

中国高等科学技术中心

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第五届全国网络科学论坛 论文摘要

论坛主要议题

- (1) 交流近年国内外网络科学与应用方面的新进展
- (2) 探讨今后我国网络科学与应用的研究发展方向
- (3) 座谈今后“复杂网络圈”的有关活动。

1. 甲型流感全球大爆发之经验统计及其传播模型

— 标度与控制

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甲型流感 (H1N1)无疑是当今波及全球范围的一种威胁最严重的公共危机。因此研究甲型流感之传播动力学,无论对于公众健康,还是对于科学研究,都至关重要。我们将探讨甲型流感之传播模式并研究其确认病例在各个不同层次之分布的Zipf律。对于严重急性呼吸道

综合症(SARS)和禽流感(H5N1)，我们也观察了类似的标度性质。为了寻求造成这些标度行为的机制，我们提出了可以同时考虑控制对于局部发生和跨区域传播两者之效应的模型。这一模型显示出强控制效应是造成标度性质的原因。虽然向跨区域旅行者施以严格控制措施，对于当地无病例区域之爆发推迟是有益的，但是我们的分析表明，抵御重点应该放到对于已经有当地病例爆发之区域的局部预防。这一研究结果不仅对于造成传染病传播的一般性机制加深了认识，而且为必须采取适当控制策略的决策者们提供了不可缺少的分析工具。

2. 生物神经网络系统的动力学与认知功能

陆启韶（北京航空航天大学）

生物神经系统是由数量极其巨大的神经元相互联结的信息网络系统，在生物体的感觉、认知和运动控制中发挥关键性的作用。本报告首先介绍神经元、大脑和一些生物神经网络的生理结构和理论模型，然后分别介绍其放电动力学和网络动态特性的一些重要问题，包括神经元的复杂放电模式、耦合神经元网络系统的同步活动和时空动力学、大脑联合皮层神经微回路的网络结构特征，探讨生物神经网络系统的动力学与认知功能研究的联系等。最后对今后研究给出一些展望。

3. 论网络最大度及其相关问题

史定华（上海大学数学系）

因为实际网络都是有限的，模型网络在模拟和分析时首先考虑的也是有限网络，所以必须讨论网络有限规模的影响。对于有限网络，由于网络最大度和量级相当的度及其所对应的结点(hub nodes)在网络拓扑结构和动力学特性中扮演着重要的角色，值得人们特别关注。

4. 复杂网络拓扑结构的动力学识别与估计

郑志刚（北京师范大学物理系）

复杂网络多年来较为得到关注的是网络结构实证研究，网络动力学与复杂性研究等，而作为反问题----利用已知的动力学输出信号来反推复杂网络内部链接结构却一直是一个复杂的问题。本报告将介绍这一反问题的研究现状，并介绍我们近来的研究进展。

5. 量子信息网络的抗消相干

毕桥（武汉理工大学）

量子信息网络能否实现最重要的问题之一是能否控制消相干的问题。尽管国际上学者们已提出许多抗消相干方法，但实际可行性十分微弱。我们提出一种新型的在子动力空间构造抗消相干法。

6. 复杂网络的空间结构

狄增如（北京师范大学管理学院）

Besides some well known common properties such as small world and community structures, recent empirical investigations suggest a universal scaling law related to the spatial structure of social networks. The probability density distribution of geographic distance r between pair of friends found to be $P(r) \propto r^{-1}$, which is similar to the

optimal navigation law found by Kleinberg [Nature, **406**, 845 (2000)]. Although the spatial scaling property is the complete answer to "six degrees of separation", the basic principle that governs its formation is less been understood. Here we propose a fundamental origin for this law based on the concept of entropy. Using both optimization model (OM) and evolutionary model (EM), we show that this spatial scaling law can be understood as a result of maximization of information entropy, which means the maximal diversity of friendships. Such spatial distribution can benefit individuals significantly in optimally collecting information in the social networks. Many real networks are embedded in geographical space and have shown spatial scaling properties, suggesting that our approach may be relevant in a wide range of networks.

