

Characteristics of Knowledge Cooperation Network in a Design-driven Domain: A Social Network Analysis

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Abstract
The field of scientific research is currently moving from an individual and single-discipline to a more cooperative discipline that combines various researchers and their capabilities. This study uses network analysis to explore the current situation and development trend characteristics of knowledge cooperation in the design field of Decoration. We construct large-scale networks using empirical data of sampled coauthored papers from 2008 to 2016. The main aims of this paper are: (a) to disclose different patterns of networking relationships among coauthored research works in the journal of Decoration and (b), to understand the mutual interaction of knowledge cooperation across regions and units in China's field of design. The study found that the depth of knowledge cooperation in the field of design in China needed to be improved, the knowledge cooperation network also had a small-world effect, and the network community gradually emerged. In addition, the Chinese design field had made major advances in international cooperation, cross-regional cooperation, and diversification in the forms of research works. These findings could be used to recognize interdisciplinary and intra-disciplinary networks where research collaboration is supported and encouraged. However, there were still problems such as imbalanced levels of knowledge output among the groups.
Keywords: design field; knowledge cooperation; social network analysis; decoration; small-world effect

1. Introduction

There has been a rise in the number of articles published worldwide by academic scholars in recent years. These published works range in different scientific areas, however, those the performance of those involved in these scientific publications has transformed over time (Parreira et al, 2017).

The independence of China's design discipline became the first-level discipline in 2012 with an indication that the discipline had achieved notable achievements in subjects like construction, personnel training, professional development, international exchanges and integration, and mapping of China's design from within. Even though the field of design is acknowledged to be undeveloped and fairly novel, it is nonetheless a discipline that is now emerging and being highly regarded (Jiang, 2013).

In China, product, graphics, and industrial design are being considered a modern discipline, but their current advancements essentially have no direct connection with Chinese customs in these fields. The growth of design through the previous century has been more influenced by the West.

Many scholars from universities and research institutes have become an important force in promoting the growth of China's design discipline. Wang Yuan rethought the design activities from the practice link (Yuan,

2010). Li Dongjin et al. conducted a deep deconstruction of the mechanism of consumer aesthetic experience in the product design field from three directions of neuroscience research, emotional response process and information processing model (Li et al, 2013). Li Pengbin and Zhang Zhe conducted an in-depth discussion on the inevitability, possibility, and development trend of artistic design (Li & Zhang, 2015). Wang Hongjiang focused on Virginia Polytechnic Institute of Architecture and Design and analyzed the path and significance of the integration of professional courses and basic courses in design disciplines (Hongjiang, 2016). Lu Mingyue conducted an in-depth research on the integration of design fields and anthropology (Mingyue, 2016). Xue Chengcheng believes that innovative creative talents in the field of design continue to emerge (Chengcheng, 2016). From the researches that were conducted above, it was, therefore, necessary to explore a new talent training path.

1.1. Social Network Analysis (SNA) Methods

In the 1930s, scholars began to pay attention to social network relationships, but it was not until the 1970s that the concept of social network analysis was actually proposed (Scott, 2017). "Social network" refers to the collection of social actors and the associations between them. Social actors can be individuals, groups, organizations, countries etc. Social network analysis concentrates on the forms of interaction between social actors and other subjects (Jun, 2009).

Social networks analysis can be attained by analyzing the structural characteristics of the network. We can categorize the key features of social networks as the operators and their connections (Oinas-Kukkonen et al, 2010).

Social networks analysis is an extensive strategy which is used to study the study social structure (Otte & Rousseau, 2002) and is also used to gain patterns of relationships between the nodes that determines the underlying social structure (Qi et al, 2012). SNA assimilates narrative data analysis while it provides ways of examining the relationship structure among its variables. This adaptable method will be particularly useful because it provides not only a possibility to analyze the specific links authors have with one another but with other variables (McKether & Friese). Additionally, one of the main purposes of SNA is to recognize the core actors in a network (Zhao & Zhao, 2016) and to find and construe patterns of social ties amongst actors (Doreian et al, 2005). The act of SNA in research has increased lately because the subject plays a significant role in numerous disciplines (Butts, 2008). Network analysis allows the study of the characteristics of associate in the fields of knowledge, as well as the existing linkages between the most essential and most prominent authors within the discipline.

Currently, many scholars have applied social network analysis approaches to the research of interdisciplinary cooperative groups (Otte & Rousseau, 2002). For example, Jozsef et al. conducted a social network analysis of scientific articles published by food policy highlighting the principal researchers in the field of food policy together with their citation and authorship networks on the foundation of 714 articles written between 2006 and 2015 (Popp et al, 2018). Niu & Qiu used social network analysis methods to study the author's cooperation relationship in the field of metrology in China, revealing the author's cooperation relationship and knowledge flow rules within the discipline (Niu & Qiu, 2014).

The rest of the paper is organized as follows. After the introduction, section 2 gives a brief literature of various research work conducted in the field, section 3 explains the research methods and data sources used for this research. The analysis and discussions are presented in section 4 and 5, then section 6 concludes with some recommendations.

2. Literature Review

Presently, many scholars, especially around the world, have done some research on the field of design, amongst them Zhou Zhichao used social network analysis approaches to quantitatively study the citation relationships among 15 highly cited authors in the field of knowledge mapping in China, revealing the development trend and research status (Zhichao, 2012). Li Aiming applied social network analysis methods to visualize the author's cooperative relationship in the field of digital libraries in China, and based on this provided a certain reference suggestion for knowledge exchange and cooperation between authors (Aiming, 2013). Peng Xiwei et al. used social network analysis approaches to construct the author cooperation relationship in the field of social computing, and summed up four cooperation models: sustainable development model, dual-core model, complete model, and bridge model (Peng Xixi et al, 2013). Xu Yingying et al. conducted an in-depth investigation of the research hotspots in the field of open access in China, based on the co-occurrence examination of key themes and social network analysis methods, and revealed the development trends and research hotspots of China's open access field from multiple angles (Xu Yingying et al, 2014).

