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Measuring and Analyzing the Openness of the Web2.0 Service Network for Improving the Innovation Capacity of the Web2.0 System through Collective Intelligence

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Abstract: Web2.0 users can create new services by combining existing Web2.0 services that offer open programming interfaces. This system of service composition forms a network, which we call the Web2.0 service network. A node of the Web2.0 service network represents a service. A link between two nodes exists, if another Web2.0 service (i.e. mashup) uses the linked services. The Web2.0 service network can be understood as an innovation system that creates value through the composition of services, representing the collective intelligence of users. Within this paper, we analyze the openness of the Web2.0 service network. Openness, which is an indicator for the innovation potential of a network, is measured using the Enhanced-EIS-Indexes. These indexes are based on Krackhardt and Stern's EI-Index. The analysis results of the indexes show that the Web2.0 service network is not as open as the evolutionary analysis of the Web2.0 service network suggested. The slight closeness of the Web2.0 service network has been identified by the Agent Behavior Index EIS_a, which highlighted that relatively more links are created within subgroups than between subgroups. It indicates that factors such as service ownership and type of service have an impact on innovation within the network.

Keywords: Social network analysis, index, network science, subgroup structure, Web2.0 system, service composition, collective intelligence, Web2.0 service network, performance evaluation, innovation, empirical data analysis.

JEL Classification Numbers: C43, D02, D23, D85, L14, L16, L22, L86, L96, M15, M21.

1. Introduction

In the Web2.0 system, users can combine Web2.0 services that offer open application programming interfaces (APIs). The composed Web2.0 services (which are called *mashups*) provide content, which can again be shared with other Internet users if it provides an open API as well. For making Web2.0 service creation simple, service providers such as Google and Yahoo provide platforms that enable users to create a variety of Web2.0 services based on their ideas and content [1] [21] [22].

The Web2.0 system evolves because of the interactions between the stakeholders in the system. These interactions of the agents organize the Web2.0 service network, which consists of nodes representing Web2.0 services and links their use by other services. The analysis of the evolutionary trends of this network could identify the drivers behind it [3]. Initial work on this topic has been performed [4] [10]. The authors analyzed the network to understand the mechanism of its structural evolution.

However, since the Web2.0 service composition itself also represents value creation, further investigation is needed. In particular, it needs to be analyzed whether the collective intelligence can be fully utilized for Web2.0 service composition, since the Web2.0 system is considered a typical example of harnessing collective intelligence [1]. The Web2.0 system enhances the pool of knowledge by allowing users to participate, create ideas, and realize their ideas through simple passing of knowledge [19]. It allows users to be innovative.

A key enabler of collective intelligence (and, therefore, innovation) is openness. It is a prerequisite together with three other enablers, namely sharing, acting globally, and peering, in order to allow participants to exchange information freely [20].

The openness of Web2.0 services distinguishes it from the first generation Web [1], in which service providers only published their service offerings and, after a contractual agreement with a customer, provided a service [2]. However, no study of the Web2.0 system has addressed the aspect of openness of the Web2.0 system in detail. In particular, no research exists that investigates the importance of openness on the full utilization of collective intelligence of Web2.0 users.

The openness of the Web2.0 service network is important since collective intelligence (and consequently innovation) can only work through the exchange of resources. Even if technology promotes user interaction, social and economic barriers may prohibit the perfect openness between competitors. For example, if the Web2.0 system has limited openness, then Web2.0 innovation is achieved in separated groups (subgroups) only but not across subgroups. In this case, the Web2.0 system is nothing but a collection of partitioned innovation groups, limiting harnessing the collective intelligence of the Web2.0 users.

In order to address this issue, this paper analyzes the impact of subgroups on the actual openness of the Web2.0 service network. The Web2.0 service network defines Web2.0 services as nodes. A link between two nodes exists, if a mashup between those two Web2.0 services has been constructed. Subgroups, which are defined through criteria such as ownership of Web2.0 services (e.g. Google, Yahoo, and Amazon) and the type of service (e.g. shopping services, map services), classify Web2.0 services into different subgroups.

In particular, we introduce the Enhanced-EIS-Indexes to measure the openness of the Web2.0 service network. The three indexes are based on Krackhardt and Stern's EI-Index. The idea behind these indexes is to compare their values, which represent the ratios of links that are generated between subgroups (i.e. external relationships), within subgroups (i.e. internal relationships), and for sole nodes (i.e. self relationships). The ratios indicate how open a network is.

The following section provides background on the Web2.0 system as an innovation system, its interrelation with collective intelligence, and how social network analysis can help to analyze it. In Section 3, we introduce the Enhanced-EIS-Indexes. Based on these indexes, the Web2.0 service network is analyzed in Section 4. The paper concludes with an analysis of the results in Section 5, stating that the Web2.0 service network is not as open as suggested by the industry but rather slightly closed.

