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Analysis of Synchronization in Hybrid Neural Circuits
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Inhibitory interneurons play an essential role in the generation and control of synchronous oscillations in brain, most prominently in gamma oscillations. In heterogenous networks, instead of exact synchrony, nearly synchronous modes arise. In the simplest inhibitory network consisting of two reciprocally coupled neurons, these nearly synchronous modes include 1:1 phase-locking at small phases (firing times that differ by less then about 10% of the network period) and "varied phase-locking" in which the interval between the firing of the two neurons is not the same every cycle, but rather constitutes a pattern that repeats every two cycles or more cycles. Existence and stability criteria for 2:2 steady phase-locked period two (2P) modes in reciprocally coupled two neuron circuits were derived based on the open loop phase resetting curve (PRC) of the component neurons using synaptic input as the perturbation. The main assumption is that each neuron returns close to its unperturbed cycle before its next input is received, thus allowing the application of PRC curves generated in the open loop configuration to prediction of closed loop network activity. The synaptic coupling in inhibitory networks has a time constant on the order of a few ms, hence a synaptic input delivered shortly before an action potential is fired can still be active after the action potential and therefore its influence can span two cycles. Therefore the PRC methods must take into account resetting that occurs in the cycle that contains the perturbation (first order) and the next cycle (second order).

Two types of 2P modes were considered, one in which the firing order changes on alternate cycles and one in which it remains constant. An intuitive graphical method was developed to find the modes. The method correctly predicted the parameter regime in which the 2P modes are exhibited in a network composed of two Wang and Buzsaki models coupled as in Skinner et al (2005) with a time constant of 1 ms. The method provides insight into which manipulations might increase near synchrony or decrease it. Our hypothesis is that the presence of the near synchronous 2P modes (and/or nP) in heterogenous 2 neuron networks facilitates near synchronous activity in larger networks with the same range of heterogeneity.

Project (or PI) Website

http://www.neuroscience.lsuhsc.edu

Publications

1. Canavier CC and Selandipalayam S. Predicting the existence and stability of period two modes in two neuron networks using the phase resetting curve, Computational Neuroscience Meeting, Edinburgh, Scotland, July 2006.