2.1. Coauthor Network

Coauthor networks can be defined as a kind of social network which has been thoroughly studied, especially in

the multifaceted networks field (Butts, 2008; Doreian et al, 2005; Newman, 2001a; b). The discipline in coauthorship networks has been studied in diverse fields by various network researchers (Kot & Grabara, 2017; Leicht et al, 2007; Newman, 2006; Shi et al, 2009). Coauthorship in research works is said to be one of the most understandable and well-known forms of collaboration networks (Glänzel & Schubert, 2004), is built on the measurement of social understanding of different authors (Koopman et al, 2015). Cooperation networks studies can form clusters on coauthorships that are based on their identity and the "unseen community" within a field (Zhao & Zhao, 2016).

About 70 years ago most research works were conducted by individual academic scholars publishing single-authored articles but this practice has changed drastically in recent times. The number of coauthored articles stated increasing since 1950 where at that time the percentage number of coauthored articles were only 8% in the Journal of American Economic Review, the number to 55% in 1993 (Hudson, 1996) and in 2014 the number rose to 81%. Consequently, in the 1980s (McDowell & Melvin, 1983) posited that the percentage of coauthored articles in the field of science increased from less than 5% to more than 30% between 1946 and 1976. As a result of the changes in the trend towards coauthorship, academic attention in collaboration works has increased among many researchers (Barabâsi et al, 2002; Katz & Martin, 1997; Laband & Tollison, 2000; Moody, 2004; Newman, 2001b). Nowadays, the design field has become more accessible than it was previously and because of globalization, there is a particularly growing interest in collaboration in the field of design. This collaboration can be seen in different ways (e.g., academic research works, research projects, publications in peer-reviewed journals or in conference papers). (Cabanac et al, 2015), stated that collaboration is mostly influenced by geographical locations, technological advances and the similarity of the actual research topics.

The differences between research fields could mean that there will be differences in variables related to citations (Slyder et al, 2011), thus, other similar factors could come up. These assumptions are consistent with (Tahamtan et al, 2016) and include the number of pages in an article (Mingers & Xu, 2010), the number of coauthors (Chung et al, 2009; Vieira & Gomes, 2010). When a researcher publishes together with their colleagues, they can establish a collaboration network, hence, a suitable picture of the relationships between individual author and coauthors can be attained after the analysis of such networks.

The differences between potential coauthors and their divergent motivations for undertaking and developing sustainable international and regional cooperation are important issues in terms of the prospects for these collaborations (Castanho et al, 2017). It is true that the harmonization of international and cross-regional collaboration is the primary result of improving its key factor, which is people and higher education and research institutions in which all the factors are related to the partnership (Kurowska-Pysz & Szczepańska-Woszczyna, 2017). In addition, there have been several studies that have sought to determine the measurement of collaboration performance (Yoon et al, 2017).

Research works in the knowledge cooperation networks are usually formed around prominent researchers. These researchers typically work as a pivot in enticing numerous researchers from several research institutions and universities (Cabanac et al, 2015). According to (Katz & Martin, 1997), research cooperation increases research quality. Narin et al. (Narin et al, 1991) found out that internationally coauthored papers can result in twice as many citations as single-authored ones. Sooryamoorthy (Sooryamoorthy, 2009) on the other hand, also discovered a positive and significant connection between the number of citations and the number of coauthors linked to articles published by South African scientists.

Previous studies have revealed that knowledge cooperation with coauthorship produces a much-advanced research impact than a single researcher in terms of the number of articles (Gazni & Didegah, 2011; Lee & Bozeman, 2005; Sooryamoorthy, 2009). The reason could be that a single researcher may not be able to mobilize all the funds required for performing research (Kling & McKim, 2000).

Coauthorship network study can be used to identify the position of an author in the knowledge cooperation network. This might offer important information on the researchers' own contribution to the research output. In combination with the K-core analysis, this helps to clarify details on the extent of the surveyed researcher's real contribution to the research output shared by themselves and the achieved citation impact of these publications (Glänzel, 2014). The distance between the connections across the communities signifies the fact that most of the journals which belong to the same community tend to cite the same publications inside their community, and seldomly reference articles from other communities (Onel et al, 2011).

According to (Acedo et al, 2006), high-quality publications are needed to develop a personal researcher career, thus, when a researcher publishes together with their coauthors, they create a unique and individual coauthor network. Knowledge cooperation network includes all those researchers who have in one way or the other added their own knowledge to the common database meaningfully and on quality during the creation of the article. Studies have indicated that knowledge cooperation makes the research achievement of the coauthors better and more effective (Gazni & Didegah, 2011).

Presently, China's related researches in the field of design have mainly focused on theoretical analysis, making the empirical researches relatively very rare. Moreover, there is not much research on the connection

between cooperative groups in the development of the design field.

Therefore, this article takes journals in the field of Decoration as an example, uses social network analysis approaches to empirically study the characteristics of its knowledge cooperation network, and tries to discover the relationships amongst the groups in the field of design by providing the knowledge cooperation and knowledge flow in the field of design in China.

