Converting simulator specific formats to NeuroML2

Open Source Brain Meeting 2019

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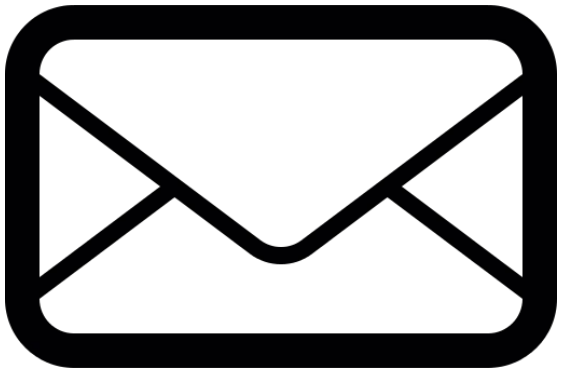
Converting NMODL to NeuroML

The Simple™, OSB sponsored way of converting models to NeuroML2



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What is NeuroML, and why should I care?

Open Source Brain and NeuroML2

- OSB accepts models in any format!
- …. but with NML2 models, magic things can happen

http://opensourcebrain.org/projects/acnet2

http://opensourcebrain.org/projects/vogelsetal2011

http://opensourcebrain.org/projects/multicompgrc

Overview - Balanced netw

Not secure | opensourcebrain.org/projects/vogelsetal2011

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Balanced network with inhibitory plasticity Vogels et al. 2011

OSB endorsed project | issues repo not found | forks 7 | stars 1

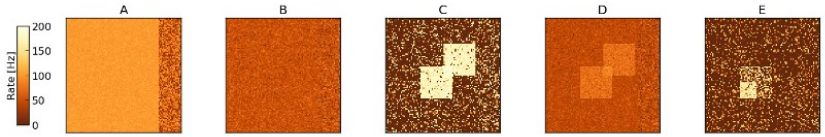
Curation against published models ★★

Vertebrate / Mammalian / Generic / Neocortex / Network model / Balanced network with inhibitory plasticity - Vogels et al. 2011

Overview Activity Models Wiki Repository

- Description
- Status
- Members
- References

Description



Network model from: Vogels TP, Sprekeler H, Zenke F, Clopath C, Gerstner W (2011) Inhibitory plasticity balances excitation and inhibition in sensory pathways and memory networks. Science 334:1569-73.

See the Wiki for more details.

Status

In development. Tested with PyNN 0.8.

PyNN support ★★ | NEURON support ★★ | NEST support ★ | Brian support ★

Members

Developer: Andrew Davison, Ankur Sinha, Padraig Gleeson

Scientific Coordinator: Vitor Chaud

References

Entrada - borismarin@gm | Sardinia2019 - Apresenta | Source code beautifier / s | NEURON | empirically-bas | neuron book hines - Goog | The NEURON Book: Ama | Overview - Multicompartm
Not secure | opensourcebrain.org/projects/multicompgrc
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Multicompartmental granule cell Diwakar et al. 2009

OSB endorsed project | issues 0 open | forks 1 | stars 0

Curation against published models

Description

Multicompartmental cerebellar granule cell model.

Based on: Diwakar S, Magistretti J, Goldfarb M, Naldi G, D`Angelo E (2009) Axonal Na+ channels ensure fast spike activation and back-propagation in cerebellar granule cells J Neurophysiol 101(2):519-32

