LFPy-tutorial CNS2013

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LFPy - Introduction

- **LFPy** is a **Python**-package for calculating extracellular potentials from multi-compartment neuron models

- **LFPy** home page: [http://compneuro.umb.no/LFPy](http://compneuro.umb.no/LFPy)

- Live LFPyLubuntu image: [http://goo.gl/1sOiM](http://goo.gl/1sOiM)
  
  - Use .iso-file with Virtualbox or similar, see [http://www.virtualbox.org](http://www.virtualbox.org)
  
  - Comes with the **Python** `--pylab` environment, **LFPy** and **NEURON** preinstalled
LFPy - Introduction

- **Topics:**
  - Why model extracellular potentials?
  - Biophysical modeling scheme (brief)
  - LFPy overview
  - LFPy installation
  - Brief explanation of the main classes in LFPy
  - LFPy usage
  - LFPy provided examples
**LFPy** - Introduction

- Why model extracellular potentials?
  - Improve understanding of experimental measurements:
  - Methods validation:
LFPy - Introduction

- Why model extracellular potentials?
  - O14: Taxidis et al.; Extracellular field signatures of CA1 spiking cell assemblies during sharp wave-ripple complexes
  - P119: Hagen et al.; Hybrid scheme for modeling LFPs from spiking cortical network models
  - P120: Ness et al.; Modeling Extracellular Potentials in Microelectrode Array Recordings
  - P417: Chintaluri et al.; Realistic simulations of local field potentials in a slice
  - others: P41, P126, P255, ...
**LFPy - Introduction**

- Forward-modeling scheme for extracellular potentials for multi-compartment neuron models:
  \[
  \Phi(r, t) = \frac{1}{4\pi \sigma_e} \sum_{n=1}^{N} \frac{I_n(t)}{|r - r_n|}
  \]

- Line-sources (Holt & Koch 1999)
  \[
  \Phi(r, t) = \frac{1}{4\pi \sigma_e} \sum_{n=1}^{N} I_n(t) \int \frac{dr_n}{|r - r_n|}
  \]

- Current conservation imply:
  \[
  \sum_{n=1}^{N} I_n(t) = 0
  \]
Why Python?

- Object oriented
- Easy to script
- Flexible
- Plethora of packages for visualizations and analysis

- [http://pypi.python.org/](http://pypi.python.org/)
  - *pypi*: ~32500 packages
- Interface other programming languages
LFPy - Installation

● Make sure **Python**-prerequisites are met:
  – **neuron** (`./configure --with-nrnpython`)
  – **Cython, NumPy, SciPy, matplotlib**
    (opt. **ipython** (notebook), **h5py**, **mpi4py**)

● Download the **LFPy** source code:
  [http://compneuro.umb.no/LFPy/downloads/](http://compneuro.umb.no/LFPy/downloads/LFPy-0.9.5.tar.gz)

● Unzip:
  `tar –xzf LFPy-0.9.5.tar.gz`

● Or, get development version of **LFPy** using subversion:
  `svn co \`
LFPy - Installation

- Install from LFPy source code:
  
  ```
  cd /path/to/LFPy
  python setup.py install --user
  ```

- Easy installation of LFPy:
  
  ```
  easy_install LFPy --user
  ```

- Small test with IPython:
  
  ```
  ipython -c "import LFPy"
  ```

- With NEURON:
  
  ```
  nrngui --python -c "import LFPy"
  ```
**LFPy – Main Classes**

- The primary **LFPy**-classes employed to set up simulations are:
  - `LFPy.Cell`
  - `LFPy.Synapse`
  - `LFPy.RecExtElectrode`

- Other classes and functions:
  - class `LFPy.StimIntElectrode`
  - functions `LFPy.lfpcalc.calc_lfp*`, `LFPy.inputgenerators.*`, `LFPy.tools.*`

- For detailed information please refer to the online documentation:
  [http://compneuro.umb.no/LFPy/classes.html](http://compneuro.umb.no/LFPy/classes.html)
**LFPy** – Main Classes

- **LFPy.Cell**:  
  - Uses **NEURON** under the hood  
  - Loads the morphology  
  - Set the neuronal properties:  
    - membrane mechanisms  
    - number of compartments  
    - Set cell location and rotation  
  - Collect the geometry into arrays  
  - Methods for segment indices  
  - positioning in 3D  
  - Simulation control
LFPy - Main Classes

- **LFPy.Synapse:**
  - attach synapse-objects onto cell objects
  - Keyword arguments:
    - **cell**—object
    - compartment index, **idx**
    - synapse type, **Exp2syn**
    - mechanism arguments
- Set up as **NetCon** objects (see **NEURON** documentation) for synaptic weights and times.
**LFPy - Main Classes**

- **LFPy.RecExtElectrode**
  - extracellular recording devices
  - Main arguments:
    - Coordinates of contact points
    - extracellular conductivity
    - method (point/line-sources)
  - Optional:
    - radius and surface normal vectors for the contacts
    - $n$-point surface area averaged potential

LFPy class—objects:
- LFPy.Synapse
- LFPy.StimIntElectrode
- LFPy.Cell
- LFPy.TemplateCell
- LFPy.RecExtElectrode
**LFPy - Usage**

- Working in local folder:
  ```
  cd /path/to/LFPy/examples/
  ```
- Have a look at the two provided **ipython** notebooks
  - Post-synaptic response of somatic synapse
  - LFPs from a single, apical synapse
- Employ an interactive ipython notesession:
  ```
  ipython notebook --pylab inline
  ```
- Two interactive examples should be available:
**LFPy - Usage**

- **Interactive example 1:**
  - Calculate the post-synaptic response of somatic synapse
**LFPy - Usage**

- Interactive example 2:
  - Calculate LFPs arising from a single, apical synapse
**LFPy** – Provided example files

- **LFPy** comes with example scripts displaying different usage cases:
  - using active cell models
  - using many synapses
  - dealing with a population of cell objects

- Example files in:
  `/path/to/LFPy/examples/`

- `.mod`-files may be compiled for active stuff, running `nrnivmodl`

  inside the examples folder
LFPy - Provided example files

- `/path/to/LFPy/examples/example1.py`:
  - Single apical synapse response. Passive membrane
LFPy - Provided example files

/path/to/LFPy/examples/example2.py:

- Spiking L5b model (Hay et al., 2011)
LFPy - Provided example files

• /path/to/LFPy/examples/example3.py:
  – Hybrid model approach with MPI
**LFPy** - Provided example files

- `/path/to/LFPy/examples/example6.py`:
  - Distributed exc/inh. synapses. Active membrane.
**LFPy - Provided example files**

- `/path/to/LFPy/examples/example_mpi.py`:
  - A small population using MPI. Active membranes.
**LFPy** - Tutorial

- Questions?
- If not, feel free to test out **LFPy** 😊