What's new with

PyNN

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FACETS CodeJam #2
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Simulator-independent model specification
("Meta-simulators")

Simulator-independent environments for developing neuroscience models:

- keep the advantages of having multiple simulators
- but remove the translation barrier.

Three *(complementary)* approaches:

- GUI (e.g. neuroConstruct)
- XML-based language (e.g. NeuroML)
- interpreted language (e.g. Python)

A common scripting language for neuroscience simulators

Goal

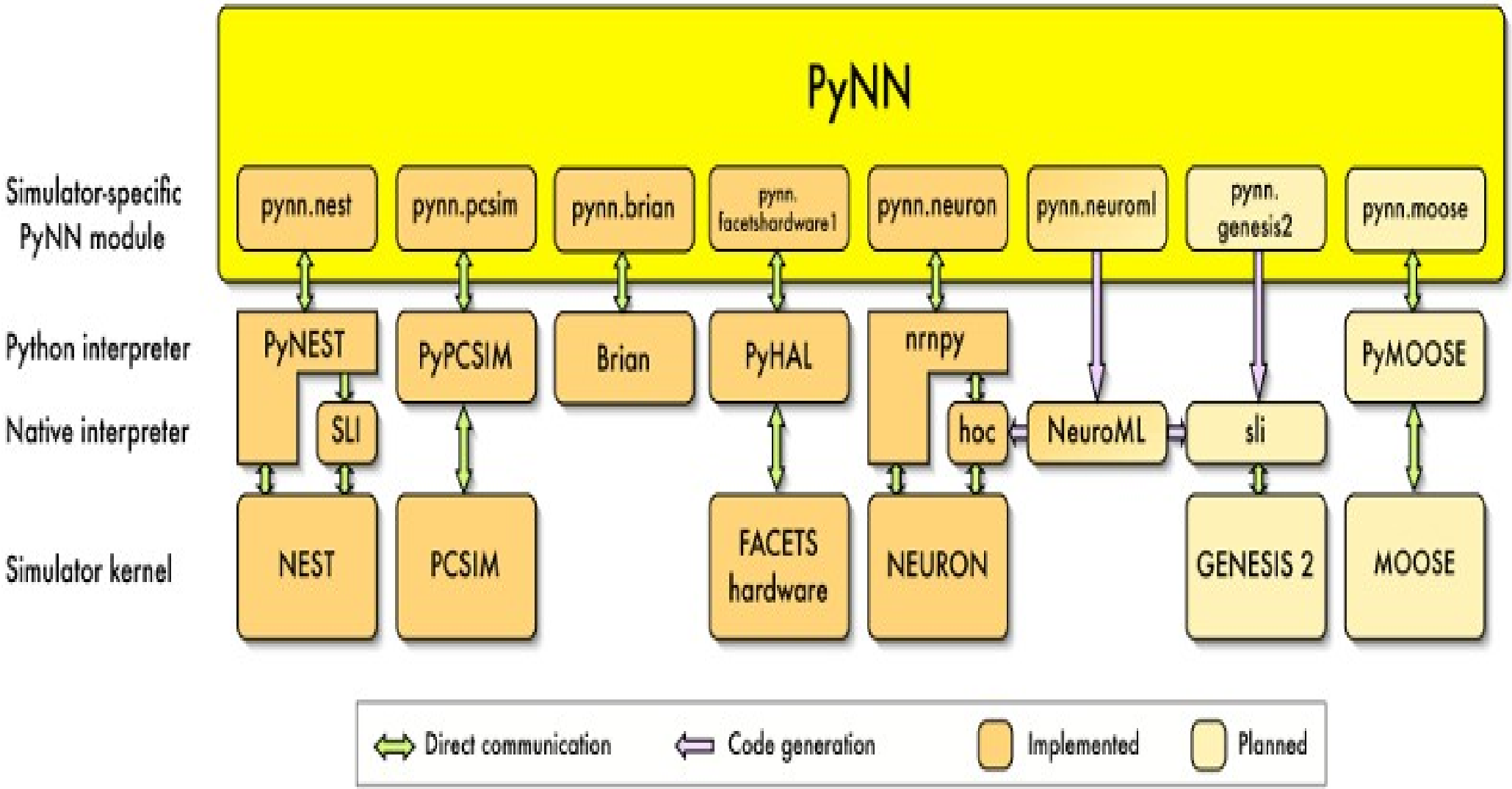
Write the code for a model simulation *once*, run it on any supported simulator* *without modification*.