Status

Currently being converted to NeuroML/neuroConstruct

NeuroML v2.x support | NeuroML v1.x support | NEURON support

Members

Developer: Padraig Gleeson

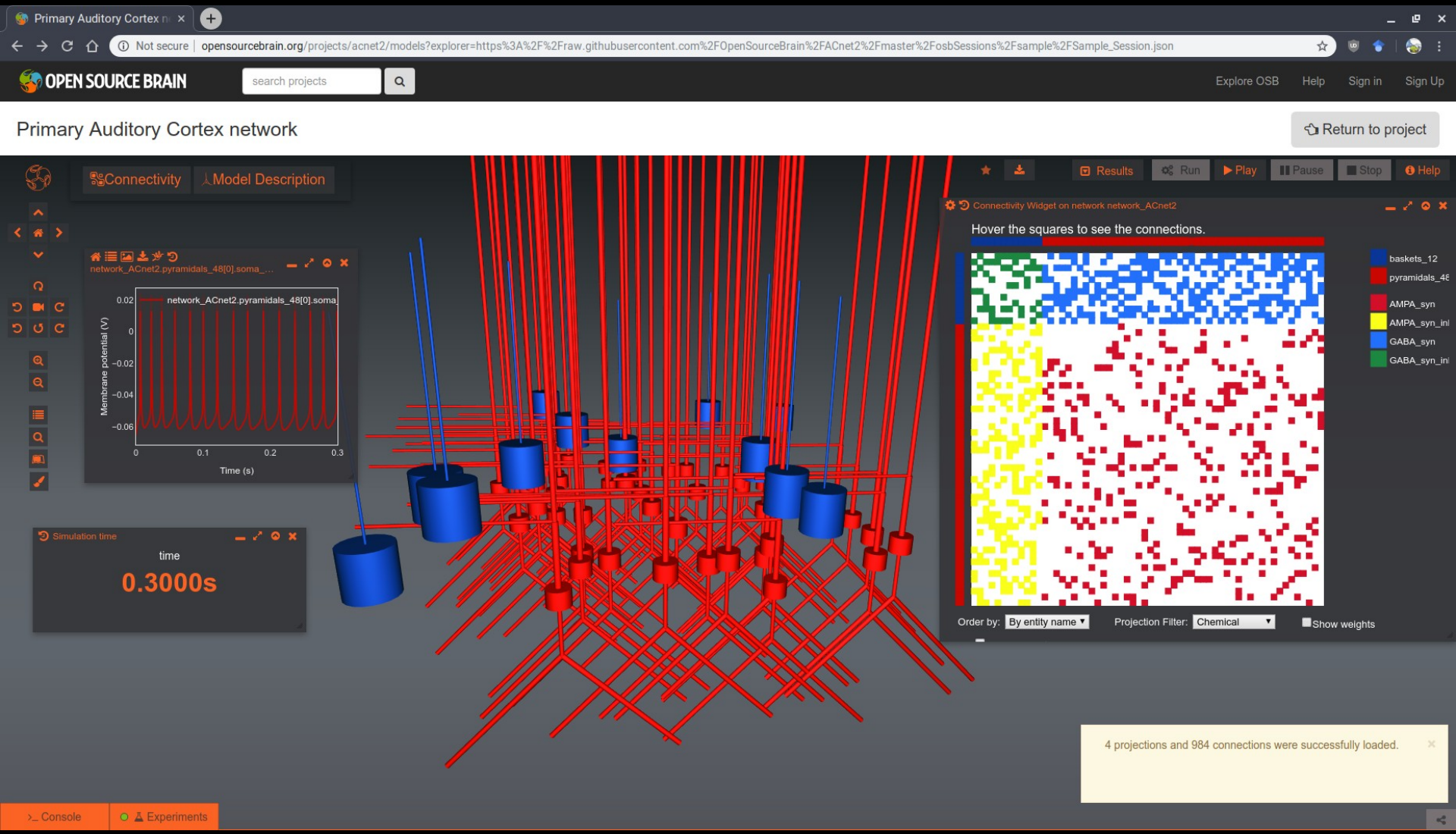
Scientific Coordinator: Martina Rizza, Sergio Solinas

References

The original published version of this model is available on ModelDB

This model was originally developed in: **NEURON**

The code for this model is hosted on GitHub: https://github.com/rizland/cereb_grc_mc.git


Primary Auditory Cortex n
Not secure | opensourcebrain.org/projects/acnet2/models?explorer=https%3A%2F%2Fraw.githubusercontent.com%2FOpenSourceBrain%2FACnet2%2Fmaster%2FosbSessions%2Fsample%2FSample_Session.json
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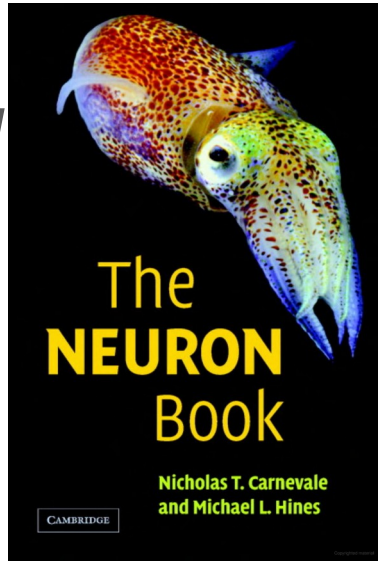
Sign Up
Primary Auditory Cortex network
Return to project
Connectivity
Model Description
Results
Run
Play
Pause
Stop
Help
network_ACnet2.pyramidals_48[0].soma_...
network_ACnet2.pyramidals_48[0].soma
Membrane potential (V)
Time (s)
Simulation time
time
0.3000s
Connectivity Widget on network network_ACnet2
Hover the squares to see the connections.
baskets_12
pyramidals_48
AMPA_syn
AMPA_syn_inl
GABA_syn
GABA_syn_inl
Order by:
By entity name
Projection Filter:
Chemical
Show weights
4 projections and 984 connections were successfully loaded.
Console
Experiments

