Growth of Hyperlink Network Formed by Web Pages of Japanese Public Libraries

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Abstract

In this study, we studied the growth of the network of Japanese public libraries formed by hyperlinks of their Web pages by comparing the network in 2007 with that in 2009. By focusing on the locality factor and degree factor, we found that two models in which each factor comes into play individually do not fully fit the hyperlink network and that cliques increase more sharply than in these models. These results indicate that neither of these factors comes into play by themselves in the hyperlink network and that cliques are characteristic of the hyperlink network. We also studied in-prefecture networks, i.e., sub networks formed of all municipal and prefectural libraries within a prefecture and which are one of the most important types of cliques, and found that these networks could be classified into four types: (A) those with few or no links; (B) those with hubs, which are prefectural libraries, but no clique; (C) those with hubs, which are prefectural libraries, and cliques; and (D) those with hubs, which are prefectural libraries, and many links and cliques. These types are also steps of a common growth process that goes from (A) to (B) to (C) to (D). The degree factor mainly comes into play in steps (A) and (B), whereas the locality factor mainly comes into play in steps (C) and (D).

Introduction

The Web has become an increasingly essential part of our lives, and social networks on the Web are coming to be regarded as very important. Researchers have researched not only private Web pages (Adamic & Adar, 2003) and social networks (Holme *et al.*, 2004) but also Web pages of academic institutions (Ortega & Aguillo, 2008) and local public agencies (Holmberg & Thelwall, 2009). These studies have attempted to ascertain the static structure of networks or their growth process. Static Studies have mainly focused on large clustering coefficient, small average shortest path, and power law degree distribution. The first two properties are the main characteristics of small-world networks and the third property is that of scale free networks. Growth studies include ones on social networks and various models to reproduce the characteristic topological properties (Albert & Barabási, 2002; Zhang *et al.*, 2010).

The importance of the Web is also increasing for public libraries, whose major mission is transmitting information to users. Library users tend to look at how to position public libraries in the Web rather than how public libraries utilize the Web. Traditionally, public libraries ensure a stable information supply to users by cooperating with each other through inter-library services such as the Inter-Library Loan (ILL). A lot of libraries also provide hyperlinks not only to outside information resources but also among them to support users who visit library buildings (Miyamoto, 2003). However, most Web users get all their information from Web pages and links rather from the actual world, because links are the sole means of connecting individual Web pages, making them visible within the overall Web universe, and reflecting importance of them and of cooperation among them in the Web. To see how to

position public libraries on the Web, it is important to research what type of vision users create from the hyperlink relationship among libraries and how they share it. Therefore, it is necessary to analyze the structure of the hyperlink network formed by Web pages of public libraries to clarify how public libraries are visible on the Web and to what extent the vision is shared among their users.

Although there are many studies on Web pages of public libraries (Prabha & Irwin, 2003; Novljian & Žumer, 2004), few have researched the hyperlinks of the Web pages of public libraries (Tang & Thelwall, 2008). So far, only Kawamura *et al*. (2009a, 2009b) have researched the structure of the hyperlink network formed by the Web pages of public libraries. They researched Japanese public libraries and demonstrated that the hyperlink network has the tendencies of both small-world networks and scale-free networks; prefectural library networks are strongly connected and could be classified into three types. They studied in-prefecture networks, i.e., networks composed of all libraries, municipal or prefectural within a prefecture, in detail and indentified more characteristics belonging to them. However, they only researched the static structure of networks. To know how the shared vision of libraries is changing, it is necessary to study the growth of networks and to examine whether the structure they found is tentative or not.

Against this background, this study is an attempt to compare the structures of hyperlink networks formed by Japanese public libraries in 2007 and 2009, and by comparing them, clarify the growth process of the hyperlink network. By analyzing our subject matter from these perspectives, we can contribute to the study of the development of library services not only on the Web but also in the actual world.

