Active Memory in Input Driven Recurrent Neural Networks

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Understanding the exact mechanism of learning and memory emerging from complex dynamical systems like neural networks serves as a challenging field of research. Traditionally the neural mechanisms underlying memory and cognition in these systems are described by steady-state or stable fixed point attractor dynamics. However an alternative and refined understanding of the neuronal dynamics can be achieved through the idea of transient dynamics [1] (reservoir computing paradigm) i.e., computation through input specific trajectories in neural space without stable equilibrium. Mathematical analysis of the underlying memory through such transient dynamics is difficult. As such information theory provides tools to quantify the dynamics of memory in such networks. One such popular measure of memory capacity in reservoir networks is the linear memory capacity [2]. It provides an indication of how well the network can reconstruct delayed versions of the input signal. However it assumes a linear retrieval of input signal and deteriorates with neuron non-linearity. Alternatively, active information storage [3] provides a measure of local neuron memory by quantifying the degree of influence of past activity on the next time step activity of a neuron independent of neuronal non-linearity. In this work we further extend this quantity by calculating the mutual information between a neuron past activity and its immediate future activity while conditioning out delayed versions of the input signal. Summing over different delays of input signal it provides a suitable measure of total input driven active memory in the network. Intuitively active memory calculates the actual memory in use i.e. influence of input history on local neuron memory. We compare memory capacity and active memory (AM) with different network parameters for networks driven with statistically different inputs and justify AM as an appropriate means to quantify the dynamics of memory in input driven neural networks.

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References

[1] M. Rabinovich, R. Huerta, G. Laurent (2008): Transient Dynamics for Neural Processing. Science, Vol. 321, No. 5885., pp. 48-50.

[2] H. Jaeger (2001): Short term memory in echo state networks. GMD Report 152, German National Research Center for Information Technology, 2001 (60 pp.)

[3] S. Dasgupta, F. Wörgötter, P. Manoonpong (2013): Information Dynamics based Self-Adaptive Reservoir for Delay Temporal Memory Tasks. Evolving Systems,doi:10.1007/s12530-013-9080-y