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Structural and trend analysis of tagging as a mechanism for organizing learning resources

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Abstract: The tagging mechanism has enabled students to organize plenty of online posts, pictures, and academic articles. Previous research has reported that the design of user interfaces for information organization may affect the way of future problem-solving and recall. Over the years, there have been considerable studies on the design of user interfaces for tagging. However, these studies put more emphasis on efficiency of tagging and future recall, but seldom on the structure of tagging outcomes and the tagging process. Therefore, the study designed and compared three types of user interfaces, that is, tag list, tag cloud, and tag network, and then employed network analysis and trend analysis to discover the structural and temporal patterns of tagging. Results of the study showed that, based on the proposed structural indicators and the trend analysis method, the three user interfaces designed for tagging have different degree of effects on tag reusing behaviors. Compared with tag list and tag network, tag cloud can lead more participants to make use of pre-used tags. By visualizing the tagging results as networks for representing the structure of information organization, we further categorized the tagging results into centralized, clustered and separated networks, which can be predicted by the weighted reused times of tags proposed in the study. Besides, participants using tag cloud interface created more clustered networks than those using the other two interfaces. The clustered network structure is corresponding to the selection strategy of the learning resources in the study.

Keywords: Tag, information organization, user interface design, memory, network analysis

1. Introduction

In the current learning environment, information technologies have been widely applied in the information problem solving process, including searching, navigating, reading, retrieving, understanding and organizing steps (Walraven, Brand-Gruwel, & Boshuizen, 2008). These information technologies, such as search engines, annotation software, bookmarks of browsers or social bookmarking services like *Diigo*, may not only alter students' habit of searching information and constructing knowledge (Brand-Gruwel, Wopereis, & Vermetten, 2005), but also affect their metacognitive learning strategies (Brown, 1987).

Before the network became popular, Wyman and Randel (1998) had indicated that information organization may affect the problem solving and recall efficiency. In the current learning environment, many information organization tools have been used in classrooms and students' daily life. For instance, Liu and Chang (2008) applied bookmarking as students' learning portfolio, described how their participants collected, shared and formed discussion groups with tagging mechanism. Maggio et al. (2009) made use of tags to assist the patrons to learn the complicated concept of medical controlled vocabulary. *Diigo*, a popular social bookmarking service on the Internet, promoted a "*Diigo in Education*" service for K12 educators, which allows teachers to collect essential and extended readings for their students. Moreover, Estellés, González, and del Moral (2010) introduced how to integrate *Diigo* into online courses, and provided several successful cases of academic situations such as sharing and keeping track of teaching resources. Im and Dennen (2013) shared their experiences of how their students contributed links and commented on others' collections via *Diigo*.

While tagging mechanism has been widely applied in current Web 2.0 services, most of the above studies put their focus on the social function of tagging such as sharing or collaborative filter.

However, this study, similar to several research (Civan, Jones, Klasnja, & Bruce, 2008; Bergman, Gradovitch, Bar-Ilan, & Beyth-Marom, 2013a, 2013b; Hsieh, Chen, Lin, & Sun, 2008; and Hsieh & Chiu, 2011), centered on the personal information organization function of tagging. The information organization refers to the process that users utilize tools to categorize or label their received information in an ordered way to enhance the efficiency of future problem solving and memory retrieving (Bergman, Beyth-Marom, & Nachmias, 2008; Wyman & Randel, 1998).

However, Wyman and Randel (1998) pointed out that different ways of information presentation may affect the structure, organization, and representation of human physical memory. For example, Marshall (1990) has found that node count and degree of connectivity, two network-based structural indexes, can predict the knowledge of learners. Gitomer (as cited in Wyman and Randel, 1998) compared two groups of repairmen with equal electronics knowledge, and found that the high skilled group can describe components of electronic circuits at a high abstract level. Regarding the user interface for tagging, Gao (2011) and Sen et al. (2006) have shown that the ways of visualizing tags, such as tag list or tag cloud, will affect the future tag selection and application.