Japanese Public Libraries: Services and Networks

Public libraries in Japan are established by local public agencies at two administrative levels: prefectural and municipal. Each prefecture is made up of a number of municipalities. As of June 10th, 2009, there were 1775 municipalities (Ministry of Internal Affairs and Communications, 2011), divided into 47 prefectures. All prefectures and about 70 percent of municipalities have their own public libraries, and all prefectural libraries and about 70 percent of municipal libraries have their own Web pages (Japan Library Association, 2010).

Providing resources is a strong motivation involved in the formation of ILL networks among libraries (which facilitates circulation of books between public libraries). ILL network is the administrative unit within which libraries are located. Standards set by the Japanese government for the establishment and operation of public libraries (Ministry of Education, Culture, Sports, Science and Technology, 2001) emphasize ‘in-prefecture’ cooperation, i.e., cooperation between all libraries, municipal and prefectural, within a prefecture. According to these standards, municipal libraries should actively cooperate in the mutual exploitation of their resources, and the networks between prefectural and municipal libraries in each prefecture are the basic element of this cooperation. Prefectural libraries in particular should function not only as large-scale libraries but also as back-up libraries for municipal libraries, and should take a lead in the liaison and coordination of the in-prefecture network. Through this structure, a library is reachable from others by small steps in actual world.

The Web shows similar characteristics. Kitaumi & Matsui (2000) examined the Web pages of Japanese public libraries from various viewpoints, including their links. They found that 63 percent of libraries provided links to local public agencies and 13 percent provided links to other libraries, and while many municipal libraries provided links to prefectural libraries, 40 percent of libraries provided no links. Goto (2002) examined the links of prefectural libraries, and discovered that all of them provided links to libraries in the same prefecture. Kawamura *et al.* (2009a, 2009b) showed that the structure of hyperlinks has the some tendencies of the ILL network and some tendencies that are different from it. Kawamura *et al.* (2009a) had

chiefly three findings. Firstly, the hyperlink network has both small-world network and scale-free network tendencies. Secondly, most of the important subgroups, i.e., the in-prefecture networks, consist of prefectural libraries or prefectural libraries and municipal libraries in the same prefectures. Thirdly, prefectural libraries are at the central position in the in-prefecture network, and the in-prefecture networks are classified into three types:

(A) those with few or no links,
(B) those with hubs, which are prefectural libraries, and but no clique, and
(C) those with hubs, which are prefectural libraries, and cliques

Kawamura *et al.* (2009b) indicates that not only prefectural libraries but also some municipal libraries occupy the central position in the networks which have many links. Like prefectural libraries, such libraries are mediators between libraries in the network and are important characteristics of the hyperlink network. However, the authors of that study only researched the static structure of networks. We thus feel it is necessary to research the dynamical growth of library hyperlink networks before we can draw definitive conclusions.

Related work

The research studying the growth of social networks including the Web goes back only a decade. Most studies look into whether structures observed in social networks could be explained by the network-dependent interactions of nodes, without reference to the intrinsic properties of nodes. These studies have had two focuses: the degree factor (or attachedness factor) and the locality factor.

Attachedness is a concept that measures how well nodes are connected, and therefore, it is usually reflected by the degree of nodes in complex networks. Barabási & Albert (1999) developed a preferential attachment theory that says high-degree nodes are always favored when building new connections, and they developed a model in which new nodes are added to the network one by one. They claimed that the probability that a node v_n will be linked to a node v_i depends on v_i 's degree. Each new node attaches itself to one of the existing nodes with a certain probability that is proportional to the number of links that the existing nodes possess. They demonstrated that this simple scheme results in a power-law degree distribution. This model was used in many studies on, e.g., scientific collaboration (Milojević, 2010) and bipartite article-author networks (Morris & Goldstein, 2007). Barabási *et al.* (2002) developed an extension to this model (BJNRSV) in which the probability that a node v_n will be linked to a node v_i depends on v_n's *and* v_i 's degree. In our study, we compared the hyperlink network with the BJNRSV model to see whether degree factor comes into play as the hyperlink network grows.