3. Research Methods and Data Sources

3.1 Sample Selection and Data Sources

The objective of this paper is to study the cooperative network characteristics of journals in the field of Decoration. The data samples are coauthored papers taken from 2008 to 2016. "Decoration" is a well-known journal in the field of design which reflects the development status and trends in the field of design in any country and has a certain degree of representation. For example, Cao Zhipeng and Pan Qiliang used the coauthored paper in 2014 as research samples to study the status of scientific research cooperation among Chinese universities (Cao Zhipeng & Qiliang, 2017). A study conducted by Hu Xiaohui and Du Debin et al. studied the evolutionary characteristics of the knowledge cooperation network in the Yangtze River Delta region using the coauthors of the 16 regions of the Yangtze River Delta (Hu Xiaohui et al, 2012); Huang Wei and Hu Pingping studied the spatial characteristics of the evolution of the knowledge cooperation network in the field of educational economics in China by using the authors of the CSCI Journal of School of Economics as the research sample (Huang Wei & Pingping, 2016). Tian Ruya and Sun Li et al. also used coauthored papers in CSCI journals to analyze the characteristics of knowledge cooperation in the fields of library and information in China (Tian Ruya et al, 2016).

Compared with the above disciplines, knowledge cooperation in the field of design is not only accomplished in the form of paper coauthorship but also have knowledge collaboration design works in the field. The CNKI database collects all forms of works in journals under “Decoration”, therefore, this article adopts the coauthored papers in journals of Decoration or other forms of design work from 2008 to 2016 (the following will be unified with other forms of design works). All the data in this paper comes from the CNKI database. (Visit address: http://www.cnki.net/)

3.1.1 Definition of terms

- Distance = the distance of the shortest path that joins two actors.
- Density = entire number of related bonds divided by the total likely number of related bonds.
- Components and cliques estimate characteristics of network subgroups.
- A component is a share of the network in which all actors are linked, either indirectly or directly.
- A clique is a subgroup of actors directly linked to each other, and none of the other member of the network is linked to all members of the subgroup. Clique study is the most familiar techniques used to categorize dense subgroups within a network.
- Centrality measures detect the most protuberant actors within a network. It can be theorized as either global or local. Global centrality signifies the number of indirect and direct bonds of a specific node while, local centrality means the direct bonds a particular node has.
- Centrality is estimated in terms of degree or betweenness. Betweenness signifies the number of periods an actor links different subgroup of a network that would otherwise not be linked.
- Degree centrality signifies the summation of all actors that are directly linked to an ego.
- The overall centralization estimate signifies how tightly a graph is prearranged around its most central point.

4. Analysis of Cooperation in Works

The statistics from the journals of “Decoration” from 2008 to 2016 showed that (see Table 1), before 2012, the rate of coauthored papers fluctuated, indicating that the overall knowledge cooperation between authors was unstable at that stage. In addition, the cooperative author's level of knowledge output was also unstable, resulting in fluctuations in the coauthorship rate. After 2012, the coauthorship rate of the works gradually increased until it reached 34.87% in 2016. This indicates that the frequency of knowledge cooperation and the output of cooperative authors’ knowledge in the field of design works had increased in the past five years. In addition, since 2008, the cumulative coauthorship rate of work had always been on the rise, indicating a good development trend in the overall knowledge cooperation in the design field.

Table 1 Coauthorship

Years	Coauthored works (Article)	Total number of works (Article)	Coauthoring rate（%）	Accumulated total number of works (Article)	Total number of works (pages)	Accumulated coauthoring rate (%)
2008	118	786	15.01	118	786	15.01
2009	137	629	21.78	255	1415	18.02
2010	122	642	19.00	377	2039	18.49
2011	162	701	23.11	539	2740	19.67
2012	156	696	22.41	695	3436	20.23
2013	147	653	22.51	842	4089	20.59
2014	156	672	23.21	998	4761	20.96
2015	169	643	26.28	1167	5404	21.60
2016	235	674	34.87	1402	6078	23.07

Table 2 displays the number of authors of each article in the journal of Decoration. The number of coauthored works with the highest number was 2, with 1,086 number of works. The proportion of total works was 77.47%. The other works with a significant proportion were 15.42% and 3.93%, respectively, while the number of works whose number of coauthors was more than five was only 3.18% of the total works. The number of coauthors within the single number of works was small. Combining with Table 1, we notice that the breadth of knowledge cooperation in the design field was increasing yearly, but the number of knowledge cooperation partners in a single work was relatively low. In the future, the design field should focus on rising the number of coauthors of a single work and enhance the knowledge cooperation of a single work.

Table 2 Number of Authors in the Journal of Decoration

Number of coauthors (a)	Number of works (Articles)	Proportion (%)
2	1086	77.47
3	216	15.42
4	55	3.93
5	8	0.58
6	13	0.94
7	10	0.72
8	7	0.50
9	3	0.23
11	1	0.07
13	1	0.07
15	1	0.07
Total	1402	100

4.1 Core Author Group Analysis

Due to many coauthors in the design field, the overall network was more complex, and it was more difficult to highlight the key points hence inconvenient for analysis. It was, therefore, compulsory to screen the coauthors to determine the core author group. Rips' law is the most frequently adopted theoretical basis for the selection of core authors in the academic community. According to Rips' law, the number of high-yielding authors who write half of all papers is equal to the total square root of all authors.

The mathematics quantification formula for the law is $\sum_{m+1}^{i} n(x) = \sqrt{N}$: where *i* is the highest number of works published by the producer, *m* is the minimum number of works published by the core author, *n*(*x*) is the number of authors writing *x* works, and *n* is the total number of authors (Qiu Junping & Guohui, 2014). The entire number of authors of the journal of Decoration from 2008 to 2016 was 4,237, and it was thus considered that there were 65 high-yield authors in the design field, that is, the number of published works was 6-7.

Based on the complete analysis, this article selects authors with 6 or more published works as the research objective. A total number of 77 core authors was considered, however, to meet the criteria of the core authors 10 independent authors were removed, thus bringing the final number to 67 core authors. To boost the purity of academic research, all core authors and other non-core authors used codes. See Table 3 for the core author code and the number of published works.