To discuss the influence of the power-law exponent on the network's structure and function, a spatial network model is proposed. Based on a regular network and subject to a limited cost C , long range connections are added with power law distance distribution $P(r)=ar^{-\delta}$. Some basic topological properties of the network with different δ are studied. It is found that the network has the smallest average shortest path when $\delta=2$. Then a traffic model on this network is investigated. It is found that the network with $\delta=1.5$ is best for the traffic process. All of these results give us some deep understandings about the relationship between spatial structure and network function.

7. Stationary Efficiency of Coevolutionary Networks: an Inverse Voter Model

朱陈平（南京航空航天大学物理系）

The definition of global efficiency E_{glob} of a network is essentially based on shortest path length and widely used in problems from many fields. However, it is not applicable to some coevolutionary objects. We advocate to substitute for it in some cases with stationary efficiency combining dynamic topology with node states. Focusing on dynamic networks with binary node states, we present an inverse voter model as an example to show how to measure it with the order parameter. Continuous phase transitions of stationary efficiency which is complementary to short range order, *i.e.*, the density of inert links, are found out with analytic approach of master equation and numerical simulations. A set of scaling relations are revealed and the sparsity of networks is emphasized, which gives valuable hints to enhancing efficiency of general social and economic systems.

8. 复杂网络社团结构的鲁棒性

樊瑛（北京师范大学管理学院）

Community structure is an important property of complex networks. Up to now, there are plentiful methods developed to detect community structures in networks. Community structure for a network can be different, usually people use function Q to measure which one is better.

However other factors should also be considered, such as whether the community structure is stable, which means a little disturbance can not cause tremendous changes. In this research, two methods are proposed, both of which paid much attention to the triangles in the network. By disturbing the initial networks and using an effective measurement function D to quantify the changes of community structure, it shows that triangles in the network have significant meanings for community structures. Modularity analyzing for disturbed networks proves robustness analysis by our methods is more reliable.

Then based on the perturbation of networks, an index R is presented which can measure the significance of communities for different networks absolutely and universally. By integrating all the similarities between the original community structures and the communities of the disturbed network and taking the null model into account, the index is successful to get rid of the scale effects. We apply the index to many artificial and real world networks, such as social networks, neural network, proteins interactions networks, and metabolic networks. The results show that our index is independent of the network size and group number. Moreover we find that the social networks usually have significant communities, while communities are comparatively fuzzy in biological networks, especially in some protein-interaction networks.

9. How to Measure Significance of Community Structure in Complex Networks

胡延庆

北京师范大学

Community structure analysis is a powerful tool for complex networks, which can simplify the functional analysis considerably. Recently, many approaches have been proposed for finding community structure, but rare of them pay some attention to the significance of community structure. Real networks we obtain from complex systems always contain error links. Moreover, most of the community detecting algorithms also have random factors. So, evaluating the significance of community structure is very important and urgent. In this paper, we bridge the significance of community structure and eigenvectors stability. Without detecting communities, the significance of community structure can be evaluated and the optimal community number also can be obtained, which is always hard for many algorithms. We also apply the method to many real networks and find that the clear community structures exist in many social networks and *C. elegans* neural network, but less significant community structure in protein-interaction networks and metabolic networks. Moreover, our method can be generalized to broad clustering problems in data mining.

10. Cluster structure and localization of brain functional

networks based on the ERP signals of auditory task

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Abstract: The brain functional networks derived from multi-channel ERP signals are analyzed based on the phase synchronization theory. The nodes of brain functional networks are represented by the channels of ERP signals, and the connectivity of brain functional networks is described by the interaction among the channels. The edge between two different channels exists only if the phase coupling index is beyond a certain threshold. The constructed brain functional networks under the resting and task states present robust small world property in consistent with the empirical facts found in previous works. We first uncover that the cluster coefficients get larger when brain is executing auditory task, which means that neighbors of a node prefer to be mutually connected to form more clustered and localized networks. Furthermore, the connectivity of networks is better under the task state. These results

suggest that the modularity of brain functional networks emerges to the internal enhanced correlation and localization when the cognitive activity of brain is acting.

