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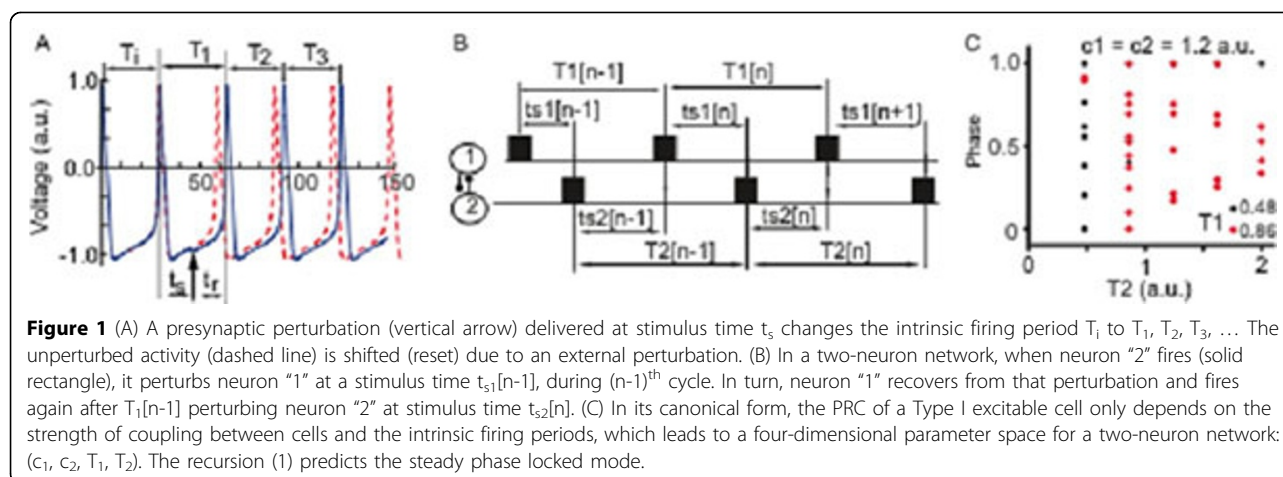
Bifurcation structure of phase locked modes in Type I excitable cells based on phase and spike time resetting curves

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From Twenty First Annual Computational Neuroscience Meeting: CNS*2012
Decatur, GA, USA. 21-26 July 2012

Some neurons are endogenous bursters, i.e., they intrinsically fire with a steady period (T_i) in the absence of external stimuli. In neural networks, the neurons constantly receive stimuli, e.g., presynaptic inputs that perturb their intrinsic activity. The transient changes in the firing frequency of a neuron due to a presynaptic input received at a stimulus time (t_s), or phase $\phi = t_s/T_i$, is tabulated by the phase resetting curve (PRC). The first order PRC is extracted in open loop, i.e., from isolated neurons, by tabulating the relative change in the firing period $F(\phi) = \Delta T_1/T_i = (T_1 - T_i)/T_i$ due to a stimulus received during the current cycle at phase ϕ (see Fig. 1A). Equivalently, we use the spike time resetting curve

(STRC) that tabulates the recovery time t_r of a neuron that received an input during the current cycle at a stimulus time t_s (see Fig. 1A). The assumption is that the open loop PRC/STRC can predict the phase locked modes of a network provided, among other requirements, that the open loop stimulus closely resembles the input the neuron receives in a fully connected network. For example, the PRC/STRC method can predict the 1:1 phase locked modes of a two-neuron network (see Fig. 1B). Assuming that the effect of the presynaptic input dies out by the time the neuron receives another input, we can derive (Figure 1B) the recursions that determine the phase locked mode:



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$$\begin{aligned}t_{s1}[n-1] + t_{s2}[n-1] &= T_1[n-1], \\t_{s2}[n-1] + t_{s1}[n] &= T_2[n-1],\end{aligned}\quad (1)$$

which can be translated into phase recursions by using the definitions $\phi = t_s/T_i$ and $T_i(\phi) = T_i(1+F(\phi))$. Very close to the bifurcation point of a Type I excitable cell, the infinitesimal PRC is $F(\phi) = cT_i(1-\cos(\phi))$, where c is a model-dependent constant [1,2]. We explored the bifurcation structure of phase locked modes of two coupled Type I intrinsic bursters (see a particular example of bifurcation diagram in Figure 1C). We also derived stability criteria for predicted phase locked modes. The advantage of the proposed approach is that it reveals the route to phase locked mode transition. The challenge of the method is representing efficiently a high dimensional solution in two dimensions. For this purpose, we used the method of multidimensional stacks.

Acknowledgements

Research supported by NSF IOS – 1054914 grant to S.A.O.

Published: 16 July 2012

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doi:10.1186/1471-2202-13-S1-P78

Cite this article as: Oprisan: Bifurcation structure of phase locked modes in Type I excitable cells based on phase and spike time resetting curves. *BMC Neuroscience* 2012 **13**(Suppl 1):P78.

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