampleio`, It is a fake IO to explain the API. If in doubt ask the list.
3. Copy/paste `exampleio.py` and choose clear file and class names for your IO.
4. Decide which **supported objects** and **readable objects** your IO will deal with. This is the crucial point.
5. Implement all methods `read_XXX()` related to **readable objects**.
6. Optional: If your IO supports reading multiple blocks from one file, implement a `read_all_blocks()` method.
7. Do not forget all lazy and cascade combinations.
8. Optional: Support loading lazy objects by implementing a `load_lazy_object()` method and / or lazy cascading by implementing a `load_lazy_cascade()` method.
9. Write good docstrings. List dependencies, including minimum version numbers.
10. Add your class to `neo.io.__init__`. Keep the import inside try/except for dependency reasons.
11. Contact the Neo maintainers to put sample files for testing on the G-Node server (write access is not public).
12. Write tests in `neo/test/io/test_XXXXXio.py`. You must at least pass the standard tests (inherited from `BaseTestIO`).
13. Commit or send a patch only if all tests pass.

9.2 Miscellaneous

- If your IO supports several version of a format (like ABF1, ABF2), upload to G-node test file repository all file version possible. (for utest coverage).
- `neo.core.Block.create_many_to_one_relationship()` offers a utility to complete the hierachy when all one-to-many relationships have been created.
- `neo.io.tools.populate_RecordingChannel()` offers a utility to create inside a `Block` all `RecordingChannel` objects and links to `AnalogSignal`, `SpikeTrain`, ...

- In the docstring, explain where you obtained the file format specification if it is a closed one.
- If your IO is based on a database mapper, keep in mind that the returned object **MUST** be detached, because this object can be written to another url for copying.

9.3 Advanced lazy loading

If your IO supports a format that might take a long time to load or require lots of memory, consider implementing one or both of the following methods to enable advanced lazy loading:

- `load_lazy_object(self, obj)`: This method takes a lazily loaded object and returns the corresponding fully loaded object. It does not set any links of the newly loaded object (e.g. the `segment` attribute of a `SpikeTrain`). The information needed to fully load the lazy object should usually be stored in the IO object (e.g. in a dictionary with lazily loaded objects as keys and the address in the file as values).
- `load_lazy_cascade(self, address, lazy)`: This method takes two parameters: The information required by your IO to load an object and a boolean that indicates if data objects should be lazy loaded (in the same way as with regular `read_XXX()` methods). The method should return a loaded objects, including all the links for one-to-many and many-to-many relationships (lists of links should be replaced by `LazyList` objects, see below).

To implement lazy cascading, your read methods need to react when a user calls them with the `cascade` parameter set to `lazy`. In this case, you have to replace all the link lists of your loaded objects with instances of `neo.io.tools.LazyList`. Instead of the actual objects that your IO would load at this point, fill the list with items that `load_lazy_cascade` needs to load the object.

Because the links of objects can point to previously loaded objects, you need to cache all loaded objects in the IO. If `load_lazy_cascade()` is called with the address of a previously loaded object, return the object instead of loading it again. Also, a call to `load_lazy_cascade()` might require you to load additional objects further up in the hierarchy. For example, if a `SpikeTrain` is accessed through a `Segment`, its `Unit` and the `RecordingChannelGroup` of the `Unit` might have to be loaded at that point as well if they have not been accessed before.

Note that you are free to restrict lazy cascading to certain objects. For example, you could use the `LazyList` only for the `analogsignals` property of `Segment` and `RecordingChannel` objects and load the rest of file immediately.

9.4 Tests

`neo.test.io.commun_io_test.BaseTestIO` provide standard tests. To use these you need to upload some sample data files at the [G-Node portal](#). They will be publicly accessible for testing Neo. These tests:

- check the compliance with the schema: hierarchy, attribute types, ...
- check if the IO respects the *lazy* and *cascade* keywords.
- For IO able to both write and read data, it compares a generated dataset with the same data after a write/read cycle.

The test scripts download all files from the [G-Node portal](#) and store them locally in `neo/test/io/files_for_tests/`. Subsequent test runs use the previously downloaded files, rather than trying to download them each time.

