Improving eligibility propagation using Izhikevich neurons in a multilayer RSNN.

Presentation 5: Evaluation meeting 1

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November 30, 2020

A quick project overview

Task: using eligibility propagation to classify phonemes.

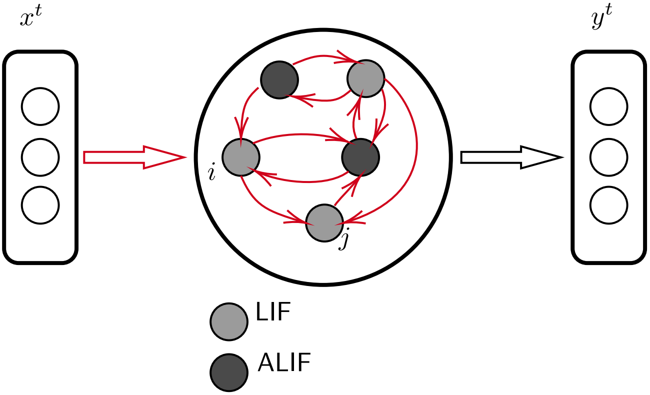
Challenges:

- Desired bio-plasubility requires online and local learning rules.
- Spiking and reccurent network: no good learning algorithm yet.

My own contribution: investigate the benefits of

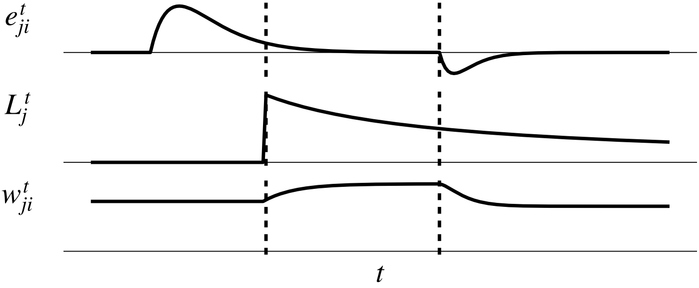
- stacking multiple recurrent layers
- using Izhikevich neurons
- various regularization methods