Similar to Civan et al. (2008) and Bergman et al. (2013a, 2013b), the author has published a paper (Hsieh et al., 2008) to compare the information organization efficiency between archiving by folder and labeling by tagging. The current study put the focus on the comparison among three user interfaces for tagging, that is, tag list, tag cloud, and tag network. Furthermore, based on the relation between information organization and personal knowledge structure (Wyman & Randel, 1998; Marshall, 1990), the study applied network visualization to each participants' tagging results as an externalization of their knowledge and memory structures as well as Sen et al.'s (2006) trend analytic method to discover the temporal features of a user's tagging tendency for applying pre-used or new tags.

2. Literature Review

2.1 User interface effects on tag selection

User interface can provide visual clues (e.g., size, color, and link) to assist users in discovering hidden information patterns and relations among concepts, retrieving information accurately and efficiently, as well as alleviate their demand on cognitive load (Gao, 2011). Regarding tagging mechanism, most of the user interfaces put the pre-used tags in order or visualize them in certain ways for future use. Therefore, in the future tagging process, a user can create a new tag for a new resource, or select (apply) a pre-used tag from the user interface.

The study implemented three kinds of user interfaces for tagging, including tag list, tag cloud, and tag network. The tag list method places tags in alphabetical order, or permutes them by their frequency (i.e., reused times, Halvey & Keane, 2007). The tag cloud method highlights tags in larger font size on a two-dimensional plane according to the reused times of tags. Lohmann, Ziegler, and Tetzlaff (2009) applied the eye-tracking method to investigate how their participants looked at the different tag cloud layouts. The eye tracking data showed that the participants not only had more eye fixations on large font size tags on the middle of the plane, but also tended to have fixations on upper left quadrant of all user interfaces. Gao (2011) classified methods of generating tag cloud into two types: according to the tag reused frequency or the tag semantic relation. We adopted reused times of tags to construct tag cloud in this study.

Based on the viewpoint that network structure can represent information organization structure (Marshall, 1990; Wyman & Randel, 1998), when a pair of tags is applied to a digital resource, it can be said that the pair of tags has a co-occurring relation between them, which can be represented by two nodes (Shen & Wu, 2005; Gao, 2011). Tags can also be viewed as concepts in human physical memory, and relations among them can be regarded as links among concepts for future retrieval. Therefore, the tags and their co-occurring relations can be visualized as tag networks, which help users to discover new concepts through connected links. For example, by network representation, social bookmarking services such as *citeulike*, *Diigo*, or *del.icio.us* recommend related articles with shared tags to users (Wu, Gordon, &Demaagd, 2004; Shen & Wu, 2005; Hsieh & Chiu, 2011). Stefaner has designed a network-based navigator allowing users to traverse the URLs on the social bookmarking service del.icio.us[1].

With regard to the evaluation of user interface usability, most of the previous studies put their emphasis on evaluating the usability of tag cloud. While evaluating the tag cloud usability on social networking, Sen et al. (2006) calculated the changes of new tag proportion to discuss how the pre-used tags affect future tag selection for movies. Gao's (2011) study resized the tag font size according to its pre-used frequency to assist future tag selection. It showed that the use of tag cloud interface can increase the wording consistency and therefore "*alleviate the physical demand perceived by users*" (Gao, 2011, p. 821).

2.2 Tag structural indicator

Since Marshall (1990) indicated that network indicator such as centrality and connectivity can be used to evaluate a user's knowledge structure and recall strategy, there has been several research works applying network analysis method to the investigation of tagging results. For example, while Cattuto, Barrat, Baldassarri, Schehr and Loreto (2009) focused on tag network dynamics, Shen and Wu (2005) employed network analysis indicators to show the structural properties of tag networks. The network indicators included degree distributions, clustering coefficients, and average path length. Hsieh and Chiu (2011) commented that the proportion of adding new tags or applying pre-used tags may affect the future network structure, which is corresponding to Sen et al.'s (2006) analytic method. Viewing tag results as networks, Kipp and Campbell (2006) investigated 64 popular URLs' tags and found that the usage of tags follows the long-tail phenomenon, which means that several tags will be reused heavily. Heymann and Garcia-Molina (2006) found that most of the users labeled resources in intuitive ways, not in logical or systematical ways, which increased the difficulty of future retrievals. Therefore, they applied the concepts of agreement, density and overlapping to generate hierarchical tag networks, and pointed out that the centrality, a network indicator, played an important role in re-constructing the hierarchical tag network.

