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An Analysis of the Openness of the Web2.0 Service Network Based on Two Sets of Indices for Measuring the Impact of Service Ownership

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Abstract: One of the important characteristics of Web2.0 is the collaboration between Web2.0 service providers. They allow users (i.e., providers, developers, consumers) to combine their services. The prerequisite for this collaboration is openness of the Web2.0 service system. Although the Web2.0 technology allows the linking of different heterogeneous Web2.0 services freely, it is only assumed that the Web2.0 system is socially open as well. Until now, it has not been studied whether it is socially open and, if so, to what degree. In this paper, we address this shortcoming by creating and analyzing the Web2.0 service network. The nodes of this network are Web2.0 services and links represent the existence of mashups. In order to measure how much the Web2.0 service network is socially open, we use six openness indices, which are based on Krackhardt and Stern's EI-Index. Our results show that the Web2.0 is not fully socially open. The reason is that users of Web2.0 services do not leverage the openness provided by the technology. Instead, they prefer using Web2.0 services of those providers that they already know, i.e. the ownership of the service impacts the users' choices.

Keywords: Web2.0 Service, Mashup, Social Network Analysis, Openness, Subgroups.

JEL Classification Numbers: C02, C43, D02, D21, D23, D85, L14, L16, L22, L86, M15, M21, O31, O32, O33.

1. Introduction

In the Web2.0 service environment, users (i.e., developers, providers, consumers) do not just use Web2.0 services but can also modify and integrate them into new Web2.0 service creations [1]. Those new creations are called mashups. In detail, a mashup is a Web2.0 service, which integrates one or more existing Web2.0 services with a function (value) added by the developer [2]. A mashup creation is possible, if the to be integrated Web2.0 services provide open APIs (Application Programming Interfaces), which allow the Web2.0 service functions to be accessed.

A key characteristic of the Web2.0 system is supposed to be the active participation of users [1, 4, 5]. This participation enables innovation, i.e., it enables users to develop new services through the creative combination of already published services, which might even belong to different providers [3]. Since Web2.0 services are linked without any central control based on these developer actions, the resulting network can be considered a network that is similar to the social network of an academic collaboration network. In such a self-organized network, a node chooses another node according to a property (e.g., the number of links that the node has) [6, 7].

In this context, the technological openness of the Web2.0 system should be distinguished from its social openness. A Web2.0 service is technologically open in the perspective that any developer can access it (if following the API standard). The developer can utilize the function and data of the service without the necessity of modifying the source code. However, the technological openness does not guarantee the social openness. The creative combination of Web2.0 services may be constrained because of several socially related reasons. For example, a company may restrict combining its services with services of its competitor by implementing a proprietary interface, which is not compatible with the interface of its competitor. Another example for this constraint is the case if developers lack knowledge on Web2.0 services of companies that they have not use yet or lack knowledge on how to combine those services. In this case, the Web2.0 system is not a creative system as a whole anymore. It is only a collection of segregated groups of services. In order to counteract any of those tendencies, it is necessary to investigate whether the Web2.0 system is already impacted by this kind of social factors. In particular, we analyze whether the Web2.0 system is socially open with respect to the ownership of the Web2.0 service and to what degree it is open. We also identify the factors that would guarantee the social openness of the Web2.0 system.

We define the Web2.0 service network, which represents the Web2.0 system, as a network of Web2.0 services (nodes) that are connected through links with each other, if a mashup exists that uses those Web2.0 services [4]. The Web2.0 service network can be classified into several subgroups according to an arbitrary criterion. In this research, we grouped it according to the ownership criterion, since we suspect that these ownership subgroups impact the social openness of the Web2.0 service network. To this kind of network, we apply a set of newly designed indices for measuring the openness of an innovation system. The results show the impact of ownership subgroups on Web2.0 service networks.

Since Web2.0 can also be considered an innovation resource for creating new Web2.0 services, the openness of the innovation resources of the Web2.0 system provides users with new business opportunities. The fact that a link is generated between existing Web2.0 services implies that their combination is valuable. Furthermore, the number of links, which a Web2.0 service has, represents its popularity. This entrepreneurial information can be captured through the analysis of the existence of linkages between nodes and the number of links of a node. Therefore, it is necessary to analyze the structure of the Web2.0 service network and, in particular, with respect to the ownership of the Web2.0 services, i.e, corporate boundaries. The findings help setting up appropriate policies for supporting the Web2.0 development.

1.1. Methodology

We designed two sets of three openness indices, measuring the openness of a network with respect to three aspects: ratio of the number of external relationships to internal relationships, the topology of the Web2.0 service network, and the activity within the Web2.0 service network.

The first index of the first set of indices is directly based on the Krackhardt and Stern's EI-index, measuring dichotomous relations [8]. The principle behind this index is to compare the number of external relationships with that of internal relationships. It analyzes the impact of openness between subgroups on the topology of networks.

The first index of the second set of three indices is an extension of the EI-index, which includes the weight of a relationship and the self relationship. The weight of a relationship is measured by counting the number of relations between two nodes. For example, a link has a count of two, if two mashups have been created between these two Web2.0 services [9]. Contrarily, only one link is counted for the EI-Index, which considers dichotomous relations. Since self relationships are a characteristic of the Web2.0 service network, we also consider links that are generated from a node to itself. That means mashups are created that are based on only one Web2.0 service. In contrast to this, a friendship network, which Krackhardt and Stern considered [8], does not consider the self relationship because being friend with oneself is unreasonable.

The remaining two indices of both sets of indices address the subgroup structure and the agent behavior. Since the openness indices are dependent on the distribution of the subgroup sizes, we calculate the subgroup structure index with the maximum possible number of external relationships (internal relationships, and self relationships). And, since the openness indices are also dependent on the behavioral pattern of agents, which is neutral on the effect of subgroup structure, the agent behavior index is calculated with the normalized number of relationships.