2. Innovation, Collective Intelligence, and Network Analysis

2.1. Innovation Capacity of the Web2.0 System through Collective Intelligence

As many examples have shown, high quality and high quantity of innovation emerges in an environment, in which agents can exchange resources beyond the boundaries of formal organizations [6] [7]. For example, in the Silicon Valley, innovation is high, since knowledge flows freely between R&D centers and start-up companies due to high mobility of human resources [5]. Chesbrough analyzed this in 2003 and defined innovation that is based on knowledge sharing as *Open Innovation* [6]. It differs from the old way of innovation, which achieves innovation through vertical integration of research, development, and marketing.

Companies that follow the open innovation approach do not open all their resources they have produced [7] [9]. For example, some open source developers for embedded Linux code reveal part of their code in order to attract potential customer. Code that provides more functionality is sold, helping them to be competitive [8]. In this system, the proprietor of core technology gains profit from an increased market size that cooperators utilizing its free resources have cultivated [7]. The proprietor, who shares its resources, benefits through collective intelligence. In information science, collective intelligence is defined as "the capacity of human collectives to engage in intellectual cooperation in order to create, innovate and invent" [23]. It requires opening access to a resource and sharing it with competitors [20].

Considering the Web2.0 System, the technology of the Web2.0 system promotes cooperation between competing firms on a single platform, enabling the use of collective intelligence of all users of the Web2.0 system and, therefore, fostering innovation. The innovation within the Web2.0 system (i.e. development of mashups) increases user utility and, if a mashup comes with open APIs, even benefits the development of further Web2.0

services. Therefore, mashups (i.e. relationships between Web2.0 services) of different firms represent innovation while the Web2.0 services can be independent and belong to different firms.

2.2. Value Chain of the Web2.0 System

The Web2.0 value chain has two types of stakeholders: the Web2.0 service provider and the user (Figure 1). The service providers, which provide a platform for executing the Web2.0 services, can be further grouped into providers that offer Web2.0 services with open APIs and those that offer Web2.0 services without APIs (which is similar to the first generation Web). Both kinds of Web2.0 services are open to all users. While Web2.0 without an open API can only be consumed, Web2.0 services with open APIs allow users to create new services by combining the Web2.0 service with other Web2.0 services and their own content. If they do so, those users (*Commercial Developer* of Figure 1) become practically Web2.0 service providers. If users only add their own content to an existing Web2.0 service, they are not considered service provider in this model (*Consumers Developing Web Sites* of Figure 1).

The motivation of users to participate in this value creation system varies, ranging from enjoying it as a hobbyist to earning money as a commercial developer. For example, Web2.0 service providers that offer services with open APIs can generate revenues by sharing profit with commercial developers, who utilize their services.

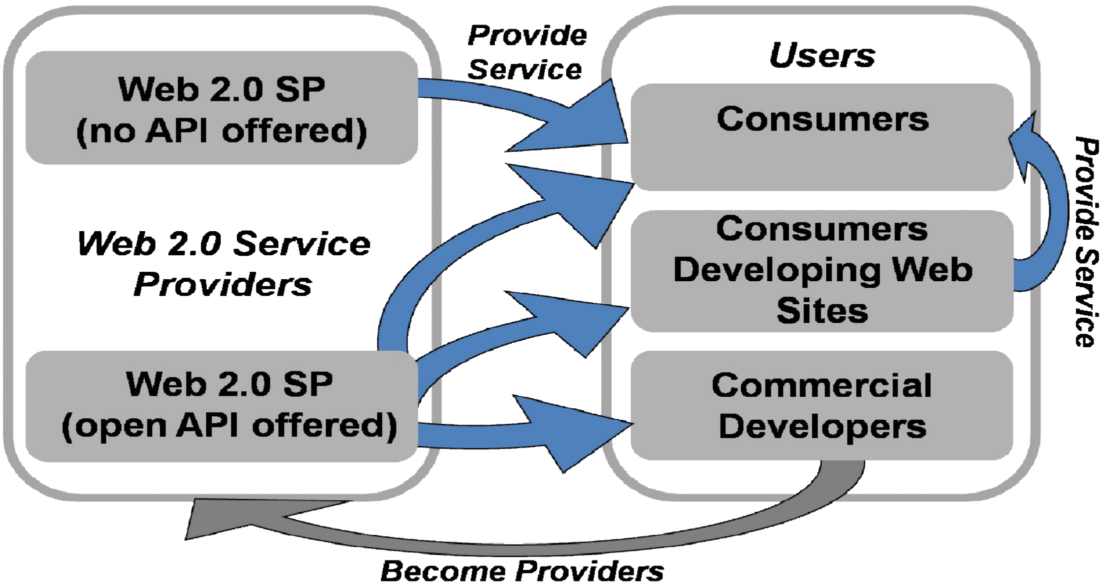


Figure 1. Provider-user relationship model for Web2.0 services.