Cattuto et al. (2009) and Schmitz et al. (2007) investigated how the change of tag network size affects that of the average path length, cliqueness, and connectedness. They believed that the social bookmarking shows collective dynamics, not a forehand and planned behaviors. Both of the studies discovered small world properties of tag networks. While the above studies used network analysis to show tag dynamics and tag results, evaluations for quantifying the tag networks are needed to predict future information organization efficacy (Pak, Pautz, & Iden, 2007). Pak et al. (2007) also commented that tagging mechanism often generated many item-specific terms, which may increase the working load of memory. The hierarchical categorization based on folder archiving has been evaluated by breadth and depth for more than one decade (Jacko & Salvendy, 1996; Zaphiris, 2000). Gao (2011) also proposed that consistent wordings will increase the usability of the whole system. In other words, a good user interface for tagging should lead users to reuse pre-used tags, rather than adding new tags endlessly.

3. Methods

3.1 System Design

To explore the effects of user interface on tagging mechanism, the researchers designed a tagging system to which instructors can upload three kinds of learning resources, including URLs, figures and PDFs, change the order of learning resources, and control the user interface displayed to students. Once an experiment is finished, instructors can download the log and take a quick view on the tagging results in the forms of both tag cloud and tag network provided by the system. Participant id, article id, tag, and timestamp were recorded in the log for future analysis.

Figure 1 illustrates the user interface for students to read a URL and tag it by adding new tags or applying pre-used tags on "Tag UIs". Three user interfaces (see Figure 2) were designed to assist tagging activities. Students were assigned different user interfaces according to their classes. Tag list

[1] http://well-formed-data.net/experiments/tag_maps/

in Figure 2 lists the tags in alphabetical order and attaches a number to each tag to indicate its reused frequency. Tag cloud visualizes the reused times of tags with different font sizes. High frequency tags are displayed in large font size. A link in a tag network further visualizes co-occurring times of a pair of tags. Whenever a student adds a new tag or reuses an old one, the user interface will be updated immediately. Furthermore, students can click a tag on tag cloud or tag network interfaces to apply it to the target URL. We utilized Force-Direct algorithm developed by Kamada and Kawai (1989) and Fruchterman and Reingold (1991) to visualize the tagging network.

Figure 1. The tagging user interface including the reading material, tagging area, and user interface (Tag UIs) for tagging activities.