These six openness indices are applied to the Web2.0 service network to analyze the social openness of the network comprehensively. The Web2.0 service network was constructed by representing collaborations between Web2.0 service providers (i.e., the existence of a mashup of two of their Web2.0 services) through a link between two nodes that represents those Web2.0 services. The data has been collected from the mashup list and the Web2.0 service list of http://www.programmableweb.com. The mashup list includes the names of mashups, Web2.0 services used by each mashup, and a short description of each mashup. The Web2.0 service list specifies information about the function, input data, output data, and the company ownership of a Web2.0 service.

Three analyses were performed to show whether the Web2.0 service network is substantially open. First, the openness indices were calculated to show the proportion of relationships between Web2.0 services of different ownership subgroups. Second, the subgroup structure indices and the agent behavior indices were analyzed to discuss which factors affect positively or negatively the social openness of the Web2.0 service network. Finally, the EI-Indices were compared with the EIS-Indices. It helps qualifying the importance of weighted relationships and self relationships.

1.2. Paper Organization

The remainder of the paper is organized as follows. The following chapter introduces the theory and the methodology for measuring openness. In chapter 3, our indices for measuring openness are defined formally. The application of the two sets of indices to the Web2.0 service network is described in chapter 4. The final chapter concludes this paper with a discussion on the implications for businesses and policy makers.

2. Scale-Free Networks, Their Construction, and Distortions

Formal and informal relationships among members in a system constitute a social network. An example of informal relationships is the friendship relationship [8]. Examples of formal relationships are technology alliances or interlocked directorates [12, 13]. Social network analysis (SNA) is concerned with measuring the position and the role of agents in these social structures as well as with characterizing the structure of the social networks [10, 11].

One of the important application areas of social network analysis is collaboration for innovation. For example, SNA allows analyzing the effect of a social network on knowledge sharing in an innovation system [8, 12, 13, 14, 15]. In this context, research showed that the position and the role of an agent affect knowledge acquisition and trust building [12, 15, 16]. The position and the role of the agent are measured by using social network indicators (e.g., degree centrality, betweenness centrality [12], and network constraint [16]). Degree centrality is defined as the number of links of an agent [11, 12]. The betweenness centrality is defined as the number of routes passing through a node [11, 12]. These measures indicate how famous or influential a node within a network is. The network constraint is defined as the total relative strength of connection between two nodes connected with each other through one or two neighboring nodes [16]. That is, the constraint c_{ij} between node i and node j is calculated as $c_{ij}=(p_{ij} + \Sigma_q p_{iq}p_{qj})^2$. Here, p_{ij} is a measurement proportional to the strength of connection between node i and node j. A high network constraint implies that the node is a limited source of ideas and, therefore, has a low innovation performance.

It has also been shown that the characteristic of the network structure affects the sharing of knowledge and the formation of knowledge among members in the system. For example, a typical property appearing in an innovation system is the scale-free characteristic and the small world phenomenon [17, 18, 19]. The topology of complex networks connects their members in the neighborhood with few links, so that information diffuses efficiently to the entire society. The social network analysis of an open source community found that the network is scale-free and self-organized, having a hierarchical structure [28].

In addition, innovation researchers also discussed the importance of collaboration through external relationships over clustered groups [13, 14], since innovation requires combinations of knowledge embedded in heterogeneous and semi-separated subgroups [15]. Social network studies also emphasized that linkages and agents intermediating heterogeneous knowledge sources are important for innovation. Granovetter calls them "bridging weak ties" [20], and Burt called them "brokerages" [16]. For example, the results of the centrality analysis of articles and contributors in Wikipedia showed that knowledge is created by users' active participation. Especially, heterogeneous knowledge was combined [30].

2.1. Subgroups and Homophily

The literature on social networks considers homogeneous node attributes. That is, they assume that nodes are identical except for the relation attributes (e.g., centralities and network constraint). But human societies usually consist of more than two types of agents (e.g., men and women with respect to their romantic relationships). A relationship can only be established between two nodes of different type. For example, a man gets married to a woman, not with a man (in general). This network, where a link always connects nodes of different types, is called a "bipartite network" [21]. The other mechanism, which controls the relationship between nodes with heterogeneous attributes, is called homophily (or assortativity). It means that there are more linkages between similar nodes than between different nodes [22]. Social networks of marriage, friendship, work advice, information transfer, and co-membership show preference for similarity with respect to physical distance [23, 24], common acquaintance [18], race, gender, age, education, occupation, behavior, and interpersonal value [22]. Consequently, homophily affects the network evolution [25].

Homophily between nodes is also susceptible to the position of the nodes in a network. Newman calculated the Pearson correlation coefficient of the degree of nodes linked together [26]. He found that social networks (e.g., the academic co-authorship network, the film actor collaboration network, and the company directors network) have a positive correlation (assortative mixing pattern) while the WWW has a negative correlation (disassortative mixing pattern). An assortative mixing pattern means that the node with a high degree prefers another node with a high degree. Similarly,

Pastor-Satorras et al. designed the connectivity correlation, which is the average degree of nodes connected to a node with a certain degree [27]. The connectivity correlation of the

IP network of Internet decays by a power function of the degree. The social network, which is formed through e-mail correspondence between open source developers, also has a decaying connectivity correlation [28]. Assortitivite mixing and decaying connectivity correlation implies that the network has a hierarchy consisting of nodes, which have few links to a hub, and hubs, which connect terminals to other hubs.

