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Adaptive multi-resolution Modularity for detecting communities in networks

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Abstract: Community structure is a common topological property of complex networks, which attracted much attention from various fields. Optimizing quality functions for community structures is a kind of popular strategy for community detection, such as Modularity optimization. Here, we introduce a general definition of Modularity, by which several classical (multi-resolution) Modularity can be derived, and then propose a kind of adaptive (multi-resolution) Modularity that can combine the advantages of different Modularity. By applying the Modularity to various synthetic and real-world networks, we study the behaviors of the methods, showing the validity and advantages of the multi-resolution Modularity in community detection. The adaptive Modularity, as a kind of multi-resolution method, can naturally solve the first-type limit of Modularity and detect communities at different scales; it can quicken the disconnecting of communities and delay the breakup of communities in heterogeneous networks; and thus it is expected to generate the stable community structures in networks more effectively and have stronger tolerance against the second-type limit of Modularity.

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Keywords: Complex networks; Community detection; Modularity; Multi-resolution

1. Introduction

Network theory provides a kind of effective way to the study of complex systems, such as the metabolic networks, protein-protein interaction networks and transportation networks [1-4]. And it has been found that these complex networks own many common topological properties [1, 2]. For example, many complex networks have been found to have community structure or modular structure, meaning the networks contain groups of densely connected vertices that are sparsely connected with the rest of the networks. The community structure or modular structure is of interest for studying the structures and functions of the networks and the dynamics taking place on the networks [5-10]. For example, Yan et al found that local targeted immunization outperforms global targeted immunization in the network with apparent community structure [11]; Wu et al showed that the abundance of communities in the social network can foster the formation of cooperation under strong selection [12]. In the past decades, community detection in complex networks attracted much attention from various fields, and a large number of community-detection algorithms have been proposed to detect the communities in the networks based on various approaches [13-22], such as spectral analysis [22], random walk [23-25], dynamics [26-29], label propagation [30], and Modularity optimization [31, 32].