Here is an example test script taken from the distribution: `test_axonio.py`:


```

# -*- coding: utf-8 -*-
"""
Tests of neo.io.axonio
"""

# needed for python 3 compatibility
from __future__ import absolute_import

import sys

try:
    import unittest2 as unittest
except ImportError:
    import unittest

from neo.io import AxonIO
from neo.test.iotest.common_io_test import BaseTestIO

class TestAxonIO(BaseTestIO, unittest.TestCase):
    files_to_test = ['File_axon_1.abf',
                     'File_axon_2.abf',
                     'File_axon_3.abf',
                     'File_axon_4.abf',
                     'File_axon_5.abf',
                     'File_axon_6.abf',
                     ]
    files_to_download = files_to_test
    ioclass = AxonIO

if __name__ == "__main__":
    unittest.main()

```

9.5 Logging

All IO classes by default have logging using the standard logging module: already set up. The logger name is the same as the full qualified class name, e.g. `neo.io.hdf5io.NeoHdf5IO`. The `class.logger` attribute holds the logger for easy access.

There are generally 3 types of situations in which an IO class should use a logger

- Recoverable errors with the file that the users need to be notified about. In this case, please use `logger.warning()` or `logger.error()`. If there is an exception associated with the issue, you can use `logger.exception()` in the exception handler to automatically include a backtrace with the log. By default, all users will see messages at this level, so please restrict it only to problems the user absolutely needs to know about.
- Informational messages that advanced users might want to see in order to get some insight into the file. In this case, please use `logger.info()`.
- Messages useful to developers to fix problems with the io class. In this case, please use `logger.debug()`.

A log handler is automatically added to *neo*, so please do not use your own handler. Please use the `class.logger` attribute for accessing the logger inside the class rather than `logging.getLogger()`. Please do not log directly to the root logger (e.g. `logging.warning()`), use the class's logger instead (`class.logger.warning()`). In the tests for the io class, if you intentionally test broken files, please disable logs by setting the logging level to *100*.

9.6 ExampleIO

`class neo.io.ExampleIO (filename=None)`

Class for “reading” fake data from an imaginary file.

For the user, it generates a `Segment` or a `Block` with a sinusoidal `AnalogSignal`, a `SpikeTrain` and an `EventArray`.

For a developer, it is just an example showing guidelines for someone who wants to develop a new IO module.

Two rules for developers:

- Respect the Neo IO API (*Details of API*)
- Follow *Guidelines for IO implementation*

Usage:

```
>>> from neo import io
>>> r = io.ExampleIO(filename='itisafake.nof')
>>> seg = r.read_segment(lazy=False, cascade=True)
>>> print(seg.analogsignals)
[<AnalogSignal(array([ 0.19151945,  0.62399373,  0.44149764, ...,  0.96678374,
...
>>> print(seg.spiketrains)
[<SpikeTrain(array([ -0.83799524,   6.24017951,   7.76366686,   4.45573701,
...
>>> print(seg.eventarrays)
[<EventArray: TriggerB@9.6976 s, TriggerA@10.2612 s, TriggerB@2.2777 s, TriggerA@6.8607 s, ...
>>> anasig = r.read_analogsignal(lazy=True, cascade=False)
>>> print(anasig._data_description)
{'shape': (150000,)}
>>> anasig = r.read_analogsignal(lazy=False, cascade=False)
```

Here is the entire file:

```
# -*- coding: utf-8 -*-
"""
Class for "reading" fake data from an imaginary file.

For the user, it generates a :class:`Segment` or a :class:`Block` with a
sinusoidal :class:`AnalogSignal`, a :class:`SpikeTrain` and an
:class:`EventArray`.

For a developer, it is just an example showing guidelines for someone who wants
to develop a new IO module.

Depends on: scipy

Supported: Read

Author: sgarcia

"""

# needed for python 3 compatibility
from __future__ import absolute_import

# note neo.core needs only numpy and quantities
```

```

import numpy as np
import quantities as pq

# but my specific IO can depend on many other packages
try:
    from scipy import stats
except ImportError as err:
    HAVE SCIPY = False
    SCIPY_ERR = err
else:
    HAVE SCIPY = True
    SCIPY_ERR = None

# I need to subclass BaseIO
from neo.io.baseio import BaseIO

# to import from core
from neo.core import Segment, AnalogSignal, SpikeTrain, EventArray

# I need to subclass BaseIO
class ExampleIO(BaseIO):
    """
    Class for "reading" fake data from an imaginary file.

    For the user, it generates a :class:`Segment` or a :class:`Block` with a
    sinusoidal :class:`AnalogSignal`, a :class:`SpikeTrain` and an
    :class:`EventArray`.

    For a developer, it is just an example showing guidelines for someone who wants
    to develop a new IO module.

    Two rules for developers:
    * Respect the Neo IO API (:ref:`neo_io_API`)
    * Follow :ref:`io_guideline`

    Usage:
    >>> from neo import io
    >>> r = io.ExampleIO(filename='itisafake.nof')
    >>> seg = r.read_segment(lazy=False, cascade=True)
    >>> print(seg.analogsignals) # doctest: +ELLIPSIS, +NORMALIZE_WHITESPACE
    [<AnalogSignal(array([ 0.19151945,  0.62399373,  0.44149764, ...,  0.96678374,
    ...
    >>> print(seg.spiketrains) # doctest: +ELLIPSIS, +NORMALIZE_WHITESPACE
    [<SpikeTrain(array([ -0.83799524,  6.24017951,  7.76366686,  4.45573701,
    12.60644415,  10.68328994,  8.07765735,  4.89967804,
    ...
    >>> print(seg.eventarrays) # doctest: +ELLIPSIS, +NORMALIZE_WHITESPACE
    [<EventArray: TriggerB@9.6976 s, TriggerA@10.2612 s, TriggerB@2.2777 s, TriggerA@6.8607 s, .
    >>> anasig = r.read_analogsignal(lazy=True, cascade=False)
    >>> print(anasig._data_description)
    {'shape': (150000,)}
    >>> anasig = r.read_analogsignal(lazy=False, cascade=False)

    """

    is_readable = True # This class can only read data
    is_writable = False # write is not supported