The models in which locality factor comes into play are based on assumptions about the local mechanisms of tie formation, which mainly relate to the distance between nodes (Toivonen, *et al.*, 2009). Kumar *et al.* (2000) developed a network model where, at each time step, a new node connects to the rest of the nodes with a constant number of edges. As this is being done, a "prototype" node is randomly chosen from the nodes already in the network. The new node copies a number of links from a "prototype" node. Davidsen *et al.* (2002) (DEB), Marsili *et al.* (2004) (MVS) and Kumpula *et al.* (2007) (KOSKK) proposed models that focused on neighbor's neighbor and form connections with network neighbors. In the MVS model and KOSKK model, a node links to a neighbor of one of its neighbors, while in the DEB model, a node is linked to another node through their common neighbor. In our study, because prefectural libraries have to take the lead in liaison and coordination of the in-prefecture network in the ILL network, we presumed that most of the links between libraries would be due to the coordination of the other libraries. If the locality factor affects the hyperlink

network's growth, the DEB model is a better fit than the other locality models for the growth process. We compared the hyperlink network with the DEB model to determine whether locality plays a role in the growth of the hyperlink network.

Data

We collected the data in almost the same manner as Kawamura *et al.* (2009): Firstly, the Web pages were chosen from the collection of links to public libraries in "Japanese library links" (Japan Library Association, 2011). The links are to web pages of all Japanese libraries. Secondly, we grouped Web pages into prefectural and municipal libraries. Accordingly, we regarded the links to and from mirror sites and branch libraries of prefectural or municipal libraries as those to and from their main library. We also determined whether prefectural libraries, which serve the largest numbers of library users, have a mirror site. We regarded the links to and from these mirror sites as those to and from the libraries.

Thirdly, we got the link data. We downloaded HTML format web pages automatically and got the link data by automatically distilling the <a> tags of the HTML pages, while we manually checked the non-HTML pages, such as JavaScript, etc. As the web pages of Japanese public libraries often show content of the web page of the local agency to which they belong and links to such libraries are often on the top page of the local public agency, we determined that Library *A* provided a link to Library *B* when the domain of the URL in the <a> tag of the web page of *A* was identical to that of *B*. But we can't, in this way, collect correctly the links to the web pages whose domain is the widely used one or the same overlapped one with other libraries. So, we manually confirm whether links to those domains are actually provided to public libraries. We conducted these work from May 31st to June 10th, 2009.

For the sake of comparison, we used the data that Kawamura *et al.* (2009) collected from January 21st to 23rd, 2007. However, because some of the local public agencies to which the public libraries belong have been integrated with other agencies, their libraries have been integrated as well. We regarded the links to and from these libraries to be those to and from the libraries they are integrated into. We also analyzed only mutual links in order to observe the strongest connections in the network. Mutual links indicate the fundamental unit of the shared vision for libraries, because if only a unilateral library provide a link, a vision that the users of one library has are not shared by the users of other library.

The basic network indicators of the overall hyperlink network in 2007 and 2009 are summarized in Table 1. The average path length is the average of the distances between pairs of nodes that are reachable. This indicates the efficiency of the network. The cluster coefficient quantifies the inherent tendency for nodes to form a clique in the network. It is the probability that the adjacent nodes of a node are connected (Wasserman & Faust, 1994). Increase in the number of 51 nodes and 200 edges indicate the hyperlink network has grown as a whole. The network grew overall by 51 nodes and 200 edges from 2007 to 2009. The 2009 national network resembles the 2007 national network in that it has many clusters, a short average path length, and a degree distribution following a power law. Moreover, the sizes of each in-prefecture network in 2009 were relatively the same as they were in 2007 (Table 2). Although the number of nodes of some in-prefecture networks declined or remained the same, most networks gained edges from 2007 to 2009.

