Neural clique networks in an unreliable environment

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Neural clique networks are memory efficient associative memories where existing edges have a fixed weight of 1 [GB11]. In such networks, a stored message is represented by a set of fully interconnected nodes. It is able to retrieve previously stored messages from partially erased or erroneous versions of them. We are interested in studying the resilience of neural clique networks with respect to unreliable communication between neurons. Our motivation stems from biological considerations.

The working of neural clique networks is as follows. To retrieve a stored message from a partially erased input, a distributed iterative algorithm is used in which two steps are repeated. The first step consists in identifying promising candidates among neurons. The second step selects which of them to activate. The authors of [GB11] claim that their proposed neural clique networks are based on known facts and hypotheses about the brain.

Most components of the brain are unreliable. For instance neurons fire spontaneously, and synapses often fail to release neurotransmitters. It has been estimated that the probability for a synapse to release neurotransmitters when stimulated is less than 50% [BS09]. We aim at assessing the resilience of neural clique networks with respect to the unreliability of its components.

With this goal in mind, we propose a mathematical model of unreliability in neural networks which is, unlike [LPGRG14], based on biological hypotheses. We assume that each synapse has an independent probability p_{rel} of releasing neurotransmitters when stimulated, and consider that a connection between two neurons consists of n_{syn} synapses. Consequently, the excitation a neuron receives from a connected firing neuron is $Binom(n_{syn}, p_{rel})$, a random variable from the binomial distribution with parameters n_{syn} and p_{rel}. We analytically study the impact of the proposed noise model on the error rate when retrieving partially erased messages and support our formulas with simulations. Surprisingly, we observe that in some cases, the noise generated by the unreliable connections can *improve* the performance of the network.

We study an example network made of 8 clusters containing 256 nodes each. By fixing $p_{rel} = 0.5$ and $n_{syn} = 10$, we observe a minor improvement of the error rate depending on the number of stored messages. When we increase p_{rel} to 0.8, we obtain a more significant improvement. We credit this result to the randomness property of avoiding local minima, as in simulated annealing. We also tested the effect of binomial noise on Hopfield networks. We observe that they suffer a minor decrease in performance.

References

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