```

```

# This class is able to directly or indirectly handle the following objects
# You can notice that this greatly simplifies the full Neo object hierarchy
supported_objects = [ Segment , AnalogSignal, SpikeTrain, EventArray ]

# This class can return either a Block or a Segment
# The first one is the default ( self.read )
# These lists should go from highest object to lowest object because
# common_io_test assumes it.
readable_objects    = [ Segment , AnalogSignal, SpikeTrain ]
# This class is not able to write objects
writeable_objects   = [ ]

has_header          = False
is_streameable      = False

# This is for GUI stuff : a definition for parameters when reading.
# This dict should be keyed by object (`Block`). Each entry is a list
# of tuple. The first entry in each tuple is the parameter name. The
# second entry is a dict with keys 'value' (for default value),
# and 'label' (for a descriptive name).
# Note that if the highest-level object requires parameters,
# common_io_test will be skipped.
read_params = {
    Segment : [
        ('segment_duration',
         {'value' : 15., 'label' : 'Segment size (s.)'}),
        ('num_analogsignal',
         {'value' : 8, 'label' : 'Number of recording points'}),
        ('num_spiketrain_by_channel',
         {'value' : 3, 'label' : 'Num of spiketrains'}),
    ],
}

# do not supported write so no GUI stuff
write_params      = None

name              = 'example'

extensions        = [ 'nof' ]

# mode can be 'file' or 'dir' or 'fake' or 'database'
# the main case is 'file' but some reader are base on a directory or a database
# this info is for GUI stuff also
mode = 'fake'

def __init__(self , filename = None) :
    """

    Arguments:
        filename : the filename

    Note:
        - filename is here just for exampe because it will not be take in account
        - if mode=='dir' the argument should be dirname (See TdtIO)

```

```

"""
BaseIO.__init__(self)
self.filename = filename
# Seed so all instances can return the same values
np.random.seed(1234)

# Segment reading is supported so I define this :
def read_segment(self,
    # the 2 first keyword arguments are imposed by neo.io API
    lazy = False,
    cascade = True,
    # all following arguments are decided by this IO and are free
    segment_duration = 15.,
    num_analogsignal = 4,
    num_spiketrain_by_channel = 3,
    ):
    """
    Return a fake Segment.

    The self.filename does not matter.

    In this IO read by default a Segment.

    This is just a example to be adapted to each ClassIO.
    In this case these 3 paramters are taken in account because this function
    return a generated segment with fake AnalogSignal and fake SpikeTrain.

    Parameters:
        segment_duration : is the size in second of the segment.
        num_analogsignal : number of AnalogSignal in this segment
        num_spiketrain : number of SpikeTrain in this segment

    """

    sampling_rate = 10000. #Hz
    t_start = -1.

    #time vector for generated signal
    timevect = np.arange(t_start, t_start+ segment_duration , 1./sampling_rate)

    # create an empty segment
    seg = Segment( name = 'it is a seg from exampleio')

    if cascade:
        # read nested analosignal
        for i in range(num_analogsignal):
            ana = self.read_analogsignal( lazy = lazy , cascade = cascade ,
                                         channel_index = i , segment_duration = segment_duration, t_start = t_start)
            seg.analogsignals += [ ana ]

        # read nested spiketrain
        for i in range(num_analogsignal):
            for _ in range(num_spiketrain_by_channel):
                sptr = self.read_spiketrain(lazy = lazy , cascade = cascade ,
                                           segment_duration = segment_duration, t_start = t_start)
                seg.spiketrains += [ sptr ]

