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Using Symmetries and Equitable Partitions Together to Find All Synchronization Clusters and Their Stability

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Many networks of coupled oscillators are observed to produce patterns of synchronized clusters where all the oscillators in each cluster have exactly the same dynamical trajectories in state space, but not the same as oscillators in other clusters. It has been difficult to predict these clusters in general. We show the intimate connection between network symmetry and cluster synchronization. We apply computational group theory to reveal the clusters and determine their stability. Other synchronization clusters are possible in addition to the symmetry clusters (SC). These are equitable partitions (EP) of the network. We show that the EP can be constructed by the merging of appropriate SC. We show that this construction also allows the derivation of further simplified stability (variational) equations for the EP case thus allowing the SC and EP approaches to compliment each other. The connection between symmetry and cluster synchronization is experimentally explored using an electro-optic network.