Recurrent Mutual Inhibition Endows a 4-neuron Circuit with Multi-functionality Via Multiple Cusp Bifurcations.

Alexander James White[1*], Pei-Hsien Liu[1], Chung-Chuan Lo[1]

Institute of systems neuroscience, National Tsing-Hua University, Hsinchu City, Taiwan,

Recurrent mutual excitation, and feedback inhibition have been well studied, yet the role of mutual inhibition is not well explored theoretically. Here using a 4-neuron spiking neuron model, we show how networks with recurrent inhibition are key in expanding the functionality of the circuit, far beyond what feedback inhibition alone can accomplish. By adding mutual inhibition to small neural motifs, decision-like functionality is off loaded into the inhibitory subnetwork. This frees up recurrent excitation for working memory, and feedback inhibition to oscillate allowing a plethora of central pattern generators to coexist with decision networks. All of these functionalities can be flexibly switched using changes in each neuron's bias current. This allows for quick, robust and flexible external control, without changing any synaptic weights. Taking advantage of dynamical systems theory and bifurcation analysis we show mutual inhibition doubles the number of cusp bifurcations in the system. This multi-functionality allows robust control of the underlying 2-cusp bifurcation structure by using bias current to push the system through lower codimension bifurcations. Thus changes in bias current can quickly switch between different functionalities. Impressively, we were able to identify 8 different logical operations with 3 different classes of inputs, distinguishing between differences in magnitude, timing, and phase. Furthermore we uncovered several types of central pattern generation, working memory, and chaos.

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Email:ajw131@case.edu