Heteroclinic channels in random networks

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A great deal of modeling effort in complex neural networks, for example modeling of working memory, has been based on attractor dynamics. Multistable systems, however, are neither robust against noise not do they take time scales occurring in neurobiological systems into account. Therefore, when modeling the brain as a dynamical system, the focus must be on the transient dynamics of the neural network. In order to obtain proper dynamics in a neurobiological context, it is desirable to focus on reproducible and robust behavior.

In particular, recent studies in cognitive neuroscience [Fri97, INvL07, JFS$^+$07] suggest that metastable states exist in a unified mental state space and that the dynamical processes are governed by transient switching between these states. Inhibitory coupled networks, where the single components compete for a finite amount of resources in form of winnerless competition, provide a model for this kind of behavior. Such a network can be realized by a generalized Lotka–Volterra (LV) model. The mathematical representation of robust and reproducible transients in such a network are stable heteroclinic sequences and stable heteroclinic channels (SHCs) as introduced in [AZR04, RHL08, RHVA08]. These mechanisms have been hypothesized to represent the transient, switching dynamics observed in complex neural networks. It was shown that SHCs can exist in a network modeled by the LV equations if the connectivity of the network is chosen according to conditions based on the input stimulus.

In a neural network however, connection strength between different elements are not fixed. For example connection strengths vary due to short term plasticity. The stimulus however, being encoded by the sensory mechanisms, has been preprocessed. This motivates the question as to whether SHCs can exist in a network where connection strengths are chosen randomly from different probability distributions, under the assumption that the stimulus satisfies some contraints. In the present research we showed analytically that transient dynamics described by SHCs can indeed exist in such a grossly organized networks. What also emerges from this study is a monotonically increasing relationship between the coupling strengths and the number of states in the heteroclinic sequence, which might lead to an estimation of the number of items stored in working memory, when modeled by these transient dynamics due to the bounded nature of biological quantities.

References

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