Table 3 Core Authors Table

The author	Number of works	The author	Number of works	The author	Number of works	The author	Number of works	The author	Number of works
X1	158	X15	20	X29	9	X43	7	X57	6
X2	118	X16	18	X30	9	X44	7	X58	6
X3	73	X17	17	X31	9	X45	7	X59	6
X4	57	X18	15	X32	8	X46	7	X60	6
X5	56	X19	15	X33	8	X47	7	X61	6
X6	52	X20	13	X34	8	X48	7	X62	6
X7	51	X21	13	X35	8	X49	7	X63	6
X8	49	X22	12	X36	8	X50	7	X64	6
X9	49	X23	12	X37	8	X51	7	X65	6
X10	49	X24	10	X38	8	X52	7	X66	6
X11	40	X25	10	X39	8	X53	7	X67	6
X12	36	X26	9	X40	8	X54	7		
X13	35	X27	9	X41	8	X55	6		
X14	33	X28	9	X42	7	X56	6		

4.2 Network structure characteristics analysis

In order to further explore the law of knowledge cooperation in the design field and the knowledge radiating effect of core authors, this article collates the core authors of the journal of Decoration between 2008 and 2016 and concluded that the core author and the non-core authors had a cooperative relationship. The knowledge cooperation matrix and visual analysis were obtained using UCINET software (see Figure 1 and Figure 2).

According to the visual network diagram, the cooperation network of the authors in the design domain presents the characteristics of small groups. That is, the entire network consists of several small group networks. The knowledge cooperation network within each small group is more complicated, and the knowledge cooperation network between different groups was sparsely different. Small groups often had one or more authors with higher centrality (in a centrally processed network graph, the larger the node, the higher the node's centrality), suggesting that these small groups were all around one group or that, more core members were formed, or there were close knowledge cooperation relationships among members of the group. In order to precisely measure the structural features of the knowledge cooperation network in the design domain, this paper figures out the structural parameters of the knowledge cooperation network in the design domain (see Table 4). From Table 4, it is notices that the knowledge cooperation network structure in the design domain exhibits the following characteristics:

(1) The scale of knowledge cooperation was large, hence the necessity for the depth of knowledge cooperation to be strengthened. The number of network nodes represents the number of principals of the knowledge cooperation network. As can be seen from Table 4, the number of knowledge cooperation network nodes was 415, indicating that from 2008 to 2016, 415 authors including core authors conducted close knowledge cooperation. The knowledge cooperation network reflecting the design field had already reached a certain scale. However, the overall network's network density was only 0.0145, which indicated that the overall knowledge cooperation network was loose, and the knowledge cooperation among network members lacked certain systematisms and interaction. From another perspective, however, a closely-connected network not only provides individuals with various resources but also becomes an important force that restricts their development (Jun, 2009). Therefore, the sparse network had fewer restrictions on internal members of the network. In other words, the overall density of the knowledge cooperation network was relatively small, indicating that the internal members of the network were not closely related to each other. Therefore, members had greater potential for knowledge cooperation and space; and members within the network would not have a strong formation. The knowledge-based cooperation path was dependent, and this also reflects the fact that the knowledge cooperation network in China's design field still had a large space for development. The average weight value at the edge of the network indicated the average number of collaborative works between different authors, and also reflected the depth of knowledge cooperation and knowledge exchange between authors. From Table 4, we could see that the average weight value of the network edge was 1.22, indicating that the average number of knowledge cooperation among the internal network members was 1.22 times, which suggests that the number of knowledge cooperation among some authors in the design field was small, with occasional and unstable characteristics. In the future, the design field should actively enhance the depth of knowledge cooperation among internal members of the network and promote the formation of long-term and stable knowledge cooperation among different members, thereby further enhancing the stability of the overall network. Combined with the

visual network diagram, we notice that the average number of knowledge collaborations in the design field was closely related to the network structure characteristics of the small groups. The small groups in the design domain knowledge cooperation network were often formed around one or a few core authors within the group rather than the core thus, there was less knowledge exchange between authors. On one hand, this kind of network structural characteristics leads to a smaller depth of knowledge exchange in the overall network and also makes small groups more dependent on core members. Therefore, the knowledge cooperation within small groups had extreme instability. In the future, the design field should also focus on the knowledge exchange within the small group of the author while expanding the scale of knowledge cooperation and enhance the importance of non-core authors in the small group network, thereby strengthening the stability of small groups of knowledge cooperation.

(2) It has a small-world effect. The small-world effect has the following characteristics: the network is sparse, decentralized, and the entire network is highly clustered. From the visual network diagram, it can be judged that the knowledge cooperation network in the design domain had small-world characteristics. However, for the sake of accuracy, this paper formalizes the small-world spectacle of the knowledge cooperation network in the design domain. The clustering coefficient and feature path length are the main variables used to measure the small-world effects of the network. If the average distance of a network is short (not more than 10) and the clustering coefficient is high, then the network can be considered to meet the small-world effect (Watts & Strogatz, 1998). From Table 4, we can see that the average distance of the knowledge cooperation network in the design domain was 3.596 (smaller than 10) and the clustering coefficient was 0.807. The network had a small average distance and a high clustering coefficient, so the network had the characteristics of a small-world network. This shows that the speed of information transfer within the knowledge cooperation network in the design domain was relatively fast. Some authors can quickly obtain information through knowledge cooperation with other entities and convey and spread it to other authors. Small-world networks play a vital role in promoting knowledge transfer and knowledge diffusion in the field of design.

(3) The group is more noticeable. According to the visual network diagram, the knowledge cooperation network in the design domain is composed of multiple small group networks, which reflects that there are multiple condensed subgroups in the network. K- core analysis is a condensed subgroup analysis method based on the degree of power. If all points in a network graph are at least adjacent to K, the network graph is called K-nucleus. From Table 4, we notice that the utmost number of K-cores in the network was 16. This indicates that small groups of knowledge cooperation networks in the field of design have been formed, and the corporate nature of the network was gradually being highlighted.