Table 1. Basic data on the hyperlink network in 2007 and 2009

	2007	**2009**
Number of nodes	1252	1303
Sum of degrees	991	1191
Minimum degree	0	0
Maximum degree	43	44

Average path length	5.61	4.07
Clustering coefficient	0.21	0.23
Exponent of degree distribution	-1.65	-1.64

Table 2. Size of "in-prefecture networks" in 2007 and 2009

Size of network (nodes)	**0~20**	**21~40**	**41~60**	**61~80**	**81~100**	**101~120**
Number of prefectures	22	18	5	1	0	1

Method of analysis

We focused on the same factors as Kawamura *et al.* (2009a), that is, subgroups of networks, especially cliques, in order to analyze differences between the static and growing structures. A clique is defined as a group of more than two nodes in which all nodes are connected to each other by links. It most clearly indicates the size of the vision of public libraries which users share, because it is the subgroup that is most strongly interconnected.

We analyzed the hyperlink network in two ways. First, we analyzed the overall network by comparing it with the DEB model's and BJNRSV model's by means of their clustering coefficients and average path lengths, their degree distributions, and numbers of cliques. The DEB model (Davidsen *et al.,* 2002) is a simple one with only two parameters, the network size N and the probability p of deleting a node. It is calculated in the following way:

(1) Select a node i randomly, and
  (a) if i has fewer than two ties, connect it to a random node,
  (b) otherwise, pick two neighbors of i and connect them if they are not already acquainted.
(2) Select a random node and with prob. p remove all of its ties.

This simple model reproduces the major features of social networks, including the short average path length, large clustering coefficient, and scale-free degree distribution.

We compared the hyperlink network with a network that followed the DEB model and had the almost same size and the same edges as the hyperlink network. We produced 1,000 DEB networks which increased by 200 edges from 2007 to 2009 and compared the average of the above four indicators, in order to determine whether the hyperlink network grew in relation to the locality factor. If the values of those indicators were close, we could say that the locality factor comes into play.

The BJNRSV model (Barabási *et al.,* 2002) takes into account the product of degree of both nodes in the network. It is calculated in the following way:

(1) Add new nodes to the network at a constant rate.
(2) Select already present nodes v_i based on their degree; the probability is defined as $a*d(v_i)/\Sigma_k\ d(v_i)$, where a is the average number of new links that an incoming node creates and $d(v_i)$ is the degree of v_i, and link between v_i and the incoming node.
(3) Select an already present node as the start node v_j and form new internal links based on its degree $d(v_j)$.
(4) Select a node v_l which does not have a link to v_j, based on its degree $d(v_l)$, and link between v_l and v_j.
(5) Repeat (3) and (4) b times, where b is the number of newly created internal links per adding node.

We compared the library hyperlink network with a BJNRSV model of the same size and the same edges in terms of clustering coefficient, average path length, exponent of degree distribution, and number of cliques. We produced 1,000 networks that increased their nodes by 51 and edges by 200, as the hyperlink network did from 2007 to 2009, and compared the averages of the four indicators, in order to determine whether the hyperlink network grew in relation to the degree factor or not. If the indicators were close, the degree factor comes into play.
Next, we observed the in-prefectural networks. Kawamura *et al.* (2009a) indicated that the unit of prefecture is important for forming hyperlink networks. We focused on cliques, as in the case of the whole network, and also on the degree of libraries and used as indicators not only the links of and to the prefectural library but also links among municipal libraries, because Kawamura *et al.* (2009b) indicated that, in some in-prefectural networks which have many links, not only prefectural libraries but also certain municipal libraries occupy a central position. Therefore, we selected the following three indicators:

- number of cliques
- number of links to prefectural library, and
- number of links among municipal libraries.

Below, we compare the hyperlink networks in 2007 and 2009 by means of these indicators, taking the classification of Kawamura *et al.* (2009a) into account. We then discuss the growth characteristics of the in-prefecture networks and overall hyperlink network and the relation between the growth process and the vision that users on the Web share of libraries.