2.3. Quality of Innovation through Openness

By allowing users to participate in the development of Web2.0 services, value is created within the Web2.0 system. The innovation comes from combining Web2.0 services in new ways. Assuming that the combination of Web2.0 services can be rated according to the number of Web2.0 services per subgroup and the type of Web2.0 services (i.e. subgroup), the quality of innovation can be illustrated in an *2n*-dimensional space, where *n* is the number of subgroups. That means each 2-dimensional plane represents one subgroup. Figure 2 depicts an example in the 3-dimensional space.

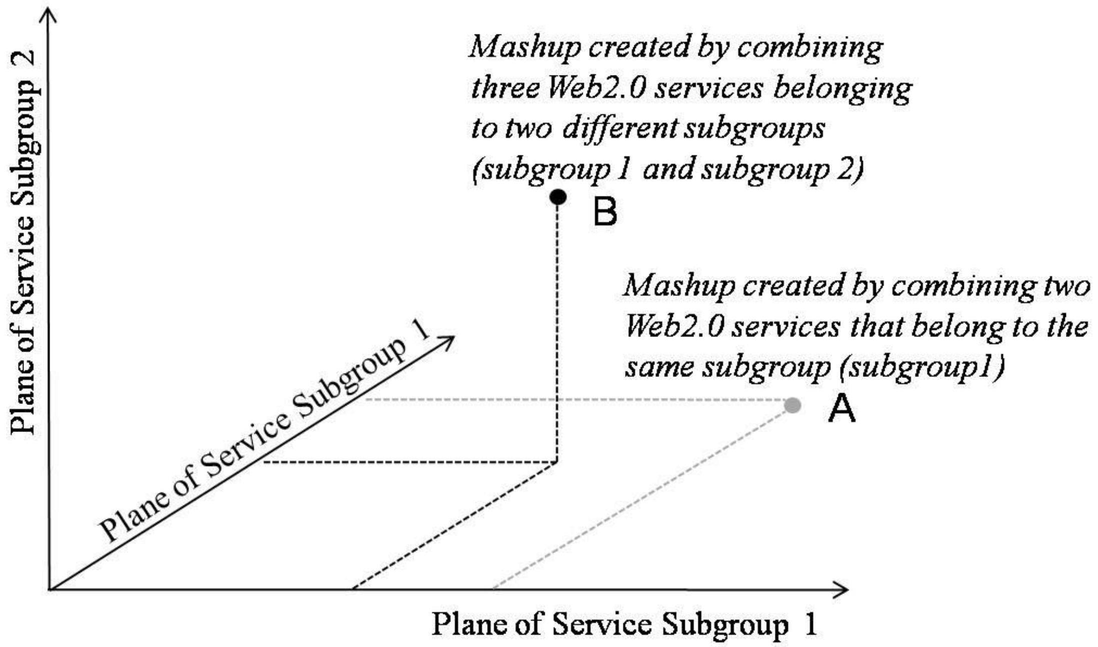


Figure 2. Example of two mashups located in two service subgroup planes.

Figure 2 shows a mashup *A*, which has been developed by combining two Web2.0 services of the same subgroup (i.e. subgroup 1). The mashup is located in one plane. Figure 2 also depicts another mashup *B*, which has been developed with three Web2.0 services belonging to two different types of services (i.e. subgroup 1 and subgroup 2). The mashup *B* can be considered more innovative than mashup *A*, since it requires openness between subgroup 1 and subgroup 2.

2.4. Social Network Analysis of the Web2.0 Service Network

After we have described how innovation is created and innovation flows are established, we need to investigate how innovation of the Web2.0 system can be measured. We need to analyze whether subgroups are open or not, i.e. whether the industry allows innovation to happen freely across different Web2.0 service subgroups (e.g. the ownership of Web2.0 services).

Essential innovation activities are not only the result of the creation of resources but also the result of the combination of resources [6]. For analyzing the resource combinations (e.g. resource sharing between firms), a network approach is useful. This approach measures the position and role of agents in a social network as well as the characteristics of the network structure [11] [12]. An agent's position within a social structure and the structural characteristics of the network can be regarded as social capital, since they determine the interactions between agents [13] [14]. For example, an agent with many social relationships can influence other agents and disseminate information quickly.