The *NEURON* simulator

Defining models in *NEURON*

https://www.neuron.yale.edu/neuron/

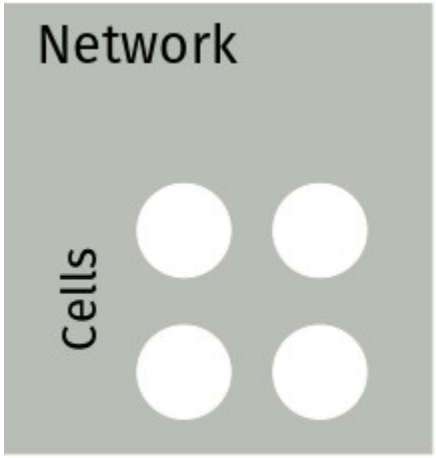
- Cells, Networks: *hoc* language (accessible from Python)
  - morphologies
  - synaptic connections
  - *.hoc* files
- Ion Channels (membrane mechanisms): *NM*
  - *.mod* files



What is NeuroML, and why should I care?

Why can OSB process any NeuroML2 file?

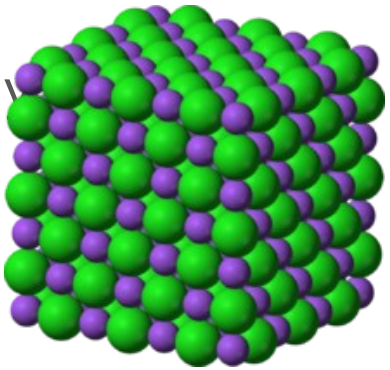
- NML is *structured* (not unlike a *Type System*)



It is all about **Structure**

Structure in NeuroML / NMODL

- A *Type System* (composability rules) is what grants NML its superpowers
- `nmodl` is also powerful, but can be used as a general purpose language
  - `VERBATIM` blocks
  - many different ways of achieving same goal
  - prone to *unstructuredness*
- OSB could in theory treat `nmodl` the same way as NML...
  - .... if only people stuck to "good practices"!



Levels of Abstraction

NeuroML2

```
<ionChannelHH id="kChan" conductance="10pS" species="k">

      <gateHHrates id="n" instances="4">
        <forwardRate type="HHExpLinearRate" rate="0.1per_ms" midpoint="-55mV" scale="10mV"/>
        <reverseRate type="HHExpRate" rate="0.125per_ms" midpoint="-65mV" scale="-80mV"/>
      </gateHHrates>

  </ionChannelHH>
```

NMODL

```
BREAKPOINT {
        SOLVE states METHOD cnexp
        gk = gkbar * n ^ 4
        ik = gk * (v-ek)
}
INITIAL{
        n = alpha(v) / (alpha(v) + beta(v))
}
DERIVATIVE states{
        n' = (1 - n) * alpha(v) - n * beta(v)
}
```

```
FUNCTION alpha(Vm(mV))(/ms){
        LOCAL x
        UNITSOFF
        x = (Vm + 55) / 10
        if(fabs(x) > 1e-6){
                alpha=0.1*x/(1-exp(-x))
        }else{
                alpha=0.1/(1-0.5*x)
        }
        UNITSON
}
```

Levels of Abstraction

Declarative vs Imperative

- NeuroML2 operates (at least syntactically) closer to the level of abstraction employed by electrophysiologists
- The gory details exist, but elsewhere: *LEMS*
  - i.e. what to do with α, β; the definition of an `ExpRate`; how all of that is converted to conductances/currents...
- But we seldom need (want!) to interact with that level (look under the hood)

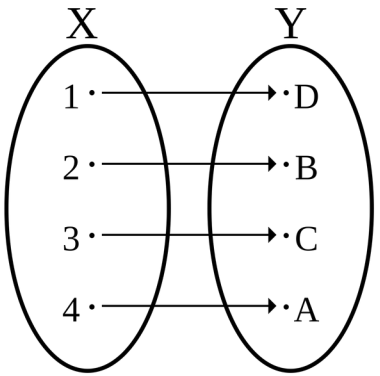
```
<Network ...>
    <Cell ...>
        <Channel ...>
            <Gate ...>
                <Rate ...>
```

```
SOLVE{...} METHOD euler
...
DERIVATIVE {...}
...
FUNCTION trap(v){...}
```

Levels of Abstraction

Direct translation

- Nevertheless, an electrophysiologist can (usually) make sense out of *carefully written* NMODL files
  - there are functions called α, β
  - the kinetics look familiar
- When languages operate at the same level of abstraction, we can directly "translate" one to another
- Morphology / hoc — similar level of abstraction



Levels of Abstraction

NetPyNE: structured network specification

i)
```
popParams['EXC_L2'] = {
'cellType':   'PYR',
'cellModel':  'simple',
'yRange':     [100, 400],
'numCells':   50}
```

ii)
```
popParams['EXC_L5'] = {
'cellType':   'PYR',
'cellModel':  'complex',
'yRange':     [700, 1000],
'density':    80e3}
```