11. 复杂网络的结构与动力学行为之间的相互关系

—以同步为研究视角

赵明（广西师范大学物理科学与技术学院）

经过十余年的研究，人们对复杂网络的结构对发生于其上的动力学行为的影响已经有了比较清晰的认识，但实际上网络上的动力学行为往往对网络的结构也存在巨大的影响，到目前为止这方面的研究并不充分，而研究两者之间的相互作用的工作就更为稀少。在我们的工作中，我们从同步的角度研究了网络的结构与动力学行为之间的相互作用关系，具体地，我们将之前的一种自适应耦合同步方式进行了广义化：网络中每个节点被其邻居耦合的强度的演化不仅仅依赖于该节点与其邻居平均状态的差异(动力学部分)，还被网络的局域结构调节 $1/k_i^\alpha$ (拓扑部分)。我们可以从理论和数值模拟两个角度证明当输入耦合强度稳定后，其值与节点的度之间满足幂律关系 $k^{-\theta}$ ，其中 $\theta = (1 + \alpha/2)$ 。加入拓扑项之后，稳定后的输入耦合强度是可调的，从而网络的整体同步能力是可调的，我们可以在理论上证明当 $\alpha \approx 1$ 时，网络的同步能力最强，并且具有最短的同步时间。我们的工作不仅深化了人们对网络的结构和动力学行为之间的相互作用关系的认识，也提供了一种通过局域自适应耦合调节网络同步能力的方法。

12. 网络系统的协调动力学与控制

周进（上海市应用数学和力学研究所）

主要介绍多个体网络系统（主要是面向实际工程技术领域中具有个体动力学特性的力学网络系统）协调动力学与控制国际上的研究现状及我们近期的有关工作。

13. Evolutionary game and friendship network

李 炜（华中师范大学复杂性研究中心）

We introduce and study an evolutionary complementarity game where in each round a player of population 1 is paired with a member of population 2. The game is symmetric, and each player tries to obtain an advantageous deal, but when one of them pushes too hard, no deal at all can be concluded, and they both lose. The game has many equilibria, and which of them is reached depends on the history of the interactions as the players evolve according to a fitness function that measures their gains across the interactions. We can then break the symmetry by assigning different strategy spaces to the populations, varying in particular with respect to the information available to the agents. The agents can, for example, adapt to the behavior of their opponents met in previous rounds, or they can try to copy the strategies of their successful friends. It turns out that, in general, the more restricted strategy spaces, that is, those which utilize less information, are more advantageous for a population as a whole as their adoption drives the equilibrium in a direction advantageous to that population.

14. 自适应性网络中的强一致舆论动力学

王茹（华侨大学）

实际网络中大多数都存在着由于节点的状态发生变化而导致的结构反馈变化，本文探讨了连续态的Sznajd模型下的耦合网络，当个体之间的态差值大于阈值时，连线会以一定的概率重绕，反之，个体的态会遵从Sznajd动力学规则演化。仿真结果表明网络的结构和功能耦合使得个体之间的信息交互加快，会形成拓扑集团，并且较快达到一致态的稳态。动力学和网络结构的相互作用对于舆论的传播起到了重要的作用。

15. 通讯网络的信息传输

周秋花（广西师范大学）

研究无标度网络考虑节点度和空闲度相结合的路由搜索策略的信息传输，与只考虑无标度网络中节点的度的路由搜索策略相比较，显著提高了网络的通讯能力，减少了信息包的平均传输时间；研究了加权网络中考虑边权信息和节点空闲度相结合的路由搜索策略的信息传输，与基于局域边权信息的路由策略相比，提高了网络的通讯能力，在拥塞状态下减小了网络负载。

16. 探索基于束晕-混沌的网络保密通信

刘强和李永（中国原子能科学研究院）

基于具有小世界特性的束晕混沌特性，利用驱动-响应同步、小世界拓扑耦合同步、多局域小世界拓扑耦合同步等方法分别设计了网络保密通信的三种电路方案，应用matlab的simulink软件进行仿真试验，

实现了对网络通信信号的加、解密，仿真实验证明了这些电路的可行性，为进一步工程设计和电路的网络实验研究提供了理论基础和参考。

17. 疾病免疫算法

纪鹏（江南大学）

当前研究的热点是如何用最小的代价对人群网络或计算机网络进行免疫。针对免疫算法的**假设条件**、**免疫对象**和**免疫原则**，分别提出自己的免疫算法：假设已知邻居节点的度数，采用最大度搜索算法，提出了局域搜索免疫策略；已知全局信息，根据边与重要节点的关系，提出了删除边的免疫策略；基于图形分割算法，通过免疫边把图形分割成大小相似的几个集团，提出了图形分割免疫策略。三种策略分别在ER 网络和BA无标度网络中，采用SIS病毒传播模型，进行了仿真试验，结果都能比目标免疫得到更小的免疫临界值。