Original network architecture



The e-prop learning algorithm – Main equation

$$\frac{dE}{dW_{ji}} = \sum_t L_j^t \cdot e_{ji}^t$$



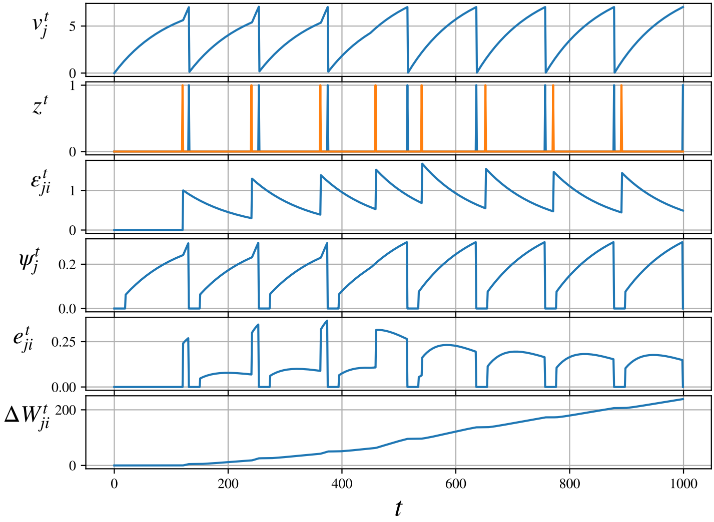
The e-prop learning algorithm – proof

$$\frac{dE}{dW_{ji}} = \sum_t L_j^t \cdot e_{ji}^t$$

$$L_j^t \stackrel{\text{def}}{=} \frac{dE}{dz_j^t}$$

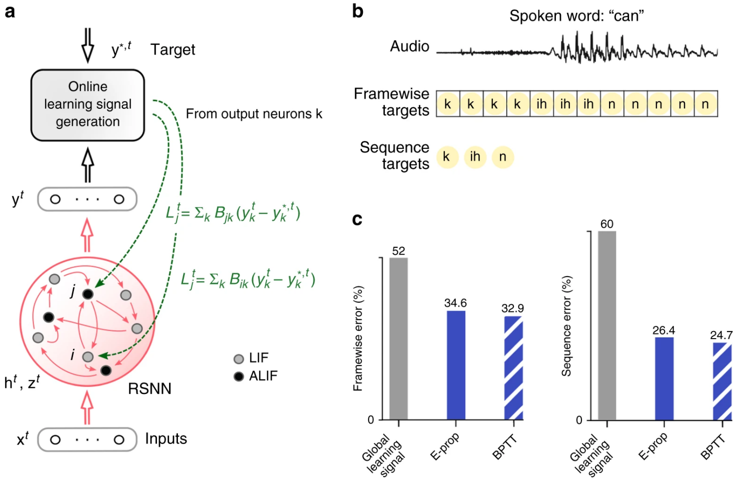
$$e_{ji}^t \stackrel{\text{def}}{=} \frac{\partial z_j^t}{\partial \mathbf{h}_j^t} \underbrace{\sum_{t' \leq t} \frac{\partial \mathbf{h}_j^t}{\partial \mathbf{h}_j^{t-1}} \cdots \frac{\partial \mathbf{h}_j^{t'+1}}{\partial \mathbf{h}_j^{t'}} \cdot \frac{\partial \mathbf{h}_j^{t'}}{\partial W_{ji}}}_{\stackrel{\text{def}}{=} \boldsymbol{\epsilon}_{ji}^t}$$

The e-prop learning algorithm – Original LIF



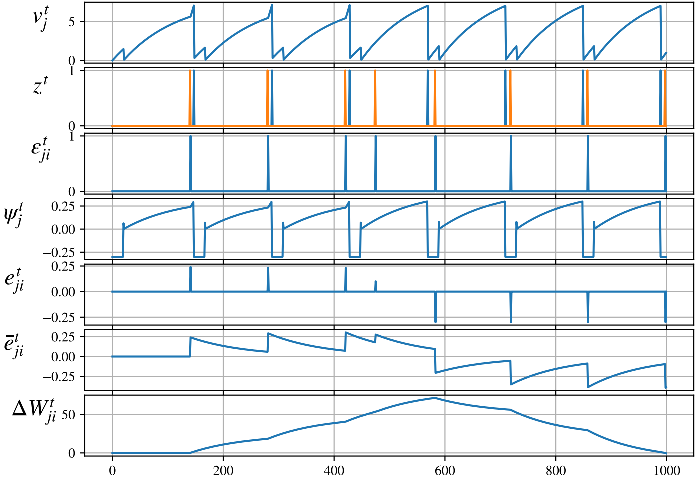
Previous results

Bellec, G., Scherr, F., Subramoney, A., Hajek, E., Salaj, D., Legenstein, R., & Maass, W. (2020). A solution to the learning dilemma for recurrent networks of spiking neurons.



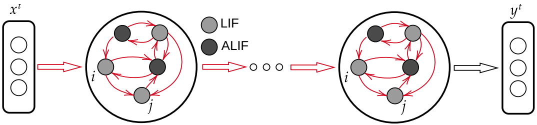
The e-prop learning algorithm – STDP-corrected LIF

Traub, M., Butz, M. V., Baayen, R. H., & Otte, S. (2020, September). Learning Precise Spike Timings with Eligibility Traces. In International Conference on Artificial Neural Networks (pp. 659-669). Springer, Cham.



My proposed contribution

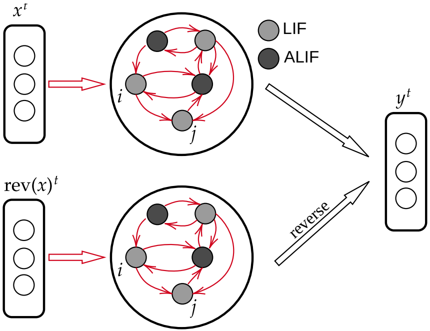
– Implement the algorithm in a *multi-layer* SRNN.



– Examine model desgns such as neuron type (e.g. Izhikevich); synaptic delay; and regularization such as metaplasticity and synaptic scaling.

Work done so far

- ☑ Implement Bellec's model with
  - ☑ 1-layer e-prop RSNN with ALIF neurons;
  - ☑ TIMIT conversion to 13 MFCCs and their first and second derivatives;
  - ☑ L^2 and firing rate regularization;
  - ☑ Adam optimizer;
  - ☑ Bidirectional network.
- ☐ Obtain Bellec's performance;
- ☐ Analyze effects of
  - ☐ N-layered network;
  - ☐ Izhikevich neurons;
  - ☐ Metaplasticity;
  - ☐ Synaptic scaling;
  - ☐ Synaptic delays.



Current observations

–

$$\lim_{e\to\infty} W^e_{\text{out}=\mathbf{0}}$$

$$\lim_{e\to\infty} b^e_{\text{out}=\mathbf{0}}$$

– Spike frequency normal but heavily affected by weight initialization. Weights in order of $[0, \frac{2}{N}]$ work well, where N is layer size.