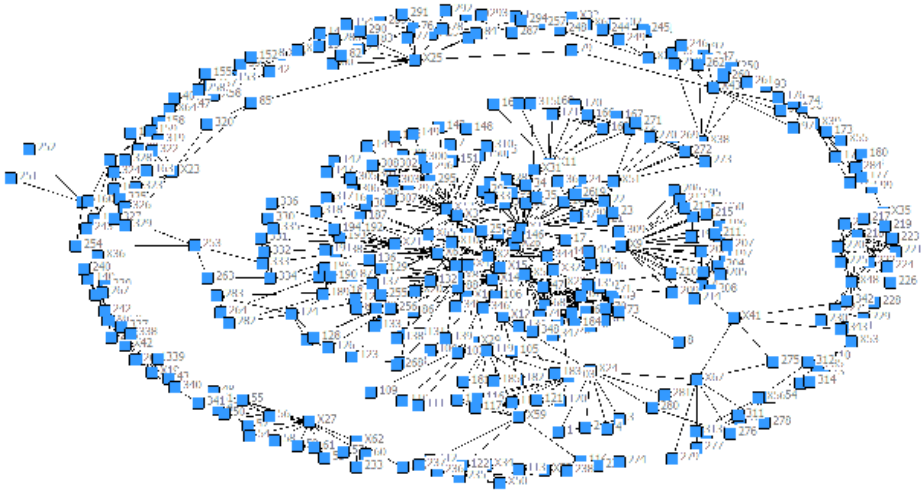

Figure 1 Knowledge cooperation network in the design field

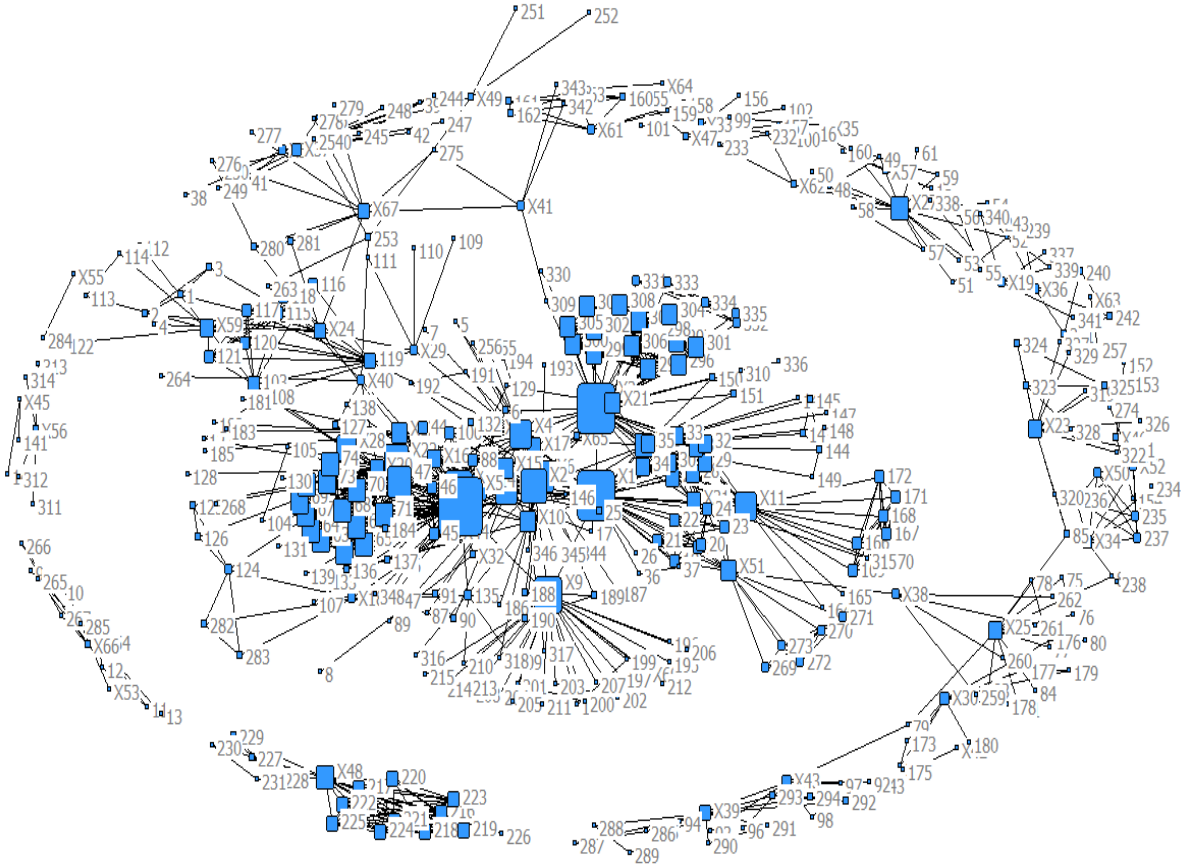

Figure 2 Knowledge map of collaborative design in a centrally managed design domain

Table 4 network structure parameter table

Variable	Value
Network density	0.0145
Number of network nodes	415
The average weight of network edge	1.22
Clustering coefficient	0.807
The average distance	3.596
Maximum number of K-cores	16

5. Network Membership Analysis

With the aim of understanding the laws and characteristics of knowledge cooperation among different members within the network, this paper studies the characteristics of knowledge cooperation network members in the design domain from three aspects: centrality measure, structural hole measure, and small group analysis.