2.2. Openness between Subgrups

Krackhardt and Stern argued that openness between subgroups increases the performance of an organization [8]. They designed the EI-Index to measure openness over subgroups. The index is defined as the ratio of the difference between the number of external relationships and the number of internal relationships to the total number of relationships. It ranges between -1.0 (completely closed) and 1.0 (completely open). Krackhardt and Stern's approach is different to those social network indicators introduced above [13, 14, 16], which are used to analyze the performance of a node. The EI-Index, however, measures the property of an entire network. It describes the effect of a network characteristic on the performance of a network (e.g., the performance of an organization consisting of heterogeneous agents) [8]. The EI-Index was also applied to the communication network of a knowledge management community [29]. The result showed that openness of subgroups (e.g., research institutes) increases due to central actors.

Social network analysis has also been applied to analyze the characteristics of the World Wide Web [4, 28, 30]. The Web2.0 service network consisting of Web2.0 services and their mashups shows an characteristic, which is different from the normal self-organized network [4]. It has a low exponent compared to regular scale-free networks [17, 18].

3. Indices for Measuring Openness

Using the concept of Krackhardt and Stern, we define openness as the relative number of relationships between members belonging to different subgroups [8]. These relationships are a key factor for diffusing knowledge that is embedded in subgroups. The level of openness ranges from complete closedness to complete openness. In a completely closed network, an agent has only relationships with other agents of the same subgroup. In a completely open network, every agent of a subgroup has relationships with all other agents of other subgroups.

Figure 1 illustrates this definition of openness through three examples. Each example shows one network, which is indicated through a solid-lined box. A dashed-lined box represents a subgroup. Solid dots define agents. A link between two solid dots represents a relationship between agents. Example (a) shows two subgroups, whose two agents do not have any relationships to other subgroups. The only relationships that exist are the relationships between the two agents of the same subgroup and the self-relationship of one agent. Example (b) depicts a network, in which one agent of each subgroup has a relationship to an agent of the other subgroup. Example (c) illustrates a network that is completely open. Each agent has relationships to all agents of other subgroups.

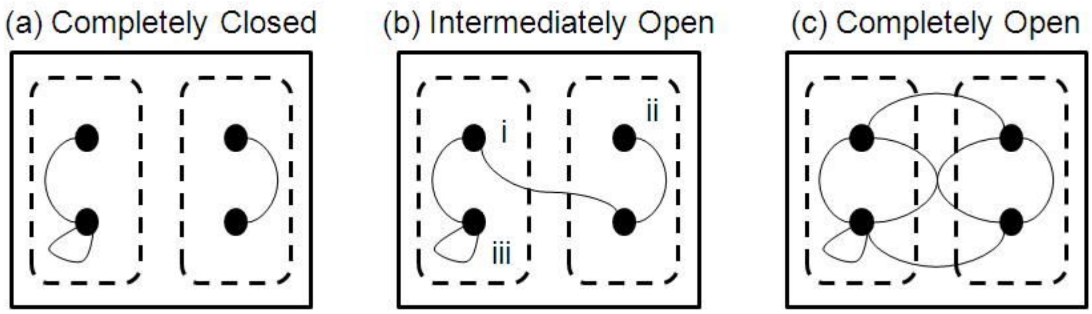

Figure 1. Examples of three networks, illustrating different levels of openness

To further differentiate networks with respect to openness, we introduce three types of relationships. These relationship types are called external relationship (*E*), internal relationship (*I*), and self-relationship (*S*). An external relationship is defined as a relationship between agents of different subgroups (link i in Figure 1b). An internal relationship is defined as a relationship between agents of the same subgroup (link ii in Figure 1b). A self-relationship is denoted as a relationship which an agent has with itself (link iii in Figure 1b). These definitions are used in our set of indices, which are introduced in the following sections.

3.1. Krackhardt and Stern's EI-Index

Krackhardt and Stern defined the EI-Index as the ratio of the difference between the number of external relationships and the number of internal relationships to the total number of relationships [8]:

$$EI = \frac{E - I}{E + I}$$

The range of the EI-Index is between -1 and 1. It is -1, if the network has only internal relationships. It is 1, if there are only external relationships in the network. It is 0, if the number of external relationships equals the number of internal relationships.

The EI-Index shows the openness between subgroups of the network. Using this index, Krackhardt and Stern analyzed the effect of openness of an organization (i.e., the informal relationships of employees to employees in other departments) on the performance of an organization in a crisis [8].

Despite its usefulness, the EI-Index has three shortcomings, if it is applied to networks representing knowledge. First, the number of external relationships increases faster than the number of internal relationships as the network size grows and the number of subgroups remains constant. Second, Krackhardt and Stern designed the EI-Index not considering self relationships [8]. Third, the EI-Index does not distinguish clearly dichotomous and multiple relationships within networks [11].

3.2. The Extended EIS-Index

To complement the EI-Index, we extend the EI-Index by including weighted links and self relationships [9]. This new index is called the Enhanced-EIS-Index. The Enhanced-EIS-Index (EIS_r) is the ratio of the difference between external relationships (E), and internal and self relationships (I and S) to the total number of relationships:

$$EIS_r = \frac{E - I - S}{E + I + S}$$

In this equation, the subscript r denotes that the Enhanced-EIS-Index is calculated using the actual number of external relationships, internal relationships, and self relationships of a given network.

The EIS-Index measures the openness between subgroups of the network. The weighted links represent the innovation activity within the network, i.e., the combination of nodes. The self relationship represents the innovation activity using only one node. Thus, the EIS-Index captures the different variations of openness by measuring how many innovation activities occur between nodes.

The Enhanced-EIS-Index varies in the range between -1 and 1. It is -1, if the network has only internal and self relationships. It is 1, if there are only external relationships in the network. It is 0, if the number of external relationships is equal to the sum of internal relationships and self relationships. In general, the value of the Enhanced-EIS-Index can be interpreted such that the larger the Enhanced-EIS-Index is, the more open the network is.