* *or hardware device*

A common scripting language for neuroscience simulators

Simulator	**Language**
PCSIM	C++ or Python
MOOSE	SLI or Python
MVASpike	C++ or Python
NEST	sli or Python
NEURON	hoc or Python
SPLIT	C++ *(Python interface planned)*
Brian	Python
FACETS hardware	Python

PyNN Approach: A standardized API



Selecting the simulator

```
from pyNN.neuron import *
from pyNN.nest1 import *
from pyNN.nest2 import *
from pyNN.pcsim import *
from pyNN.moose import *
from pyNN.brian import *

import pyNN.neuron as sim
```

Overview:
PyNN low-level API

setup() and end()

```
setup(timestep=0.1, min_delay=0.1, debug=False)

setup(timestep=0.1, min_delay=0.1, debug='pyNN.log',
      threads=2, shark_teeth=999)

end()
```

create()

```
create(IF_curr_alpha)

create(IF_curr_alpha, n=10)

create(IF_curr_alpha, {'tau_m': 15.0, 'cm': 0.9}, n=10)

>>> IF_curr_alpha.default_parameters
{'tau_refrac': 0.0, 'tau_m': 20.0, 'i_offset': 0.0,
 'cm': 1.0, 'v_init': -65.0,'v_thresh': -50.0,
 'tau_syn_E': 0.5, 'v_rest': -65.0, 'tau_syn_I': 0.5,
 'v_reset': -65.0}
```

create()

```
>>> create(IF_curr_alpha, param_dict='foo': 15.0)
    Traceback (most recent call last):
      .
      .
      .
    NonExistentParameterError: foo

    >>> create(IF_curr_alpha, param_dict='tau_m': 'bar')
    Traceback (most recent call last):
      .
      .
      .
    InvalidParameterValueError:
        (<type 'str'>, should be <type 'float'>)
```

create()

```
create(IF_curr_alpha, 'v_thresh': -50, 'cm': 0.9)

create('iaf_neuron', 'V_th': -50, 'C_m': 900.0)
```

Standard cell models

```
IF_curr_alpha
IF_curr_exp
IF_cond_alpha
IF_cond_exp,
IF_cond_exp_gsfa_grr
IF_facets_hardware1
HH_cond_exp,
EIF_cond_alpha_isfa_ista
SpikeSourcePoisson
SpikeSourceInhGamma
SpikeSourceArray
```

Standard cell models

Example: Leaky integrate-and-fire model with fixed firing threshold, and current-based, alpha-function synapses.

Name	Units	NEST	NEURON
v_rest	mV	U0	v_rest
v_reset	mV	Vreset	v_reset
cm	nF	C†	CM
tau_m	ms	Tau	tau_m
tau_refrac	ms	TauR	t_refrac
tau_syn	ms	TauSyn	tau_syn
v_thresh	mV	Theta	v_thresh
i_offset	nA	I0†	i_offset

†Unit differences: C is in pF, I0 in pA.

ID objects

```
>>> my_cell = create(IF_cond_exp)
>>> print my_cell
1
>>> type(my_cell)
<class 'pyNN.nest2.ID'>
>>> my_cell.tau_m
20.0
>>> my_cell.position
(1.0, 0.0, 0.0)
>>> my_cell.position = (0.76, 0.54, 0.32)
```

connect()

```
spike_source = create(SpikeSourceArray,
                      {'spike_times': [10.0, 20.0, 30.0]})
cell_list = create(IF_curr_exp, n=10)

connect(spike_source, cell_list)


connect(sources, targets, weight=1.5, delay=0.5,
        p=0.2, synapse_type='inhibitory')
```

record()

```
record(cell, "spikes.dat")

record_v(cell_list, "Vm.dat")
```

Writing occurs on `end()`

run()

```
run(100.0)
```

Simulation status

```
get_current_time()

get_time_step()

get_min_delay()

num_processes()

rank()
```

Random numbers

```
>>> from pyNN.random import NumpyRNG, GSLRNG, NativeRNG

>>> rng = NumpyRNG(seed=12345)
>>> rng.next()
0.6754034
>>> rng.next(3, 'uniform', (-70,-65))
[-67.4326, -69.9223, -65.4566]
```

- Use `NativeRNG` or `GSLRNG` to ensure different simulators get the same random numbers
- Use `NativeRNG` to use a simulator's built-in RNG

Random numbers

```
>>> from pyNN.random import RandomDistribution

>>> distr = RandomDistribution('uniform', (-70, -65),
...                            rng=rng)
>>> distr.next(3)
[-67.4326, -69.9223, -65.4566]
```

