A Complex Network Model of Knowledge Collaboration in Virtual Community: Based on Wikipedia Community

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Abstract

Wikipedia is a typical konwledge collaboration community. Though it's network topology has been studied by many schloars, the relationship among users and the affiliation among topic and users still remain ignored. This paper propose two kinds of networks: one-dimensional network aiming at modelling users collaboration in this commutity and two-dimensional network aiming at modelling users and topics affiliation. The result shows the two kinds of networks are both complex networks. The one-dimensional network has scale-free structure, and its degree distribution is subject to the power law and possesses obvious small world phenomenon. At the early stage of the network development, the network does not possess hierarchical topology. However, when the network size increases with time, the network gradually reveals unapparent hierarchy. Furthermore, we observed that there is positive relationship between the density of the one-dimensional network and the scale ratio, and an insignificant positive correlation between the clustering coefficient and the scale ratio. In the two-dimensional network model, we found the theme degree and the topic size have consistent law: subject to the power-law distribution. In addition, the cumulative distribution function of the topic size is exponential function.

Key words: Wikipedia; Knowledge collaboration network; Scale-free structure; Small-world effect; Topic approximation; Scale ratio

1. Introduction

Research of complex network is being popular in recent years among scholars especially from areas of computer science and social science. The scientific understanding to the quantitative and qualitative characteristics of complex network has been studied in different aspects such as sociology, mathematics, life sciences, engineering and many others. The main differences between complex

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network and ordinary network are some non-trivial topologicl features occured in complex network such as small worlds effect[1], scale-free[2], power law[3] and so on. A typical example of complex network is collaboration system. In this network, collaborators are represented by nodes of the network and their connnections are represented by edges. A piles of literatures have analyzed the statistical propeties[4, 5, 6] and give the mechanism of the network evlovement.

Wikipedia is the world largest online-encyclopedia based on wiki system, characterized as "ultra-lightweight" content management systems [7]. It is often seen as the typical knowledge-cooperation social newtork in a virtual practice community. The huge content serves as an excellent example of a large complex network[8], thus attracted the intense attention of scholars because of its' unique characteristics. Unlike other social networks on the Internetsuch as blog, the collaboration in Wikipedia is expanding denotedly and connotedly while the collaboration in blog is non-themed or variable- themed. It will talk about a topic with a very full depth[9].

Topics and users constitute Wikipedia. A topic is a content entry of Wikipedia relatively indepentent, meanwhile cross-referred to other topics. The topology of topic netwotk has been examined from several facets. Capossi etc described topics by vertices and hyperlinks between them as edges, thus represent this encyclopedia as a directed graph[10]. Their research shows Wikipedia has similar topological properties to the World Wide Web. Zlatić etc use same methods and thoroughly studied the network characteristics such as as their degree distributions, growth, topology, reciprocity, clustering, assortativity, path lengths, and triad signicance proles in different language versions[11]. Bolikowski focused on the link between diferent language edition of topics and found the topic size distribution obeys the power law[12]. Some other scholars analyzed the network alongwith time slices[13]. The interesting thing is , as metioned before, though users are another foundation of Wikipedia content creation, they are ignored by current researchers in network analysis. There are interaction between users themself and connections between users and topics, both form a network and remain unclear of the topology and properties of the network.

This paper keeps eyes on these two kinds of networks: the one-dimensional network, representing users connections; the bipartite network, which ties users and topics. Through an empirical study of en-Wikipedia networks data from January 2004 to January 2008, we discover that many properties of these two networks are similar to other complex networks.

The rest of the paper is organized as follows. In section 2, we introduce the complex social network to model knowledge collaboration in Wikipedia community. The empirical analysis of the one-dimensional properties is presented in section 3. Section 4 examines properties and scale of the bipartite network. Section 5 is the conclusions and discussions.

2. The network structure of knowledge collaboration in Wikipedia community

Wikipedia can be depicted as an open content encyclopedia. Allowing unrestricted access to any third party to copy, modify, thus, it provides great convenience for people from various sectors. On the meantime, the users can increase their knowledge and enrich themselves. As of April 25, 2009, according to Wikipedia statistics[1], the English version has 16,550,111 entries and more than 9,505,160 registered users. Wikipedia allows users to edit the topics collabortively. They can add new content, fix other's error, revert previous edit. The collaboration content creation activities thus connect the user who engaged in the same topic into a network, which is our reseach object.

As to the characteristics of Wikipedia knowledge collaboration network, we build a collaborative knowledge network model, shown in Figure 1. There are also two types of ties: connections, noted as C, and afilliations, noted as A. C is the collaboration among users, shown by white lines, while A express the affiliation between topics and users, noted as T and U respectively, shown as dark color lines.

