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Synchronization of Pulse-Coupled Oscillators

Brain rhythms are generated by neural oscillations. Neurons communicate via action potentials (spikes). If the effects of these spikes on their postsynaptic targets are sufficiently brief, we can approximate the coupling as pulsatile. We study coordination between neurons biased in a nonlinear dynamical regime in which they emit regularly spaced spikes as part of a limit cycle. We simplify the pulsatile coupling by assuming its only effect is to shorten or lengthen the interval until the next spike is emitted. We tabulate these effects as a type of phase response curve (PRC) sometimes referred to as a spike time response curve. We derived criteria for the existence and stability of global synchrony and of alternating patterns between single oscillators or synchronous clusters based upon the PRC. The slopes of the PRC at the points at which inputs are received are critical for determining stability. Transmission delays shift the phase at which an input is received, and in some cases alter the form of the stability criteria. We apply our results to cases of optogenetically-driven theta-nested gamma oscillations in entorhinal cortex. Although have we focused on a neural context, many of these results generalize to any network of coupled oscillators.