Results

Analysis of the Overall Hyperlink Network

Table 3 summarizes the statistics of the hyperlink network in 2009, the DEB network, and the BJNRSV network model. The clustering coefficient and exponent of the degree distribution of the hyperlink network are similar to those of the DEB network, while the average path length of the hyperlink network is lower and its number of cliques is higher. This indicates that the hyperlink network is more effectively connected and has larger cliques in comparison with the DEB network. The locality factor is not the only factor affecting its growth. Comparing the hyperlink network with the BJNRSV model, we find that the average path lengths and exponents of the degree distribution are similar, while the clustering coefficient and number of cliques of the hyperlink network are larger. This indicates that the hyperlink network has more and larger cliques than the BJNRSV network has and that the degree factor is not the only factor affecting its growth.

Table 3. Comparison of the whole hyperlink network, DEB model and BJNRSV model

	network	DEB	BJNRSV
Number of nodes	1303	1252	1303
Sum of degrees	1191	1191	1191
Average path length	4.07	4.77	4.26
Clustering coefficient	0.23	0.25	0.16
Exponent of degree distribution	-1.64	-1.66	-1.61
Number of cliques	2945	2601.83	1723.18

From the comparison, we concluded that the hyperlink network does not grow by locality factor alone or by degree factor alone. Hyperlink networks have more cliques than either model can account for. It is thus necessary to observe the group of nodes characteristic, in-prefecture network, in detail.

Analysis of In-prefecture Networks

Table 4 compares in-prefecture networks in 2007 and 2009 on the basis of three indicators. In 2009, 31 in-prefecture networks had increased the number prefectural library links from that of 2007 and all prefectural libraries had links. Twenty-one in-prefecture networks increased links among municipal libraries and 11 networks did not have link among municipal libraries. In particular, networks in Mie and Kyoto had many prefectural library links but none among municipal libraries. Cliques formed in the Akita, Yamagata, Shiga, Wakayama and Miyazaki networks. The increases and decreases in cliques in the networks that already had cliques varied. Some networks, such as Hokkaido and Niigata, had sharp increases.

In summary, the structural changes of the networks could be classified into the following types:

1. those in which links of prefectural libraries increased, but cliques did not form,
2. those in which links between prefectural libraries and municipal libraries and among municipal libraries increased and cliques formed
3. those in which links and/or cliques increased, and
4. those in which links and cliques remained the same or decreased.

Applying the classification of Kawamura *et al.* (2009a) to the in-prefecture networks in 2009 (Table 5) revealed that all networks were applicable to the classification. This indicates the networks in 2009 can be classified in the same manner as the networks in 2007. However, some networks have changed to other types during the period from 2007 to 2009. Two network changed from (A) into (B), and five networks from (A) or (B) into (C). Two networks, Nagasaki and Kagawa, changed from (C) or (B) into (A), but had broken links or technical problems that hampered our gathering of data, especially in the prefectural libraries, and hence, they may be exceptional cases. Therefore, the results would indicate a commonality of network structure transition, from (A) to (B) to (C).

