Commun Nonlinear Sci Numer Simulat 19 (2014) 4068–4079

Contents lists available at ScienceDirect

Commun Nonlinear Sci Numer Simulat

journal homepage: www.elsevier.com/locate/cnsns

Structure properties of one-mode collaboration network model based on rate equation approach

Long Wang *, Yinghong Ma

School of Management Science & Engineering, Shandong Normal University, Jinan, China

ARTICLE INFO

Article history:
Received 7 November 2013
Received in revised form 11 April 2014
Accepted 16 April 2014
Available online 24 April 2014

Keywords:
Collaboration network
Correlation of node degrees
Degree distribution
Joint degree distribution
One-mode RDP model
Rate equation approach

ABSTRACT

The rate equation approach is very useful to describe the dynamic structure property of collaboration network, especially in calculating the node degree distribution and the joint degree distribution, and considering the correlation of node degrees. In this paper, we referee the two-mode collaboration network model (RDP), and translate it into one-mode RDP model. By the rate-equation approach, we study the node degree distribution in the one-mode RDP model (RDP) with numerical simulations verifying the feasibility of the model. It is proved that the node degree distribution of the model is a right-skewed power-law like distribution with the exponent γ in interval $(1,3]$. For the large enough node degree k, it can be proved that the node degree distribution is approximately power-law distribution. The joint degree distribution are also got by utilizing rate-equation approach and the node degree distribution. Through the joint degree distribution, we find that the correlation relationship of node degrees is nontrivial correlation relationship among the degrees of connected nodes that formed by spontaneously. Finally we get the clustering coefficient of the RDP model by calculating the mathematical expectation of degree distribution.

1. Introduction

Many real systems can be described by complex networks in which a node represents the system's elementary unit, and an edge represents the interaction or relationship between a pair of nodes. Duncan Watts first presents the theory of scale-free network whose degree distribution follows a power-law, at least asymptotically. Examples include social network, World Wide Web [1], and even biological interacting networks [14]. Complex network research upsurge first derives from Watts-Strogatz 'small-world' network model [19] and Barabasi-Albert model (BA model) [2,3]. Social network [18], a special complex network, has attracted a great deal of interest in social scientific field. The collaboration network [15,17] which is an interesting social network has also gained much attention from many researchers.

A collaboration network is a network consisting of a variety of individuals (e.g. organizations or people) who are largely autonomous, geographically distributed, and heterogeneous in terms of their operating environment, culture, social capital and goals. The discipline of collaboration network focuses on the structure, behavior, and evolving dynamics of networks of autonomous entities that collaborate to better achieve common or compatible goals [6]. Examples of this kind of network are movie actors related by co-starring the same movie, scientists related by co-authoring a scientific paper, etc. Collaboration network can be represented as bipartite graph with two types of nodes. It generally contains "project" and "participant"

* Corresponding author. Tel.: +86 13698617216.
E-mail addresses: w.long163@163.com (L. Wang), yinghongma71@163.com (Y. Ma).

http://dx.doi.org/10.1016/j.cnsns.2014.04.007
1007-5704/

denoted by two disjoint node sets, and the relationships between projects and participants are usually represented as edges respectively. For one example, in scientific research collaboration network [15], scientific research persons are the participants, and the projects are the published scientific papers. If a paper C is published with two scientists, A and B, are cooperated, the edges are (A, C) and (B, C). Obviously, there are two kinds of degree distribution in the collaboration network model, namely project nodes degree distribution and participant nodes degree distribution. Project nodes degree indicates the size of the project, such as the number of authors in each paper; participant nodes degree indicates the number of participants and projects, such as the number of papers that is published by each author. In this paper, we study collaboration network as evolving bipartite graph model (RDP model) [17].

In [17], Ramasco et al. present a more influential collaboration network, a self-organization evolution model (RDP model) in which a part of nodes are the projects and the other part are the participants. In the evolving process of RDP model, n participants are created in each moment t. Among the n participants, m participants are 'new' participants who have not any experience, and the rest of $n - m$ participants are chosen from the 'old' participants by the preferential attachment mechanism with a probability proportional to the number k of projects. With master equation method, Ramasco et al. [17] find that the participants' degree distribution approximately displays a power-law distribution in the collaboration network (RDP model).

Collaboration network has many real applications, such as, scientific collaboration network [15], music network [16]. In [16], they analyze the network of contemporary popular musicians. It is the collaboration network in which two musicians are connected if they have performed in or produced an album together. Researching the collaboration network, formed naturally by the actual professional acts of artists, may teach us how musical tendencies spread via formation of profession relationships between musicians, which could prove worthwhile for musicology. So it is very interesting and meaningful to research collaboration network.

We find that there are few articles considering structure properties of collaboration network by rate-equation approach [11]. For using rate-equation approach, we translate the two-mode RDP model that is a bipartite graph to one-mode RDP model that is the one-mode projection of the bipartite graph. The main motivation in this study is that using rate-equation approach to calculate the joint degree distribution and study the node degree correlation is very convenient. We can get the joint degree distribution by utilizing rate-equation approach. Through the joint degree distribution, we find that the correlation relationship of node degree is nontrivial correlation relationship among the degrees of connected nodes that formed by spontaneously. Of course, the degree distribution of collaboration network can also be got by utilizing rate-equation approach. So we think that it makes sense to study the structure properties of collaboration network by rate-equation approach.

In this paper, by rate equation approach, we analyze the properties in the collaboration network model (RDP model). These properties include the participants' degree distribution, the joint order-degree distribution, and the correlation of node degrees, etc. We organize this study as following: In Section 2, we give the collaboration network self-organization evolution model (RDP model), and transform the model into the one-mode projection of the bipartite graph. By rate equation approach, we find that the network participant nodes degree distribution is a right-skewed power-law like distribution with exponent $1 < \gamma < 2$ or $\gamma = 3$, and for the large enough node degree k, the participant nodes degree distribution is approximately power-law distribution. And we present some numerical simulations to proof the feasibility of the model. In Section 3, we consider the node degree correlation using rate equation approach, and obtain the joint degree distribution in network steady state. Through the network steady state joint degree distribution formula, we find that the correlation relationship of node degrees is nontrivial correlation relationship among the degrees of connected nodes that formed by spontaneously. We also discuss several special cases and obtain some interesting conclusions by the node degree correlation of the RDP model. In Section 4, we present the clustering coefficient of the one-mode RDP model by calculating the mathematical expectation of degree distribution. Finally, we give the conclusions and the further research problems.

2. RDP model and degree distribution

Bipartite network has many interesting applications, such as Metabolic network [10], library network [13], music network [12,16], trade network [9] etc. The trade network is a bipartite network. It contains two kinds of nodes, seller nodes and buyer nodes. The connections usually appear between sellers and buyers. In [12], they analyze web-downloaded data on people sharing their music library, that they use as their individual musical signatures. The system is represented by a bipartite network, nodes being the music groups and the listeners. Corresponding to collaboration network, the listeners amount to participants and the music groups can be seen to projects.

In [17], Ramasco et al. propose a collaboration network model with self-organization evolution process (RDP model). The collaboration network is a bipartite network.

The RDP model is defined as the following:

1. At each time step a new project with n participants is added.
2. m participants are new, without previous experience, of the n participants playing in a new project.
3. The rest $n - m$ participants are chosen from the 'old' participants with preferential attachment mechanism with a probability proportional to the number k of projects that they previously participated in.