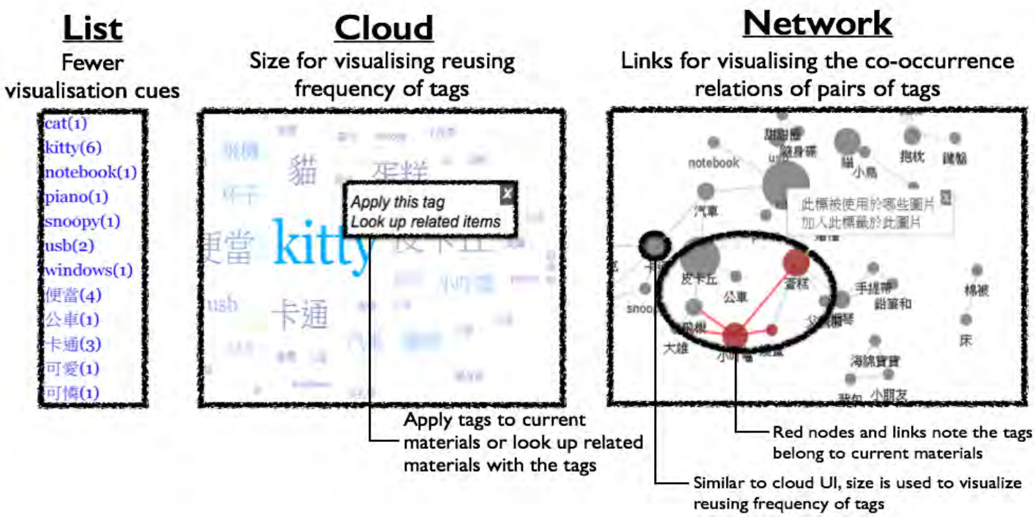

Figure 2. Examples of tag list, cloud, and network for tagging activities.

3.2 Experiment Designs

To investigate the effects of user interfaces on information organization, three classes from a vocational school in northern Taiwan were selected purposefully. Participants of the three classes belong to three different branches irrelevant to information science. The experiments were conducted in the course "Introduction to Computer Science," where the three classes were assigned to use tag list (n = 40), tag cloud (n = 31) and tag network (n = 34) as experimental groups.

The materials used were 30 computer science related online articles selected by researchers and course teachers from three Taiwanese websites (i.e., *techorange.com*, *inside.com.tw*, and *wired.tw*). The topics of these articles cover the issues including social networking sites, mobile phones and apps, as well as network marketing, tools, and online startup.

For each class, the authors first introduced the concept of information organization and demonstrated the tagging system for 40 minutes. After that, the participants played a labeling game designed by the authors for 20 minutes and were encouraged to use several terms to describe the characteristics of their classmates. Finally, the participants were requested to read and tag the 30 articles in 90 minutes. The authors taught these courses by ourselves and the original course instructor remained in the classroom for assistance.

The system recorded (article, tags, timestamp) entries for each tag adding operation. Besides, with the consent of the course instructor and students, the authors used digital video recorder to record the teaching process and student responses. After the experiments, several participants' logs were filtered out due to meaningless tags in their logs (e.g., "aaaaa", "123", "44444"). The final effective samples are 36, 28, and 29 participants for tag list, tag cloud and tag network respectively.

Each participant's tagging result was visualized as tag network for further comparison. In addition to descriptive analysis, on the basis of Marshall's (1990) viewpoint on information organization and Sen et al.'s (2006) analytic method, we recognized "reused times of tags" as an important factor that can be analyzed with three indicators. The first one is the number of distinct tags used by a participant. The tendency of adding new tags to label learning resources will lead to a higher number of distinct tags. The second indicator calculates the reused times of the highest frequency tag. For example, a participant was found to label all 30 articles with the tag "technology". His/her reused times of the highest frequency tag would be 30, which means that the participant considered the tag "technology" the core concept during the experiment. It should be noted that labeling all learning resources with the same tag hardly makes significant differences between them, and leads to a less effective information organization.

In addition to the indicator quantifying the use of highest frequency tag, we employed Hirsch's (2005) *h*-index as the third indicator to quantify middle frequency tags. The use of middle frequency tags can be viewed as a means to show the general characteristics of learning resources, while the use of low frequency tags to show the specific characteristics. The *h*-index, known for its avoidance of extreme value, was originally created to analyze the productivity and impact of a scholar (Hirsch, 2005). The original definition of *h*-index is that a scholar has index *h* if *h* of his/her papers have been cited at least *h* times. The application of *h*-index in our study for evaluating a user's behavior of reusing tags can be that if *h* of the tags has been reused at least h times, the user receives an h value as the quantifying value of his/her use of middle frequency tags.