Overview:
PyNN high-level API

Populations

```
p1 = Population((10,10), IF_curr_exp)

p2 = Population(100, SpikeSourceArray,
                label="Input Population")

p3 = Population(dims=(3,4,5), cellclass=IF_cond_alpha,
                cellparams={'v_thresh': -55.0},
                label="Column 1")

p4 = Population(20, 'iaf_neuron', {'Tau': 15.0,
                                   'C': 100.0})
```

Populations
Accessing individual members

```
>>> p1[0,0]
    1
    >>> p1[9,9]
    100
    >>> p3[2,1,0]
    246

    >>> p3.locate(246)
    (2, 1, 0)

>>> p1.index(99)
100

>>> p1[0,0].tau_m = 12.3
```

Populations
Iterators

```
>>> for id in p1:
...   print id, id.tau_m
...
0 12.3
1 20.0
2 20.0
...

>>> for addr in p1.addresses():
...   print addr
...
(0, 0)
(0, 1)
(0, 2)
...
(0, 9)
```

set(), tset(), rset()

```
>>> p1.set("tau_m", 20.0)

>>> p1.set('tau_m':20, 'v_rest':-65)

>>> distr = RandomDistribution('uniform', [-70,-55])
>>> p1.rset('v_init', distr)

>>> import numpy
>>> current_input = numpy.zeros(p1.dim)
>>> current_input[:,0] = 0.1
>>> p1.tset('i_offset', current_input)
```

Recording

```
# record from all neurons in the population
>>> p1.record()

# record from 10 neurons chosen at random
>>> p1.record(10)

# record from specific neurons
>>> p1.record([p1[0,0], p1[0,1], p1[0,2]])


>>> p1.printSpikes("spikefile.dat")

>>> p1.getSpikes()
array([])
```

Position in space

```
>>> p1[1,0].position = (0.0, 0.1, 0.2)
>>> p1[1,0].position
array([ 0. ,  0.1,  0.2])

>>> p1.positions
array([[...]])

>>> p1.nearest((4.5, 7.8, 3.3))
48
>>> p1[p1.locate(48)].position
array([ 4.,  8.,  0.])
```

Projections

```
prj2_1 = Projection(p2, p1, AllToAllConnector())

prj1_2 = Projection(p1, p2, FixedProbabilityConnector(0.02),
                    target='inhibitory', label='foo',
                    rng=NumpyRNG())
```

Connectors

```
AllToAllConnector

OneToOneConnector

FixedProbabilityConnector

DistanceDependentProbabilityConnector

FixedNumberPostConnector

FixedNumberPostConnector

FromFileConnector*

FromListConnector

(* cf Projection.saveConnections(filename))
```

Connectors

```
c = DistanceDependentProbabilityConnector(
        "exp(-abs(d))",
        axes='xy',
        periodic_boundaries=(500, 500, 0),
        weights=0.7,
        delays=RandomDistribution('gamma', [1,0.1])
    )
```

Weights and delays

```
>>> prj1_1.setWeights(0.2)

>>> weight_list = 0.1*numpy.ones(len(prj2_1))
>>> weight_list[0:5] = 0.2
>>> prj2_1.setWeights(weight_list)

>>> prj1_1.randomizeWeights(weight_distr)

>>> prj1_2.setDelays('exp(-d/50.0)+0.1')
```

[Note: synaptic weights are in nA for current-based synapses and μS for conductance-based synapses]