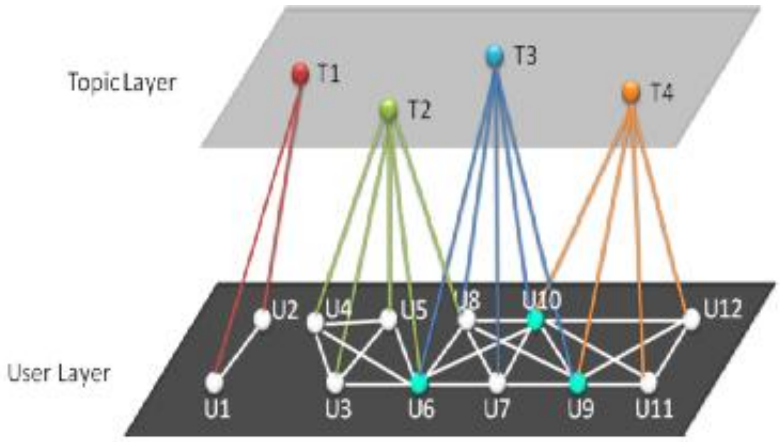


Figure 1: The Two-dimensional, Wiki-based Knowledge Collaboration Network Model

This figure depicts two kind of networks: one-dimensional networks of single-layer and bipartite two-dimensional networks. In the single-layer networks, all the users involved in the same topic collaboration process builds an Undirected and Unweighted Complete Sub-graph (UUCSG), shown as [u1-u2] [u3-u6] [u6-u10] [u9-u12] in Figure 1. The entire single-layer network is composed of N UUCSGs, in which N represents the number of topics. The whole network can be expressed as an adjacency matrix, noted by B_u. For bipartite networks, it's UUCSG is constructed by all the UUCSGs in the single-layer networks and

[1] http://s23.org/wikistats/wikipedias_html.php

the topics which the UUCSGs belong to. The number of nodes is equal to the numbers of the user nodes. Each bipartite network focuses on certain areas but ignore others. It constitutes a circle which has high cohesion but loosely-coupled. Therefore, the bipartite networks can be described as an adjacency matrix B_t.

$$B_u = \begin{array}{c} \\ u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \\ u_6 \\ u_7 \\ u_8 \\ u_9 \\ u_{10} \\ u_{11} \\ u_{12} \end{array} \begin{array}{c} \begin{array}{cccccccccccc} u_1 & u_2 & u_3 & u_4 & u_5 & u_6 & u_7 & u_8 & u_9 & u_{10} & u_{11} & u_{12} \end{array} \\ \begin{pmatrix} 0 & 1 & & & & & & & & & & \\ 1 & 0 & & & & & & & & & & \\ & & 0 & 1 & 1 & 1 & & & & & & \\ & & 1 & 0 & 1 & 1 & & & & & & \\ & & 1 & 1 & 0 & 1 & & & & & & \\ & & 1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & & \\ & & & & & 1 & 0 & 1 & 1 & 1 & & \\ & & & & & 1 & 1 & 0 & 1 & 1 & & \\ & & & & & 1 & 1 & 1 & 0 & 1 & 1 & 1 \\ & & & & & 1 & 1 & 1 & 1 & 0 & 1 & 1 \\ & & & & & & & & 1 & 1 & 0 & 1 \\ & & & & & & & & 1 & 1 & 1 & 0 \end{pmatrix} \end{array} \quad B_t = \begin{array}{c} \\ u_1 \\ u_2 \\ u_3 \\ u_4 \\ u_5 \\ u_6 \\ u_7 \\ u_8 \\ u_9 \\ u_{10} \\ u_{11} \\ u_{12} \end{array} \begin{array}{c} \begin{array}{cccc} T_1 & T_2 & T_3 & T_4 \end{array} \\ \begin{pmatrix} 1 & & & \\ 1 & & & \\ & 1 & & \\ & 1 & & \\ & 1 & & \\ & 1 & 1 & \\ & & 1 & \\ & & 1 & \\ & & 1 & 1 \\ & & 1 & 1 \\ & & & 1 \\ & & & 1 \end{pmatrix} \end{array}$$

We define scale ratio between users and topics in the bipartite networks, described as $W = N_{user}/N_{topic}$. We then can depict the whole collaboration activities in the content-generating community and analyze their properties.

3. The empirical study of single-dimensional knowledge collaboration network

Wikimedia provides the archivess of wikipedia contents dumped regularly from Wikipedia's website. There are several types of archive: pages-articles contains current versions of article content, pages-meta-current is a complete current snapshot archive. Besides pages-articles content, discussion and user pages are also included. The third type is pages-meta-history contains complete text of every revision of every page which very suitabel for research. In this study, we choose enwiki-20081008-stub-meta-history.xml[2] as our research data. It contains no page text but only revision metadata before December 8th 2008. Since our concern is on the collaboration activies, the text content of the topics is not neccesary to our study. Because the Wikipedia community was in its early stage before 2003, we re-select the data from 2004 to 2008 in order to better observe the changes of the network properties at different time periods. We divided the time duration into months, build 48 sub-networks of each month from January 2004 to December 2007 and analyze the properties of the 48 sub-networks.

Before analysing, The data archive has to be cleansed and refined:

1. Abandon all the contributors data in the above-mentioned time periods and all the related contributors versions, discussion pages, for these data are useless to our study.

[2] http://download.wikimedia.org/enwiki/20081008/

2. Exclude anonymouse contribution. Wikipedia allows anonymous edit and show the editor's IP addresses. However, we are unable to check the identity and track his activities without user ID. Only registered user are included in this study.
3. Delete isolated nodes, namely, the topics which have only one contributor. We presume that there is no collaboration relationship between this user and other users under isolated nodes.

In order to illustrate the data changes, ultimately the 24 odd-numbered subnets are selected as representatives to describe the network characteristics. The summary of the cleared network data are shown in table 3, which clearly describes the static parameters changes of the knowledge collaboration networks over time. The increasing amount of the one-dimensional knowledge collaboration networks is decided by the growth of the Wikipedia community. With the Wikipedia culture is receiving increasing attention since 2004, the scale of the Wikipedia virtual community is gradually expanding. There were more than 1400 million pages in Wikipedia until October 2008. The network scale grew quickly from 2004 to the mid of 2007, nevertheless, declined gradually later. In order to observe the network changes with time in more details, this paper gives a more figurative description of the topological properties of the one-dimensional complex network of knowledge-oriented collaboration. We will discuss from five aspects: Power Law, average degree, clustering coefficient, small world and hierarchical network.