Since tagging mechanism is an information organization method, there may not be a clear correlation between information organization and learning efficacy. Therefore, rather than evaluating the results of learning performance, we conducted a recall test with 15 items to assess the influence of tagging on recall efficacy. One sample item is "*Please indicate that which option is the 2011 restaurant recommendation service based on atmosphere.*"

4. Results

4.1 Descriptive analysis

Table 1 shows the descriptive results of the three experimental groups (i.e., tag network, tag cloud, and tag list). On average, participants of the tag cloud group used the fewest tags to label the learning resources with a low standard deviation. Comparing the total number of tags and that of distinct tags, we found that the experimental groups using tag interfaces of list and cloud tend to reuse pre-used tags. Also, participants of the tag cloud group have a higher average of reused times of the highest frequency tags and *h*-index than the other two groups, which means that tag cloud can lead users to generate more high and middle frequency tags. According to the concept of information organization, high and middle frequency tags, compared with low frequency tags, can better reflect the main topics of the learning resources.

Correlations of the three indicators for evaluating different levels of reusing tag frequency are shown in Table 2. Both *h*-index and reused time of the highest frequency tags have a significantly negative correlation with the number of distinct tags in all three experimental groups, which means that the behavior of reusing tags may decrease that of creating new tags. The experimental group using tag cloud had the highest significantly negative correlation between the number of distinct tags and the other two indicators. (-0.87*** and -0.72***).

Table 1. Descriptive results of the tags used in the three different user interfaces (total number of articles is 30).

		Mean	Median	Max.	Min.	Std.
Total number of tags	**Network**	170.37	157	286	145	33.25
	Cloud	155.07	151.5	185	139	10.19
	List	165.77	158	298	101	30.92
Number of distinct tags	**Network**	142	143	286	85	39.99
	Cloud	108.1	109.5	156	24	31.48
	List	124.8	132	258	12	50.32
Reused time of the highest frequency tags	**Network**	10.00	6	30	1	8.45
	Cloud	11.43	10	29	2	6.85
	List	11.18	12	30	1	6.92
***h*-index of middle frequency tags**	**Network**	4.12	3	7	1	1.54
	Cloud	4.97	4	8	2	1.52
	List	4.41	3	9	1	1.93

Table 2. Correlation among reused time of the highest frequency tags, *h*-index, and number of distinct tags in three user interface experiment groups.

	Network	Cloud	List
Number of distinct tags vs. *h*-index	-0.71 (t=-5.30***)	-0.87 (t=-9.16***)	-0.63 (t=-4.95***)
h-index vs. reused times of the highest frequency tags	0.71 (t=-3.06***)	0.56 (t=3.45**)	0.672 (t=5.44***)
Number of distinct tags vs. reused times of the highest frequency tags	-0.50 (t=5.30***)	-0.72 (t=-5.30***)	-0.561 (t=-4.07***)

4.2 Visualization and Structural Analysis

By visualizing the tagging results as network structures, we named Hsieh et al.'s (2008) two types of tag networks as centralized and separated networks, and further added the third type in the current study as clustered network, as shown in Figure 3. The three networks are defined as follows: 1) a tag network is categorized as a "separated network" when it has more than 10 disconnected subcomponents; 2) a tag network is categorized as a "centralized network" when one or two of it tags has been applied for more than 20 learning resources; 3) if a tag network belongs to neither of the previous cases, it will be categorized as a "clustered network." Centralized networks should have high reused times of the highest frequency tags but low *h*-index, while clustered networks have relatively high *h*-index. On the contrary, both indicators in separated networks should be low. With a focus on 3 to 4 main topics, the knowledge structure of learning resources in the study are believed to be better represented by clustered networks, as shown in Figure 3. The proportions of final tag network structures of the three experimental groups are shown in Table 3. The result indicates that participants using tag cloud interface created more clustered networks, while those using tag network interface created more separated networks.

