Phase-Selective Entrainment of Nonlinear Oscillator Ensembles

Background: Biological, chemical, and other natural ensembles are noisy and difficult to characterize or manipulate. Establishing spatiotemporal structures in these ensembles requires controlling large collections of complex, nonlinear dynamical units.

Technology Description: A method to construct weak, globally-applied, open-loop control inputs that dynamically synchronizes a collection of heterogeneous, nonlinear oscillators. The method is particularly useful when feedback information is unavailable, initial conditions are unknown, and the oscillators are subject to uncertainty in parameters and stochastic disturbances. The ability to entrain weak signals can advance current neurostimulation and neuromodulation techniques used for the treatment of Parkinson’s, epilepsy, sleep disorders, cardiac arrhythmias, chronic pain, and other conditions.

Schematic of pattern switching from letters ‘O’ to ‘K’.

From left to right: spatial distribution of phase offsets, structure on the unit circle, and sketch of the ideal interaction function.

a) No evident pattern in 20 electrochemical oscillators when given zero input. Rhythmic elements are represented by a color gradient corresponding to phase offsets where yellow is “on” and blue is “off”.

b) When controls are applied, the ensemble is quickly entrained to form the pattern for the letter ‘O’.

c) A precursor waveform is applied to generate phase offsets. Some clusters lose entrainment.

d) Ensemble produces the ‘K’ pattern.

e) Ensemble is quickly returned to ‘O’.

Stage of Development: Our method for entrainment has been numerically and experimentally verified by successfully designing waveforms to entrain Hudgkin-Huxley neurons, Morris-Lecar neurons, and electrochemical oscillators.


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