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Design and Evaluation of Mutual Awareness Function in Social Bookmarking Service to Foster Collaborative Information Gathering

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Scientific researchers need support for their information gathering from the Web, because the growth of Internet accessibility raises the problem of Internet information overload. Social Bookmarking Service (SBS) is a promising technology to solve the problem by the benefit of collaborative information gathering. The paper describes the design and evaluation of a novel function of SBS to foster collaborative information gathering by providing mutual awareness information about browsing behaviors of SBS users. This information increases the probabilities of discovering the useful information by recommending the potential collaborators to the user. A case study on an experimental SBS was performed to evaluate the feasibility of the mutual awareness information for individuals and research communities. In order to verify the validity of the design quantitatively, an experiment was conducted using agent-based simulation based on an extension of the SIR model for epidemics. The results, either from the case study or the agent-based simulation, argue the effectiveness of the proposed function to provide mutual awareness information for fostering collaborative information gathering in SBS.

1. Introduction

Scientific researchers need support for their information gathering from the Web, because the growth of Internet accessibility raises the problem of Internet information overload [11]. Scientific researchers spend a lot of effort on gathering and monitoring information sources, such as online publications and journals, for the most useful and relevant information for their work. Since information gathering is the initial stage of research process [40], individual researchers may need to collaborate with other researchers who have the same interested topic, in order to increase the probabilities of discovering the potential information. They not only want to know "who knows what" but also want to know "who knows who" because it is more useful and fast to find an expert on a topic related to the issue at hand. In the language of social software, they can preserve the needs of scientific researchers by facilitating collaborative activities for information gathering purposes [39].

Social Bookmarking Service (SBS) is a promising technology to solve the problem of Internet information overload by the benefit of Collaborative Information Gathering (CIG) [34]. SBS is a type of social software that allows people to organize, share, and discover bookmarks for information resources on the Web with user's own keywords. This feature of SBS can be used to create connections and matchmaking among people without regards to physical space offering some opportunities to contact with [32]. SBS can foster social interaction among people by allowing people to browse into others' libraries [1),34]. This benefit ultimately leads to colleagues who share research interests and fosters CIG among like-minded people. A number of research studies on CIG present that the potential information can be provided through information gathering and interacting in a group [3),4]. The information hints, which come from others, can be used to increase individual gathering performance [16),17]. Although SBS presents its benefit for social search, the knowledge of others' activities is needed to be extent to take advantage of social navigation [10] for individual information gathering purposes.

The paper describes the design and evaluation of a novel function of SBS to foster collaborative information gathering by providing mutual awareness information about browsing behaviors of SBS users. The proposed function facilitates people to gather the potential information as well as to discover the like-minded people through awareness of other users, since awareness is highlighted as an important factor for successful collaboration [14),42]. In order to develop the new function, the research applies software development methodology consisting of requirement, analysis, design, implementation, and evaluation steps [36]. The requirement of supporting functions is extracted from a survey on existing SBS and an analysis of the information gathering process. The analysis step then investigates the possibility of utilizing CIG in SBS to fulfill the requirement. After analysis step, the design of mutual awareness function and implementation of a

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prototype SBS was studied. A case study on an experimental SBS was performed to analyze the users' behaviors in order to evaluate the feasibility of the mutual awareness function. Finally, the proposed design was evaluated by using agent-based simulation to analyze the effect of adding mutual awareness mechanism in bookmark diffusion among like-minded people quantitatively.

The paper is organized as follows. Section 2 describes a survey on of social bookmarking service for scientific researchers and related work in comparison. Section 3 presents a literature review on collaborative information gathering. Section 4 then describes the design of mutual awareness function in SBS. Section 5 presents a case study on an experimental social bookmarking service, ReMarkables. Section 6 describes the design evaluation based on agent-based simulation. Section 7 describes the discussion and Section 8 describes conclusion and future work.

2. Social Bookmarking Service for Scientific Researchers

2.1 Existing Functions of Social Bookmarking Service

The emergence of Social Bookmarking Service (SBS) has prompted a second look at this kind of collaborative software [32]. A number of SBS are used in the scientific research communities, e.g., CiteULike [6] and Connotea [7),28]. These systems share a number of features: 1) allow individuals to create personal collections of bookmarks and instantly share their bookmarks with others, 2) use keywords or tags that are explicitly entered by the user for each bookmark. These tags allow the individual user to organize and display their collection with labels that are meaningful to them. And 3) provide chance to access through the entire bookmark collection to see other information sources of interest. Marking content with tags is a common way of organizing content for future navigation, filtering or search [15]. **Figure 1** depicts the fundamental functions of SBS for research communities.