3.3. Subgroup Structure

Openness depends on two factors, the subgroup structure and the agent behavior. For measuring openness due to the subgroup structure, we define an index similar to the Enhanced-EIS-Index, using the maximum possible number of relationships. This way it is possible to determine the proportion of external, internal and self relationships for a certain subgroup distribution. This index, the Enhanced-EIS_s-Index, is the ratio of the difference between the maximum possible external relationships ($E*$) and the maximum possible internal and self relationships ($I* + S*$) to the total maximum number of relationships:

$$EIS_s = \frac{E^* - I^* - S^*}{E^* + I^* + S^*}$$

We name this index Subgroup Structure Index of the EIS-Index, because the maximum possible number of links depends on the distribution of the size of the subgroups. The index indicates openness, which is a consequence of the subgroup distribution.

The range of the EIS_s-Index is variable for a given number of subgroups. It depends on the distribution and size of the subgroups in the network, as illustrated in Figure 2. The bold curve is the upper bound of the Subgroup Structure Index and the light curve is the lower bound of the index. The curves overlap, if the number of subgroups K equals to the number of nodes N in the network and if the number of subgroups equals 1. An analytical analysis can be found in Appendix A. In general, the Subgroup Structure Index increases as the number of subgroups increases. Our analytical analysis also shows that the Subgroup Structure Index is positive, if the number of subgroups is larger than a threshold point (point E in Figure 2). That means that a network is inherently open, if a sufficiently large number of subgroups exist.

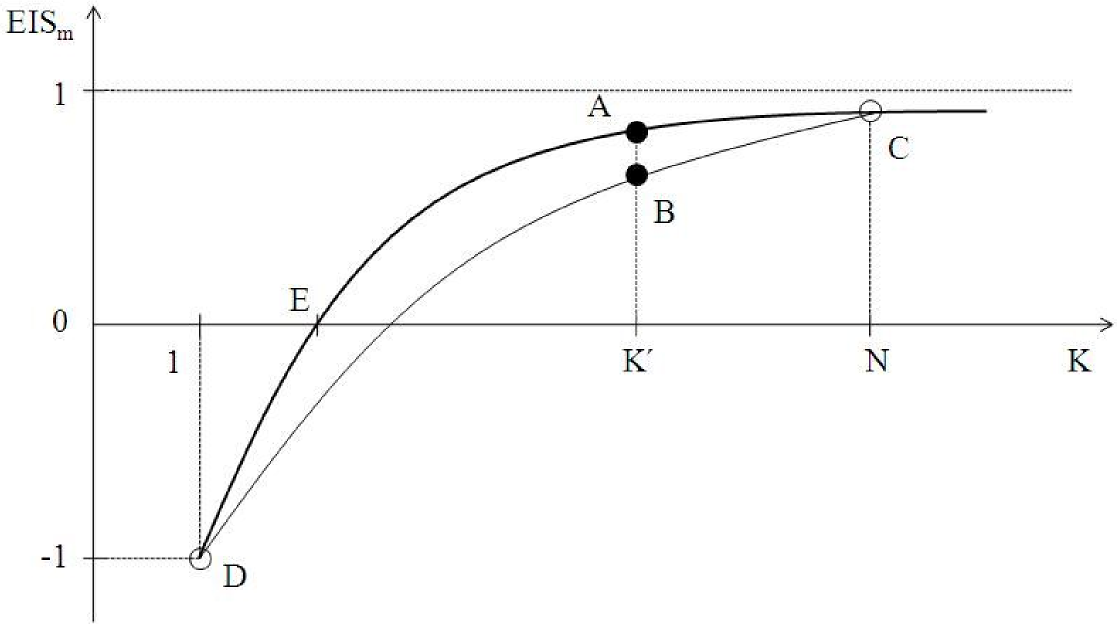

Figure 2. Analysis result of the Subgroup Structure Index ranges for varying numbers of subgroups

In the same way as the EIS_s-Index, the EI_s-Index is defined as the ratio of the difference between the maximum possible number of external relationships and the maximal possible number of internal relationships to the total maximum possible number:

$$EI_s = \frac{E^* - I^*}{E^* + I^*}$$

We name it the Subgroup Structure Index of the EI-Index. The range of EI_s is very similar to that of EIS_s. The range of EI_s is bounded by two concave curves. The minimum of EI_s is -1, if the network involves only one subgroup. But, the difference is that the maximum of EI_s is 1, if the network consists of N subgroups each of which involves only one node. In this case, the total maximum possible number of relationships is equivalent to the maximum possible number of external relationships. This difference between EI_s and EIS_s results from the effects of self relationships. Since a subgroup could entail a self relationship, even if it consists of one node only, the EIS_r does not reach 1.

3.4. Agent Behavior

In order to measure openness with respect to the agent behavior, we introduce the Agent Behavior Index. This index considers the normalized numbers of external relationships, internal relationships, and self relationships. The normalized number of relationships is defined as the ratio of the measured number of relationships to the maximum possible number of relationships. As a reference, the normalized number of external relationships e is:

$$e = \frac{E}{E*}$$

The Agent Behavior Index (EIS_a) is the ratio of the difference between the normalized number of external relationships (e) and the normalized number of internal and self relationships ($i + s$) to the sum of the normalized numbers:

$$EIS_a = \frac{e - i - s}{e + i + s}$$

The formula of the Agent Behavior Index of the EIS-Index describes how many relationships an agent has in average. The range of the index varies between -1 and 1. It is -1, if the normalized number of external relationships is zero. It is 1, if the normalized numbers of internal and self relationships are zero.