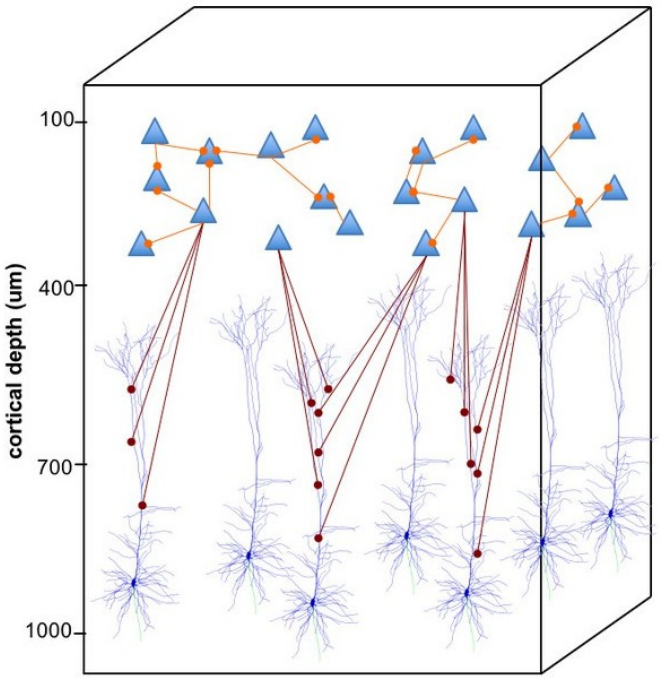
iii)
```
cellParams['PYR_simple'] = {
'conds': {'cellType': 'PYR',
          'cellModel': 'simple'},
'secs':  {'soma':
           'geom': {'diam': 18, 'L': 18},
           'mechs': {'hh':
                     {'gnabar': 0.12,
                      'gkbar': 0.036,
                      'gl':    0.003,
                      'el':    -70}}}}
```

iv)
```
importCellParams(
label =    'PYR_complex',
conds =   {'cellType':   'PYR',
           'cellModel': 'complex'},
fileName = 'L5_pyr_full.hoc',
cellName = 'PYR_L5')
```

vi)
```
synMechParams['AMPA'] = {
 'mod':   'Exp2Syn',
 'tau1':   0.8,
 'tau2':   5.3,
 'e':      0}
```

vii)
```
connParams['L2->E2'] = {
 'preConds':    {'y': [100, 400]},
 'postConds':   {'pop': 'EXC_L2'},
 'probability': '1*exp(-dist_3D/200)',
 'weight':       0.4,
 'delay':        5,
 'synMech':      'AMPA'}
```

viii)
```
connParams['E2->L5'] = {
 'preConds':    {'pop': 'EXC_L2'},
 'postConds':   {'y':   [700,1100],
                 'cellModel': 'complex'},
 'convergence': 25,
 'weight':      '0.001 * post_ynorm',
 'delay':       'dist_3D/propVelocity',
 'sec':         'allDend',
 'synMech':     'AMPA',
 'synsPerConn': 3}
```



Dura-Bernal, Salvador, et al. "NetPyNE, a tool for data-driven multiscale modeling of brain circuits." Elife 8