Since individual researchers need support for their information gathering process [24], it is important to take account into how to develop the effective information system to support information gathering purpose. In the context of knowledge management, social software provides the necessary support for conversations and collaboration, for knowledge creation, sharing and publication [1].

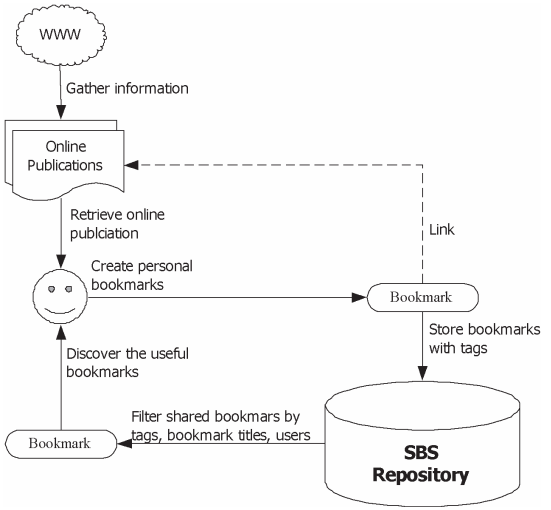

Fig. 1 The fundamental feature of social bookmarking service.

Among the types of social software, SBS benefits for supporting knowledge discovery, not only in scholarly digital libraries [13] and corporate environment [8),31] but also for academic community [17),28].

3. Information Gathering in Social Bookmarking Service

SBS provides its fundamental functions, i.e., tagging system and related users list, to facilitate the chance to access through the entire bookmark collections of others for seeking other information resources of interest in the way of social navigation [30]. By the basic concept of SBS, it allows users to share their personal bookmarks with others. People in SBS can discover whom else links to the interested information and that can ultimately lead to collaborators who share research interest. Furthermore, it enables researchers to capitalize the insights of other researchers to locate information related to their interested topics, even in areas that are not obviously connected to the primary topics. Thus it opens new directions when they browsed into others' libraries navigated by tags attached with bookmarks. **Figure 2** illustrates a typical scenario of information gathering and discovering in SBS for individual researchers. It starts from keyword search.

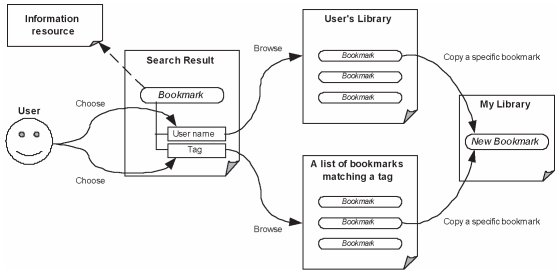

Fig. 2 Information gathering and discovering in social bookmarking service.

Individual information seekers retrieve a bookmark list matching the keyword. This collection of bookmarks may lack of sufficient information, so individuals need to find out the new bookmarks by selecting tag or user name attached with each displayed bookmark in order to find new bookmarks. In this way, individual information seekers may discover the useful bookmarks using the existing functions of SBS solely.

Due to the benefit of collaboration for extending the way of information gathering of individuals [9], it is an important issue to develop social software such as SBS in order to support for the collaborative activity. Research collaboration takes advantages of sharing knowledge and experience as well as facilitates opportunities to generate the new idea or perspective that individual would not have grasped. By collaborating with others, individual researcher can be aware of others' information and knowledge [19]. Although SBS offers tagging system for social navigation, it is an issue whether the existing function of SBS is sufficient for information gathering to individual researchers. SBS should pay attention to support information gathering for scientific researchers, since information gathering is the necessary stage of research process [40].

4. Related Works

There are some studies on social interaction and how to provide the knowledge of others' activities in SBS. A number of literatures are selected here as related work because of its similar idea to provide awareness information to users in SBS, which are all different from the idea described in this paper. The results of these studies also show the general benefit of awareness information for collaboration activity.

Dogear [31] is a social bookmarking site designed for a large enterprise. It provides the evidence that community browsing was the most frequently used and confirms the value of the social aspects of the system. This contributes the idea of fostering CIG by providing awareness information in SBS, which is one of the elements for fostering social interaction in online spaces. Although Dogear presents the benefit of community browsing, it is based on the general function of SBS for enterprise that people know each other. Users in an experimental SBS, named *ReMarkables* [18] construct the collaboration process through mutual awareness function recommends the potential collaborators without restriction of the relation.

