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April 3, 2024

— Semester Project

1 Problem Statement

Computational neuroscience and closely related engineering disciplines emerged from explaining how the brain works. To achieve this, scientists/engineers attempt to model the brain and simulate it. The most common approach is to use spiking neural networks (SNNs) to model the brain. However, since the brain is a very complex system, that is hard to explain and make use of the observation directly to design a new device out of this observation. On the other hand, verification of such stochastic models is not straightforward. Therefore, simulations are needed.
There are different approaches [1] to solve the issue of simulation of such complex networks using computational and memory resources efficiently. Brian2 [2] is a Python library that is developed for scientists to model and simulate a complex network that has a certain structure. That is, neuron groups, synapses, and input areas are the main building blocks. Brian2 allows users to specify any arbitrary solvable neuronal dynamics. In this presentation, I will follow the outline provided and explain first why it is important to have such a simulation tool. Then, I will talk about the two numerical methods used to solve indicated dynamics. Explaining the two methods for time management of the simulation and the limitations of the tool from the engineer's perspective, I will follow up with a very simple example. Then, I will conclude the presentation.

2 Outline

The outline is provided as follows:

- What are complex spiking neural networks? (Introduction)
- Outline
- Why do people study this topic, and why it is important?
- Simulation of brain (SNNs) and common approaches.
- Brian2 Library general structure (State updaters).
- Numerical Methods Employed (Ex. Euler's and Heun's Method) (1/2)
- Numerical Methods Employed (Ex. Milstein Method)(2/2)
- Clock is driven vs. event-driven simulation.
- Limitations of the current version from an engineering point of view.
- Example: Homeostatic Regulation
- Conclusion.

3 References

References

[1] R. Brette, M. Rudolph-Lilith, N. T. Carnevale, M. L. Hines, D. Beeman, J. M. Bower, M. Diesmann, A. Morrison, P. H. Goodman, F. C. Harris, M. Zirpe, T. Natschläger, D. Pecevski, B. Ermentrout, M. Djurfeldt, A. Lansner, O. Rochel, T. Viéville, E. B. Müller, A. P. Davison, S. E. Boustani, and A. Destexhe, "Simulation of networks of spiking neurons: A review of tools and strategies," *Journal of Computational Neuroscience*, vol. 23, pp. 349–398, 2006.

[2] M. Stimberg, R. Brette, and D. F. Goodman, "Brian 2, an intuitive and efficient neural simulator," *eLife*, vol. 8, p. e47314, Aug. 2019.

Submitted by Ahmet Akman 2442366 on April 3, 2024.