Example: NMODL to NeuroML2

How we can help

- `pyneuroml` https://github.com/NeuroML/pyNeuroML

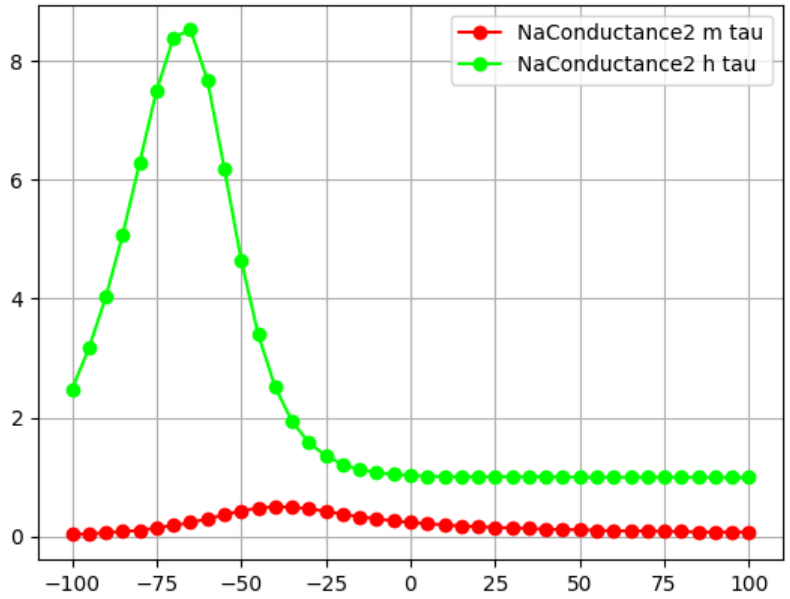
  `$pip install pyneuroml`

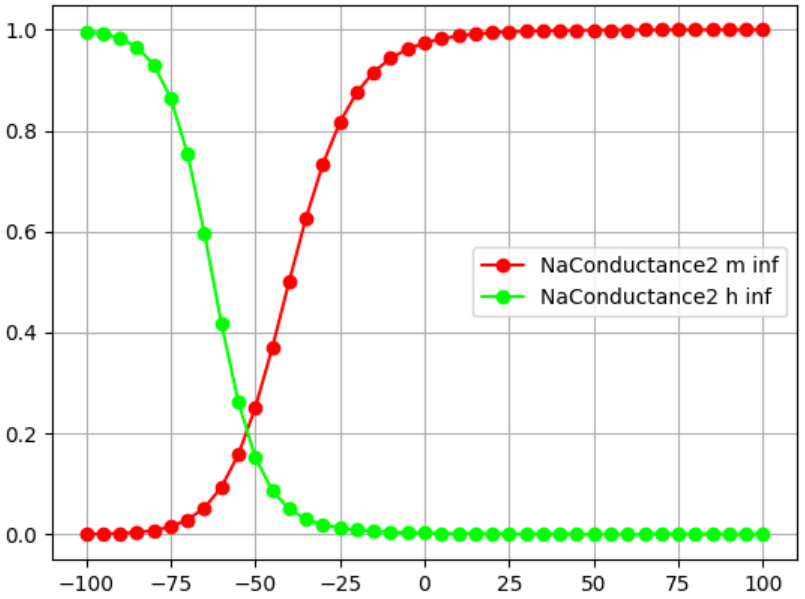
- everything you need to get started with NeuroML2, bundled in a single Python package

Example: NMODL to NeuroML2

Exploring channel dynamics with `pyneuroml`

```
> pynml-modchananalysis NaConductance2.mod
```