3.1. The analysis of scale-free structure

Degree distribution is one of the most importand peoperty of a network because of its inherent important topology information and network evolution information. The degree of the node refers to the number of the node's adjacent nodes or the number of adjacent edges. Barabsi and Albert proposed a scale-free network model, known as the BA model[14]. In this model, the degree distribution of nodes applies to power-law distribution. In our network descriptions, the degree of Node i is described as follow:

$$K_i = \sum_{j \in \mu_i} C_{ij} \tag{1}$$

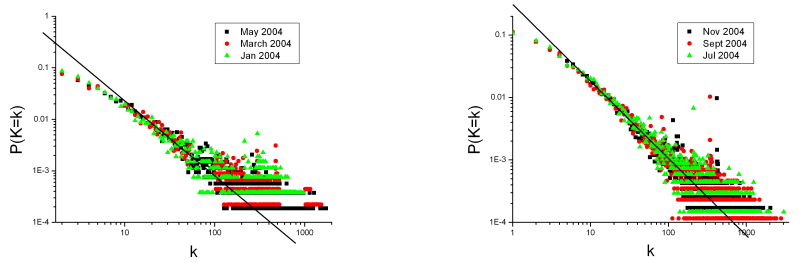
$\mu_j$represents the adjacency matrix of the user node. If node i and j are linked, the value is 1, otherwise 0. Degree distribution of a node refers to the probability of a node with exact degree k in the selected network. Studies show that degree distribution of BA scale-free network is in line with the shifted power-law, that is $P(K = k) \sim k^{\gamma} + \alpha$, both the γ and α are constants.

The degree distributions of the above 24 Wikipedia subnet are displayed as curves in double logarithmic coordinates, as shown in Figure 2. To show conveniently, each subgraph in Figure 2 identifies the subnets of three months.

Master equation method is adopted to further analyze degree distributions of the above collaboration networks[15]. Degree distribution function of the BA

Table 1: The 24 odd-numbered Wikipedia data summary from 2004 to 2007

	Users	Pages	W	Average Degree	Clustering Coefficient	Density
Jan-04	2634	18650	0.141233	83.125	0.642991	0.063141
Mar-04	4807	37733	0.127395	85.467	0.640963	0.035567
May-04	5344	35688	0.149742	88.263	0.629839	0.033039
Jul-04	6814	57986	0.117511	94.662	0.651261	0.027789
Sep-04	8621	66186	0.130254	113.226	0.648146	0.026271
Nov-04	11757	97336	0.120788	116.668	0.654176	0.019848
Jan-05	12343	61389	0.201062	91.989	0.632225	0.014907
Mar-05	15943	91034	0.175132	102.796	0.630041	0.012896
May-05	20323	113260	0.179437	104.417	0.678814	0.010276
Jul-05	27127	140591	0.19295	135.279	0.647197	0.009974
Sep-05	30125	153697	0.196003	125.932	0.650241	0.008361
Nov-05	37182	190484	0.195197	117.661	0.662213	0.006329
Jan-06	61349	276782	0.221651	156.882	0.676517	0.005114
Mar-06	83577	331995	0.251742	157.1	0.7016	0.003759
May-06	95454	336581	0.283599	157.751	0.705743	0.003305
Jul-06	104253	371719	0.280462	152.648	0.712564	0.002928
Sep-06	122794	395049	0.310832	151.984	0.697645	0.002475
Nov-06	138858	396855	0.349896	154.183	0.724345	0.002221
Jan-07	154494	449403	0.343776	151.459	0.720432	0.001961
Mar-07	168900	492561	0.342902	176.884	0.719482	0.002095
May-07	160008	474705	0.337068	224.048	0.693921	0.0028
Jul-07	138543	432391	0.320411	174.423	0.701221	0.002518
Sep-07	146961	454726	0.323186	230.81	0.702132	0.003141
Nov-07	145782	440376	0.33104	189.126	0.71322	0.002595



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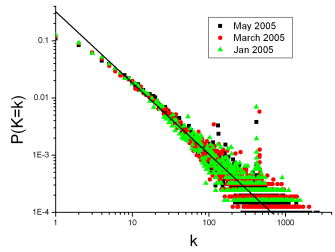

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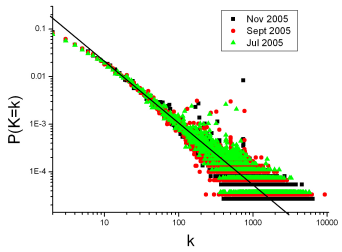

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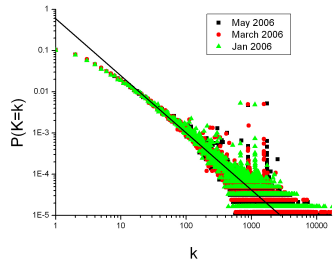

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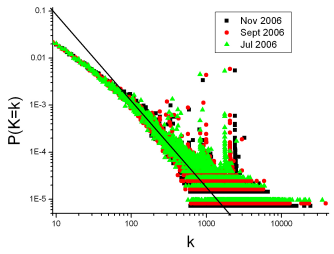

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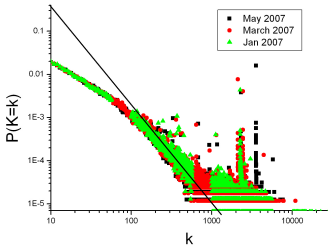

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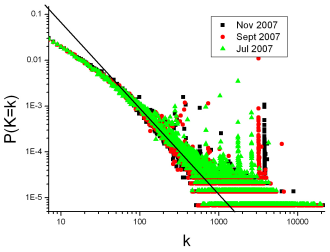

(h)

Figure 2: Distribution of degree in odd months under Log-Log coordinates from 2004 to 2007

network can be similarly described by the Power-law function with Power index for the 3. As Figure 2 shows, the slope of the power-law distribution functions of the collaborative knowledge network in log-log coordinates is approximate to 0.01–0.001, and the functions have similar interception of linear approximatiton. Therefore, these networks are BA scale-free network and the properties conform to the BA scale-free network.

