Thermodynamics of Neural Networks

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Entropy

- Our brains find the most efficient way to organize themselves
- Learning is a transformation of a neural network at the expense of energy

Main Steps of the Learning Process

1. Gather information from environment
2. Build models from the collected data using neural networks
3. Processing previously unseen inputs by applying model and making decisions based on output of model

Goldt et al.

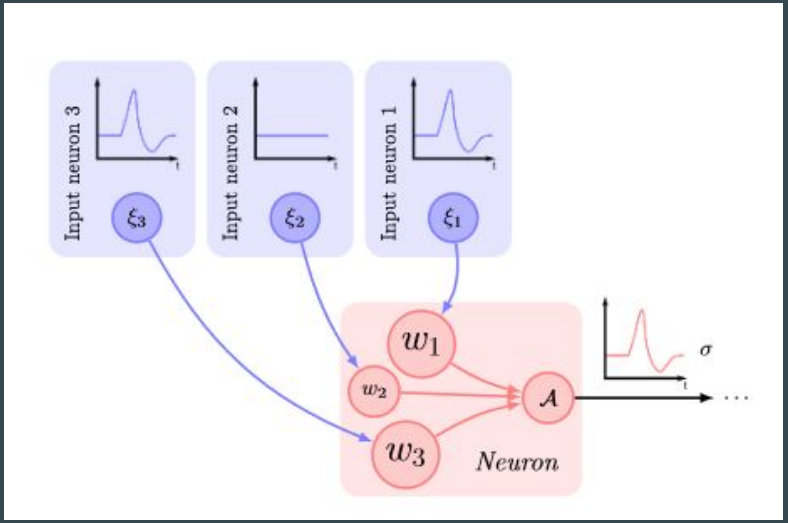
- Methods of stochastic thermodynamics: integrated framework to analyze interplay of dissipation and information processing in fluctuating systems far from equilibrium

Experiment

- Study learning of rule by neural network
- Define rules as Boolean functions
- Network builds model of this rule by looking at pairs of input and binary output

- Focus is final step in learning process, i.e. how well can the network emulate the function after a training period?

Experiment



Snapshot in time of simple neural network

- Goal of learning is to adjust weights (connections between neuron of interest and input neurons) of the network such that the label predicted by the neuron equals the true label for any input

Results

- Network's ability to generalize the rule from the examples and apply to previously unseen inputs is bound by the dissipation of free energy by the components of the network as a consequence of entropy
- The slower a neuron learns, the less heat and entropy it produces, increasing its efficiency

Consciousness

- Side effect of entropy?????
- Normal wakeful states characterized by biggest number of possible configurations of interactions between neural networks representing the highest entropy values