In the same way as the EIS_a Index, the EI_a-Index is defined as the ratio of the difference between the normalized number of external relationships (e) and the normalized number of internal relationships (i) to the sum of the normalized numbers.

$$EI_a = \frac{e - i}{e + i}$$

EIa is also called Agent Behavior Index of the EI-Index. It ranges from -1 (network includes no external relationships) to 1 (network has only external relations).

3.5. Theorems

Based on the definitions of the Agent Behavior Index and the Enhanced-EIS-Index, we can formulate the following theorems. The EIS_r-Index is -1, if and only if the Agent Behavior Index (EIS_a) is -1. The EIS_r-Index is 1, if and only if the EIS_a is 1.

For the proof of the theorems, $EIS_r = -1$ implies that the network contains no external links. In this case, the normalized number of external relationships is always zero, independent to the subgroup structure index. Thus, $EIS_a = (-i - s) / (i + s) = -1$, if $EIS_r = -1$. In the same way, if $EIS_a = -1$, then $e = 0$, $E = 0$ for any $E*$. Similarly, it is also easy to prove that $EIS_r = 1$ is equivalent to $EIS_a = 1$.

However, the EIS_r-Index in the intermediate region ($-1 < EIS_r < 1$) does not yield the same value as the Agent Behavior Index, and vice versa. For example, suppose a network, whose size is 2 and which consists of two subgroups of size 1. In this case, the Enhanced-EIS-Index is 0 at $E = S = 1$ and $I = 0$, while the Agent Behavior Index is 1/3.

Table 1 summarizes the six openness indices that have been defined.

Table 1. Summary of the 2 sets of openness indices

	Name	Description
EI_r	EI-Index	Considers the actual number of external relationships compared to the number of internal relationships
EI_s	Subgroup Structure Index of EI	Considers the maximum possible number of external relationships compared to the maximum possible number of internal relationships
EI_a	Agent Behavior Index of EI	Considers the number of external relationships compared to the number of internal relationships
EIS_r	EIS-Index	Considers the number of external relationships compared to the number of internal and self links
EIS_s	Subgroup Structure Index of EIS	Considers the relative maximum possible number of external relationships compared to the maximum possible number of internal and self relationships
EIS_a	Subgroup Structure Index of EIS	Considers the relative number of external relationships compared to the number of internal and self relationships

4. Analysis

4.1. Description of Data

In order to construct the Web2.0 service network, a list of Web2.0 services and mashups were obtained from the Web site www.programmableweb.com. The surveyed data covers the period from September 2005 to May 2007. The size of the Web2.0 service network comprises 231 nodes. 1886 mashups were considered for constructing the Web2.0 service network. Each mashup utilized 1.6 Web2.0 services in average.

An example of a Web2.0 service network is shown in Figure 3. Within this sample Web2.0 service network, Google Search and Delicious.com are linked to each other through the mashup categola, which uses Google Search and Delicious.com.

The 231 Web2.0 services belong to 157 companies (Figure 4). For our analysis, we classified all Web2.0 services according to their ownership to any of those 157 companies. This classification is called subgroup classification according to company ownership. In average, a subgroup consists of 1.5 Web2.0 services. However, the size of subgroups is quite inhomogeneous. Among the subgroups, 10 subgroups such as Yahoo, 37signals, and Amazon.com, include more than two Web2.0 services. The largest two subgroups (Google and Yahoo) provide 23 Web2.0 services each. 147 subgroups are constituted of only one Web2.0 service.