TopicMark [17] is a topic focused bookmarking service for professional groups, which presents the specific topic generation process and the autonomous aggregation of information resources. While TopicMark harvests knowledge of users, the mutual awareness information provides further the presence of users' activities by their browsing behavior.

CiteSeer collaboratory [13] facilitates community building and collaboration for the users of CiteSeer [5]. The system uses notification systems to convey the presence of others' searching behaviors whereas the mutual awareness information provides presence of others' browsing behaviors to users. It eases to interpret the information in Browsed users list in ReMarkables.

5. Collaborative Information Gathering in SBS

5.1 Information Foraging Theory

Information foraging theory [35] explains information-seeking behavior in human groups. It is being developed to understand and improve human-information interaction by assuming that human optimize the gain of information per unit time cost. **Figure 3** shows the benefits of cooperative information foraging. It describes that as long as the diversity of information foragers (H) increases with group size, then the size of a group increases the overall power of cooperative discovery in means of rate of return to individual. The research on information foraging theory has developed cooperative information foraging model [4] that

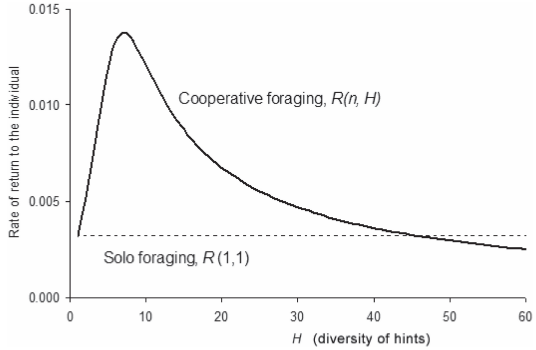

Fig. 3 Benefits of cooperative information foraging.

shows the effect of the diversity of information seekers and their footprints to each other and how this diversity directly affects the size of collaboration groups. The model assumes that information hints, which come from other searchers, can facilitate people to discover knowledge more quickly and thoroughly by foraging in groups. It provides the design principle of successful social software that allows groups of people to interact with other in order to discover knowledge at a faster speed than the individual information seekers.

5.2 Fostering Social Interaction in Online Spaces

Since interaction is necessary for successful collaboration, a literature on online spaces proposed the important elements that foster social interaction in online spaces as place-making, common ground, awareness, and interaction mechanisms [26].

`Place making` is the spatial metaphors to frame and interpret social information and exploit spatial properties to guide social interactions in the online space.

`Common ground` refers to share understanding of participants in an online space. It facilitates participants to easy understand the sense of that online space.

`Awareness` refers to the knowledge of the presence of other people including their interactions and activities.

`Interaction mechanisms` enable participants to choose when and how to interact with others. In some case, the presence of other actions may provide some clues for knowing of others' actions and characteristics.

The current SBS for research communities has implemented the fundamental functions for fostering social interaction in online spaces as place making, common ground, interaction mechanisms, and awareness in some part. Social interaction in SBS can be performed through (1) *browsing* others' libraries and (2) *copying* a bookmark from other's library. By aware of others' activities, individual information seekers may discover the potential collaborators and make social interaction with them. Interacting with the potential collaborators magnifies individual information gathering boundary in the way of collaborative activity. This means that awareness is necessary for fostering CIG and should to be provided as a new function of SBS.

5.3 Analysis of Information Gathering Behavior in SBS

A number of researches studied the users' behaviors for information discovery according to the usage of social navigation and how social navigation can be used to enhance information discovery in SBS [12),23),29)]. The result of usage pattern analysis shows that tagging system is an effective way for information gathering where users frequently select tags in a bookmark list to find a new bookmark. In addition to navigation through tags, users prefer to explore the bookmark libraries of others to find the related bookmarks around the focused topic and discover frequently bookmarks in the bookmark libraries of the selected users. Users prefer to navigate through others' libraries to gather the useful information for their interest [23)]. Due to the information gathering behavior, SBS should provide the presences of others' activities to the users to facilitate social interaction as well as CIG in the online spaces.