5.1 Centrality measure

In the knowledge cooperation network, if there is a continuous knowledge cooperation relationship between an author and other authors, then the author resides in the center of the knowledge cooperation network. The higher the relative degree is, the more the author's power and influence are greater in the network. The relative point centrality is calculated as $C(n_i)=\frac{d(n_i)}{n-1}$, where: C ($n_i$) represents the relative degree of the center of the node n_i, n is the overall number of nodes, and d (n_i) represents the absolute degree of the center of the node n_i, where the calculation formula is: $d(n_i)=\sum_j X_{ij}$, $X_{ij}=0$ (if node n_i and n_j are not directly abutting), X_{ij}=1 (when node n_i is directly abutting to n_j).

According to Table 5, the authors of the top three relative degrees of centrality are X2, X5, and X1, and the

relative degrees of their center of degrees are 1.691, 1.515, and 1.252, respectively, indicating that the above authors have the highest power and influence in the network. It also reflects the highest number of authors engaging in direct knowledge cooperation with them. The authors above have the most significant direct knowledge dissemination and diffusion in the network.

Table 5 Centrality Measurement Table

Rank	Author number	Degree	Centrality of degree
1	X2	77.000	1.691
2	X5	69.000	1.515
3	X1	57.000	1.252
4	X9	55.000	1.208
5	X3	45.000	0.988
6	X8	45.000	0.988
7	X7	42.000	0.922
8	X4	42.000	0.922
9	X6	39.000	0.856
10	X14	35.000	0.856

5.2 Structure Hole Measurement

Structural holes refer to the non-redundant links between two actors. Structural holes provide opportunities for their occupants to obtain “information benefits” and “control interests,” and thus have advantages over other members of the network (Burt, 2009). The measurement indexes of structural holes mainly include effective scale, efficiency, the degree of limitation, and degree of hierarchy. Among them, the larger the effective scale and efficiency value, the greater the influence of this point in the network; the degree of restriction reflects the node and other nodes. The freedom and irreplaceability of inter-connections are also the most accurate indicators for estimating the number of holes in the network structure. The smaller the degree of restriction, the more positions the node occupies in the network; the degree of hierarchy means restrictive. (Bin, 2016).

From Table 6, we can see that X5, X1, X3, and X9 have the largest effective scale, indicating that the above authors occupy the most effective factors in the knowledge cooperation network. Combined with the measure of centrality, it is observed that the above authors have comparatively high relative degrees of centrality, suggesting that the above authors have a greater influence in the knowledge cooperation network. The efficiency of a node is comparable to the ratio of the effective size and the actual size of the node. The efficiency values of X29, X33, X35, X38, X42, X45, X46, X47, X53, X55, X56, X63, and X64 are both 1, indicating that the author's effective size is equal to the actual size. The degree of restriction can directly reflect the core author's ability to use structural holes in the knowledge cooperation network. From the table, it can be known that the limits of X9, X5, X1, X3, and X8 are the smallest, indicating that the above members occupy the largest number of structural holes in the network. The limitations of other authors act as a "bridge" of knowledge cooperation between many authors in the network, controls the core resources of the network, and can act as a vital role in knowledge linkage and transmission in the network. Additionally, it can be observed from the restriction degree distribution that there are many structural holes in the knowledge cooperation network in the design domain, indicating that there are additional authors who have different degrees of control over knowledge cooperation and knowledge diffusion within the network. Most knowledge information in the network requires to be passed by them. This is the part where the author can directly control the direction and speed of knowledge dissemination within the network. The ranks of X35, X42, X53, X55, X60, X63, and X64 are the largest, indicating that the above-mentioned core authors have the most significant limitations of other authors.

Table 6 Structure Hole Table

The author	Effective scale	effectiveness	Restriction	Hierarchy	The author	Effective scale	effectiveness	Restriction	Hierarchy
X1	29.378	0.794	0.074	0.015	X35	1.000	1.000	1.000	1.000
X2	18.440	0.738	0.092	0.047	X36	3.800	0.760	0.413	0.061
X3	28.568	0.772	0.076	0.019	X37	6.714	0.959	0.194	0.040
X4	12.789	0.673	0.106	0.036	X38	5.000	1.000	0.200	0.000
X5	33.047	0.769	0.070	0.025	X39	7.667	0.852	0.270	0.002
X6	17.870	0.777	0.091	0.019	X40	4.667	0.778	0.276	0.020
X7	13.421	0.706	0.111	0.028	X41	4.600	0.920	0.259	0.038
X8	21.741	0.805	0.080	0.031	X42	1.000	1.000	1.000	1.000
X9	25.385	0.976	0.056	0.031	X43	7.750	0.969	0.164	0.036
X10	8.846	0.680	0.130	0.027	X44	1.000	0.143	0.350	0.001
X11	12.053	0.634	0.152	0.012	X45	2.000	1.000	0.500	0.000
X12	10.000	0.714	0.122	0.032	X46	3.000	1.000	0.333	0.000
X13	12.867	0.858	0.126	0.030	X47	3.000	1.000	0.333	0.000
X14	10.294	0.606	0.137	0.022	X48	9.875	0.617	0.195	0.012
X15	5.308	0.408	0.171	0.019	X49	3.500	0.875	0.363	0.043
X16	4.167	0.347	0.184	0.012	X50	1.000	0.200	0.597	0.000
X17	7.909	0.719	0.145	0.022	X51	8.571	0.612	0.218	0.009
X18	4.333	0.722	0.363	0.005	X52	2.667	0.444	0.455	0.029
X19	4.600	0.920	0.300	0.050	X53	1.000	1.000	1.000	1.000
X20	10.167	0.847	0.151	0.022	X54	4.600	0.920	0.300	0.050
X21	11.000	0.786	0.148	0.039	X55	1.000	1.000	1.000	1.000
X22	7.667	0.365	0.172	0.012	X56	4.000	1.000	0.250	0.000
X23	11.167	0.931	0.148	0.039	X57	2.333	0.778	0.611	0.052
X24	7.667	0.852	0.219	0.036	X58	4.600	0.920	0.300	0.050
X25	10.636	0.967	0.132	0.034	X59	7.167	0.597	0.235	0.026
X26	3.889	0.432	0.251	0.020	X60	1.000	1.000	1.000	1.000
X27	14.333	0.956	0.122	0.021	X61	4.000	0.667	0.396	0.054
X28	2.882	0.170	0.198	0.007	X62	2.333	0.778	0.611	0.052
X29	6.000	1.000	0.167	0.000	X63	1.000	1.000	1.000	1.000
X30	7.500	0.938	0.203	0.037	X64	1.000	1.000	1.000	1.000
X31	2.818	0.256	0.247	0.011	X65	1.500	0.375	0.313	0.000
X32	2.333	0.778	0.348	0.000	X66	2.333	0.778	0.611	0.052
X33	3.000	1.000	0.333	0.000	X67	7.889	0.877	0.202	0.047
X34	4.143	0.592	0.362	0.045					