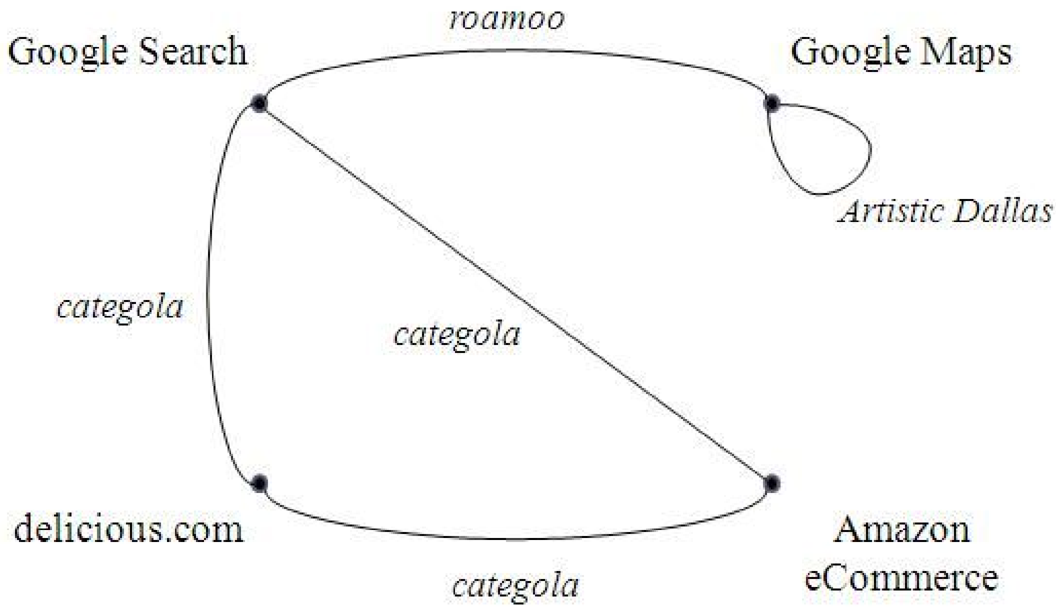

Figure 3. An example of the Web2.0 service network

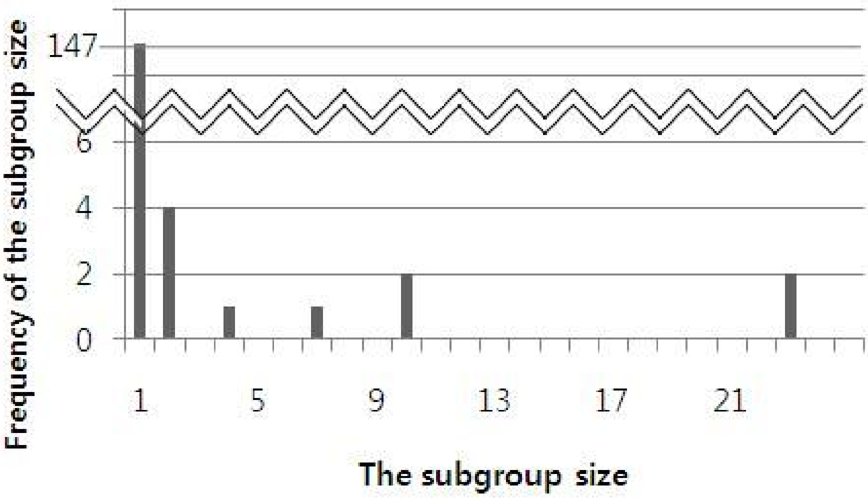

Figure 4. Distribution of subgroup sizes under the classification scheme company ownership

4.2. Descriptive Analysis

In order to apply the set of openness indices on the Web2.0 service network, we measure the number of external relationships, internal relationships, and self relationships with respect to the subgroup classification scheme company ownership (Table 2).

As Table 2 shows, the Web2.0 service network consists of 2864 external relationships, 486 internal relationships, and 3096 self relationships. Based on the subgroup classification company ownership, the maximum possible number of dichotomous relationships was calculated as well. The result is that the company ownership subgroups in the Web2.0 service network can comprise at most 25967 external relationships, 598 internal relationships, and 231 self relationships. The normalized numbers of relationships were calculated, using the measured number of relationships and the maximum possible number of relationships. As shown in Table 2, the normalized numbers of external, internal, and self relationships are 0.1103, 0.8127, and 13.4026, respectively.

Table 2. The number of relationships of the Web2.0 service network considering weighted links

	External Relation-ships	Internal Relation-ships	Self Relation-ships
The number of weighted relationships	2864	486	3096
The maximum possible number of different (dichotomous) relationships	25967	598	231
The normalized number of weighted relationships	0.1103	0.8127	13.4026

In order to investigate the effect of self relationships on the final results, we also calculate the EI-Index as well as the EI_s and the EI_a indices. Therefore, we also measure the number of dichotomous relationships in the Web2.0 service network with respect to the subgroup classification scheme company ownership (Table 3).

Table 3 depicts the numbers of different external and internal relationships. As expected, they are lower than the numbers of weighted relationships. The network of dichotomous relationships involves 1748 external relationships and 168 internal relationships. Consequently, the normalized numbers of dichotomous relationships are lower than the one for weighted links as well. The normalized numbers of external and internal relationships are 0.0673 and 0.2809, respectively.

Table 3. Number of relationships of the Web2.0 service network considering different (dichotomous) links

	External Relationships	Internal Relationships
The number of different (dichotomous) relationships	1748	168
The maximum possible number of different (dichotomous) relationships	25967	598
The normalized number of different (dichotomous) of valued relationships	0.0673	0.2809

4.3. Analyzing Indices to the Data Set

Based on the numbers of weighted relationships in the Web2.0 service network, the Enhanced-EIS-Index EIS_r, the Subgroup Structure Index EIS_s and the Agent Behavior Index EIS_a are calculated (Figure 5). The Enhanced-EIS_r-Index is -0.11. The Subgroup Structure Index is 0.94, and the Agent Behavior Index is -0.98.

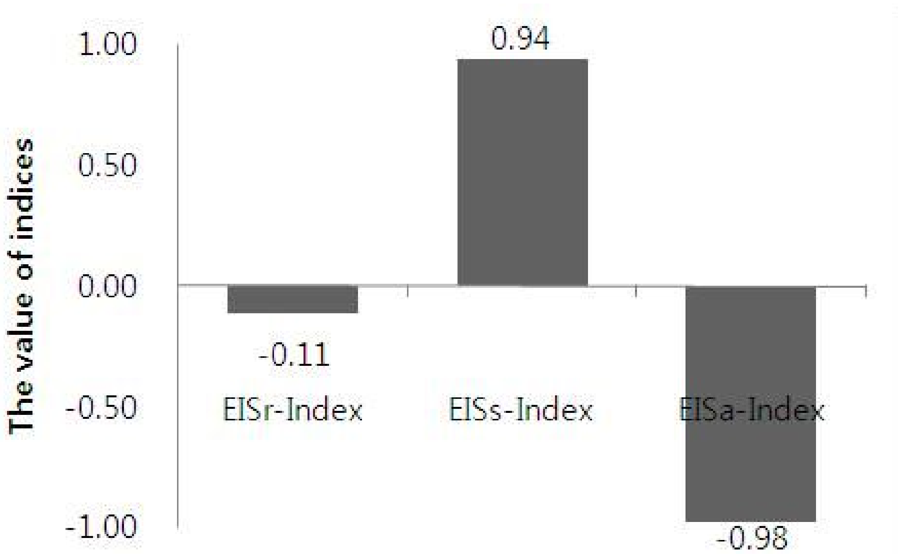

Figure 5. The Enhanced-EIS-Index, the Subgroup Structure Index, and the Agent Behavior Index for weighted relationships of the Web2.0 service network

Figure 5 illustrates clearly that the subgroup structure of the Web2.0 service system significantly stimulates openness (EIS_s = 0.94). However, this tendency is neutralized by the low EIS_a index value (-0.98). This low value highlights that mashup creation is only stimulated for existing Web2.0 services of the same subgroup. That means a user tends to mash up new Web2.0 services within the same subgroup mainly. Conclusively, this explains the low EIS_r value of the Web2.0 service network (EIS_r = -0.11), revealing that the Web2.0 service network is slightly closed.