6. Design of Mutual Awareness Function

6.1 A Scenario of Collaborative Information Gathering in SBS

According to the analysis of information gathering behavior in SBS, awareness of who may has similar research interests and might browse the user's library can be provided by the information about browsing behaviors of other users. A scenario for the development of collaboration in SBS based on the utility of awareness is described in the reference [21)]. **Figure 4** depicts how mutual aware-

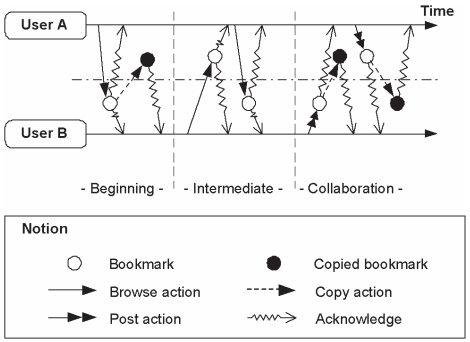

Fig. 4 A scenario of collaborative information gathering in social bookmarking service.

ness of browsing behaviors contributes the discovering of the useful bookmarks in the way of collaborative activity. The scenario can be separated into 3 phases; Beginning phase, Intermediate phase, and Collaboration phase:

A scenario for the development of collaboration in SBS is summarized as:

(1) `Beginning phase`
When a user browsed into other's library, the action is recorded in the list of browsed users and frequently browsed usernames are displayed in the upper area of the list. A user can find an interesting other users in the browsed users list.

(2) `Intermediate phase`
When a user browsed into other's library, the action is also recorded in the other's list of the browsed users and frequently browsed other usernames are displayed in the upper area. The other user can find an interesting user and they may start mutual browsing.

(3) `Collaboration phase`
When a user posted a new bookmark, the event is notified to other users who have browsed the posted user's bookmark library. If the new bookmark is valuable for another user, it can foster the other's research and result in posting of a new bookmark from others. The interaction through the browsed users list can foster collaboration in SBS.

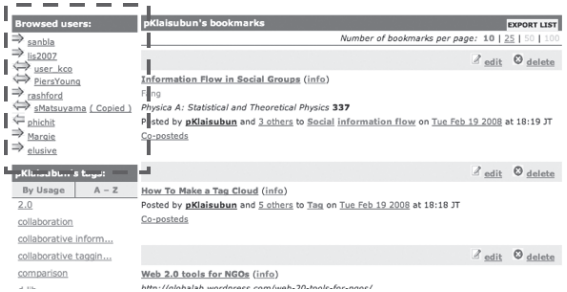

Fig. 5 Browsed users list function in a social bookmarking service.

6.2 User Interface Design

A new mechanism for fostering CIG in SBS is designed as a function providing mutual awareness information about browsing behaviors [22]. The aim of this function is to provide information about whom the user has browsed into that library and who has browsed into the user's library. By aware of others' browsing behaviors, the user may browse into other's library that seems to be the like-minded people and discover useful bookmarks in other's libraries. The mutual awareness function can be implemented with the user interface as shown in **Fig. 5**. The Browsed users list appears as a global navigation after logging to SBS. Usernames in the list present others who have interaction with the user. It is classified into 3 types according to the direction of arrow that represents users' browsing behaviors: Forward direction (⇒) means user browsed other's library whereas backward direction (⇐) means other who browsed into user's library. Mutual direction (⇔) is the information about both users browsed mutually into each other's library. By clicking a username in this list, the user can browse into the library of that username.

6.3 Algorithm Design

The Browsed users list has been generated according to the browsing behaviors of the user. When the user interacts with others by browsing into their library, the system will check the pair between the user and another. In case of this pair has not been created, the function will create a pair of users and show another's username in the Browsed users list with *forward direction*. At the same time, the system will create the username with *backward direction* in the Browsed users list

of other. The direction of browsing will be modified to *mutual direction* whether the pair of users has browsed into each other's library. When a user browses into others' libraries, the Browsed users list is updated by the following procedure.

Procedure check action user X ⇒ Y
  For clicking username **do**
    If there exists X for Y
      If there exists relation X ⇐ Y
        Then Update relation as X ⇔ Y
      Else insert new records with relation X ⇒ Y **and** X ⇐ Y

Where X is a user, Y is a user whom was browsed by X.

7. Case Study on a Prototype System

7.1 Objective

An experimental Social Bookmarking Service, named ReMarkables [18),37)] has been conducted to evaluate the effect of awareness information about browsing behaviors on information discovery in CIG. The effect of providing awareness information about browsing behaviors is measured by the conversion rate [2)] for click through the Browsed users list. The conversion rate is classified into 2 actions: (1) the ratio of copying a bookmark from others' libraries and (2) the ratio of accessing to original resource by clicking a bookmark title in others' libraries.