To distinguish different characteristics of social capital, Walter et al. (2007) surveyed prior research on structural indicators (e.g. network density, structural hole, and centrality) with respect to inter-firm and intra-firm innovation [15]. They argued that a hub-client structure with a small number of core firms as hubs is most efficient for inter-firm innovation activities while a structure with many redundant ties between departments (e.g., subgroups) is an effective structure for intra-firm innovation activities.

To investigate the effect of openness of subgroups on the performance of an entire organization, Krackhardt and Stern (1988) developed the EI-Index [16]. The EI-Index is defined as the difference between the number of external and internal links divided by the total number of links. An external link is defined as a link between subgroups while an internal link is defined as a link within a subgroup. The index is *1*, if all members only have relationships between their subgroups, and *-1* if the relationships exist only within subgroups. Krackhardt and Stern applied this index to friendship networks of organizations [16]. The result showed that organizations, in which subgroup members interacted with members of other subgroups, yielded a high performance in a crisis. For analyzing the effect of interaction across boundaries of subgroups on the innovation of organizations, the EI-Index has also been applied to the communication network of the Knowledge Management Group at Fraunhofer-Gesellschaft [17] and to the research collaboration networks of multi-national R&D centers in Scandinavia [18].

3. An Index for Measuring Openness

3.1. The Web2.0 Service Network

The Web2.0 service network is defined as a set of nodes, representing Web2.0 services with open APIs, and links indicating the existence of a mashup that uses the nodes being connected [4]. In addition to belonging to the Web2.0 service network, Web2.0 services are also classified into groups (subgroups). The classification criterion allocates each Web2.0 service into exactly one subgroup.

Within this paper, we consider two subgroup classification criteria. First, Web2.0 services are classified according to their *type of service* (e.g. subgroup *Map Services*, subgroup *Picture Storage Services*, and subgroup *Shopping Services*). For example, the Web2.0 services Google Maps and Yahoo Maps belong to the subgroup *Map Services*, and Google Checkout and Yahoo Shopping are grouped into the subgroup *Shopping Services*.

Second, Web2.0 services are grouped according to their *ownership*, i.e. the company that owns the Web2.0 service. With respect to this classification, the Web2.0 services Google Maps and Google Checkout are classified into the subgroup *Google*, and Yahoo Search and Yahoo Shopping are placed in the subgroup *Yahoo*.

3.2. Characteristics of the Links of the Web2.0 Service Network

Our model distinguishes the types of relationships between Web2.0 services of a Web2.0 service network. The types are self-relationships, internal relationships, and external relationships (Figure 3). A Web2.0 service has a self-relationship, if a mashup exists that has been developed based on only this Web2.0 service. A link between two Web2.0 services represents an internal relationship, if both Web2.0 services, which have been used by a mashup, belong to the same subgroup. A relationship between two Web2.0 services is considered to be an external relationship, if these two Web2.0 services belong to different subgroups. In Figure 3, the italicized numbers next to the links (ties) represent weights of the ties. For example, the value of 3 next to the external relationship means that the two nodes are connected through three mashups.

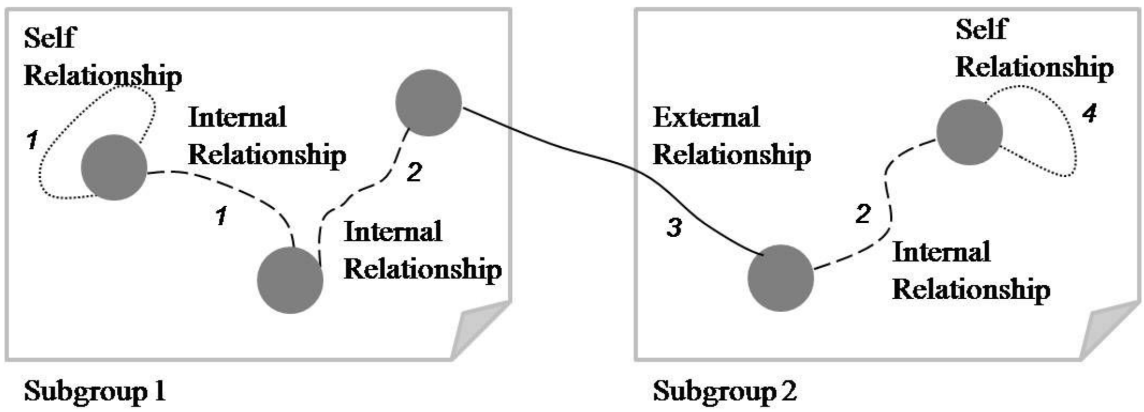


Figure 3. Example of self relationships, internal relationships, and external relationships in a social network such as the Web2.0 service network.

