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Evolution of network architecture in a granular material under compression[1]

DANIELLE BASSETT, University of Pennsylvania

As a granular material is compressed, the particles and forces within the system arrange to form complex and heterogeneous collective structures. However, capturing and characterizing the dynamic nature of the intrinsic inhomogeneity and mesoscale architecture of granular systems can be challenging. Here, we utilize multilayer networks as a framework for directly quantifying the evolution of mesoscale architecture in a compressed granular system. We examine a quasi-two-dimensional aggregate of photoelastic disks, subject to biaxial compressions through a series of small, quasistatic steps. Treating particles as network nodes and inter-particle forces as network edges, we construct a multilayer network for the system by linking together the series of static force networks that exist at each strain step. We then extract the inherent mesoscale structure from the system by using a generalization of community detection methods to multilayer networks, and we define quantitative measures to characterize the reconfiguration and evolution of this structure throughout the compression process. To test the sensitivity of the network model to particle properties, we examine whether the method can distinguish a subsystem of low-friction particles within a bath of higher-friction particles. We find that this can be done by considering the network of tangential forces, and that the community structure is better able to separate the subsystem than consideration of the local inter-particle forces alone. The results discussed throughout this study suggest that these novel network science techniques may provide a direct way to compare and classify data from systems under different external conditions or with different physical makeup.

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