The size of these networks are continually growing. Every day there are many new users joining in Wikipedia community. The new node prefers to connect to those big nodes with higher degree. This phenomenon is also known as "the rich get richer" or "Matthew Effect". In our case, new users tend to participate in editing the topics whose editors are big nodes. Here the so-called big nodes are referred to as more active users. The way of network evolution is moving closer to the central node, thereby forms the polarization between the rich and the poor. The scale-free networks can grow from very few nodes to a complex network with a large number of nodes. When the quantity of the network nodes grows to a certain scale, the network will indicate that: only a few users have a large number of connected nodes, while the rest of users only have a small number of connections, namely, the long tail phenomenon.

3.2. The changes of average degree

With the development of the Wikipedia culture, more and more people devote their efforts to contribute to the free encyclopdia. There are two reasons explain the increase of the users: the first is the increasing new topics. According to the internal data of Wikipedia, new topics have increased dramatically each year. Wider scope of content enables more users to join in the topic editing. The second is that more and more users are participating in the contribution under the existing topics. Therefore, the average degree is introduced to describe the number of relationship within Wikipedia users network, noted as $AverageDegree = \sum_i K_i/\text{Number of Users}$

The change curve of average degree over time is shown in Figure 3. Obviously, the average degree presents an upward trend. The upward shock indicates the number of the innate relations of the networks increasing intensively. In the Wikipedia community, average degree concussion is often caused by the editing shock of the topic node. Take the topic the Festival as example, the number of the editing increases apparently in January and February of each year. Another example is "financial crisis". The amount of editing increases sharply in 2008. Therefore, the average degree is closely related to the degree of concern within Wikipedia topic.

3.3. The changes of clustering coefficient

Clustering coefficient, also known as congregate extent, describes the clustering effect of the complex network, reflecting the property of "Like attract like". Suppose that the degree of a node i in the network is k_i , k_i -nodes are neighbor's of i which connecting to i. C_i refers to the Clustering Coefficient of the Node i, defined as the ratio between the real number of the edges among

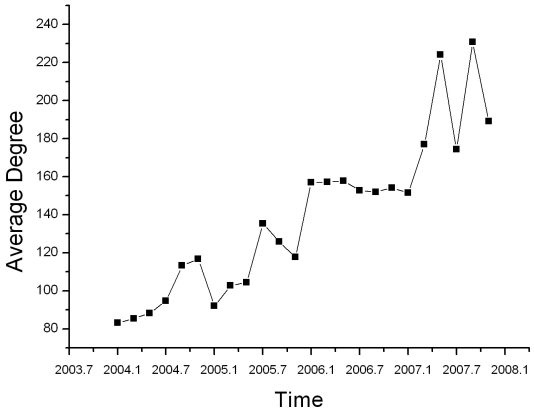

Figure 3: The changes of the average degree from 2004 to 2007

the k_i-nodes, noted as E_i, and the possible total number of edges: $k_i(k_i-1)/2$. So $C_i = 2E_i/k_i(k_i-1)$. The Clustering Coefficient of the whole network C is the average of all the nodes clustering coefficient.In one-dimensional network, C value tend to be a certain non-zero constant despite of the increasing of network size, that is, when $N \to \infty, C = O(1)$. The clustering coefficient of the free-scale network can be defined as $C = \beta[\ln(t)]^2/t$. β is network evolution constant.

The changes of the Clustering Coefficient of the knowledge collaboration one-dimensional network are shown in Figure 4.

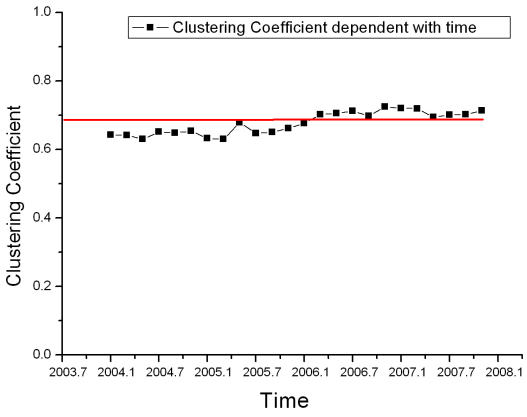

Figure 4: The changes of clustering coefficient from 2004 to 2007

Figure 4 shows that the clustering coefficient averages to 0.55. In fact, many types of complex networks, especially social networks, arent entirely random network. As a community of practice, Wikipedia network shows the "people to group" features. This conclusion is obvious, according to the definition of communities of practice: the people who pay attention to certain subject, and with strong passion for this topic, increase their knowledge and skills through communicating and exchanging knowledge in this field with each other sustained[18]. Members of the community participate in editing the pages of some topics in accordance with their interests, hobbies, professional.