3.3. Measures for Evaluating the Openness of Networks

In order to analyze the Web2.0 service network, we use two types of measures. The first type of measure is used to compare the relative relationships of the three types of links (i.e. self relationship, internal relationship, external relationship). The second type of measure, which is an enhancement of the Krackhardt and Stern Index, is used to investigate the ratio between external links and the internal and self links (Section 3.4).

3.4. Relative Relationship Value

The first type of measure, which is called relative relationship value, helps weighting the relative importance of the three types of links. It ranges between 0 and 1. The relative relationship value of the self (or internal or external) links is defined as the ratio of the number of self (or internal or external) relationships and the total number of links in the network.

In order to explain the structural characteristic of the network through a comparison of these relative relationship values, we also introduce the two terms *dominant* and *superior*.

A relative relationship value is called *superior*, if it is larger than another relative relationship value. A relative relationship value is called *dominant*, if it is larger than the sum of the other two values. That is, a superior (or dominant) relative relationship value indicates that its characteristic is strongly (or very strongly) represented in the network.

3.5. The Enhanced-EIS-Indexes

Applying Krackhardt and Stern's EI-Index to the Web2.0 service network has two limitations. First, binary link weights, as used by Krackhardt and Stern's EI-Index, only show the existence of relationships but do not represent the strength of ties between nodes. Therefore, the same combination of Web2.0 services used for developing different mashups would not be considered. However, since the strengths of links express the importance of nodes, this information is valuable for the analysis of the Web2.0 service network.

Second, the EI-Index, which identifies only internal and external links, does not allow representing mashups that have been developed based on one single Web2.0 service. These mashups have been created by simply adding information to one existing Web2.0 service. For the analysis of the Web2.0 service network, self-relationships represent a significant fraction and, therefore, have to be considered in the analysis of the network.

The Web2.0 service network can be analyzed comprehensively, if we enhance Krackhardt and Stern's EI-Index by including self-relationship and weighted links. Following the format of Krackhardt and Stern's EI-Index, we can define the Enhanced-EIS-Index EIS_r as:

$$EIS_r = (E - I - S) / (E + I + S) \qquad \textbf{(1)},$$

where, E, I, and S are the number of external, internal, and self-relationships of the network, respectively.

To distinguish the effects of the social network structure on the Enhanced-EIS-Index EIS_r, we introduce two more indices, which are similar to the Enhanced-EIS-Index. The first index considers the network size (i.e. the number of nodes) and the subgroup structure by determining the maximum possible number of dichotomous external (internal, and self) relationships that a network can generate at most. For example, the network in Figure 3 has 5 nodes, of which 3 nodes belong to subgroup 1 and 2 nodes to subgroup 2. Therefore, the network can at most generate 6 external dichotomous relationships, 4 internal dichotomous relationships, and 5 self dichotomous relationships. By using the maximum possible number of external E*, internal I*, and self S* links of the dichotomous network [16], we define the *Enhanced-EIS$_s$-Index* as:

$$EIS_s = (E^* - I^* - S^*) / (E^* + I^* + S^*) \qquad \textbf{(2)}.$$

The resulting EIS_s value indicates the openness of a network that the subgroup structure of the network allows. Since the maximum possible number of links depends on the distribution of the size of the subgroups, we also call this index *Subgroup Structure Index*. Considering our example, we get EIS_s = (6-4-5) / (6+4+5) = - 0.2.

The second index considers the normalized numbers of relationships, while excluding the effect of the subgroup structure. The normalized number of external (internal, and self) relationships e (i, and s) is defined as ratio of the number of external (internal, and self) relationships and the maximum possible number of external (internal, and self) relationships. For example, the network shown in Figure 3 has 1 external relationship, 3 internal relationships, and 2 self relationships. And it can hold at most 6 external relationships, 4 internal relationships, and 5 self relationships. Hence, the normalized number of external (internal, and self) relationships is 0.166 (0.75, and 0.4). By applying the normalized numbers of external, internal and self links (e, i, and s), we can define the *Enhanced-EIS_a-Index* as:

$$EIS_a = (e - i - s) / (e + i + s) \qquad \textbf{(3)}.$$

Since the effect of the subgroup structure is neutralized in this index, the resulting EIS_a value represents the openness of a network without the subgroup structure effect. Since the normalized numbers of links represent the average numbers of relationships of agents in the network, we also call this index *Agent Behavior Index*. In our example, the Index EIS_a = (0.166-0.75-0.4) / (0.166+0.75+0.4) = -0.7468.