Table 4. Comparison of in-prefecture networks in 2007 and 2009

	pref links		muni links		clique	
	2007	**2009**	**2007**	**2009**	**2007**	**2009**
Niigata	17	18	40	49	230	661
Hokkaido	15	21	7	38	5	225
Hyogo	26	29	26	37	115	182
Tokyo	43	41	36	53	142	164
Aichi	31	32	34	34	263	153
Tochigi	18	18	15	21	42	96
Saga	8	10	14	28	14	81
Kanagawa	23	24	21	30	29	57
Saitama	30	33	44	38	47	36
Kumamoto	8	11	8	13	5	32
Miyagi	10	12	5	9	9	27
Gunma	13	12	7	12	7	24
Shizuoka	11	14	12	10	21	21
Toyama	9	11	8	9	18	18
Fukuoka	16	28	6	13	5	17
Osaka	20	21	8	13	8	16
Tottori	7	10	5	12	7	15
Chiba	29	29	9	8	11	10
Ishikawa	8	9	2	5	2	9
Nara	9	9	6	5	8	7
Okinawa	5	8	3	4	3	6
Oita	7	6	6	3	16	5
Gifu	21	21	6	4	6	4
Ibaraki	16	23	7	5	4	4
Hiroshima	10	15	2	3	2	3
Yamagata	0	7	4	4	0	3
Fukui	9	9	1	2	1	2
Miyazaki	0	5	0	4	0	2
Okayama	12	15	2	1	2	1
Aomori	6	8	1	2	1	1
Nagano	9	12	2	1	1	1
Akita	5	5	0	1	0	1
Wakayama	0	4	1	1	0	1
Shiga	10	13	0	1	0	1
Nagasaki	4	1	3	1	5	0
Kagawa	3	2	1	0	0	0
Yamaguchi	6	5	1	0	0	0
Yamanashi	9	10	1	0	0	0
Kyoto	11	13	0	0	0	0
Mie	13	13	0	0	0	0
Ehime	6	3	0	0	0	0
Fukushima	9	9	0	0	0	0
Iwate	5	7	0	0	0	0
Kagoshima	5	9	0	0	0	0
Tokushima	2	3	0	0	0	0
Shimane	1	4	0	0	0	0
Kochi	0	0	0	0	0	0

Table 5. Classification of in-prefecture networks in 2007 and 2009

	2007	2009
(A) Networks with few or no links	6	3
(B) Networks with hubs, which are prefectural libraries, and but no clique	11	10
(C) Networks with hubs, which are prefectural libraries, and cliques	30	34

Cliques increased exponentially in the five (C) networks, Hokkaido Niigata, Hyogo, Saga, and Tochigi, reaching more than 50. This indicates the structures of these networks are going beyond level (C), because all of them have many links and cliques and the shared vision of users for libraries in these networks must have radically developed. A fuller analysis of this trend will require us to research networks that have many links and cliques.

Discussion

The analysis revealed that the structure of in-prefecture networks can be classified into following types, similar to those of Kawamura *et al.* (2009a):

(A') those with few or no links (4 networks),
(B') those with hubs, which are prefectural libraries, but no clique (8 networks),
(C') those with hubs, which are prefectural libraries, and cliques (30 networks), and
(D') those with hubs, which are prefectural libraries, and many links and cliques (5 networks).

These types are also steps of common network growth process and most networks grow from (A') to (B') to (C') to (D') (Figure 1). Firstly, in networks of (A'), links are provided between prefectural libraries and municipal libraries ((B')). Secondly, municipal libraries links among themselves and cliques consisting of prefectural libraries and municipal libraries form ((C')). Thirdly, cliques increase exponentially ((D')).
The results show that the degree factor mainly comes into play in (A') and (B') networks and that it has some effect in (C') networks. The locality factor mainly comes into play in (D') networks and has some effect in (C') networks. The growth process of hyperlink networks mixes the locality factor with the degree factor.