5.3 Core Authors Small Group Analysis

According to the features of the network structure, the maximum number of K-cores in the knowledge cooperation network in the design domain was 16, and the corporate nature of the network had emerged. In order to further accurately analyze the characteristics of small group members in the network, this paper uses the factional analysis function of UCINET software to analyze the core authors' small groups. When the smallest number of nodes is set to 2, and the maximum number of distances is 2, six small groups can be obtained.

Group 1 includes two authors, X27 and X62, all of whom are from the School of Digital Media at Jiangnan University. The key themes of the cooperative works include urban public art and digitalization. From 2008 to 2016, the author group published a total number of 14 works, of which 11 were collaborative works. The coauthoring rate was 78.57%, indicating that the author group was more inclined in cooperation with other authors. In addition, the number of knowledge cooperation within the two author groups was only once, and the number of knowledge collaborations with other authors outside the group was 10, indicating that the author group had a strong knowledge diffusion and radiation functions and could drive the knowledge of other authors outside the group.

Group 2 includes three authors X34, X50, and X52. All of them were from the Xinjiang Normal University's Academy of Fine Arts. The theme of the collaborative works was to study the native culture and raw soil architecture. The author group published a total number of 21 works from 2008 to 2016, but only 5 of them were cooperative works, and the coauthoring rate of the works was 23.81%. Compared with group 1, the authors of group 2 were more inclined to be independent and less knowledgeable in communication with other authors. Such an authoritarian group tends to severely reduce the number of knowledge cooperation in the field of design,

hindering knowledge transfer and knowledge diffusion in the field. In addition, the depth of cooperation among internal members of such author groups was relatively small, and the number of knowledge cooperation between groups and external authors was also relatively small. The entire group was relatively close, which was not conducive to the inflow of external knowledge information, and it was not conducive to the internal knowledge information of the group.

Group 3 mainly consisted of five authors: X12, X24, X29, X41, and X67. They came from four universities: Tsinghua University, Beijing Technology and Business University, Beijing Jiaotong University, and the Delft University of Technology in the Netherlands. The themes of the works included the Chinese and Western Design Art Review with the growth of Chinese and foreign design art research and many other aspects. The author group published a total number of 61 works from 2008 to 2016, among which 35 were collaborative works, and the coauthoring rate was 57.38%. Compared with group 1 and group 2, the most significant feature of this group was the internationalization of author cooperation and research themes. The group's authors were from four universities in China and abroad. This reflects that China's design field has started to cooperate with foreign countries in related fields, and also in the research topics as well which also involves differences and integration of Chinese and Western art and design in knowledge cooperation models. Not only can the elimination of the barriers of knowledge exchange brought about by the differences between traditional, geographical and cultural backgrounds, but it can also encourage China's design community to actively absorb advanced Western design knowledge and promote the essence of Chinese design fields to jointly promote the development of China's design disciplines in the process of knowledge cooperation with international design fields.

Group 4 mainly includes seven authors of X2, X4, X5, X7, X8, X12, X15, and X16. Five of the authors were from Tsinghua University, one from the Beijing Forestry University and the other from Lanzhou University of Technology. The authors of this group published a total number of 342 works from 2008 to 2016, including 128 collaborative works, and the coauthoring rate was 37.43%. It can be seen from the author unit distribution that the group was formed by the relevant scholars of Tsinghua University. The average number of authors in the group was 49. It can be seen that this group is a high-yield group.

Looking at the trend of the number of works, the group's creative process can be divided into three stages. The first stage is from 2008 to 2010. The number of works of the group during the three years was 191, accounting for 55.85% of the total number of works. The second stage was from 2011 to 2013, during which the number of works of the group dropped significantly to 76; the third stage was from 2014 to 2016, the author's level of creativity had stabilized at this stage, and the number of works was 75, basically the same with the second stage. Another distinctive feature of this group was the diversification of the forms of collaborative works. The results of this group's knowledge cooperation were no longer restricted to traditional design papers, but also included works of art and design, abstracts of design meetings, views of design works, and design fields. Character interviews and others that form a variety of works, on one hand, reflected the flexibility and mobility of knowledge cooperation in the design field in China, on the other hand, it also played a positive role in promoting the all-round development of China's design discipline.

Group 5 included 11 authors of X1, X3, X6, X9, X10, X11, X13, X17, X31, X38, and X51. The authors were from Tsinghua University, Southeast University, Beijing Technology and Business University, Suzhou University of Science and Technology, and Changshu Institute of Technology. The number of collaborating works among the authors of the six institutions of the Beijing Film Academy between 2008 and 2016 was 95. The cooperative works of the group were similar to Group 4, including design papers, works of art, and design forum records. In this form, the most outstanding feature of this group was inter-regional and inter-organizational cooperation among authors. For a long time, information irregularity between the traditional geographical estrangement and different units has become the main influencing factor that restricts the flow of knowledge in various fields in China. This view has been confirmed by many scholars in China (Qiu & Chao, 2011). However, the authors of the group came from six different units, four different urban areas, and were typically cross-regional and inter-unit knowledge cooperation types. This showed that China's design field was building knowledge cooperation relationships between different regions and different units, trying to solve the traditional problems of geographical separation and information asymmetry.