4. Analysis

4.1. Description of Empirical Data

Data has been gathered from the Web site http://www.programmableweb.com, which lists Web2.0 services that have been registered by the owners of the services. In total, 2374 Web services had registered between September 1st, 2005 and May 31st, 2007, of which 445 are Web2.0 services that offer open APIs and 1929 are mashups. Besides, 8 mashups also provide open APIs. However, 226 Web2.0 services were eliminated from the data set, since they are not used in any mashup during the survey period. As a result, only 219 services with open APIs are used in the analysis.

The resulting Web2.0 service network can be classified into 143 subgroups with respect to the *ownership* criterion and into 47 subgroups with respect to the *type of service* criterion. The size of these two sets of subgroups is heterogeneously distributed. Among the 143 subgroups created through the ownership criterion, 134 companies provided only one Web2.0 service. Only nine companies (e.g. Google, Yahoo, and StrikeIron) provided more than two Web2.0 services (Figure 4).

The results that are shown in Figure 4 indicate that the distribution of Web2.0 services is not uniform over all companies. That is, a small amount of subgroups have a majority of Web2.0 services with open APIs, and a large part of subgroups includes only few Web2.0 services. It reflects that the Web2.0 service industry is influenced by a few companies.

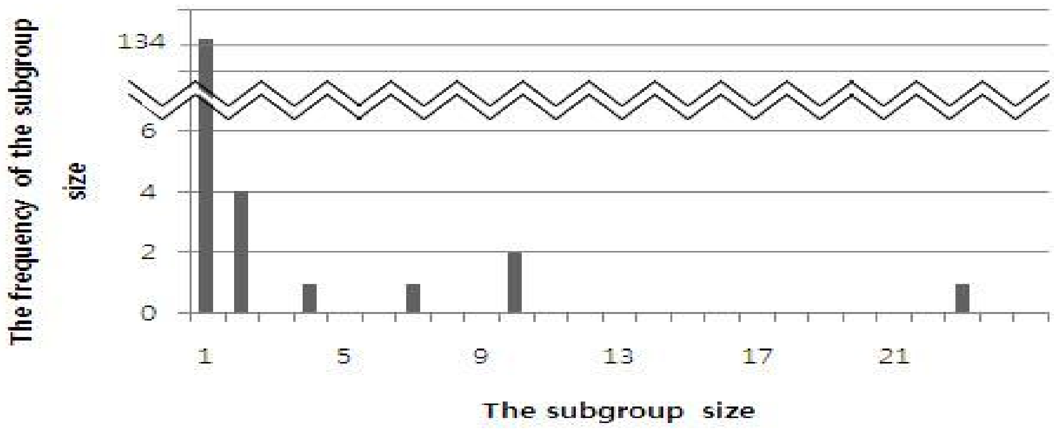


Figure 4. Distribution of the subgroup size for subgroups based on the ownership criterion.

Among the 47 subgroups that are created through the type of service criterion, 34 subgroups provide less than 5 Web2.0 services. Only one subgroup consists of more than 20 Web2.0 services (Figure 5).

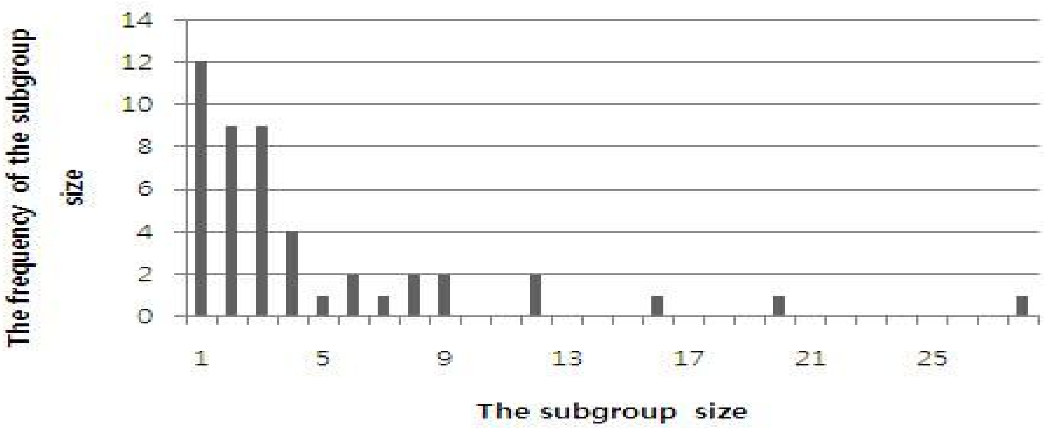


Figure 5. Distribution of the subgroup size for subgroups based on the type of service criterion.

Figure 5 illustrates that the distribution of Web2.0 service is also uneven for the type of service criterion. A majority of Web2.0 services belong to a few service types (e.g., Map Services and Shopping Services). It mirrors that Web2.0 system is constituted through a few focal services (e.g., Mapping Service) which are supported through peripheral services.