In order to show the effect of self relationships on this result, we calculate the EI-Index based on the values shown in Table 3. In addition to this, we calculated the Subgroup Structure Index (EIs) and the Agent Behavior Index (EI_a).

The calculation of the EI-Index results in 0.82. The calculation of the EI_s is 0.95 and the calculation of the EI_a is -0.61. Figure 6 illustrates these results.

The comparison of the index values shows that the Enhanced-EIS-Index captures a slight closedness of the Web2.0 service network, while the EI-Index does not. This is due to the reason that the EI-Index measures only the existence of relationships (i.e. dichotomous links) while the Enhanced-EIS-Index measures all relationships (i.e., weighted links) and self relationships within a network.

The results show that the number of self relationships has a significant impact on the results. The number of Web2.0 services that are created based on just one Web2.0 service is significant higher than the number of mashups that are created across company ownership boundaries.

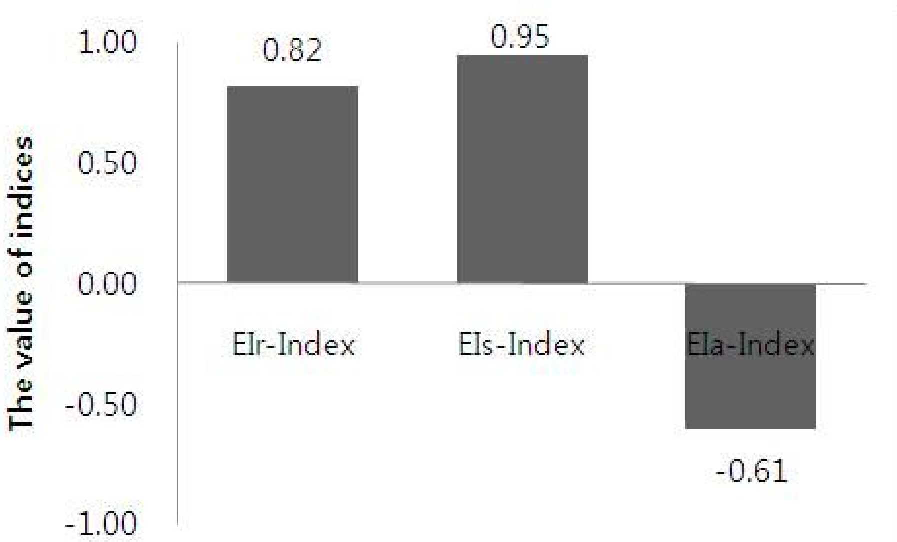

Figure 6. The EI-Index, the EIs-Index, and the EIa-Index for dichotomous relationships of the Web2.0 service network

Therefore, the combination of these 6 indices allows analyzing a network comprehensively. Since our understanding of the meaning of the absolute values of the indices is narrow, we use the combinations of these indices to draw conclusions. If we only calculated the EI-Index, we could discuss the openness of the existent relationships (by comparing external relationships with internal relationships) only. In this case, we would omit the innovation coming from a single Web2.0 service and the function added through a user. This innovation is measured by self relationships, which are frequently ignored in social network analysis. In the Web2.0 service network, EIS_r is negative while EI_r is positive. It means that a majority of innovation in the Web2.0 system has been achieved through adding value to a single existing Web2.0 service. The Web2.0 system has pursued innovation by bridging innovation resources (Web2.0 services) embedded in a variety of companies.

Moreover, the subgroup structure indices and the agent behavior indices explain the level of the openness inherent to the network. The subgroup structure index shows the openness that the subgroups structure of the network brings. The agent behavior index indicates the openness, which comes from the agents and is independent to the openness coming from the subgroup structure. In the Web2.0 service network, the subgroup structure indices (EI_s and EIS_s) are positive and the agent behavior indices (EI_a and EIS_a) are negative. That means, although the industry allows an open environment because of standardized Web2.0 technology, the agent behavior on the Web2.0 system is closed. It is supposed that this closed agent behaviors is partly due to Internet users' limit knowledge about Web2.0 services offered by more than two companies, and partly due to a company's effort to lock users in its system by providing proprietary platforms (e.g., Google Application Engine and Amazon Web Services) with proprietary interfaces. In summary, the openness of the Web2.0 service network results from the overlap of the open subgroup structure and the closed-oriented behavior of agents.

It is also noticeable that the value EIS_r itself is insignificant while EI_r = 0.82 is substantially larger than the EIS_r-Index. By comparing these indices, we can analyze the relative difference within the system. Therefore, our approach to measuring openness does not need to answer whether a certain value of an index is large or low. Instead, it only requires a comparison of the values of the indices in order to determine whether the network is open or closed. This is why we created and applied six openness indices for analyzing the Web2.0 service network.

5. Discussion and Conclusion

This paper introduced five new openness Indices, the Enhanced-EIS-Index, two Subgroup Structure Effect Indices (EIS_s, EI_s), and two Agent Behavior Indices (EIS_a, EI_a). These indices complete the EI-Index of Krackhardt and Stern. All indices were used to measure the social openness of the Web2.0 system. The Web2.0 system is represented through the newly defined Web2.0 service network, in which nodes denote Web2.0 services and links the existence of mashups.

Our analysis results show that the Web2.0 service system allows combining heterogeneous Web2.0 services. However, the results of the openness indices also suggest that the Web2.0 service network is not completely open from a social and entrepreneurial perspective. This is in contrast to the general belief that the Web2.0 system is an absolutely open system. The belief is based on the fact that the Web2.0 system is technically open.