3.4. Small world phenomenon

Small world phenomenon reflects a kind of social network characteristics: most of the people and their friends are in the same circle of people. Many studies have shown that small-world phenomenon exists in many real networks. Small world phenomenor indicated by two characteristics: shorter average path length and higher clustering coefficient. The average path length L is the average length of all minimum number of edges connecting a pair of vertices. Because of the large calculation scale of the average path and the limitation of calculation, this study only calculates and analyzes the average distances of the 6 subnetworks: the 1st, 18th, and 35th weeks of 2004 and 2005 whose size are still relatively small, as shown in table 2.

Table 2: The clustering coefficient and average distance

	Clustering Coefficient	Average distance
04 1st week	0.5085	2.546
04 18th week	0.5020	2.745
04 35th week	0.4965	2.819
05 1st week	0.4804	2.980
05 18th week	0.4956	3.009
05 35th week	0.4991	3.191

Table 2 indicate two conclusions. On the one hand, the clustering coefficients discussed above are around 0.5, which is higher. On the other hand, the average path length is small, that is, any two people in the network can find each other through less than 4 individuals on average. Because of the shorter path between nodes, the cost of information transferring is lower than in networks with other structures. The result shows a user is easy to find an cooperator alongwith an proper path, which in turn improve the efficiency of collaboration.

3.5. Hierarchical network

Studies have shown that the topology modules in some networks are organized in accordance with Hierarchy[16, 17]. One of the most important quantitative indicators of the hierarchical Network is the dependent relationship between clustering coefficient and degree of a node obey the power-law distribution: $C_i \sim k_i^{-\beta}$. This indicates the nodes with very small degree possess high

clustering coefficient, while the nodes with high degree have lower clustering coefficient, whose role is to connect the different modules.

To test whether the on-domensional networks are hierarchy networks, we select subnet of January and March of 2004, 2005, and 2006 as representatives, shown in Figure 5. These figures show the network doesnt show obvious linear features when the network scale is small. The small scale network is consistent with the BA scale-free network characteristics and doesnt possess hierarchical topology. Furthermore, the clustering coefficient C_i shows little direct relation with the degree k_i of the node i. We see the network doesnt contain the hierarchical mechanism which is conductive to the module emergence at the early stage of the structuring process. However, when the network size increases with time, the network gradually reveals certain level of hierarchy. As the network size increases, network mechanism helps the emergence of modules.

4. The study of the wiki bipartite network

In recent years, bipartite networks have attracted more and more people's attention[18, 19, 20]. Actually, many real-world networks are naturally bipartite, such as the actors-films network[18], the Scientist Co-authorship Collaboration network[19, 20], the knowledge-cooperation network and so on.

The two-dimensional networks are bipartite network much larger than the one-dimensional networks, interacting more and collaborating more among users. Not only direct collaboration, but indirect collaboration and topic nodes are also included in this network model. Therefore, it is significant to study the two-dimensional networks of the knowledge collaboration.

4.1. The theme distribution of the user node

Topics are created and edited by users. The affiliations depicted in figure 1 demonstrate these kind of relationships. The theme degree K_t is the quantification of affiliations between the user nodes and topic nodes. For a given user node i the theme degree is a random variable, defined as:

$$K_{ti} = \sum_{j \in t_i} T_{ij} \tag{2}$$

In this definition, t_i denotes the adjacency matrix of Bt matrix of the user node i. If the user node i get involved in edting the topic j, then $T_{ij} = 1$, otherwise it is 0. The theme degree is another important quantified indicator that portrays the degree of user participating in the topic. Figure 6 presents the curves of the theme degree probability distribution in odd months of 2004-2007 under Log-Log coordinates.

Obviously, the theme distribution curve of the bipartite network is similar to the one-dimentional network, which subjects to the power-law distribution, that is:

