GPU-Accelerated LIF Spiking Neuron Networks Simulator Proposal

Emre Sagir s339049

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1 Introduction

The project will be implemented as a compact and lightweight from-scratch SNN simulator with GPU-acceleration. The network model is decided to be single-layer recurrent LIF SNN.

2 Implementation

The network is a second order system with a single layer and recurrent dense connectivity. There is two different model as neuron and synapse. Current simulator focusing on discrete-time dense SNNs to create a solid baseline before continuing with sparsity configuration.

For neuron model, the discrete-time implementation of the Leaky Integrate-and-Fire (LIF) model as discussed by Stan and Rhodes [1] allows for efficient sequence modeling in SNNs. The implemented neuron models equations given in the Appendix. The synapse model is decided as current-based exponential synapse model which it's equation given in appendix as well.

The baseline cpu implementation is done and can be accessed in my github repository.

3 Roadmap

The single thread C implementation will act as a baseline and correctness reference, pytorch version is also implemented for benchmark. The basic gpu version implementation will have one thread for each neuron. Then optimized version will focus on memory access patterns, shared-memory tiling, and decreasing kernel launch overhead.

4 Benchmark

The implemented versions will be compared each other as cpu, basic-gpu, optimized-gpu. On the other hand, pytorch and an established simulator version (will be decided later) will be also compared. Lastly, profiling will be done with Nsight to analyze the time per-step, occupancy, memory bandwidth.

References

[1] Matei-Ioan Stan and Oliver Rhodes. Learning long sequences in spiking neural networks. *Scientific Reports*, 14(1):21774, 2024.

5 Appendix

5.1 Neuron Model Equations

$$u[t] = \beta u[t-1] + (1-\beta)i[t] \tag{1}$$

$$u[t] \leftarrow u[t] - s[t-1]\theta \tag{2}$$

$$s[t] = \Theta(u[t]-\theta) = \begin{cases} 1, & \text{if } u[t] > \theta \\ 0, & \text{otherwise} \end{cases} \tag{3}$$

5.2 Synapse Model Equations

$$g_i[t] = \alpha\, g_i[t-1] + \sum_j w_{ji}\, s_j[n] \tag{4}$$