Computational Lab Notebook

AdEx implementation in NetPyNe

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Last Revision: 2022-02-26

Contents

1 Information

1.1 Project name

Adaptative Exponential Integrate and Fire (AdEx) implementation in Netpyne

1.2 Project date

This project started in June 2021

1.3 Motivation

The Kerr Lab implemented a previous version of the AdEx model. The basic idea here was to implement an AdEx Class.

Should netpyne provide a basic NEURON models, such as AdEx, izhikevic, integrate and fire?

Do NEURON provide those models?

To solve those questions, I propose to implement the AdEx model in NEURON and then, plug it into NetPyNe, as a new functionality.

1.4 Publications

1. NetPyNe Paper (Dura-Bernal et al., 2019)

1.5 Digital verification

not yet

1.6 Links

- The NetPyNe project is available at http://www.netpyne.org/
- Dura-Bernal Laboratory could be reached at http://dura-bernal.org/
- The whole project is archived in github as digital repository. It may be found in the following link: https://github.com/jpalma-espinosa/netpyne

1.7 Additional Credits

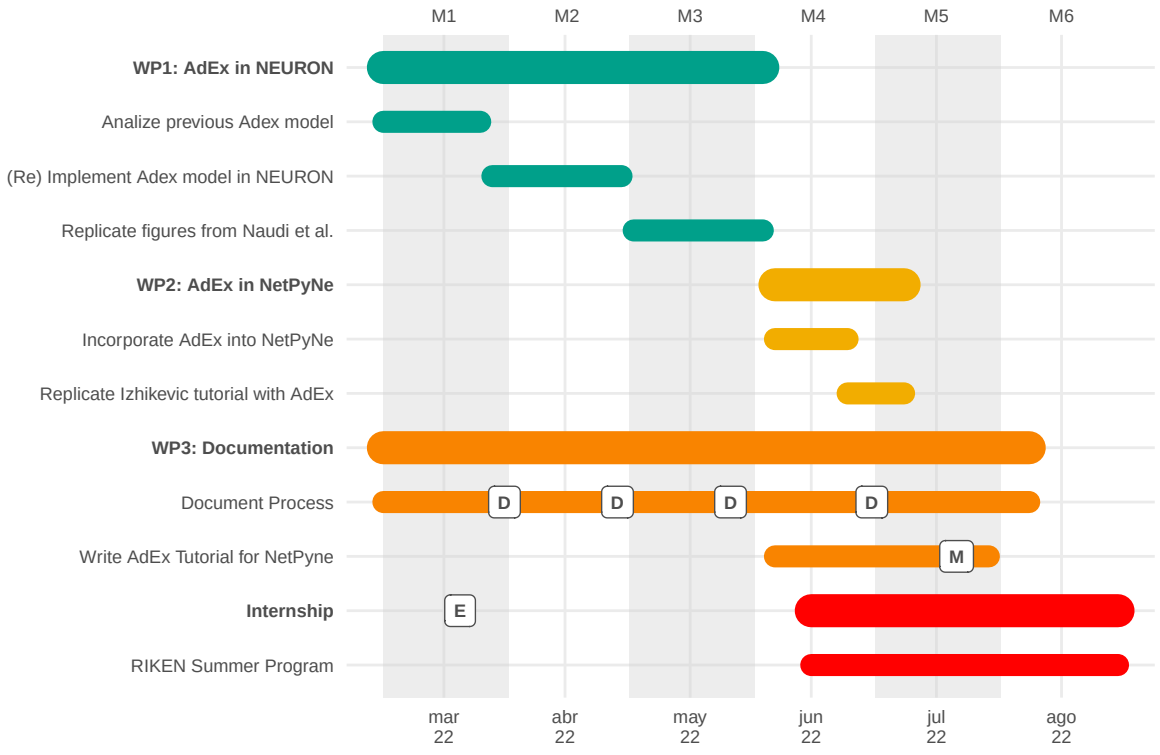
- This document was done with the Eisvogel Template, by Pascal Wagler

2 Changelog

Date	Commit	log
2022-02-26 20:47:25	1abe955	Computational Lab Notebook File updated
2022-02-26 20:29:36	cb63c70	update in project structure. New documentation available
2021-07-20 20:44:24	10a7bcb	Pseudo working example of Adex2021b
2021-07-07 05:46:44	4601b03	Changed typo in README
2021-07-07 05:35:18	be151ad	Upload new documents. Thoughts and ideas in README
2021-07-01 06:40:27	026e684	Notes name changed
2021-07-01 06:30:44	ffda310	Ball-Stick class is created (not working).

