Construcitng null networks for community detection in complex networks

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Abstract
Communities are virtually ubiquitous in real-world networks, and the statistic of modularity index Q is the classical measurement for community detection algorithms. However, the relationship between the modularity property and network multilevel micro-scale structures is still not clear. In this paper, we study community detection results both in artificial and real-life complex networks by constructing different order null networks, and the results uncover that how micro-structures (such as degree distribution, assortativity and clustering coefficient) affect community properties. Meanwhile, we also propose two novel null networks (increasing or decreasing community intensities) to verify the robustness of different community detection algorithms. Our results indicate that the modularity index Q is not a suitable statistic to measure the weak community property which is widely available in empirical networks. Our findings can not only be used to test the robustness of different community detection methods, but also be helpful to uncover the correlation of network structures between microcosmic and mesoscopic scales.

Conclusion
In summary, we maintained the micro-scale structures by constructing traditional 1k-3k null networks (see Fig.1 (a)-(d)) to study how micro-scale structures affect community properties. Experimental results (see the blue line of Fig.4) demonstrate that the 1k-3k micro-structures are not enough to keep community properties, but 3k micro-scale structure is a significant micro-structure for maintaining the meso-scale characteristics of the original network.

Meanwhile, we maintained the community structure characteristics by constructing two novel null network (see Fig.2) to study the impact of the two types of edges on community structures. The results (see the red line and green line of Fig.4) suggest that rewiring the two types of edges has a small impact on community structures, in the case of maintaining the community structure characteristics. Experimental results (see Fig.4) demonstrate that keeping community properties of the original network but not keeping its micro-scale structures are enough for community detection. We used the null network of rewiring edges within a community (see Fig.2(b)) to study the impact of a single community structure on the entire network. The results (see Fig.5) suggest that the inner topology structures of every community have different roles in community properties of the entire network.

Furthermore, we changed community structure characteristics by constructing two novel null networks (see Fig.3) to verify the performances of different community detection algorithms. We find that the performances of these detection algorithms have a significant difference when the edges in community structures have different intensities. Our results (see Fig.6) indicate that modularity Q is not a suitable index for the network with weak community structures.