Final Year Project
Project Proposal

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Implementing a spiking neural network with floating-point neurons into GeNN to compare the performance to that of a few-spikes neural network in computer vision.

Abstract

Modern Artificial Neural Networks (ANN) still require a lot of processing power. For instance, AlphaGo used approximately 1MW of power to run, whilst a human brain only uses 20W. [1]

Unlike units in ANNs which continuously exchange real-valued activations, neurons in spiking neural networks communicate infrequently using binary events called spikes like neurons in biological brains. This reduced communication means that, theoretically, SNNs could offer a much more energy- efficient alternative to ANNs.

Training SNNs from scratch remains tricky but there are several promising approaches for converting already trained ANNs to SNNs. The current limitation with SNNs is that they require a lot of signal spikes in order to achieve the same task performance as ANNs; the aim for this final year project will be to investigate a potentially more efficient means of spike based encoding called floating-point conversion against an existing method and to evaluate their performance using a computer vision trained neural network using the respective encoding method.

1 Aims

Over the summer I was able to carry out undergraduate research into Spiking Neural Networks (SNN) where I primarily investigated a floating-point method of spike encoding. The purpose of this Final Year Project (FYP) is to build on the knowledge gained over the summer to more closely compare the performance of different spike encoding and to implement a floating-point method into GeNN.

2 Primary Objectives

1. Implement a network of few-spikes [2] neurons for image recognition
   - 1.1 Start with a more basic data set (i.e. MNIST [3])
   - 1.2 Finish with a more complex data set (i.e. CIFAR-10 [4] or Omniglot [5])
2. Implement a network of floating point neurons for image recognition
   - 2.1 Start with a more basic data set (i.e. MNIST)
   - 2.2 Finish with a more complex data set (i.e. CIFAR-10 or Omniglot)
3. Assess performance of different spike coding methods

3 Extension

1. Investigating primacy code [6] as a potential for more efficient spike coding

4 Relevance

Artificial Neural Networks (ANN) make up a large portion of my Computer Science with Artificial Intelligence degree, it is the building blocks behind computer vision, machine learning, NLP etc. SNN are an extension from ANN with an aim to increase the efficiency of neural networks, allowing them to be more accessible on smaller, handheld devices or just more efficient on scaled up neural networks.

5 Resources Required

This project is primarily programming focused, therefore the only hardware resources needed is access to a computer which can be done either from the Chichester Labs or via a personal computer. The software requirements involve the use of GeNN (GPU enhanced Neural Networks) which is a University developed software at Sussex, I have already been introduced to GeNN through my summer research, however, will need to improve on my understanding of GeNN to implement a SNN into it.

6 Timetable

A usual week I will commit to 1 weekly meeting with my supervisor on a Wednesday at 13:00. I will have 4 allocated hours during University time to work on the project, however, I expect to work on this more into the evenings so expect around 5-6 hours on some weeks.

Figure 1: An example of an average week with FYP allocated time

7 Bibliography of background reading

Currently I am reading the relevant chapters of two books at the University library; Pulsed Neural Networks by Wolfgang Maass and Christopher M. Bishop [7] and, Spiking Neuron Models by Wulfram Gerstner and Werner Kistler [8].

I will also be practicing and improving my ability to coding within GeNN with tutorials for GeNN found on their website.

For my extension task, I will be reading "Wilson CD, Serrano GO, Koulakov AA, Rinberg D. A primacy code for odor identity".

8 Interim log

Weekly meetings have been set up on a Wednesday at 13:00, these will continue each week unless either supervisor or student are unable to attend.

So far we have had a Zoom call to discuss Final Year Project ideas and outline what primary objectives and extensions should be laid out, and an in person meeting to check that the proposal outlines the aims and objects needed for this project.

References

[1] Jacqueline Ling. Power of a human brain, 2001.

[2] Christoph Stöckl and Wolfgang Maass. Classifying images with few spikes per neuron. *CoRR*, abs/2002.00860, 2020.

[3] Li Deng. The mnist database of handwritten digit images for machine learning research [best of the web]. *IEEE Signal Processing Magazine*, 29(6):141–142, 2012.

[4] Alex Krizhevsky, Vinod Nair, and Geoffrey Hinton. Cifar-10 (canadian institute for advanced research).

[5] Brenden M. Lake, Ruslan Salakhutdinov, and Joshua B. Tenenbaum. Human-level concept learning through probabilistic program induction. *Science*, 350(6266):1332–1338, December 2015.

[6] Christopher D. Wilson, Gabriela O. Serrano, Alexei A. Koulakov, and Dmitry Rinberg. A primacy code for odor identity. *Nature Communications*, 8(1):1477, Dec 2017.

[7] Wolfgang Maass and Christopher M. Bishop. *Pulsed Neural Networks*. MIT Press, Cambridge, MA, USA, 1999.

[8] Wulfram Gerstner and Werner M. Kistler. *Spiking Neuron Models: Single Neurons, Populations, Plasticity*. Cambridge University Press, 2002.