7.2 Method

7.2.1 Implementation

`ReMarkables` has been developed as an extension of open source software Connotea code [7)], which provides fundamental functions of social bookmarking service, i.e., personal reference management and sharing bookmarks among users. ReMarkables is written in Perl and uses MySQL as database, which constitutes an experimental web-based Research Collaboration Support System [25)]. The system offers a new function of providing awareness information about browsing behaviors to the users. The difference between the proposed function and the existing functions is the way of conveying the information to the user. Browsed users list facilitates individuals to discover the potential information from others' libraries whereas the existing functions, i.e., Recent activities function offer the knowledge of posting behaviors.

7.2.2 Feasibility Analysis

An empirical study on quantitative and qualitative evaluation of the effect of awareness information about browsing behavior was performed as follows. The behaviors of 21 subjects were recorded in the web server logs over the period of two months. The subjects were asked to use ReMarkables for their information gathering purpose. The criterion of information discovery in this experiment is either the subject clicked the bookmark title to access to the original resource or copied the bookmark into subject's library after clicking through the username in the Browsed users list. During two months, the users' activities were recorded in the web server logs and database. There were 52,295 bookmark data that were imported from other SBS for the tags that the subjects have interested in. The analysis of the effect was based on 3,087 users' actions recorded in the ReMarkables database.

The navigation functions of the system for information gathering are classified into 3 types as Global navigation, Local navigation, and Bookmark links. These three types of navigation represent different users' strategies in their information gathering process.

(1) `Global Navigation`: navigation through main functions of the system
- By keyword (Search)
- By frequency (Popular Links)
- By time (Recent Activities)
- By awareness information (Browsed users)

(2) `Local Navigation`: exploring through a bookmark collection
- By tags of others (Users' Tags)
- By tags used by others (Related Tags)
- By Tags describing the bookmarks in the list (Tag describing these bookmarks)
- By users who posted bookmarks in the list (Users who posted these bookmarks)

(3) `Bookmark Links`: exploring through a selected bookmark
- By users who posted a selected bookmark in the entire list (Users)
- By tags attached with a selected bookmark in the entire list (Tags)

The collected data was analyzed by extracting the times of click through for each navigation type. The patterns of users' behaviors for their navigation were extracted through the Web server log data. The number of times for click through and conversion was recorded. The effect of awareness information about browsing behaviors was analyzed by comparing click through and conversion rate for each navigation function including the mutual awareness function.

7.3 Result

The effect of the mutual awareness information on information discovery is evaluated by comparing the conversion rate to the other navigation functions, which are the general functions of the current SBS. The conversion rate provides an estimate of the usefulness of the result of click through including Browsed users list. In some case it can be over 100% since a user can click the bookmark title or copy the interesting bookmarks in several times after click through a navigation function. The proportion of conversion rate for click through navigation function is calculated through Eq. (1).

$$\%conversion\_rate = \frac{\#conversion}{\#click\_through} \times 100 \quad (1)$$

Table 1 shows the results to navigation type. Since the proposed mutual awareness function is implemented in the Global navigation function, the consideration of the result focuses on the feasibility of the Browsed users list comparing with others Global navigation functions. The conversion rate of accessing to the original resources shows that the ratio of clicking the bookmark titles for click through Browsed users list (33%) is greater than the existing functions of SBS such as Popular Links (28%) and equivalent to Recent Activities (33%). The ratio of clicking the bookmark titles provides the opportunities to discover the valuable information as the consequence. The result of conversion rate of copying bookmarks for click through Browsed users list (25%) is less than the existing Global Navigation functions as Popular Links (56%) and Recent Activities (27%) but greater than Search function (17%). Although the results of conversion rate of copying bookmarks for Browsed users list is less than that of the existing function, it does not imply the less usefulness of the proposed function. Since the conversion rate of clicking bookmark title for Browsed users list is comparable to other existing functions, it argues the effectiveness of the proposed mechanism for the information discovery. By considering the result, it shows the feasibility of the proposed mutual awareness mechanism for information gathering and discovering in the research communities.

Table 1 Results to Navigation Type in ReMarkables.

