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Inducing synchronization in complex networks via stochastic resetting in the Kuramoto model

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Collective synchronization is an emergent phenomenon in physical, biological, and technological systems, where local interactions enable dynamical adjustment among oscillators. In complex networks, the Kuramoto model provides a fundamental framework to study the transition between incoherent and synchronized states; however, synchronization typically requires sufficiently strong coupling, which limits its controllability in subcritical regimes. In this work, we investigate an extension based on the stochastic resetting of subsystems, defined as random interruptions that restore the phase of a fraction of nodes to a reference value. We analyze this dynamics on different network topologies using numerical simulations and a mean-field theoretical approach, evaluating the role of the resetting rate, the fraction of reset nodes, and structural heterogeneity in the synchronization transition.

Our main result shows that stochastic resetting can induce synchronization even in regimes where the original dynamics remains incoherent. This mechanism acts as a local realignment process that counteracts phase dispersion and reduces the effective coupling threshold. These findings identify resetting as an effective strategy to promote and control collective coherence in complex oscillator networks.

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