HebbNet: A Simplified Hebbian Learning Framework to do Biologically Plausible Learning

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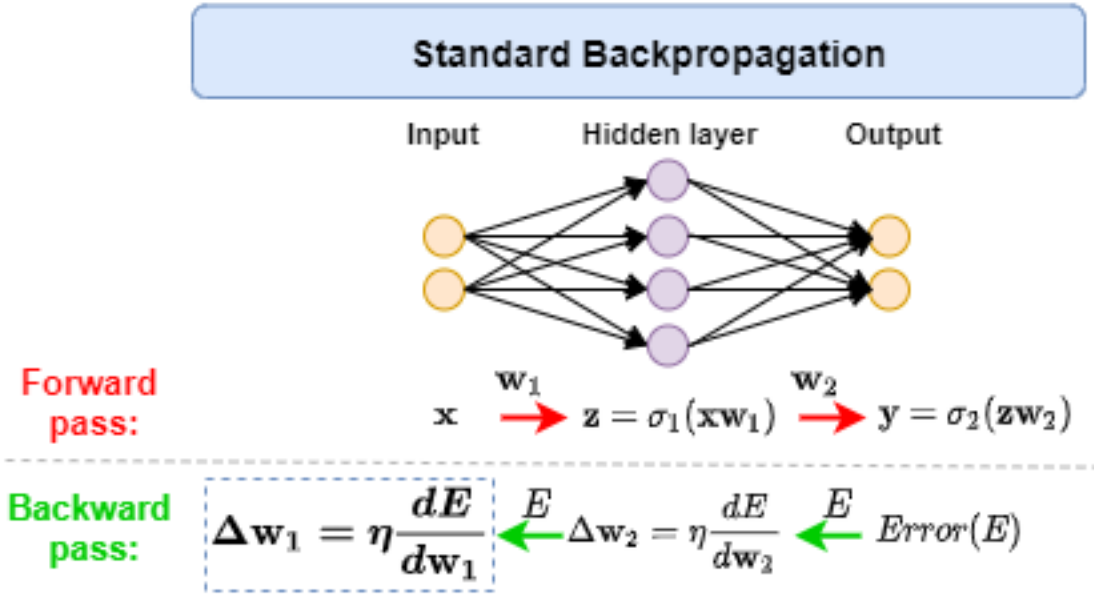
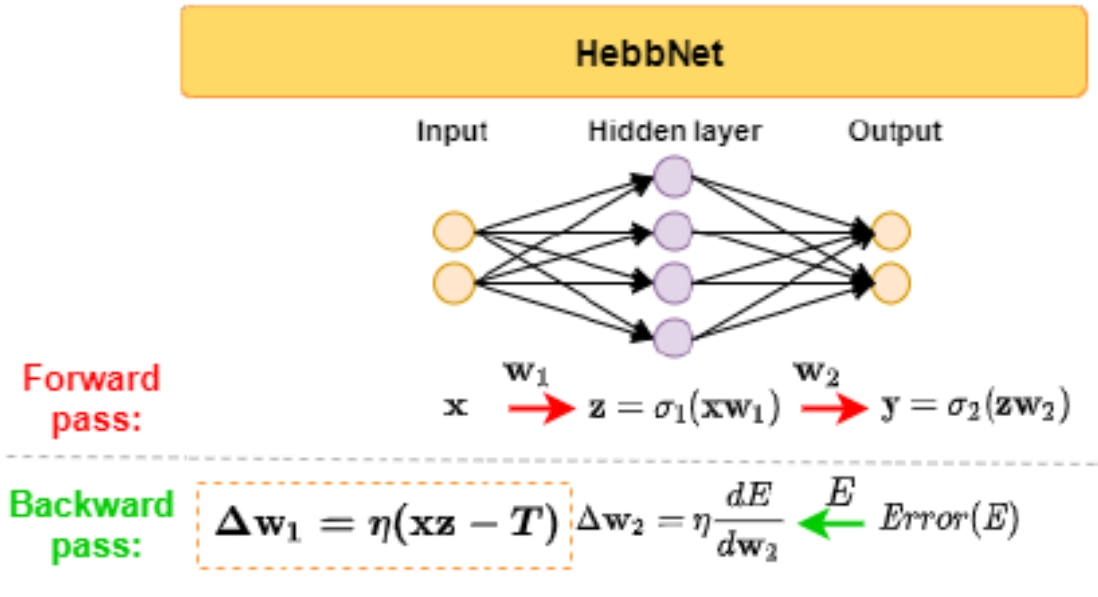
What is Hebbian Learning?

- An algorithm for training neural networks
- Is biologically plausible
- Does not require any error or feedback to be backpropagated





Current algorithms are slow and complex

- State-of-the-art network from Krotov [1] uses a two-phase training regime
- The Hebbian layer is first trained for 1000 epochs then the SGD weights are trained for another 500 epochs
- Also requires 5 distinct hyper-parameters, on top of standard hyper-parameters
- ~12,600 runs required to find best combination of hyper-parameters

[1] Krotov, D., and Hopfield, J. J. Unsupervised learning by competing hidden units. In: Proceedings of the National Academy of Sciences 116, 16 (2019), 7723–7731".