3 Work Plan (Gantt Chart)

wp	activity	start_date	end_date
WP1: AdEx in NEURON	Analize previous Adex model	22-03-01	22-03-25
WP1: AdEx in NEURON	(Re) Implement Adex model in NEURON	22-03-28	22-04-29
WP1: AdEx in NEURON	Replicate figures from Naudi et al.	22-05-02	22-06-03
WP2: AdEx in NetPyNe	Incorporate AdEx into NetPyNe	22-06-06	22-06-24
WP2: AdEx in NetPyNe	Replicate Izhikevic tutorial with AdEx	22-06-24	22-07-08
WP3: Documentation	Document Process	22-03-01	22-08-08
WP3: Documentation	Write AdEx Tutorial for NetPyne	22-06-06	22-07-29
Internship	RIKEN Summer Program	22-06-15	22-08-30



Deliverables: Montly meeting update. **M**ilestone: Full project presentation (labmeeting). **E**vent: Result from RIKEN

Apparently, there is no current AdEx.mod implemented in NEURON. I will first replicate the AdEx.mod file/model based on what Kerr Lab did previously. To achieve this goal, the tasks will be: - ~~[ ] Implement and analyze AdEx model implemented in neuron (.mod) (Sprint 1)~~ - [ ] Analyze AdEx model implemented in neuron (.mod) (Sprint 1) - [ ] Re-Implement AdEx model in NEURON (Adex.mod) (Sprint 2) - [ ] Replicate the Izhikevic tutorial, but now incorporating the AdEx model ~~(Sprint 2)~~(Sprint 3). - [ ] Replicate figures from Naud et al. ~~(Sprint 3)~~(Sprint 4). - [ ] Write AdEx tutorial and test it for publication on the website ~~(Sprint 4)~~(Sprint 5).

4 Daily Report

4.1 Jun 7th, 2021

I was able to run the izhikevic tutorial. Also, I wrote the Adex.mod file, by replicating what was done with izhi2007b.mod. However, I am still not able to produce a spike in the Adex model. The izhikevic one has some strange way of calculating the derivative states. What is the difference between those two forms of calculation? Also, how can I incorporate the synapses in the Adex neuron?

The izhikevic (and adex) is implemented as a POINT PROCESS (see also NEURON documentation), contrary to the HH model.

4.2 Jun 30th, 2021

I was on halt because I had to deal with my master thesis. I am now a Master of Science :D.

Because the previous implementation wasn't sucessful, I asked wheter AdEx should be defined as a mechanism or a point neuron (see De Schutter book, Ch. 7). The way that NEURON is implemented, makes logical to define AdEx as a point process and define it as ARTIFICIAL_CELL. To do this, I have to understand how `NET_RECEIVE(w)` process works.

This code block is better defined in the Neuron Book (Ch. 10)

4.3 Jul 6th, 2021

I only read a couple of documents from Neuron tutorial and from a MIT tutorial on Neuron. The important part here was to examinate how to properly define the puntual neuron AdEx. It seems that my model needs to considerate an external current *FROM* an external point mechanism. For this, I will need to re-study the integrate and fire model that is proposed in the Neuron Github page

4.4 Jul 19th, 2021

After the meeting with Salvador, on Jul 6th, and by following his advices, I replicated what was developed in the izhikevich model. In particular the b part. Briefly, the models could be sumarized as:

Characteristic	Izhi2003a	Izhi2003b	Izhi2007a	Izhi2007b
Kind	P.Proc.	P.Proc.	P.Proc.	P.Proc.
Section	Dummy	Regular	Dummy	Regular

Characteristic	Izhi2003a	Izhi2003b	Izhi2007a	Izhi2007b
Synaptic input	yes	no	yes	yes
Synaptic method	$g'_{syn} = -g_{syn}/\tau_g$	—	AMPA/NMDA/GABAA dynamics	cell dependent
Implemented in Netpyne	no	no	yes	no

I focused on replicating the Izhi2007b.

Results:

1. I was able to build and compile Adex2021b (I am keeping the name scheme). 2. I was able to replicate the Izhikevic tutorial, but now using Adex (adex.ipynb).