$$P(k_t) \sim k_t^{\gamma} + \alpha \tag{3}$$

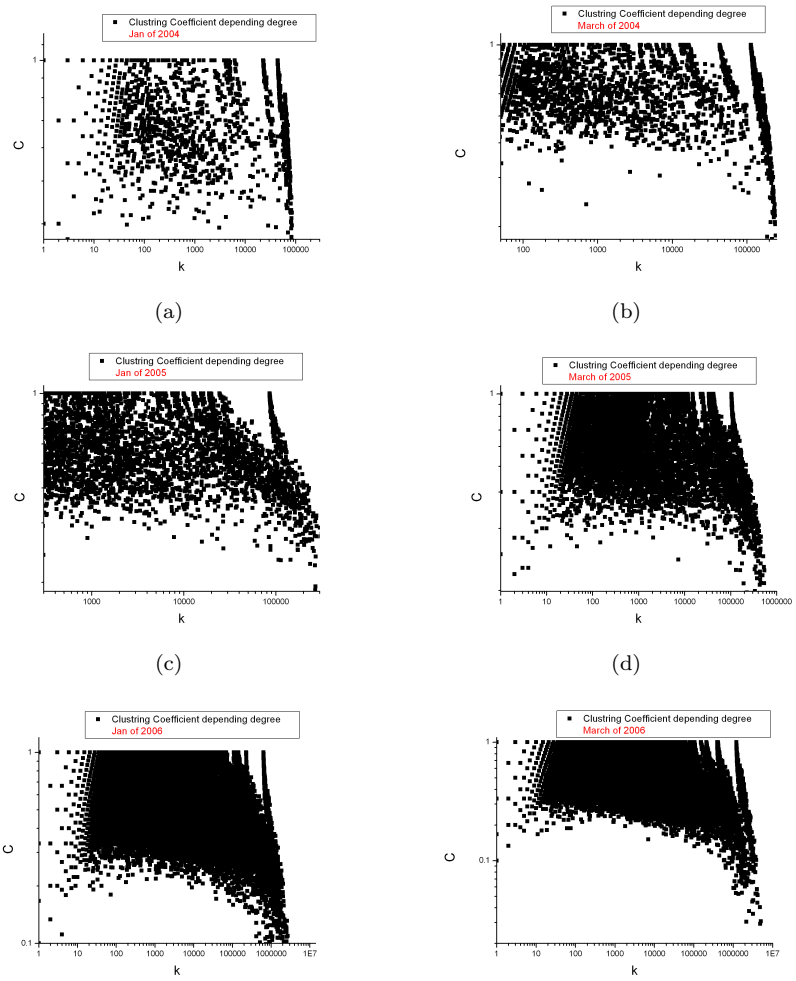

Figure 5: Relationship between cluster coefficient and degree under Log-Log coordinate

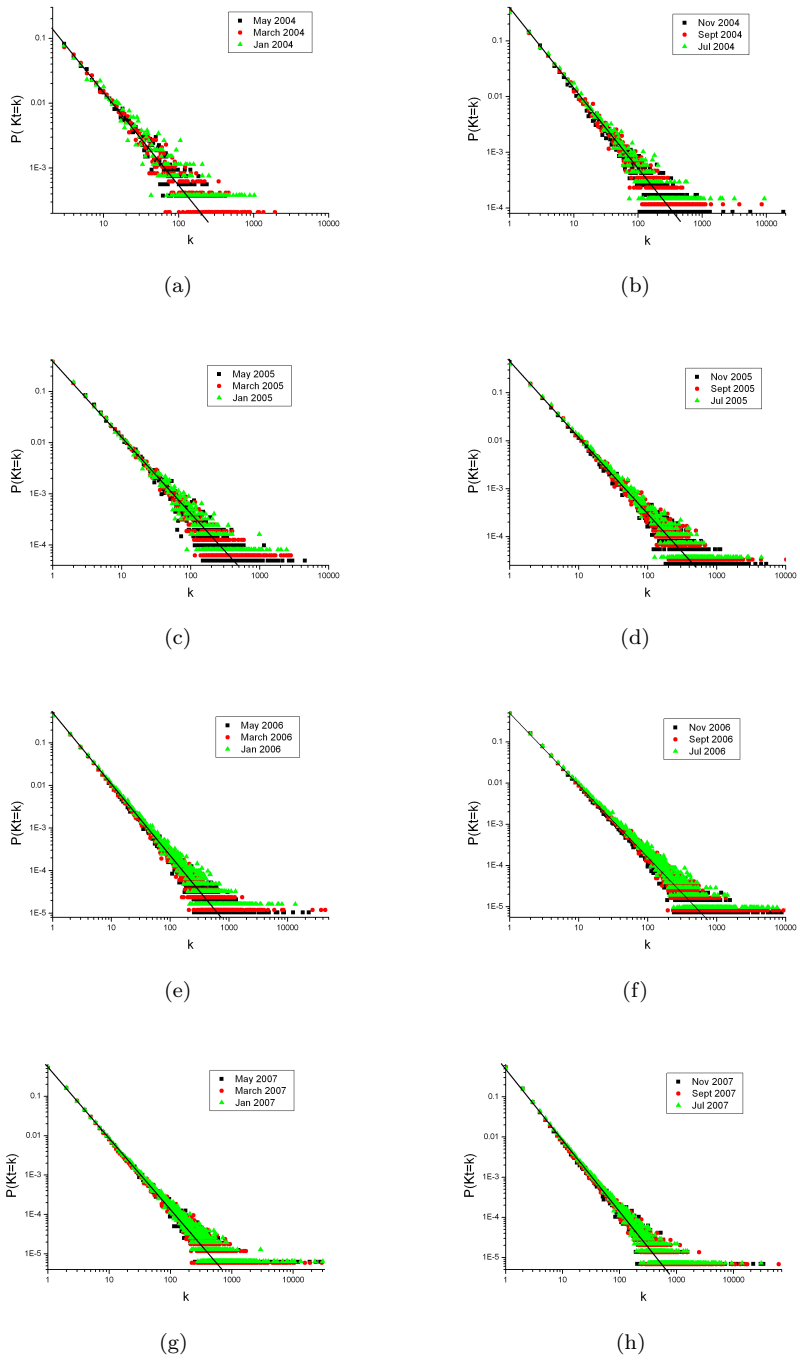

Figure 6: Distribution of theme degree in odd months from 2004 to 2007

As network size expanding, new nodes prefer to connect with those big nodes with higher degrees. This result means in a enough large network a small number of user nodes connect with a great part of themes nodes, while most of user nodes only participate in a small number of topic contribution, presenting obvious feature of the Long Tail.

4.2. The study of topic size

In the the bipartite network, besides the number of topic nodes, another important quantitative indicator is the number of user nodes of the topic nodes, which portrays the number of user nodes belonging to a certain topic node j, noted as topic node size: $s_j = \sum_{i \in t_j} T_{ij}$. t_i represents the adjacency matrix of the Bt matrix of the topic node j. If the user node i belongs to the topic node j, then $T_{ij} = 1$, otherwise 0. It is apparent that the topic size is the sum of the column vector elements in the matrix. Note the topic size as random variable T. The curves of the function $P(T = t)$ and $P(T > t)$ in Log-Log coordinates are shown in Figure 7. Here lists 8 curves of the sub-networksof every January and July of 2004-2007 in Wikipedia data.