The Web2.0 system is supported by standardized technology (e.g., XML, SOAP, and AJAX), which allows different Web2.0 services to technically interconnect.

According to Krackhardt and Stern's experimental simulation, an organization which includes open subgroups shows a better performance [8, 31]. Krackhardt and Stern measured the correlation between the survival period of an organization and the openness between subgroups in the organization. By comparing several organizations, they concluded that the survival period depends on the openness. In the case of the Web2.0 service network, however, we only have one network. Although this makes it impossible to show openness (or its antonym: closedness) directly, we can state, based on the relationship between the six openness indices used and the index values measured, that the Web2.0 service network is not socially open to its full extent.

Our results suggest that the reduced openness of the Web2.0 service network is related to company ownership. Web2.0 services are rarely combined across boundaries between companies. Self relationships account for about 50% of all links. That means most of the mashups are created on the basis of only one existing Web2.0 service. This closedness of the Web2.0 service network impedes the creativeness of the network.

In particular, our research decomposed the effect of the subgroup structure and the agent behavior on the openness of the network. The subgroup structure index is calculated from the maximum possible number of relationships, which reflects the distribution of the subgroup size in the network. It implies the potential openness that the design of the subgroup structure gives to the network. The agent behavior index is measured based the normalized number of relationships (i.e., the ratio between the actual number of relationships and the maximum possible number), therefore excluding the impact of subgroup structures.

In the Web2.0 service network, the effect of the subgroup structure on the openness is opposite to that of the agent behavior. For subgroups based on the company ownership, the subgroup structure index of the Web2.0 service network is almost at maximum (EIS_s = 0.94), while the agent behavior index is almost at minimum (EIS_a = -0.98).

The low agent behavior index means that some factors hamper the external link creation between subgroups though the subgroup structure is organized as an open structure. It can be conjectured that the impediment factors are: first, the proprietary interface of services provided by companies and, second, the lack of information for Web2.0 users. As an example for the second case, we consider Google App Engine (GAE), which is the Web2.0 service development platform provided by Google, and Amazon Web Services (AWS), which is the Web2.0 service development infrastructure provided by Amazon [32]. A user, who is trained to use GAE, may be unaware of services of AWS, which are complementary with services of GAE. An example for the first case is that the user knows a Web2.0 service in AWS, which is supplementary to a service in GAE, but cannot mash them up since their interfaces are incompatible.

Concluding, this research stresses the necessity to measure the openness of the Web2.0 system, since openness is an important driving force for innovation. By revealing that the

Web2.0 service network is not as socially open as assumed, actions can be undertaken to remove these barriers to a fully open Web2.0 system.

This research leaves some further studies. First, the data period (2005 ~ 2007), which we used, shows only an initial stage of the Web2.0 service network. Until now, new Web2.0 services have been provided steadily. At present (August 31st, 2010), there are 2112 Web2.0 services listed on http://www.programmableweb.com while only 445 Web2.0 services were published on May 31st, 2007. Therefore, the network structure including the openness may have changed.

In addition to this, we focused only on the openness between Web2.0 service providers, because it represents the efficient utilization of innovation resources. However, the openness of the Web2.0 service system does not only depend on company boundaries but also on service areas. Therefore, we plan to analyze the openness between service areas in the future as well and understand its impact.

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Appendix

A. The Boundary of the Subgroup Structure Index

Assume that a network, whose size is N, consists of K subgroups. Let u_k be the size of subgroup k. Then, the maximum possible number of external relationships is defined as:

$$E^* = \frac{1}{2}\left[\left(\sum_{k=1}^{K} u_k\right)^2 - \sum_{k=1}^{K} u_k^2\right]$$

The maximum possible number of internal relationships is defined as:

$$I^* = \frac{1}{2}\left[\sum_{k=1}^{K} u_k^2 - \sum_{k=1}^{K} u_k\right]$$

The maximum possible number of self relationships is defined as:

$$S^* = \sum_{k=1}^{K} u_k$$

Based on these definitions, the Subgroup Structure Index is derived as follows:

$$EIS_S = \frac{E^* - I^* - S^*}{E^* + I^* + S^*}$$

$$= \frac{\frac{1}{2}\left[\left(\sum_{k=1}^{K} u_k\right)^2 - \sum_{k=1}^{K} u_k^2\right] - \frac{1}{2}\left[\sum_{k=1}^{K} u_k^2 - \sum_{k=1}^{K} u_k\right] - \sum_{k=1}^{K} u_k}{\frac{1}{2}\left[\left(\sum_{k=1}^{K} u_k\right)^2 - \sum_{k=1}^{K} u_k^2\right] + \frac{1}{2}\left[\sum_{k=1}^{K} u_k^2 - \sum_{k=1}^{K} u_k\right] + \sum_{k=1}^{K} u_k}$$

$$= 1 - 2\frac{\sum_{k=1}^{K} u_k^2 + N}{N^2 + N}$$

Without proof, the Subgroup Structure Index has a minimum, if the size of one subgroup is N - $(K$ - 1$)$ and the size of other subgroups is 1. Consequently, the minimum can be calculated as follows:

$$EIS_S^{\min} = 1 - 2\frac{(N - K + 1)^2 + (K - 1) + N}{N^2 + N}$$

Additionally, without proof, the Subgroup Structure Index has a maximum, if the size of all subgroups equals N/K. Therefore, the maximum can be calculated as shown in the following equation:

$$EIS_S^{\max} = 1 - 2\frac{N/K + 1}{N + 1}$$

Using these results of the maximum and minimum calculations, we can draw the range of the Subgroup Structure Index, as shown in Figure 2.

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