morphforge

Biophysical simulation in Python

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Outline

About Me & My Work

- Collaboration with Alan Robert's experimental lab

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- Locomotive networks in Xenopus *laevis* tadpoles

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- Modelling:
  - Small Networks (2000 neurons)
  - Hodgekin-Huxley type models of different neuron classes
  - Morphology of neurons important due to electrical coupling

Previous Workflow (MSc Project)

- Initial channel modelling
  Handwritten .hoc & .mod files (`NEURON`)

Previous Workflow (MSc Project)

- Effects of changing parameters
  Cheetah generated .hoc & .mod files, scripts for building, re-import data as CSV for plotting

Previous Workflow (MSc Project)

- $\cdots$ *months passed* $\cdots$

Previous Workflow (MSc Project)

- Network modelling
  2 x YAML + XML files converted into another XML neuron containing network & output specification $\implies$ cheetah generated .hoc & .mod files, Makefiles for building, re-import data from csv as for plotting, caching of results in a directory.

Previous Workflow (MSc Project)

- Time for a rethink ?!?!?

Motivation

Morphology
- FACETS Code Jam '09 - Phillip Rautenberg
- Morphology Reconstructions in Bristol
- DIADEM Project

Simulation
- Large Parameter Sweeps

What is morphforge?

Python Libraries for:

- Handling neural **morphologies**

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Python Libraries for:

- Handling neural **morphologies**
- Defining & running **biophysical simulations**
- Analysing & storing simulation **results**
- Simplifying **parameter sweeps**

Morphologies

Morphologies

- Represent morphologies as a **tree of cylinders**
- Cylinders can be assigned regions and/or id's.

Import/Export & Visualisation

- Create morphologies in Python
- Load and save **.swc** files.
- Load **MorphML** files

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- Morphologies can be visualised using:
    - 2D projections in **matplotlib**
    - 3D visualisation in **MayaVi**

Analysis & Manipulation

- General purpose data structure
- Minimal classes + loose coupling $\Longrightarrow$ **Visitor** pattern
- (Example of straightening tadpole)

Examples

Simulations

Simulation Overview

- Simulator Agnostic Description of:
    - Neurons
    - Active membrane channels (HH-style)
    - Passive membrane properties
    - Voltage & current clamps
    - Recording electrodes (voltages, currents & membrane properties)

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- Simplification of plotting

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- Simplification of plotting
- Basic trace analysis
- Caching simulation results

Neuron Specific

- Uses python-neuron interface
- Use existing .mod files directly
- Behind the scenes:
  - Generate .hoc and .mod files
  - Compiles .mod files
  - Registers .mod files into neuron-instance

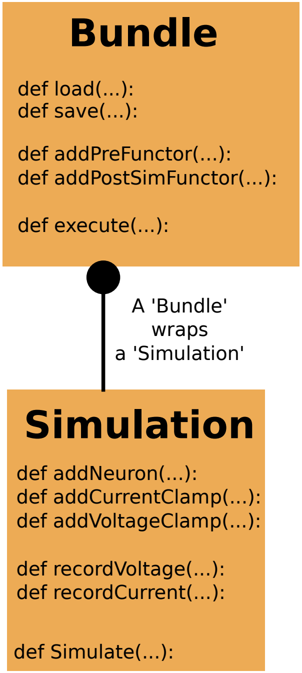
Simulation Examples

Sweeps & Bundles

Bundles

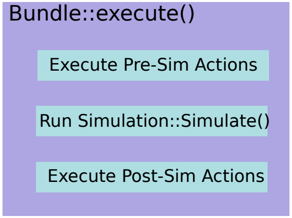
A wrapper around Simulation objects, in order to:

- Attach pre/post-simulation **functors**
- Encapsulate **serialisation**



```
def load(...):
def save(...):

def addPreFunctor(...):
def addPostSimFunctor(...):

def execute(...):
```

```
def addNeuron(...):
def addCurrentClamp(...):
def addVoltageClamp(...):

def recordVoltage(...):
def recordCurrent(...):


def Simulate(...):
```



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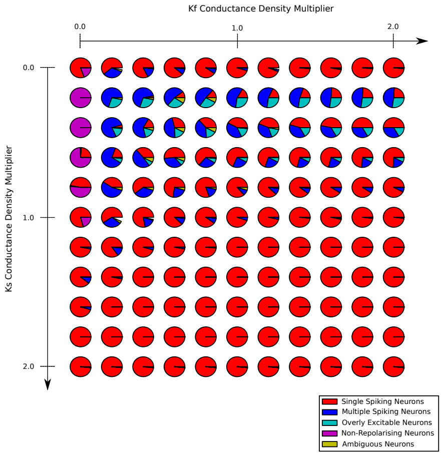
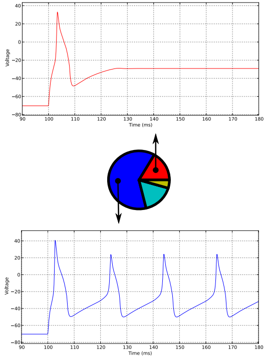
- The BundleServer is started on a single machine and acts as a daemon, keeping a track of which bundles have been handed out to which clients.
- The BundleClient can be started on many clients. Each client contacts the server, requests n Bundles, runs them, notifies the server about whether bundles ran successfully or not, then requests more bundles....

Parameter Sweeps Results Examples

- Modelling the effects of conductances on firing behaviour
- Na, Ca, Kf, Ks, Lk channels + injected current
- 110,000 simulations run in a night over 30 computers

Parameter Sweeps Results Examples





From Here

WishList

High Priority	- Interface for neural connectivity - Documentation & testing
Low Priority	- Summary pdfs/tex output - Loading *ML formats

Collaboration

- Code is in a mercurial repository - email s0897465@sms.ed.ac.uk
- To be made public (advice on open licenses)
- Is this useful to other people?
- Integration with other open-source tools
- Keen to find collaboration.....

Acknowledgements

- Juan Reyero (Magnitude Units Package)
- Enthought (MayaVi Package)
- Everyone working on scientific python libraries!
- NEURON & Python Interface
- Organisers of Code Jams
- Supervisors: Alan Roberts & David Willshaw

Thankyou!