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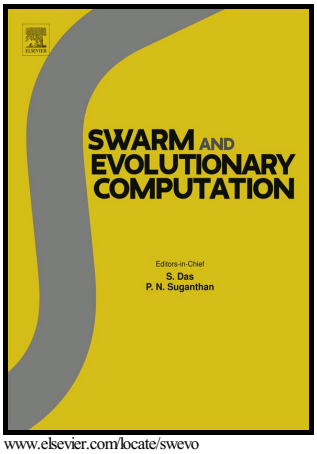

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Detecting composite communities in multiplex networks: a multilevel memetic algorithm

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Abstract

Nowadays, many systems can be well represented by multiplex networks, in which entities can communicate with each other on multiple layers. A multiplex network under each layer has its own communities (i.e., a higher-order organization with a group of similar nodes) while it has a composite structure which is most likely to describe its community structures at all layers. Many algorithms have been proposed to detect communities in unweighted single-layered networks, but most of them cannot be well applied to detect composite communities in multiplex networks. The aim of this paper is to detect composite communities in weighted multiplex networks using a multilevel memetic algorithm. First, a simplified multiplex modularity is adopted for evaluating the fitness of composite communities, and then the community detection problem in multiplex networks is modeled as a combinational optimization problem. Second, we devise a multilevel memetic algorithm that combines a network-specific genetic algorithm with problem-specific multilevel local search operators. In the presented algorithm, the network-specific knowledge (i.e., the layer neighborhood and the consensus neighborhood) and the problem-specific information (i.e., the fast computation of multiplex modularity under each local refinement) are adopted to guide its search processes. Last, extensive experiments are performed on eight real-world networks ranging from social, transport, financial to genetic areas, and the results demonstrate that our algorithm discoveries composite communities in multiplex networks more accurately than the state-of-the-art.

Keywords:
Composite community detection, multiplex networks, memetic algorithm, multilevel local search

1. Introduction

Complex network has demonstrated to be a simple but effective model reflecting the fundamental structures and behavior attributes of real systems in the domains of sociology, finance, transportation, ecology, genetics, and etc [3, 34]. Nodes in complex networks interpret the agents of real systems while the edges among nodes reflect the interconnections of entities. Most existing studies mainly model real systems to single-layered networks with homogeneous links, i.e., interconnections between entities are only reflected by a single type of link and their weights are set to the same value. However, many real systems are heterogeneous, i.e., their communications exist in multiple platforms and they are different in types and weights [8, 36, 47]. For instance, in social systems, individuals can communicate with each other through the following platforms: Facebook, Telephone, Webchat and Email. In transportation systems, travellers can choose bikes, buses, taxies, trains, boats and airplanes as transportation way, and the travel cost under each transportation way are different. These systems can be properly represented by multiplex networks with a set of nodes and multiple layers of weighted links. Links in different layers interpret the different types of activities of agents in the systems and their weighted values represent the communication degree of pair of agents [33, 45].

Community structure, a macroscopic structure of networks, reflects the higher-order organization and functionality which are hidden in the low-order nodes and communications of the networks [36]. A community in a single-layered network is composed of a set of similar nodes [17, 20]. However, it has no uniform definition in a multiplex network as the network under each layer has its own community structures which cannot well reflect its composite community structure (i.e., the uniform communities under all layers) [36]. The detection of communities of networks are important to understand the structural functionality (e.g., motif structure, small world, scale-free structure, robustness, synchronization, and controllability) and individual behaviors (e.g., spreading, competition, balance, cooperation and evolution) of complex systems [6, 14, 22, 27, 29, 42, 52]. Recently, many community detection algorithms have been presented for single-layered networks [25]. However, they cannot be well applied to multiplex networks as their results only reflect the community property of the networks at one layer.

Compared with a single-layered network, a multiplex network has more complex communities and topology structures. The community detection in multiplex networks is not an easy problem and it has to solve the following problems: i) the definition of composite community and ii) the utilization of comprehensive topology structures in multiplex

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