4.2. Trend Analysis of Relative Relationship Values

In order to illustrate the trend of the relative relationship values across time, we calculate the relative relationship values for the self, internal, and external relationships for each month during the period from September 2005 to May 2007. The relative relationship values that are shown in Figure 6 and Figure 7 for each month are based on the cumulated data up to the month shown. For example, the self relationship value in July 2006 is the total number of self relationship in the Web2.0 service network from September 2005 to July 2006.

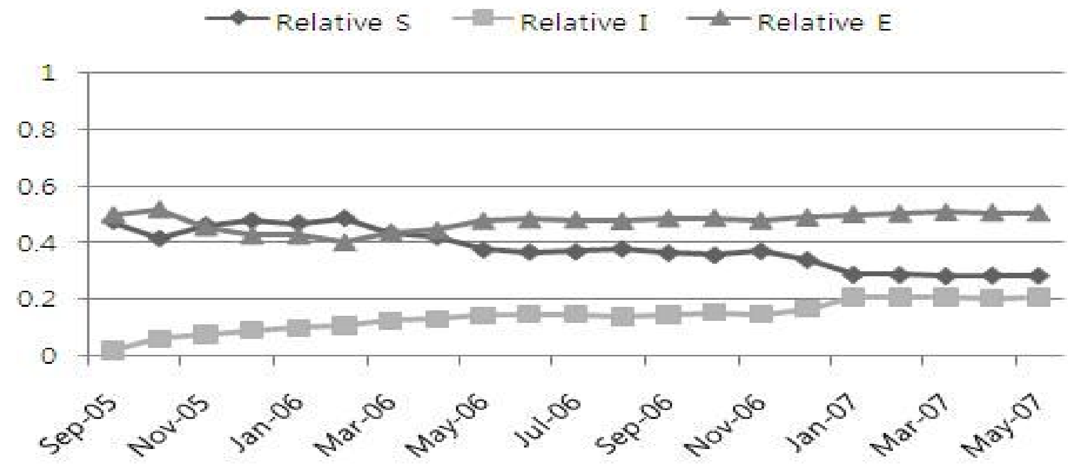


Figure 6. The trend of relative relationship values calculated for the self, internal, and external links with respect to the ownership criterion.

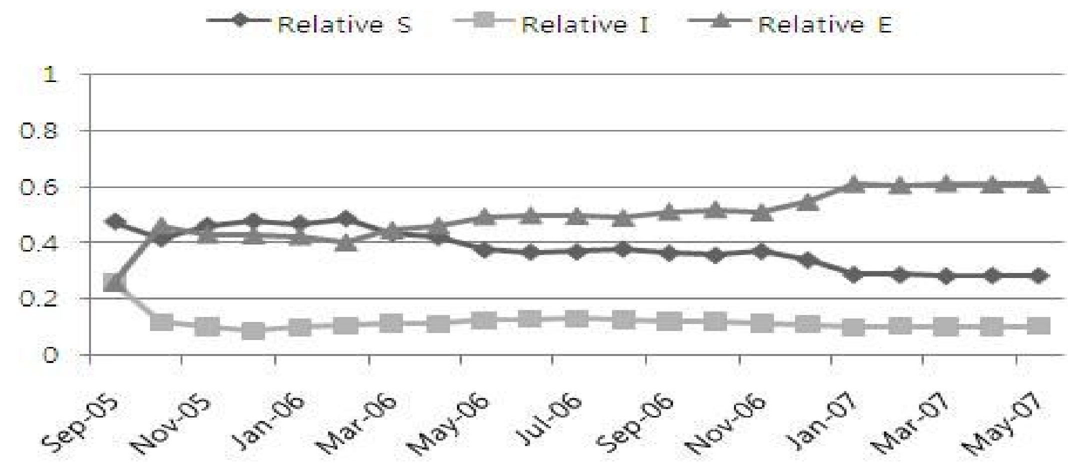


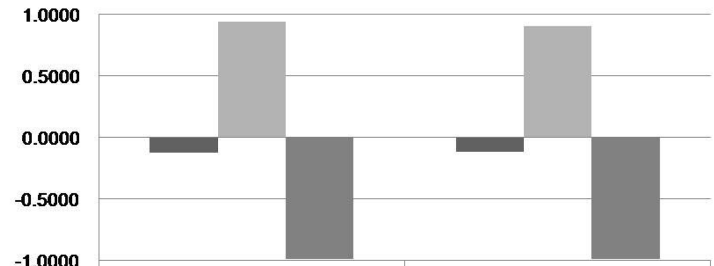
Figure 7. The trend of relative relationship values for the self, internal, and external links with respect to the type of service criterion.