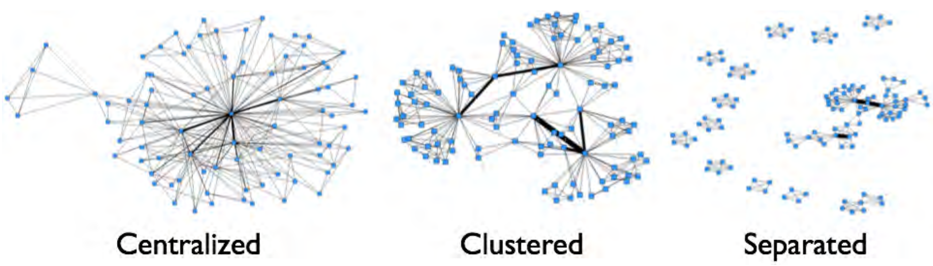

Figure 3. Three typical structures of tag networks: centralized, clustered, and separated.

Table 3. Network visualization results of each user interface.

	Network	Cloud	List
Centralized	4 (13.8%)	2 (7.1%)	3 (8.3%)
Clustered	7 (24.1%)	16 (57.1%)	18 (50.0%)
Separated	18 (62.1%)	10 (35.7%)	15 (41.7%)

4.3 Sequential Analysis

By recording timestamps of the tagging activities, we can conduct a trend analysis on the tagging process. We defined the “new tag proportion” for each article as the number of new tags divided by the total number of tags. An example (3, 0.8) denotes that a participant added four new tags and applied one pre-used tag for the 3rd article. According to the results shown in Figure 4, line charts of the three experimental groups show valleys at 12th, 16th, and 19th, and peaks at 11th, 13th, and 18th learning resources. Those valleys indicate that most of the participants happen to apply pre-used tags on these articles. Since the articles appeared in the same order, the consistency of tag usage among participants shows that they have followed the instruction and taken the tagging task seriously. Besides, the average number of new tags decreases in the process of the tagging experiment, especially in the experimental group using tag cloud interface, which means that tag cloud interface has relatively effective influences on leading users to use more pre-used tags.

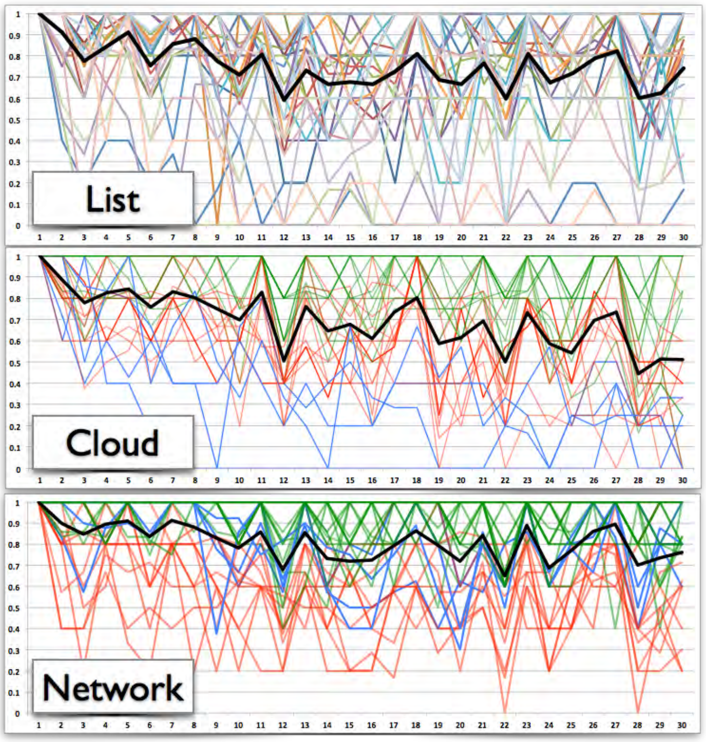

Figure 4. Line charts of the new tag proportion in the three user interfaces. Each line represents a participant’s tagging behavior.

While the above line charts displayed the difference of new tags used in the tagging process, they could not show that of the use frequency of pre-used tags. Therefore, the equation shown in Figure 5 is used to weight the score by tags’ reused times (*t* stands for each tag in an article *p*). *k*-mean algorithm was applied to cluster the lines into three groups colored by blue, red, and green. An interesting observation is that, in all the three experimental groups, the clustered weighted reused times seem to be a good factor to predict the final tag network structure (i.e., centralized, clustered, and separated network structures as shown in Figure 5).

