The Effect of Biologically-Inspired Mechanisms in Spiking Neural Networks for Neuromorphic Implementation

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Background and Motivation

- What level of biological detail should be included in the implemented network model?
- The complexity level of the neuron and synapse model have a corresponding effect on the complexity of the hardware, and thus potentially affect the scale of network that can be feasibly implemented as well as the device’s efficiency.

Basic Network Model

- Neuroscience-Inspired Dynamic Architecture network model:
  - Simple integrate and fire neurons with refractory period.
  - Synapses with weights and delays.
  - Activity simulated using discrete event simulations.
  - Neurons are laid out in 3D space.
  - Delay values on synapses are correlated with Euclidean distance between pre- and post-synaptic neuron.
  - Number, placement, and parameters of neurons and synapses are discovered with an evolutionary optimization.

Bio-Inspired Mechanisms

- Leaky neurons:
  - Parameter: Governs how quickly charge level decays to resting charge.

- Synaptic Potentiation and Depression:
  - Active synapse causes postsynaptic neuron to fire -> small increase in synapse weight.
  - Active synapse during postsynaptic neuron’s refractory period -> small decrease in synaptic weight.
  - Parameter: The minimum amount of simulation time between weight changes. Governs how quickly the weight value can change.

Applications

- Exclusive-Or (XOR): Word sizes w=1,2,3,4. Streaming inputs of words a and b, and output of network expected to be c=a \oplus b.
- Iris Classification Task: Four inputs for each instance, corresponding to an iris’s petal length, petal width, sepal length, and sepal width. Output corresponds to iris type.
- Pole balancing: A version of the inverted pendulum task, with position and velocity as input. Output is a force value to apply to one side of the cart.

Results

- Overall Training Performance
- Generalization Performance

Conclusions

- Neither leak nor potentiation/depression have a clear effect on either training performance or generalization performance.
- Leak has relatively little effect on both training and generalization performance.
- Potentiation and depression tended to hurt performance on the whole.
- This may indicated that neuromorphic device designers may err on the side of simpler models.
- Future work:
  - More complex leak and potentiation and depression models moving forward.
  - More complex applications, especially those with more temporal interdependence.

References


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