```

```

        # create an EventArray that mimic triggers.
        # note that ExampleIO do not allow to access directly to EventArray
        # for that you need read_segment(cascade = True)
        eva = EventArray()
        if lazy:
            # in lazy case no data are readed
            # eva is empty
            pass
        else:
            # otherwise it really contain data
            n = 1000

            # neo.io support quantities my vector use second for unit
            eva.times = timevect[(np.random.rand(n)*timevect.size).astype('i')]* pq.s
            # all duration are the same
            eva.durations = np.ones(n)*500*pq.ms
            # label
            l = [ ]
            for i in range(n):
                if np.random.rand()>.6: l.append( 'TriggerA' )
                else : l.append( 'TriggerB' )
            eva.labels = np.array( l )

        seg.eventarrays += [ eva ]

    seg.create_many_to_one_relationship()
    return seg

def read_analogsignal(self ,
    # the 2 first key arguments are imposed by neo.io API
    lazy = False,
    cascade = True,
    channel_index = 0,
    segment_duration = 15.,
    t_start = -1,
    ):
    """
    With this IO AnalogSignal can be acces directly with its channel number

    """
    sr = 10000.
    sinus_freq = 3. # Hz
    #time vector for generated signal:
    tvect = np.arange(t_start, t_start+ segment_duration , 1./sr)

    if lazy:
        anasig = AnalogSignal([], units='V', sampling_rate=sr * pq.Hz,
            t_start=t_start * pq.s,
            channel_index=channel_index)
        # we add the attribute lazy_shape with the size if loaded
        anasig.lazy_shape = tvect.shape
    else:
        # create analogsignal (sinus of 3 Hz)
        sig = np.sin(2*np.pi*tvect*sinus_freq + channel_index/5.*2*np.pi)+np.random.rand(tvect.size)
        anasig = AnalogSignal(sig, units= 'V', sampling_rate=sr * pq.Hz,

```

```

        t_start=t_start * pq.s,
        channel_index=channel_index)

    # for attributes out of neo you can annotate
    anasig.annotate(info = 'it is a sinus of %f Hz' %sinus_freq )

    return anasig

def read_spiketrain(self ,

                    # the 2 first key arguments are imposed by neo.io API
                    lazy = False,
                    cascade = True,

                    segment_duration = 15.,
                    t_start = -1,
                    channel_index = 0,
                    ):
    """
    With this IO SpikeTrain can be accessed directly with its channel number
    """
    # There are 2 possible behaviours for a SpikeTrain
    # holding many Spike instance or directly holding spike times
    # we choose here the first :
    if not HAVE SCIPY:
        raise SCIPY_ERR

    num_spike_by_spiketrain = 40
    sr = 10000.

    if lazy:
        times = [ ]
    else:
        times = (np.random.rand(num_spike_by_spiketrain)*segment_duration +
                 t_start)

    # create a spiketrain
    spiketr = SpikeTrain(times, t_start = t_start*pq.s, t_stop = (t_start+segment_duration)*pq.s,
                        units = pq.s,
                        name = 'it is a spiketrain from exampleio',
                        )

    if lazy:
        # we add the attribute lazy_shape with the size if loaded
        spiketr.lazy_shape = (num_spike_by_spiketrain,)

    # ours spiketrains also hold the waveforms:

    # 1 generate a fake spike shape (2d array if treshold > 1)
    w1 = -stats.nct.pdf(np.arange(11,60,4), 5,20)[::-1]/3.
    w2 = stats.nct.pdf(np.arange(11,60,2), 5,20)
    w = np.r_[ w1 , w2 ]
    w = -w/max(w)

    if not lazy:

```

```
# in the neo API the waveforms attr is 3 D in case tetrode
# in our case it is mono electrode so dim 1 is size 1
waveforms = np.tile( w[np.newaxis,np.newaxis,:], ( num_spike_by_spiketrain, 1, 1) )
waveforms *= np.random.randn(*waveforms.shape)/6+1
spiketr.waveforms = waveforms*pq.mV
spiketr.sampling_rate = sr * pq.Hz
spiketr.left_sweep = 1.5* pq.s

# for attributes out of neo you can annotate
spiketr.annotate(channel_index = channel_index)

return spiketr
```

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If I've somehow missed you off the list I'm very sorry - please let us know.

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Contributing

The people behind the project (see [Authors and contributors](#)) are very open to discussion. Any feedback is gladly received and highly appreciated! Discussion of Neo takes place on the [NeuralEnsemble mailing list](#).

Source code is on [GitHub](#).

The [bug tracker](#) is at:

`https://github.com/NeuralEnsemble/python-neo/issues`

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