Navigation Type	#Click through	Conversion		Conversion rate	
		Copy	Access	Copy	Access
Global Navigation					
Search	210	35	138	17%	66%
Popular Links	18	10	5	56%	28%
Recent Activities	33	9	11	27%	33%
Browsed users	60	15	20	25%	33%
(1) Forward Direction	58	15	20	26%	34%
(2) Backward Direction	2	0	0	0%	0%
Total	321	69	174	21%	54%
Local Navigation					
Users' Tags	37	4	16	11%	43%
Related Tags	55	24	35	44%	64%
Tag used in the bookmarks	75	13	99	17%	132%
Users who posted the bookmarks	13	4	13	31%	100%
Total	180	45	163	25%	91%
Bookmark Links					
Tag	9	3	2	33%	22%
User	7	4	1	57%	14%
Total	16	7	3	44%	19%
Grand Total	**517**	**119**	**340**	**23%**	**66%**

In addition to quantitative analysis, qualitative data has been examined by a user survey. Questionnaires for the user survey were asked to the subjects in order to evaluate the validity of the experiment and the function of Browsed users list for their information gathering. Unfortunately, only 11 subjects (52.4% of the subjects; 5 subjects are professional researchers whereas 6 subjects are graduate students) have responded to the user survey. **Table 2** shows the result of user survey. The result shows that 64% of the subjects agree that using SBS provides the chances to discover the like-minded users and found the useful bookmarks from others' libraries. Concerning with browsing behaviors, 82% of users agree that they browse into others' libraries because their bookmarks are interested. From the validity of providing mechanisms for CIG, it can be explained as that: 56% of users agree that CIG yield more undiscovered bookmarks than individual information gathering. This result confirms that users prefer to use SBS in order

Table 2 The result of questionnaire for the subjects.

Question and Answer	#
Q1. Why do you use social bookmarking service?	
- It eases to maintain bookmark collection on the web.	73%
- It eases to discover the like-minded people.	64%
- It eases to discover the useful bookmarks from others' bookmark libraries.	45%
Q2. Why do you browse others' bookmark libraries?	
- I interested in the bookmarks of others.	82%
- I interested in the bookmarks of others matching a tag.	55%
- The copied bookmarks come from others.	18%
Q3. Why do you participate in collaborative information gathering?	
- It yields more useful information than individual seekers.	56%
- Individual seekers can discover a new bookmark from this activities.	45%
- Individual seekers can discover a bookmarks list related to search topic.	45%

to discover the like-minded people and gather information efficiently from others' libraries.

8. Design Evaluation

8.1 Object

In order to verify the validity of the design quantitatively, an experiment using agent-based simulation based on an extension of the SIR model for epidemics was conducted [20]. A research on information diffusion presents that awareness mechanism affects the diffusion time of bookmarks [38]. The conceptual hypothesis to be verified is that "mutual awareness function fosters Collaborative Information Gathering in Social Bookmarking Service."

8.2 Method

To apply agent-based simulation, the conceptual hypothesis is reformulated as an operational hypothesis that "diffusion time for the case of adding the influence of mutual awareness is less than that of the base case." The diffusion time is defined as the time for all agents to complete gathering all bookmarks in the same community. Agents in a community gather similar bookmarks exclusively. For this simulation, the base case is the situation that all agents interact with others without the additional mechanism. Each agent browses into others' libraries randomly. The agent-based model has been developed according to the propagation of bookmarks among the like-minded people.

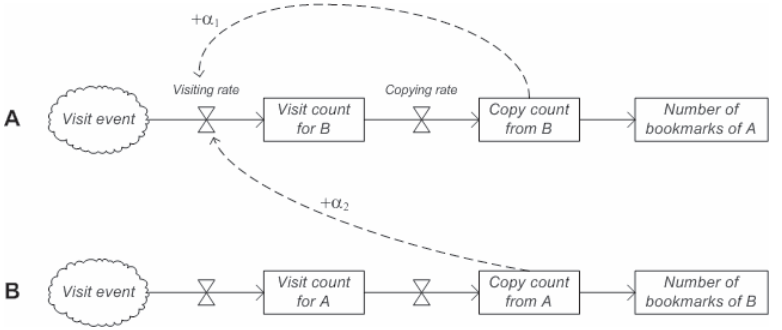

Fig. 6 System dynamics model for the user's behavior in social bookmarking service.

8.2.1 Modeling

Since SBS allows people to browse others' libraries and copy interesting bookmarks of others into individual own library, it contributes the information diffusion of bookmarks among the like-minded people. Information diffusion in SBS can be modeled as an extension of the SIR model [27] for the spread of bookmarks among the like-minded people. The SIR model is a basic model for simulating the phenomenon of virus infection among the population. There are three primary states of individual with respect to the spread of disease: Susceptible, Infectious, and Recovered. During epidemic process, new infections occur because infected individual contact with susceptible individual. The susceptible individuals are infected based on probabilities of infectious of the disease and their personal characteristics.