HebbNet simplifies this based on 2 simple rules

Vanilla Hebbian learning:

- Multiplies activations

$$\Delta w_{ij} = \eta x_i z_j \tag{1}$$

Activation thresholds:

- Thresholds the product

$$\Delta w_{ij}^t = \eta^t \begin{cases} x_i^t z_j^t & \text{if } t = 1 \\ x_i^t z_j^t - \frac{1}{t-1} \sum_{k=1}^{t-1} x_i^k z_j^k & \text{otherwise} \end{cases} \tag{2}$$

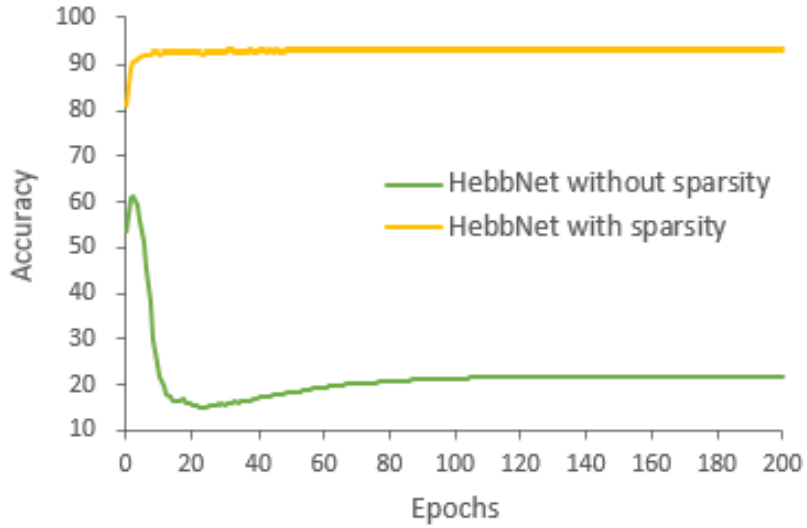
Gradient sparsity:

- Selectively update weights

$$\Delta \mathbf{w} = \begin{cases} \Delta w_l \mid \Delta w_l \in \Delta \mathbf{w} & \text{if } \Delta w_l \geq m \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

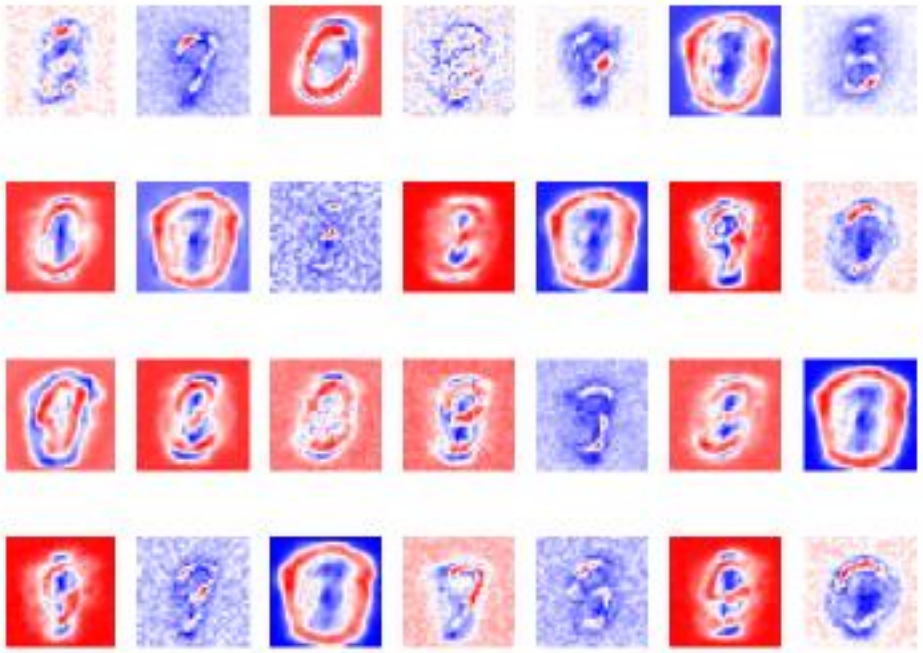
The rules enable HebbNet to learn successfully

Method	Test Acc.
Vanilla Hebbian (VH)	10.28%
VH + thresholding	65.36%
VH + thresholding + sparsity	**93.25%**



Ablations on key components of HebbNet on the MNIST dataset. Adding all the components together enables HebbNet to achieve high accuracy

HebbNet performs well on MNIST & CIFAR-10



Internal representations learnt by the Hebbian layer on MNIST. Showing a subset of 28 neurons. Red color indicates larger weights while blue indicates smaller weights. As can be seen, the neurons learn a range of different patterns. They learn both full patterns (digit 7 in row 1, column 2) and partial patterns (an arc in row 4, column 7). Hence, the Hebbian weights robustly learn pattern representation.

Method	Test Acc.	Epochs
Vanilla Hebbian	15.23%	200
Backprop (same hyper-params)	30.68%	200
Backprop (tuned hyper-params)	41.28%	200
Krotov and Hopfield, 2019	50.75%	1500
Amato et al., 2019	41.78%	20
HebbNet (Ours)	**45.69%**	**200**

Thank you

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