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Understanding neural activity through piece-wise linear models

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In recent years there has been an upsurge of interest in fitting real spike train data to nonlinear integrate-and-fire (IF) models [1]. Such models are often preferred over more detailed conductance based models for their small number of parameters and low computational overhead. Moreover, the nonlinearities in such models can often be caricatured by piece-wise linear (pwl) forms, allowing the construction of action potential shapes in closed form as well as the calculation of phase response curves. With the inclusion of pwl adaptive currents they can also support bursting behavior, though remain amenable to mathematical analysis at both the single neuron [2] and network level [3]. In fact pwl models caricaturing conductance based models such as that of Morris-Lecar have also been studied for some time now and also recently been shown to be mathematically tractable at the network level [4].

In this work we give a summary of recent progress in understanding pwl neuron models of both conductance and IF type. In particular we focus on pwl models of FitzHugh-Nagumo type and describe in detail the mechanism for a canard explosion. As regards IF models we focus on a variant of the adaptive absolute IF model that can support bursting. In both cases we study dynamics at the network level in the presence of gap junction coupling. In particular we uncover the conditions for gap-induced transitions between synchrony and asynchrony analytically.

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