Group 6 included 22 authors such as X14, X18, and X20. The group had the largest number of authors. The authors came from universities such as Tsinghua University and Beijing Normal University. Compared with Group 4 and group 5, the overall number of authors of the group was relatively small and the level of knowledge production was low. Among them, the author with the highest number of works was X14, and the total number of works was only 33, which was far less than that of Group 4, thus, the average number of works (49) and the highest number of works in group 5 (158).

According to the analysis of small groups, knowledge cooperation in the field of design in China has the following characteristics:

- There are close knowledge exchanges between core authors and non-core authors of some knowledge cooperative groups, for example, group 1. This shows that this type of author group itself had a strong

knowledge of radiation function. This part of the authors could weaken the core-periphery pattern of knowledge cooperation networks in the field of design in China through knowledge cooperation with non-core authors and enhance the breadth of knowledge cooperation in the field of design in China. Simultaneously, it also shows that the design field in China was using core authors to promote knowledge cooperation among non-core authors. In the future, the core-periphery spatial pattern of knowledge cooperation networks in design fields in China will further be weakened. Contrary to the authors mentioned above, there are also some authors whose knowledge cooperation networks were relatively closed, such as group 2. This part of the author was less probable to cooperate with non-core authors, even if the depth of collaboration between core authors was small. This type of knowledge cooperation group was not conducive to the output of knowledge information within the group, but it was also difficult to receive the latest knowledge of the outside world, and it had a certain degree of a hindrance to the knowledge cooperation and knowledge diffusion in the field of design in China.

- A breakthrough has been attained in the internationalization of knowledge cooperation in the design field in China. According to the characteristics of the group 3's knowledge cooperation, the group not only focused on knowledge cooperation among different countries, but also the research themes of the group were closely associated with the internationalization of design disciplines. Sino-foreign knowledge cooperation has injected new vivacity into the flow of knowledge in China's design field, and simultaneously, it has greatly increased the soft power of China's design disciplines.
- The form of knowledge collaboration in the field of design tends to be diversified. The most accepted form of knowledge cooperation results is academic papers, but the results of knowledge cooperation between Group 4 and group 5 include works of art and design, perceptions of design works, task interviews in design fields, design forum records, and many other forms of diversified works. The form not only enriched the knowledge circulation channels in China's design field accelerated the speed of knowledge flow in China's design field but also provided a wealth of reference experience for the growth of other disciplines in China.
- Geographical obstacles and information asymmetry barriers to knowledge cooperation in the design field were gradually being broken. For example, the authors of group 5 came from different regions and units. Cross-regional knowledge cooperation could enhance the connectivity of knowledge diffusion between different regions.
- There is a large difference in the level of knowledge production among different groups. For example, both groups 4 and 5 belonged to the high-yield author group. In contrast, the level of knowledge output of group 6 was relatively low. This imbalance in the level of knowledge output makes the knowledge in China's design field concerted in a few high-yielding author groups, which not only slows the flow of knowledge in China's design field but also increases the instability of the overall knowledge cooperation network.

6. Conclusion

Collaboration in research can effectively enhance research activity. It is therefore important for research collaboration to be supported and encouraged (Beaver, 2001; Hara et al, 2003; Katz & Martin, 1997; Link et al, 2002).

In this paper, a single case study method was selected making use of social network analysis method and UCINET software to analyze the characteristics of knowledge cooperation network structure and network member characteristics between core authors and non-core authors in the field of design in China. The paper used the knowledge cooperation networks of the core authors of the journal of Decoration from 2008 to 2016. The following conclusions and recommendations were drawn:

Firstly, there was a large-scale of knowledge cooperation in the field of design in China, but the overall depth of knowledge cooperation needed to be strengthened since the average number of knowledge collaborations in the analysis of the network structure was relatively small. This showed that there were more sporadic and fragmented knowledge cooperation relationships in the design field in China. It is, therefore, our suggestion that authors in the design field should pay more commitment to establishing a long-term knowledge cooperation mechanism and maintain a stable relationship in knowledge cooperation. The stability of group members can enhance the research depth in their research fields.

Secondly, the knowledge cooperation network in China's design field was in line with the small-world effect that consisted of multiple sub-networks, formed around one or more core authors. The advantage of the small-world network is that it has a fast flow of knowledge and timely delivery of information. However, this kind of decentralized small-world network had strong instability, where there was a lack of connection between the various sub-networks and an overall loose network. On the other hand, each sub-network was formed around some core authors which often occupies more structural holes in the network, so the overall knowledge cooperation network will have a strong reliance on the few core authors occupying structural holes. There

should, therefore, be a focus on the aptitude to create knowledge among all authors within the team, hence, enhancing the centrality and influence of each author, plummeting the number of structural holes occupied by the core authors, and enhancing the stability and connectivity of the overall network.

Thirdly, even though China has accomplished some major breakthroughs in international, cross-regional, and diversification of cross-regional cooperation respectively in its field of design, there were still some author groups that were relatively independent and had unbalanced levels of knowledge output. To curtail this, there should be a focus on establishing relationships in knowledge cooperation between high-yielding author groups and low-yielding author groups, and improve the capacity of knowledge creation in low-yielding author groups through knowledge cooperation channels, and increase their knowledge output levels. China should also continue to maintain the existing advantages of international and cross-regional cooperation, to further enrich the forms of cooperation between different regions and author groups, thereby reducing the number of independent author groups in the field of design.

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