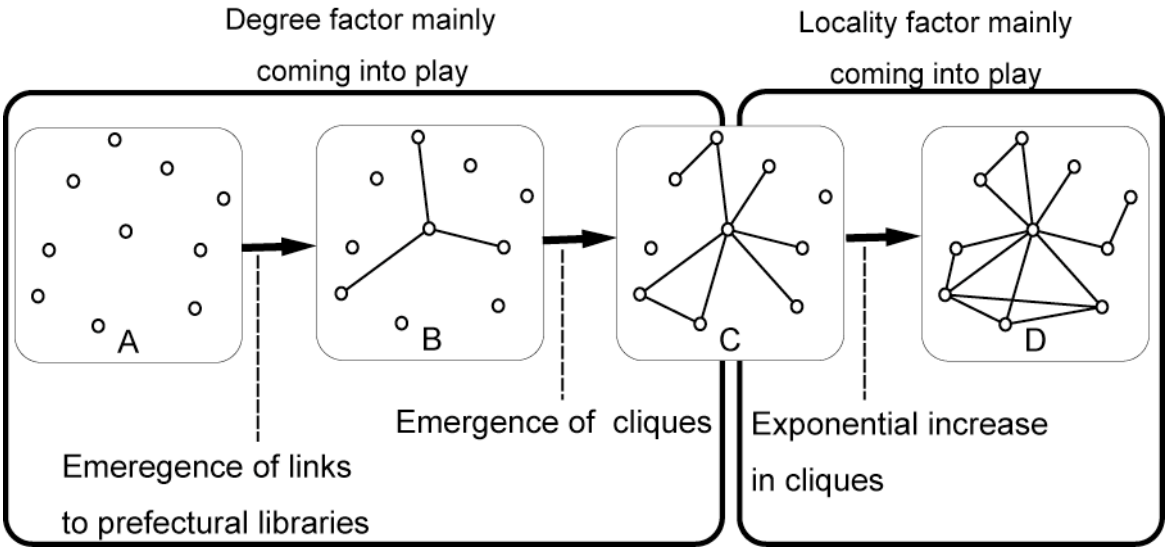

Figure 1. Dendrogram constructed by cluster analysis

Because the hyperlink network indicates the shared vision of users for public libraries on the Web, its growth process indicates the following grow process of the shared vision. Initially, users can't find library networks at all (situation (A')). Next, users recognize municipal libraries connected to the prefectural library (situation (B')). After municipal libraries link among themselves, users find parallel relationships among municipal libraries, and the formation of cliques makes some of them gradually more aware of extent and homogeneity of library services (situation (C')). Finally, an exponential increase in links and cliques happens when lot of users share the vision that public libraries maintain strong cooperation with each other (situation (D')).

Conclusion

In this study, we researched the growth process of the network of Japanese public libraries by analyzing and comparing hyperlinks on their Web pages in 2007 and in 2009. We focused on the locality factor and degree factor and compared the hyperlink network with simulated networks built according to the DEB model or the BJNRSV model, in which each factor comes into play respectively, by means of the clustering coefficient and average path length, the degree distribution, and number of cliques. The results showed that these models partially fit the actual hyperlink network but that cliques increase more sharply than these models would indicate. Moreover, this shows that one factor does not come into play independently of the other in the hyperlink network and that cliques are characteristic of the hyperlink network. We also found that the in-prefecture networks, which are the most important cliques, can be classified into four types;

(A') those with few or no links (4 networks)
(B') those with hubs, which are prefectural libraries, but no clique (8 networks)
(C') those with hubs, which are prefectural libraries, and cliques (30 networks), and
(D') those with hubs, which are prefectural libraries, and many links and cliques (5 networks).

These types are also steps of a common growth process of the hyperlink network, which grows from (A') to (B') to (C') and to (D'). The degree factor mainly comes into play in the network of (A') and (B'), and it plays a role in some networks of (C'). The locality factor mainly comes into play in networks of (D') and in some networks of (C').

This growth process can be interpreted as follows: in early steps, users regard prefectural libraries as being in the central position of the in-prefecture network, irrespective of their distance from prefectural libraries, which standards set by the Japanese government emphasize. In the latter steps, many cliques form and the vision that users share changes radically in step (D').

In the future, we should research not only inside but also outside of the hyperlink network. There are two directions that should be pursued. The first direction focuses on the other networks by links to the Web pages of public libraries, namely the network among public libraries and all the Web pages that are connected to them, including university pages, local government pages, and Yahoo! pages, etc. Information transmission cannot be archived only by public libraries. For example, highly academic information requires the help of professional organizations. How such connections among public libraries and other organizations grow in the Web will indicate how libraries are positioned in the Web from other perspectives.

The second direction focuses on library circumstances in the actual world, such as their geographical proximity or relation to a local public agency to which it belongs. To explore this direction requires not only quantitative research assessing, say, the distance between libraries, but also qualitative research, such as interviews with librarians.

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