18. 量子高斯信道的互信息和量子并行性

郭柳（武汉理工大学）

构造量子信息网络的可行性信道之一是量子高斯信道。我们讨论了量子高斯信道的互信息量的计算问题并提出了量子并行性的方案。

19. Unevenness of Loop Location in Complex Networks

曾安（北师大）

The loop structure plays an important role in many aspects of complex networks and attracts much attention. In the previous works, lots of

researchers studied the total number and the dynamic effect of the loops. In this paper, we focus on the uneven location of loops, which makes some parts of the network rich in loops while loops sparse in some other parts. If this effect is significant enough, some rich loop clubs emerge. We propose a node removing process to analyze the rich loop club phenomenon and present an index to measure the unevenness of loops location. The empirical analysis shows that the unevenness of loops location varies in different real networks. Surprisingly, despite fewer total loops, some of real networks, especially the neural networks and some food web networks, have rich loop clubs which are more loopy than the corresponding communities of counterpart random ones.

20. Spreading of Epidemic Based on Human and Animal Mobility Pattern

罗丹（北京师范大学）

Recent studies have shown that human and animals' mobility follows a Levy Flight pattern. Stimulated by the deluge of H1N1 this year, we study the relationship between epidemic spreading and the interactions of human and animals from a network perspective. In this paper, we construct a one-dimensional weighted network, which possesses Levy flight spatial structure properties under a restriction on total energy. Under the classical SIS and SI epidemic spreading models, we employ the reaction equation and numeric simulation, and find that

$\alpha = -2$ is the phase transition point of epidemic threshold of effective spreading rate, and this conclusion can be extended to the cases of high-dimensional networks. Moreover, we also find that the epidemic is the most efficient when $\alpha = -2$. These results would be helpful for people to understand the effect of mobility pattern on epidemic spreading.

21. 连续系统和离散系统中的广义同步研究

闵乐泉（北京科技大学数学力学系）

22. 未来网络科学与工程若干问题

李兵（武汉大学）

23. 中国有机化工原料供应链网络结构研究 ——复杂网络视角

石海佳（清华大学环境科学与工程系）

研究构建并分析了 2006 年我国大陆地区以及八大经济区域的有机化学工业原料供应链网络，根据网络相关指标将不同地区产业规模划分为三个等级，并从路径长度分布的角度对该行业的发展进行透视，得出了目前行业结构三种不同的表现形式。

24. 复杂网络间节点匹配

宣崎（浙江大学）

25. The Hurst Exponent Analysis of the Chinese Fund Market

邓为炳（华中师范大学复杂性研究中心）

Applying the statistical hypothesis testing, we investigate several non-linear properties embedded in the return series of the Chinese Fund Market (CFM), which suggests the series is non-normal, auto-correlative and heteroskedastic. We hereby analyze the Hurst exponent of the return series in different time scales on the basis of the detrended fluctuation analysis (*DFA*) algorithm, and discuss the fractal behavior of the CFM. Furthermore, by studying the correlation of different weights in the volatility, we find the persistent long-range power-law correlation exists in the time series. We also provide hints that the above statistical properties are insensitive to the funds kind, and may be irrelevant to the market phases. Our work may reveal the self-similarity characteristics of the financial market and show a better understanding of the CFM.

26. 生命网络体系的虚熵研究

何祖坦（武汉理工大学）

研究生命网络体系的激发子同光子的相互作用及熵。

27. 同步，协同，中性稳定性和流型的稳定性

陈天平（复旦大学数学系）

28. 网络科学杂谈：回顾与展望

方锦清（中国原子能开展研究院）

本报告企图简要回顾我国从 2004 年“第一届全国网络科学论坛”至今五届以来，包括国内一系列网络科学理论与应用会议，及其总体研究和发展的基本概况和若干特点。针对今年美国《Science》上复杂系统与网络专辑的文章，进行了初步的分析，发表自己的观点和评论性意见。同时，提出对于今后网络科学和应用的若干挑战性课题。