Synaptic Metaplasticity in Binarized Neural Networks

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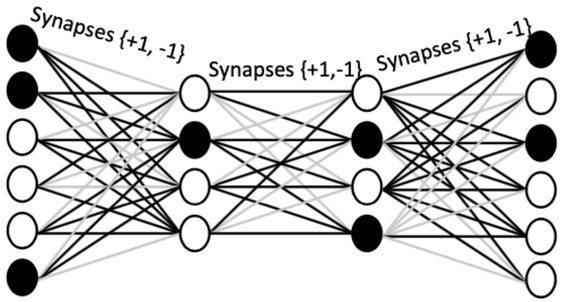
Summary

- **Catastrophic forgetting** is an issue common to artificial neural networks in stark contrast with the brain.
- Neuroscience suggest that **real synapses are complex** and **metaplastic** instead of being merely a scalar value.

- **This work** :

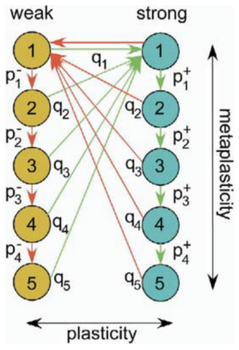
1. Binarized Neural Networks hidden weights are relevant for consolidation
2. We show a principled explanation for a tractable sub problem
3. The resulting consolidation strategy does not need task boundaries and can be applied to Continual learning and Stream learning

Binarized Neural Networks [1]



The training process requires hidden weights

Synaptic Metaplasticity [2]

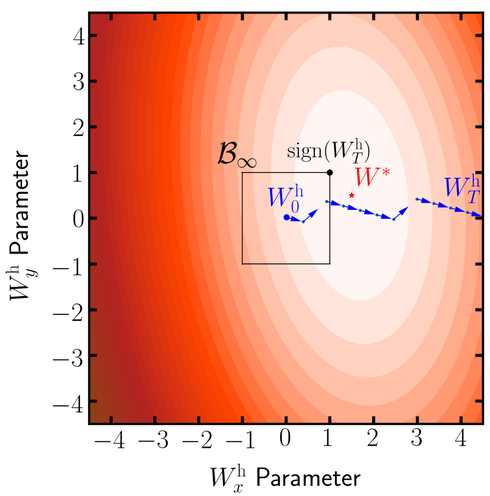


- Metaplastic update proposed in this work :

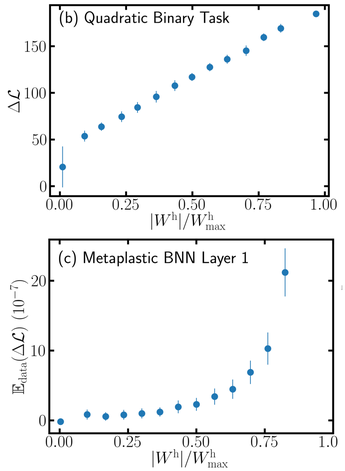
$$W^{\mathrm{h}} \leftarrow W^{\mathrm{h}} - \eta U_W \cdot f_{\mathrm{meta}}(m, W^{\mathrm{h}}) \quad \text{if} \quad U_W W^{\mathrm{h}} > 0$$
$$W^{\mathrm{h}} \leftarrow W^{\mathrm{h}} - \eta U_W \quad \text{otherwise.}$$

Toy Problem Study

- Our approach can be understood theoretically in the case of a Quadratic Binary Optimization task



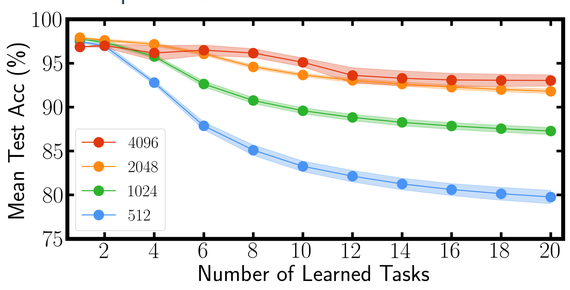
- High hidden weights quantify the contribution to the loss optimization



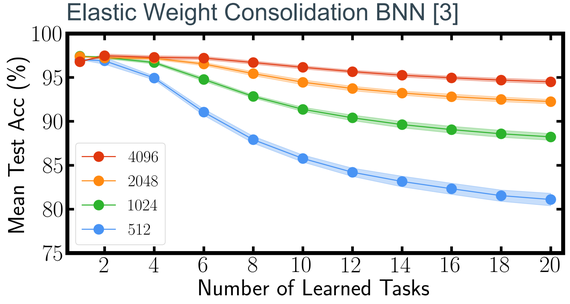
Continual Learning

Canonical benchmark : permuted MNISTs

Metaplastic BNN



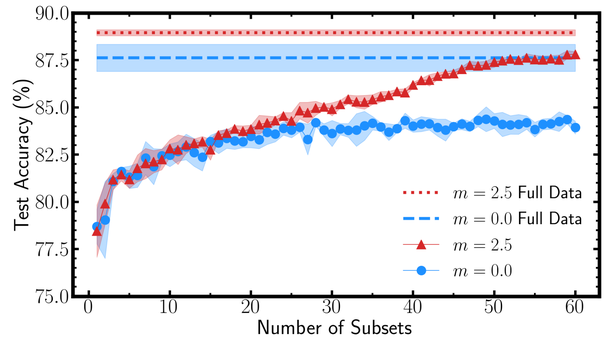
Elastic Weight Consolidation BNN [3]



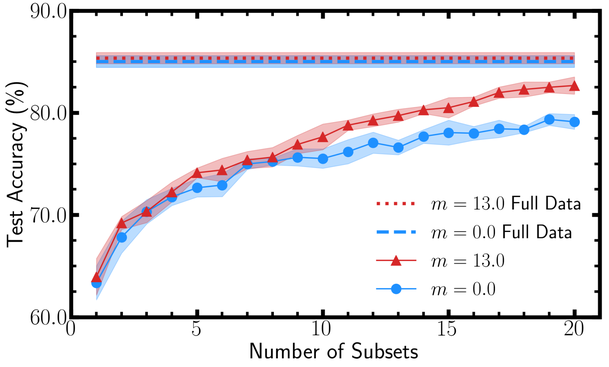
Stream Learning

The network is learning a given task by **learning sequentially subsets of the whole dataset**

Fashion MNIST



CIFAR-10



References

[1] Hubara, Itay, et al. "Binarized neural networks." *Proceedings of the 30th international conference on neural information processing systems*. 2016.

[2] Fusi, Stefano, Patrick J. Drew, and Larry F. Abbott. "Cascade models of synaptically stored memories." *Neuron* 45.4 (2005): 599-611.

[3] Kirkpatrick, James, et al. "Overcoming catastrophic forgetting in neural networks." *Proceedings of the national academy of sciences* 114.13 (2017): 3521-3526.