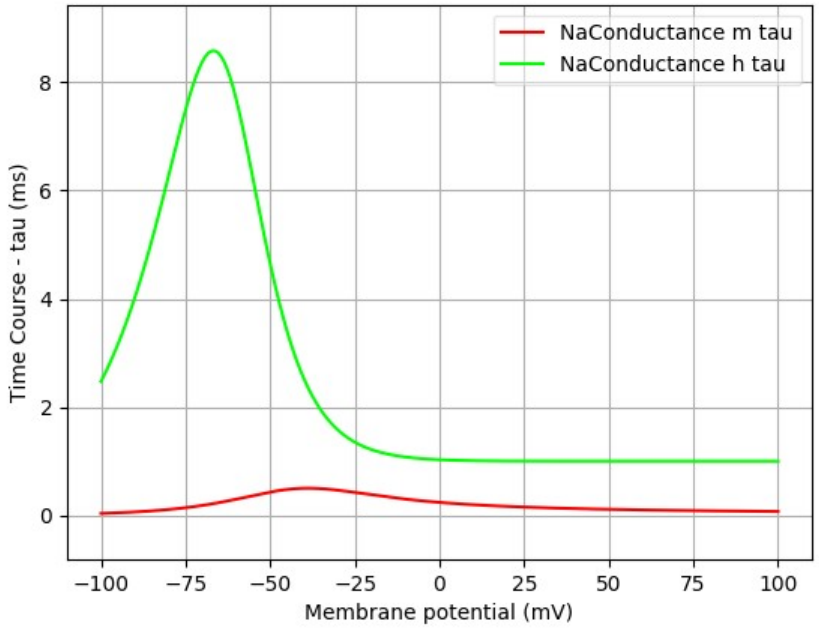


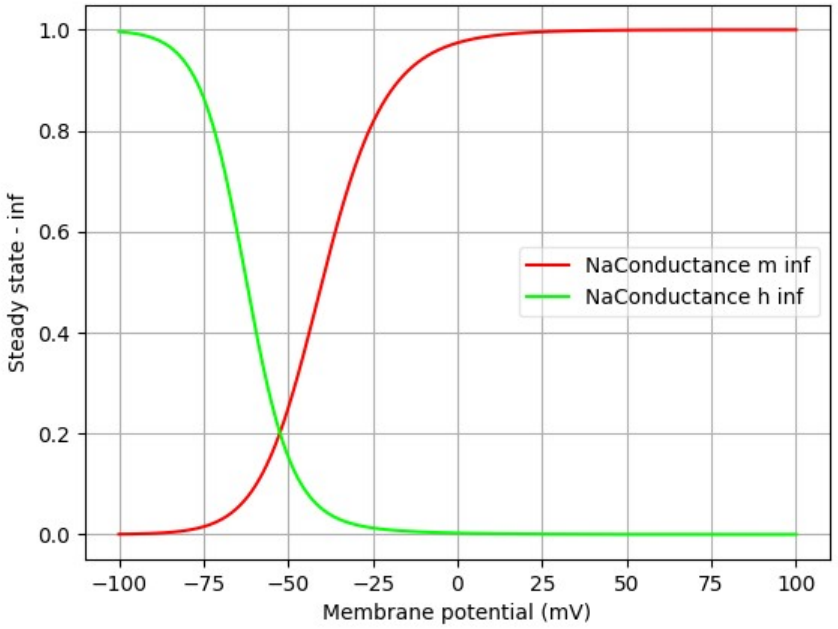


Example: NMODL to NeuroML2

Exploring channel dynamics with `pyneuroml`

```
> pynml-channelanalysis NaConductance.channel.nml
```





More reasons for NeuroML

What do we get besides visualization/simulation on OSB?

- Once we have a model in NeuroML, we (usually) need to convert it back to a simulator-specific format in order to simulate it.
- Does that mean we need to go back to NMODL after all that?
- OSB visualization is not all you get. Given its *regular structure*, we were able to create a number of *exporters:*

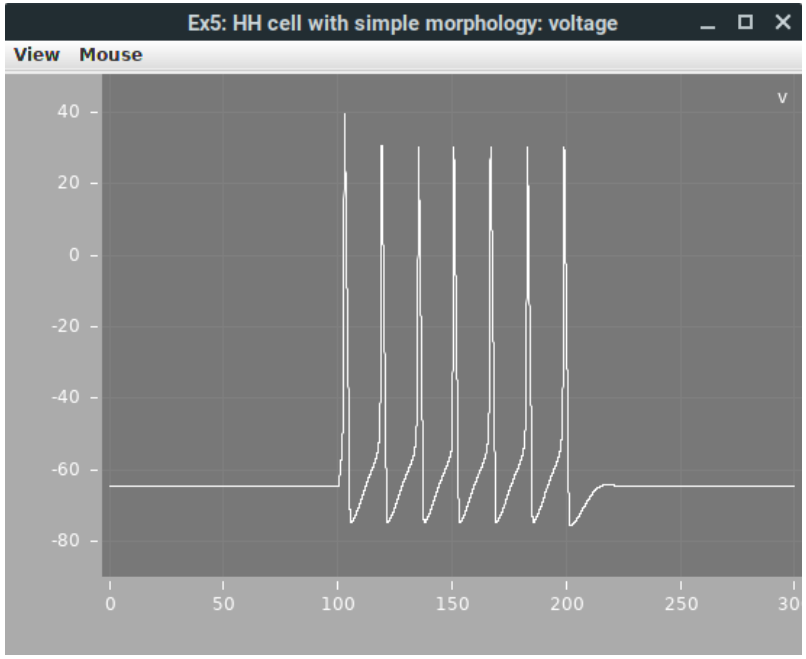
NeuroML2	NEURON	XPP
	MOOSE	BRIAN
	NEST	PyNN