With respect to the ownership criterion, Figure 6 shows that the relative relationship value of the internal links increases steadily (The curve is named *Relative I* in Figure 6). This means that the number of mashups developed with Web2.0 services belonging to a same subgroup increases over time. However, it is low during the entire period, and reaches only a value of about 0.2 at the end of the observation period in January 2007. The relative relationship values of the self and external links are equal during the initial period (The curves are named *Relative S* and *Relative E* in Figure 6). In the later period, however, the relative relationship value of the external link is superior. This implies that the Web2.0 service network is open in the later periods. In particular, we can state that there are Web2.0 services of different ownership subgroups, which are not bound by the ownership of the Web2.0 service.

With respect to the type of service criterion, the comparison of the relative relationship values shows that the relative relationship value of the external links is superior and dominant at the end of the observation period (The curve is named *Relative E* in Figure 7). Furthermore, the relative relationship value of the self links decreases after being superior in the initial period (The curve is named *Relative S* in Figure 7). This trend shows that the structure of the Web2.0 service network is independent of the types of services. The Web2.0 service network evolves such that it destructs the barriers of service types.

4.3. Analysis of Enhanced-EIS-Indexes

The Enhanced-EIS_r-Indexes for the Web2.0 service network under both subgroup criteria, the ownership criterion and the type of service criterion, are about - 0.12 for the period of May 2007 (Figure8).



	Ownership Subgroups	Type of Service Subgroups
EIS Index	-0.1220	-0.1195
Subgroup Structure Index	0.9386	0.9017
Agent Behavior Index	-0.9917	-0.9914

Figure 8. The Enhanced-EIS_r-Indexes, the Subgroup Structure Indexes EIS_s, and the Agent Behavior Indexes EIS_a for the Web2.0 service network of May 2007 with respect to the ownership criterion and the type of service criterion.

The Subgroup Structure Indexes EIS_s for both subgroup criteria are very high, namely 0.9386 and 0.9017. It shows that the Web2.0 service industry is organized such that new Web2.0 mashups can be created through the combination of existing Web2.0 services that belong to different subgroups. It exhibits openness.

However, looking at the Agent-Behavior-Index EIS_a for the ownership criterion and the type of service criterion, we can see that they are -0.9917 and -0.9914. That implies that Web2.0 services have been used to establish relatively more links within subgroups than across subgroups. It suggests that users are captivated within subgroups. This complies with the theory that agents are more likely to make relationships with colleagues of the same subgroup, with who they share a common culture and a strong communication channel [16]. Similarly, we can suspect that a user, who is familiar with a service type or with the programming interface of a particular company, may tend to apply Web2.0 services of the same service type or the same company. In both cases, the cost for developing new Web2.0 services is low, since the user can reuse his/her existing knowledge about a type of service and programming interfaces of a company, respectively.

Consequently, these results show that the Web2.0 service network is not as open as expected and suggested by the comparison of the relative relationship values of Section 4.2. The Enhanced-EIS-Indexes, that have been introduced, helped identifying that there are preferences for establishing links within the same subgroup. This also explains the low EIS_r value of the Web2.0 service network ($EIS_r = -0.12$), revealing that the Web2.0 service network is even slightly closed.

5. Discussion of the Openness of the Web2.0 System

In this paper, the Web2.0 service network was defined as a network of innovation activities impacted by subgroups of Web2.0 services. The network is driven by the development of Web2.0 services through users, exhibiting the collective intelligence of the Web2.0 system. The openness of the Web2.0 service network stands for creating combinations of Web2.0 services of different subgroups. This openness of resources promotes sharing of Web2.0 service between subgroups.

Many of our measures (i.e. the relative relationship values (Figure 6 and Figure 7), the Enhanced-EIS_r-Index, and the Subgroup Structure Index EIS_s) indicate that the network is actually open. Therefore, we may say that the Web2.0 service network is open, fostering innovation.

However, one of our Enhanced-EIS-Indexes reveals that the Web2.0 service network is not completely open, rather slightly closed. The Agent-Behavior-Index EIS_a showed that the creation of links within subgroups is preferred to the creation of links between subgroups. This shows closeness, which has not been identified before.

Therefore, we can state that type of service subgroups and ownership subgroups negatively impact the use of the collective intelligence, limiting innovation. New compositions of Web2.0 services are preferably created within subgroups. Users prefer subgroups, with which they are already acquainted.

In the future, we will extend our research by considering the original Krackhardt and Stern Index in conjunction with the Enhanced-EIS-Indexes. In addition to this, an evolutionary model, which considers the behavior of agents and the impact of subgroups, is planned to be simulated.

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