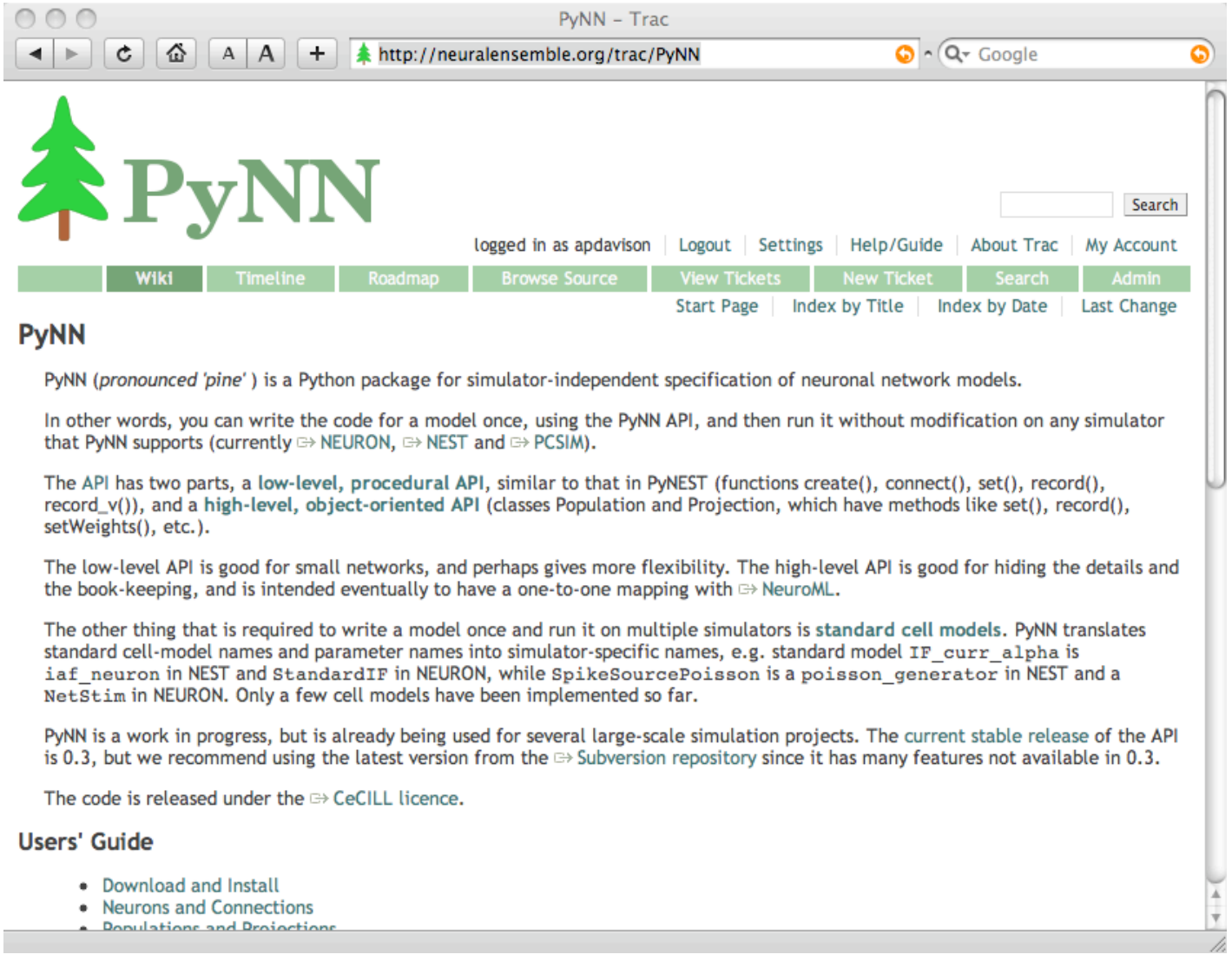
Weights and delays

```
w_array = prj.getWeights()

prj.printWeights(filename)
```

Synaptic plasticity

```
# Facilitating/depressing synapses
depressing_syn = SynapseDynamics(
                        fast=TsodyksMarkramMechanism(**params))
prj = Projection(pre, post, AllToAllConnector(),
                 synapse_dynamics=depressing_syn)

# STDP
stdp_model = STDPMechanism(
               timing_dependence=SpikePairRule(
                                    tau_plus=20.0,
                                    tau_minus=20.0),
               weight_dependence=AdditiveWeightDependence(
                                    w_min=0, w_max=0.02,
                                    A_plus=0.01, A_minus=0.012)
             )
prj2 = Projection(pre, post, FixedProbabilityConnector(p=0.1),
                  synapse_dynamics=SynapseDynamics(slow=stdp_model))
```