It means that, if we recognized that the clustered network structure is a better information organization, we can predict the final structure of users' tagging behaviors according to their early tagging activities, and provide them useful suggestions to help them organize their materials more effectively and efficiently.

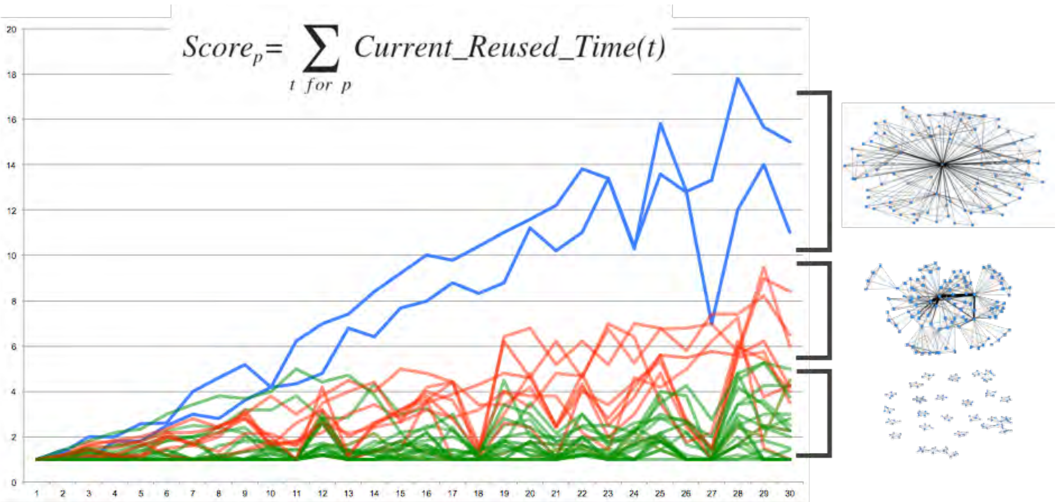

Figure 5. The results of weighted pre-used tags by reused times. Blue, red and green stand for the result of *k*-mean clustering algorithm ($k = 3$). The three clusters match the network representation of final tagging results on the right side.

5. Conclusion and Discussion

The study designed different user interfaces to assist our participants in the tagging activities, and investigated their effects on the tagging behaviors. Significant effects were found in the descriptive results and trend analysis of the reused frequency of tags. Furthermore, in terms of information organization, tag cloud interface serves as a better guide for the participants to reuse pre-used tags. Although the tag network interface provides more visual clues, too much information on it failed to help the participants to reuse pre-used tags or improve the wording consistency of tags.

Based on the concept of network-based indicators for evaluating information organization by Marshall (1990), we adopted Shen and Wu's (2005) idea to turn final outcomes of tagging activities into network structures for further observation. Three types of networks, centralized, clustered, and separated, were used for categorization of the tagging results. We found that the tag cloud group had more clustered networks than the other two groups. The clustered type of network means that participants found multiple topics from the learning resources, which are corresponding to those selected by the researchers and the course teacher. Unlike the tag cloud group, participants using the tag network interface tended to create many disconnected subcomponents, suggesting that the tag network interface designed in the study cannot help participants to organize their information well. Combining the observation on network structures and the trend analysis, we found that weighting the reused times of tags can predict the network structures of final tagging outcomes. A possible future work is, based on the reused times of tags, we can design a tag recommendation mechanism to guide users to construct a better information organization structure for future navigation.

Nevertheless, the limitation of the study was due to the experiment method. The tagging activities on a bookmarking system in real life should be a long-term behavior. Since the participants were requested to finish the task in 90 minutes on our designed system, the results could be bias due to the system design and time limits. For example, the tag network interface has richer information clues than the other interfaces, and therefore takes more time to understand and become familiar with it. With a time limit, rich information clues may demand additional cognitive load.

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