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Structure, Inference, and Optimization in Complex Networks

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Modern models for complex networks have aimed to realistically describe empirical data: they detect salient features, and they provide interpretations guided by statistical principles. Yet the extent of our capabilities to infer is contingent upon our expectations of the structure, how we represent it, as well as factors like measurement uncertainties and available metadata. In this dissertation, I make modeling and algorithmic contributions in this direction. I first investigate the inference of the community structure in bipartite networks. For instance, a network in which edges connect people with the foods they eat is bipartite, as are other networks of associations between two classes of objects. Using methods from Bayesian statistics I extend the theory and numerically compare the sensitivity of the model with their high-resolution counterparts. Next, I enhance a convex optimization program for hierarchical ranking in directed networks to handle datasets that are erroneous, time-varying, or have node attributes. I highlight the development of specialized first-order solvers for memory-efficient computations. Going beyond the graph-based representations, I then consider higher-order structures, where I introduce a recursive, heuristic algorithm for the NP-complete *simplicial complex realization problem.* Finally, I conclude by discussing the implications of these ideas for diversifying and advancing tools for modeling complex networks.