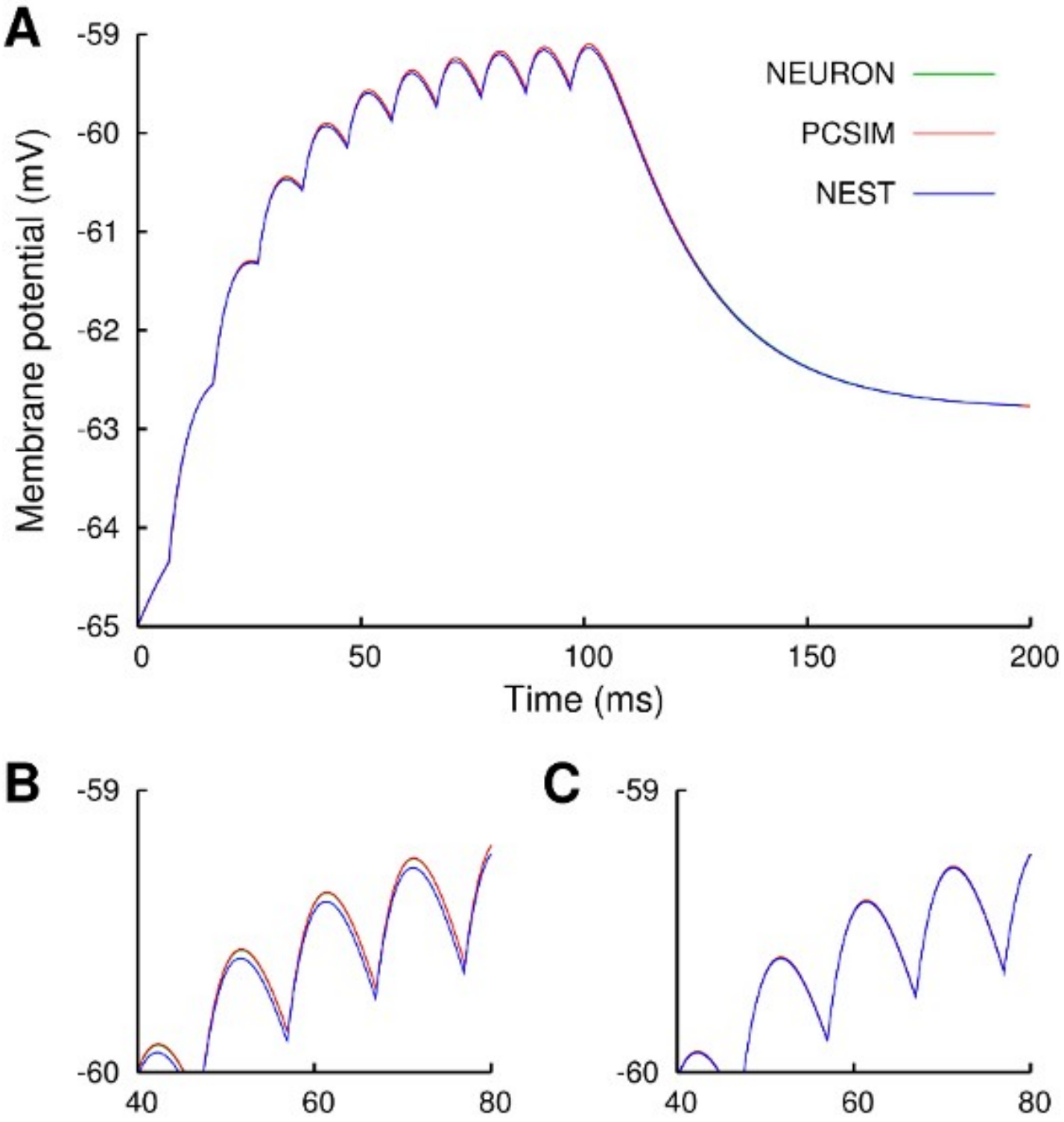
How to participate in PyNN development

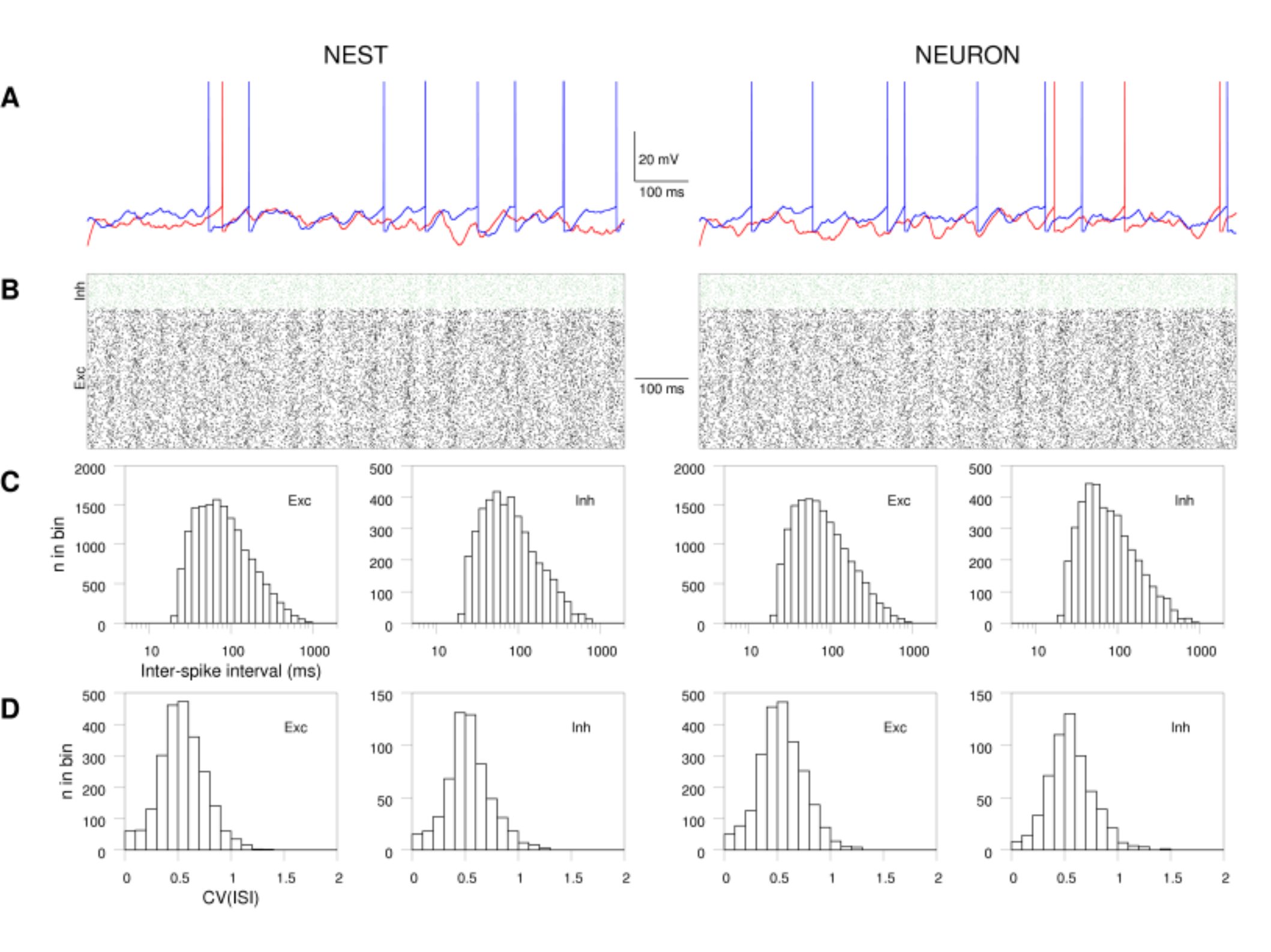


http://neuralensemble.org/PyNN

Why might PyNN be important for this INCF initiative?

- Declarative XML
  - Not generally human generatable or even readable
  - PyNN is human generatable and can generate NeuroML
- Standards compliance verification
  - A test-suite for compliance
  - Write once in PyNN for all
  - No testing of the various test suites, no bash|perl


A
-59
-60
-61
-62
-63
-64
-65
Membrane potential (mV)
0
50
100
150
200
Time (ms)
NEURON
PCSIM
NEST
B
-59
-60
40
60
80
C
-59
-60
40
60
80


NEST
NEURON
A
20 mV
100 ms
B
Inh
Exc
100 ms
C
n in bin
Exc
Inh
Exc
Inh
Inter-spike interval (ms)
D
n in bin
Exc
Inh
Exc
Inh
CV(ISI)

- Implement XML importer/parser for PyNN
  - Writing and maintaining Python+PyNN support for a given simulator is orders of magnitude more appealing than writing and maintaining a compliant XML parser. PyNN can provide this.
- PyNN API user extensions in terms of the API
  - Such extensions supported by all simulators implementing the API
  - Maintain existing isomorphism between PyNN API Object Model and NeuroML for I&F networks
  - Avoid re-inventing a general modeling language in XML with associated difficulties to parse and support downstream.

1 API (PyNN low-level)

- create, connect

2 Object model (PyNN high-level)

- Population, Projection

3 Object Declarative Mapping (à la ORM for DBs)

- PyNN <=> NeuroML

Main message:

- Unification of simulator object models (hard)
- Declarative model format through ODM (easy)

The FACETS Project

CodeJam Workshop #3

When: ~7-10.10.2009

Where: Bernstein Center for Computational Neuroscience Freiburg

Contact: Abigail Morrison (abigail@brain.riken.jp)

CodeJam #1 (2007)

Heidelberg

CodeJam #2 (2008)

Gif-sur-Yvette