Figure 7 shows the distribution function curve and the cumulative distribution function curve of the topic size. Obviously, the two curves in Log-Log coordinate are both Quasi-linear curves. The cumulative distribution function is exponential function, which is different from the conclusions that are drawn from the complex networks research on the reality network. Previous studies show the cumulative distribution function is described as Shifted Poisson distribution, appearing the long tail. The figure indicats the topic size scattered proportionately in a certain range for most of topics, and only a few of them have extreme large topic size. Contrary to the one-dimensional network, there are competitive relationships between the topic nodes and the user nodes, which is called the bipartite competition network.

4.3. The relationship between the network density and the scale ratio

The scale ratio W is the ratio of the number of user nodes and the topic nodes in the network:$W = N_{user}/N_{topic}$. It describes the relative value between the topic layer and the user layer of the the bipartite network. The changes curve of the scale ratio W of Wikipedia over time is shown in Figure 8. With time passing,the scale ratio W is rising gradually. When rising to 0.35, W is becoming more and more stable with slight fluctuations. Data shows that there was a downward trend in Wikipedia scale ratio after 2006. Since we exclude non-collaborating users, either no contribution or working alone, we can draw a conclusion that the increase the users and topics is in a favorite way. New users collaborate with others actively and new topics attract a goupe of users. In addition, network density has become the most commonly used measure of the network analysis. According to graph theory, the network density is used to aggregate the total distribution of various lines so as to measure the gap between such distribution and a complete graph. Sepecifically speaking, density refers

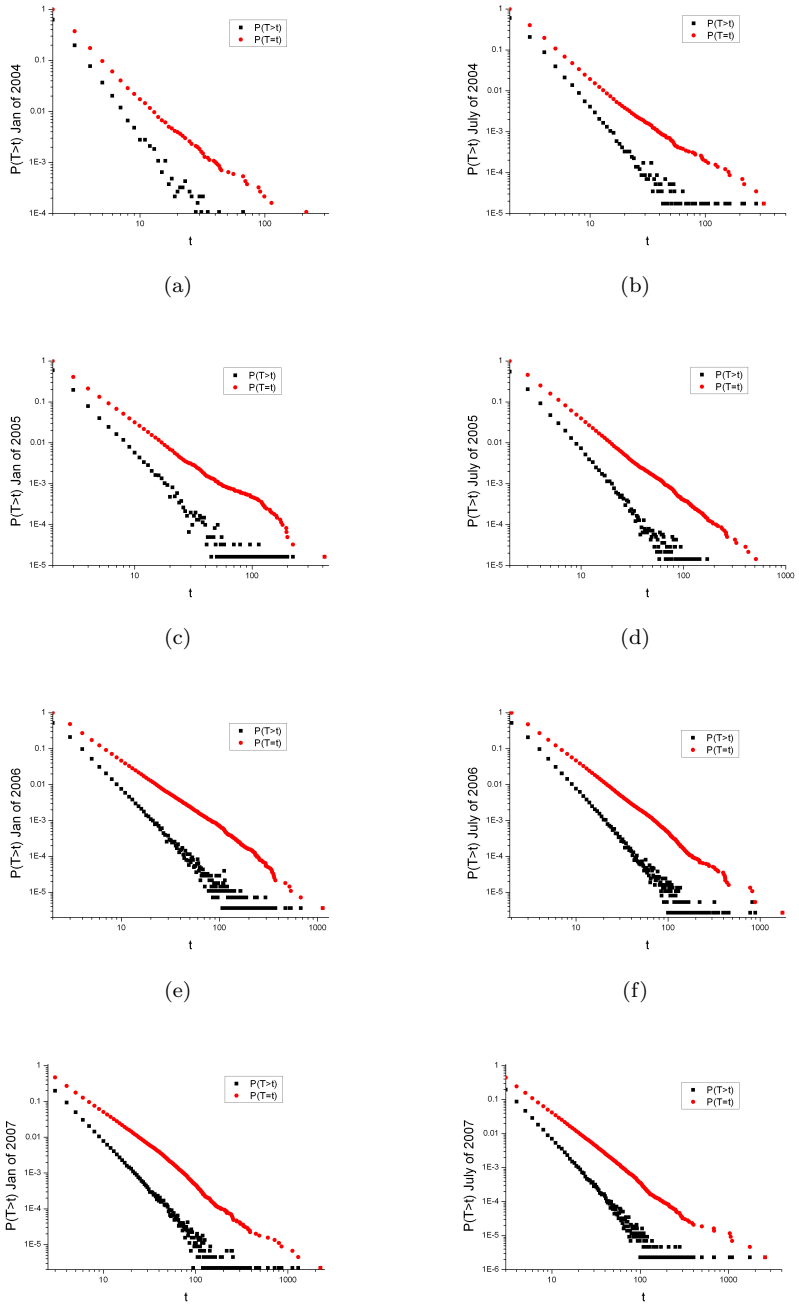

Figure 7: The topic size probability distribution in Log-Log coordinates from 2004 to 2007

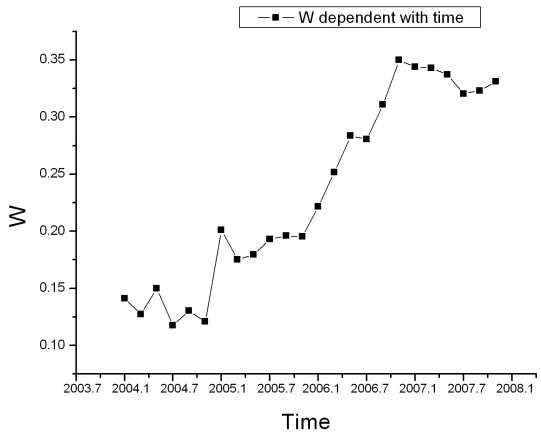

Figure 8: the changes curve of the scale ration W over time

to the close degree between various nodes of a network. In the non-oriented and absence of weight-absent networks, the density can be expressed as:

$$Density = \frac{n \times AverageDegree}{n \times (n-1)/2} = \frac{2 \times AverageDegree}{n-1} \tag{4}$$