There are two actions related to information diffusion in SBS: visiting others' libraries and copying bookmarks into individual own library. The state transfers from S to I occurs as a result of these actions. In order to model the proposed mutual awareness function in SBS, the transfer rate r in the SIR model is assumed to depend on the probability of copying action between like-minded people. **Figure 6** depicts the system dynamics model for the user's behavior in SBS and there are four rules for agent behaviors. Visiting rate and influence rate for the browsing behaviors of agents represents the strength of social interaction in an online space. The copying actions affect the browsing behavior of an agent in information gathering process.

Table 3 Parameters of the simulation.

Parameter	Description	Value
people	The number of agents	100
n-bookmarks	The number of bookmarks	100
n-communities	The number of communities gathering similar bookmarks	10
visiting rate	The ratio of visiting others' bookmark libraries randomly in a time tick	1-100%
copying rate	The ratio of copying a new bookmark from others' bookmark libraries in a visited time	100%
influence rate	Additional visiting rate according to awareness function	1-100%

R1: Each agent randomly visits other agents with a visiting rate for a unit time.
R2: An agent copies a new bookmark with a copying rate.
R3: Copying count from A to B increases the visiting rate by α_1.
R4: Copying count from B to A increase the visiting rate by α_2.

Where α_1 is the influence parameter stands for the influence of forward awareness mechanism and $\alpha_1 + \alpha_2$ stands for mutual awareness mechanism.

8.2.2 Simulation

A simulation program based on the agent-based model is developed using NetLogo version 4.0.2 [33] in order to simulate different situations in which the influence of awareness mechanisms is added [20),38]. The developed simulation program is based on the sample models of NetLogo such as Virus model and Small Worlds model. Each agent behaves according to the rules described in the last section. In the initial state, each agent has either one of the bookmarks in the own community. Each community has equal number of different bookmarks in the initial state. **Table 3** shows the parameters of the simulation. The values of the elements are determined by the preliminary sensitivity analysis.

The controlled parameters in the simulation are influence rate and visiting rate. Influence rate is the additional visiting rate that reflects the influence of awareness mechanism. Base on the rules for agent's behavior described in Section 8.2.1, the visiting rate for the base case is the given value without adding α_1 or α_2. For the case of adding influence of awareness mechanism, the browsing behavior will be affected by the additional parameter (α_1 or ($\alpha_1+\alpha_2$)). To evaluate the difference in diffusion time correctly, it needs to compensate the increase of visiting rate due to the influence of awareness mechanism.

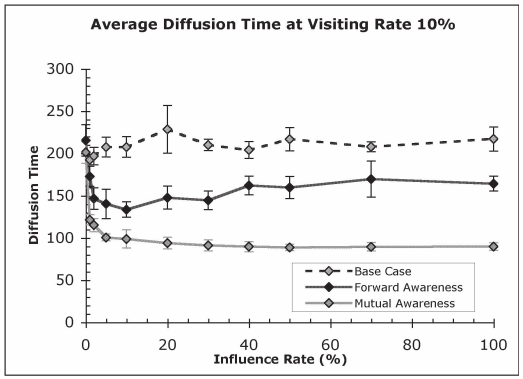

Fig. 7 The average diffusion time for forward awareness, mutual awareness, and without awareness.

The observed parameter is the diffusion time of bookmarks. The diffusion-time was measured for all agents to copy all bookmarks in the own community through Eq. (2), where ticks is the simulation time units and average-visiting-rate is computed through Eq. (3).

$$diffusion\_time = ticks \times average\_visiting\_rate \tag{2}$$

$$average\_visiting\_rate = \frac{total\_visiting}{total\_checking} \tag{3}$$

In Eq. (3), *total_visiting* is the total counts of visiting and total-checking is the total counts of checking to determine visiting in a simulation.

8.3 Results

The results of simulation show the relation between the influence of awareness mechanism and the diffusion time of bookmarks. The data was taken 10 times for each condition and then the average diffusion time was calculated. **Figure 7** shows the average diffusion time with 95% confidence interval for conditions; with forward awareness to copying, with mutual awareness to copying, and without awareness. By adding the influence of awareness mechanism, the diffusion time decreases in the region of small influence rate and increases gradually after attaining minimum in the case of forward awareness.

We also interested in the dependency of diffusion time on visiting rate. **Figure 8** shows the result of simulation for the influence of forward awareness by

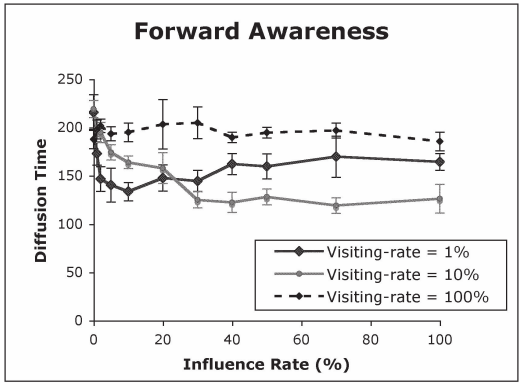

Fig. 8 Diffusion time for the influence of forward awareness.