Drawbacks:

1. my neuron does not fire, even further, I get an error

```
See http://neuron.yale.edu/neuron/credits

loading membrane mechanisms from
 ↪  /home/javier/Neuroscience/netpyne/AdEx/x86_64/.libs/libnrnmech.so
Additional mechanisms from files
 "./mod/adex.mod" "./mod/izhi2007b.mod"
nrniv: unable to open font "*helvetica-medium-r-normal*--14*", using "fixed"
oc>     -65
Segmentation violation
Backtrace:
terminate called after throwing an instance of 'std::regex_error'
  what():  regex_error
Aborted (core dumped)
```

I need to debug the .mod file, but I don't know how

5 Preliminary Results

5.1 Objectives

6 Meetings

7 Computing tools, code snippets, and tips.

7.1 CODE: Fast prototipying in code (2021-12-27)

One of my biggest mistakes is to try to build, at first, a very complicated piece of software, which is amendable for programmer, but also efficient as hell. **I must focus on building a working piece of software and then improve it!**

7.2 CODE: git store credential

general formula:

```
// local
git config credential.helper store
// global
git config --global credential.helper store
```

```
$ git config credential.helper store
$ git push http://example.com/repo.git
Username: <type your username>
Password: <type your password>
```

Notice that **Password** is the code obtained from the github access token *several days later*

```
$ git push http://example.com/repo.git
[your credentials are used automatically]
```

8 Papers summary

8.1 Selective attention model with spiking elements

8.1.1 Introduction

1. Visual attention in human and monkey brains is realized by a large-scale distributed neural network that includes several cortical and subcortical areas with bottom-up and top-down flow of information between them.
2. **Despite intensive studies of neuronal activity related to attetnion, it is still unclear what neuronal mechanisms are used by the brain to implement attention.**
3. Two types of attentional modulation has been proposed:
    - Increased excitation of neurons representing attended stimuli is observed while neural activity evoked by unattended stimuli is reduced to a low level.
    - Gamma range oscillations correlate with the activity of neurons in the attentional focus.

The model proposed by the authors, using hodgkin-Huxley neurons, aims to elucidate how selective attention can be represented by the synchrony and suppresion of neural activity in a network of interactive spiking elements

8.1.2 Results

1. The model exhibits five global dynamical states: Partial synchronization A; Transition state; Global synchronization; Partial synchronization B; Quiescence.
    1. Partial synchronization is interpreted as selective attention, where population A or B is “attending” to some stimuli.
    2. Transition state is interpreted as different degrees of attention concentration (could be attentional shift?)
2. **There remain many uncertainties abouth the complete bifurcation structure of the model, therefore further investigations are required**
3. In the simulations, selective attention (associated with partial synchronization) always favours a group with higher frequency

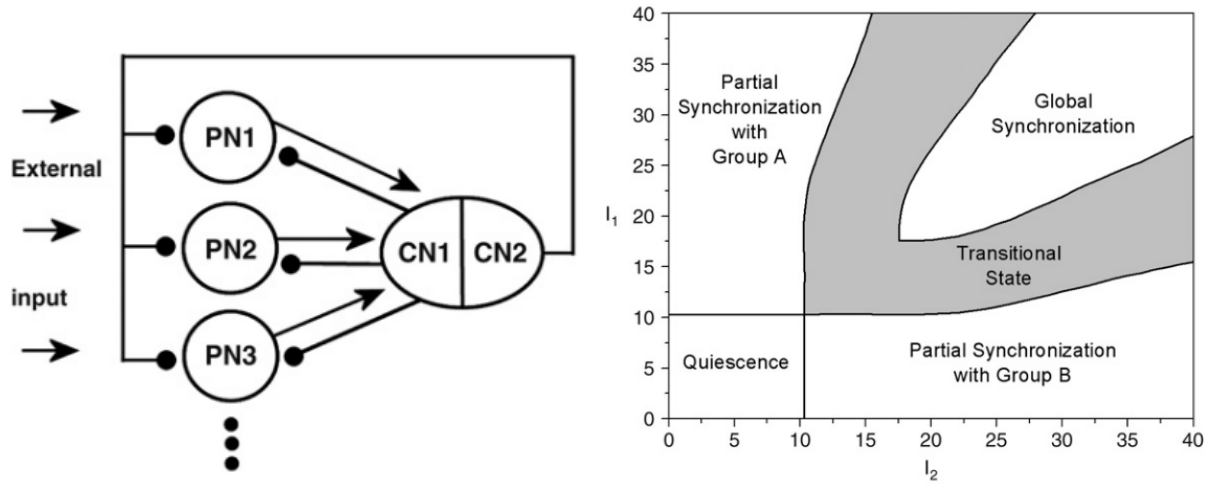


Figure 1: Model(left) and bifurcation space(right)

References

Dura-Bernal, S., Suter, B. A., Gleeson, P., Cantarelli, M., Quintana, A., Rodriguez, F., et al. (2019). NetPyNE, a tool for data-driven multiscale modeling of brain circuits. *Elife* 8, e44494.