When the topic nodes are in a certain number, the network density is smaller if the user nodes are more. When the user nodes are fixed but the number of the topic nodes increase, more links are bound to be built among the fixed users, which means that the network density is certain to grow. Figure 9 indicates the relationship between the Wikipedia density and the scale ratio. From Figure 8 and 9, it is clearly shown that there is a downward trend in the network density with the increasing of the scale ratio W which means the relative value of the number of the user nodes number and the topic nodes number increases. This is because the relationships between the user nodes are linked through the topic nodes. In order to establish more links between the users in the knowledge collaboration network, two efficient methods are efficient to keep a dense network: the first is to increase topic nodes to adapt to the user nodes increasing speed; the other is to encourage the topic contributors(users of Wikipedia), especially those more active, new topic-created users.

4.4. The relationship between the clustering coefficient and the scale ratio

In Section 3, we show the clustering coefficient fluctuates in a relatively small range. In order to thoroughly analyze the bipartite knowledge collaboration network, this article further studies the relationship between the clustering coefficient C and the scale ratio W. The clustering coefficient of the whole network can be expressed by the average clustering coefficient: $\bar{C} =$

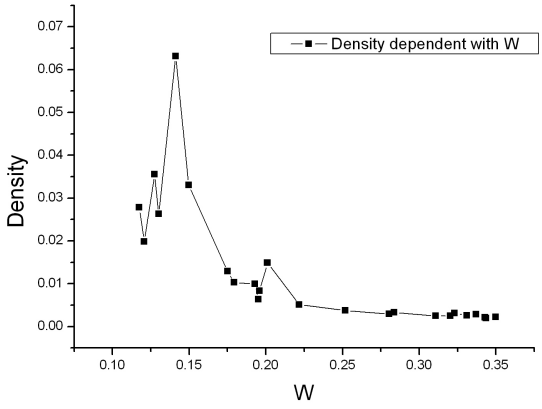

Figure 9: The relationship between the Wikipedia density and the scale ratio with the lunar cycle

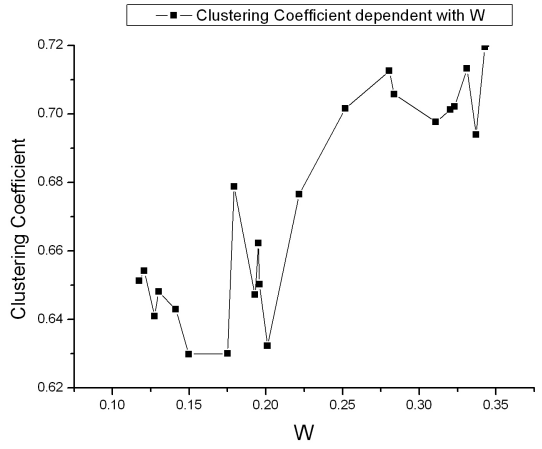

Figure 10: The relationship between the clustering coefficient and the scale ratio

$2 \times \sum E_i/k_i(k_i-1)N_{user}$. The relationship between the average Wikipedia clustering coefficient $\bar{C}$ and the scale ratio is shown in Figure 10.

With the increase of W, the clustering coefficient does not decrease, but increases slightly. Although the data is not very ideal, they are consistent with the objective network. On the one hand, the scale ratio W is not continuous, but just discrete points; on the other hand, according to the studying on the clustering coefficient in section 3, thre fluctuation is small. Such insignificant positive correlation between the clustering coefficient and the scale ratio illustrates the balanced growth between Wikipedia user nodes and the topic nodes, which is essential for the steady change of the clustering coefficient.

5. Conclusion

Analysing the interaction between users and topics is important to understand the mechanism of content collaboration behavior. In this paper, we propose a knowledge collaboration network model using Wikipedia archive data, and analyze the statistical properties of the network. We have found that the one-dimensional network of this model is a scale-free structure and its distribution function is subject to the characteristics of the power law, BA scale-free structure growth and preferential attachment. From the observation on the changes of the average degree, the number of the relationships in the knowledge collaboration network shows cyclical fluctuations, and the links tend to closer. In the one-dimensional knowledge collaboration network, with the increasing of network size, the clustering coefficient will be inclined to a non-zero constant0.65. Meanwhile, the network average distance is less than 4, which reflects that the small-world effect exists obviously in the knowledge collaboration network. At the early stage of the network development, the network doesnt possess hierarchical topology. However, when the network size increases with time, the network gradually reveals certain level of hierarchy. In addition, in the knowledge collaboration bipartite network, the theme distribution of the subject node is the same as the degree distribution of BA model of the one-dimensional network: subject to the power-law distribution and possessing the characteristic of long tail. In the one-dimensional network, the network density grows with the growing of the scale ratio, however, the clustering coefficient increases concussively, which presents an insignificant positive correlation between the clustering coefficient and the scale ratio. The limitation of this study is root from the limited data processing ability to the huge Wikipedia data. We have to select some slice the data and divided into sub-networks. The phrase change of hierachicl topology is not included in this paper neither. All will be the future research works.

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