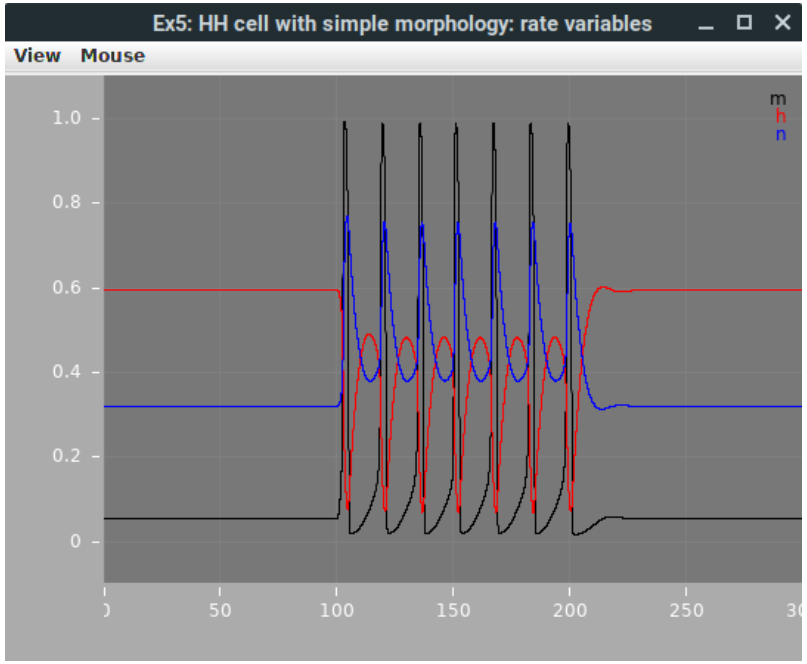
Example: PyNeuroML usage

Exporting NeuroML2 to different formats

- Native interpreter (Java)

```
> pynml LEMS_NML2_Ex5_DetCell.xml
```



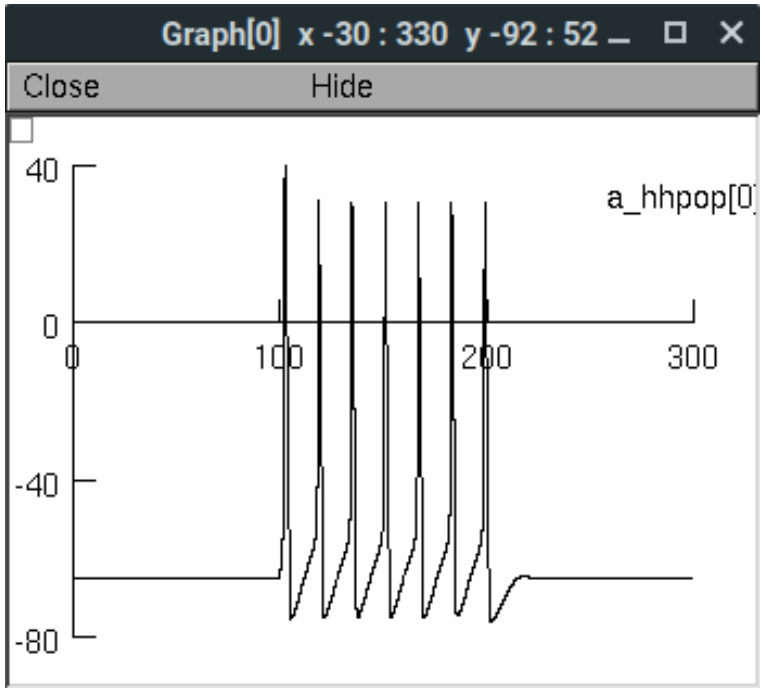


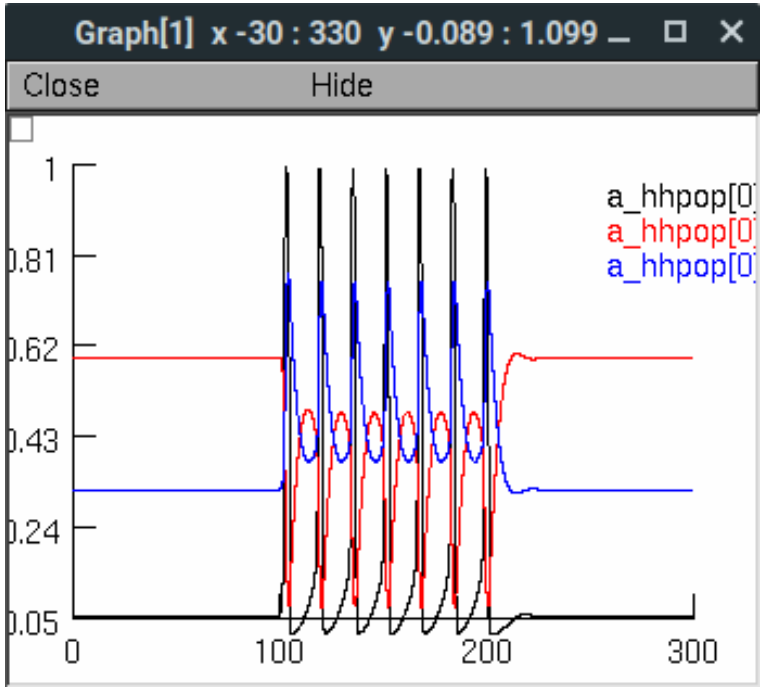
Example: PyNeuroML usage

Exporting NeuroML2 to different formats

- *NEURON*

```
> pynml LEMS_NML2_Ex5_DetCell.xml -neuron
```



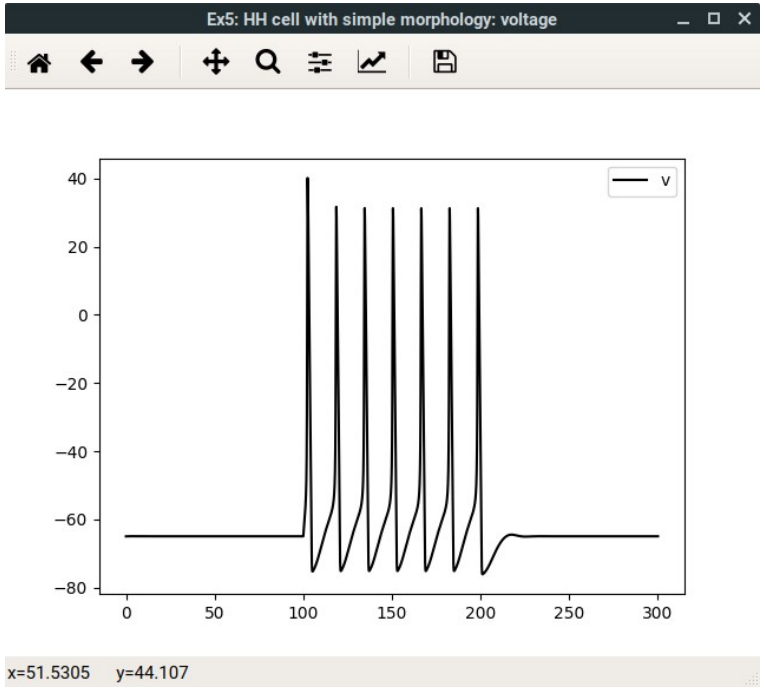


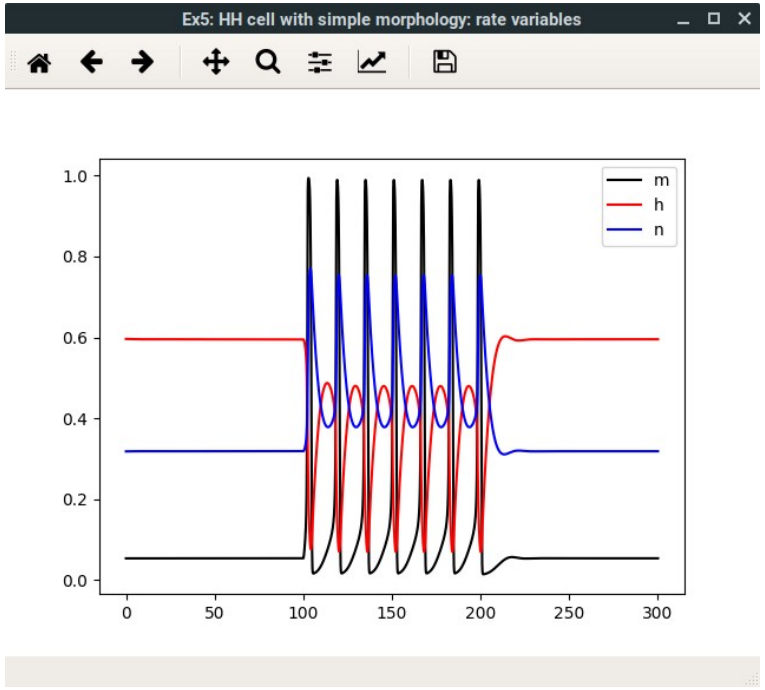
Example: PyNeuroML usage

Exporting NeuroML2 to different formats

- *Brian2* https://brian2.readthedocs.io/

```
> pynml LEMS_NML2_Ex5_DetCell.xml -brian2
```

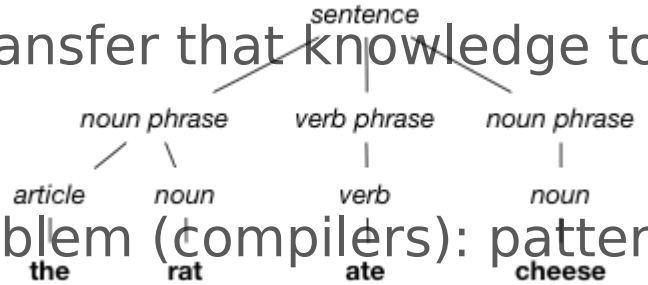




Future Plans

Automated conversion (whenever applicable)

- The final frontier: automatic conversion from NMODL to NeuroML2
- We first have to parse NMODL *syntax*: https://github.com/BlueBrain/nmodl
- Hard part: *semantic* analysis
- “Expert” humans can figure out that a *mod* file is employing HH formalism
- How can we transfer that knowledge to th translator?
- Interesting problem (compilers): pattern m symbolic computing



We want DATA!

How does all that apply to experimental data?

- *Structured* information is central to OSB (and associated technologies)
- A number of other initiatives have also recognised *the need to standardize*
- Example: the *Neurodata Without Borders* Consortium has created a standard for neurophysiology data, NWB:N
- More on that tomorrow!

NEURODATA:N
WITHOUT BORDERS

ALLEN BRAIN ATLAS
DATA PORTAL

BRAIN RESEARCH THROUGH ADVANCING INNOVATIVE NEUROTECHNOLOGIES
BRAIN INITIATIVE

Thank you!
Questions?