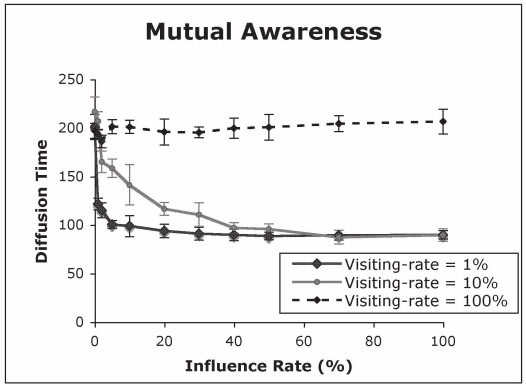

Fig. 9 Diffusion time for the influence of mutual awareness.

controlling visiting rate and influence rate. The diffusion time for 1% visiting rate decreases until influence rate is 10% and then increases. The diffusion time for 10% visiting rate, on the other hand, decreases gradually and tends to constant when the influence rate is greater than about 30%. From these, the diffusion time for visiting rate 1% intersects the diffusion time of 10% visiting rate at the 20% influence rate.

Figure 9 shows the result of simulation for the influence of mutual awareness. In both cases of 1% and 10% visiting rate, the diffusion time tends to reduce explicitly and reach constant when the influence rate is greater than visiting rate. The results provide another obvious evidence that the effect of mutual awareness does not exist for the case of visiting rate is 100%, where the diffusion time remains constant while the influence rate increases from 0% until 100%.

9. Discussion

The empirical study on *ReMarkables* shows the feasibility of implementing the mutual awareness mechanism for fostering CIG in SBS. The Browsed users list function recommends the potential collaborators of information gathering to the SBS users. The major differences between the proposed function and the previous researches in related work are the way to harvest the knowledge of others' activities as well as yield the potential collaborators to the user. The mutual awareness mechanism harvests the knowledge of others' activities from their browsing behaviors and recommends the people who may be the potential collaborators based on this information. Recommending the potential collaborators through the Browsed users list does not only facilitate social interaction between like-minded people, but also contribute community building in online spaces.

The quantitative result of case study for the users' actions compared to other navigation functions shows the positive effect of the function on information gathering in SBS. The conversion rate for click through Browsed users list is comparable to the existing functions of current SBS. Although the conversion for click through Browsed users list with Backward direction shows zero effect, the result does not imply that awareness information about users who browsed the user's library has no effect. The reason is because the result of user survey provides another evidence that users prefer to use SBS to discover others who may has similar interested topics. It does not only increase the chance of social interaction by clicking the usernames in the Browsed users list, but also provide awareness about the like-minded people to the user. Users who have mutual interaction by browsing each other's bookmark libraries provide benefit (potential information) to each other's. Due to the positive effect of providing mutual awareness information about browsing behaviors, we argue that providing mutual

awareness information about browsing behavior is feasible to foster CIG in SBS in the respect of expanding the boundary of gathering information as well as recommend the potential collaborators to the users.

The results of agent-based simulation argue the effect of awareness mechanism on information diffusion among population for bookmark gathering. By the simulation, It confirms the effect of the mechanism decreases the diffusion time even for the small value of the influence rate. The difference of diffusion time between forward awareness and mutual awareness presents the evidence that the effect of mutual awareness is greater than that of forward awareness. It indicates that providing mutual awareness is more effective than one-way awareness in order to foster collaborative information gathering in social bookmarking service. The result of diffusion time for awareness mechanism indicates that the effect of the mutual awareness mechanism really exists for both cases of visiting rate is 1% and 10% when influence rate is greater than visiting rate. From these results, we argue that providing mutual awareness fosters information diffusion that models collaborative information gathering in social bookmarking service.

10. Conclusions and Future Work

The paper describes the design and evaluation of a novel function of Social Bookmarking service (SBS) to foster Collaborative Information Gathering (CIG) by providing mutual awareness information about browsing behaviors. SBS is a promising technology to solve the problem of Internet information overload by the benefit of CIG. The research methodology starts by extracting the requirement of supporting information gathering for scientific researchers. The analysis step then presents the benefit of CIG and the important elements to foster social interaction in online spaces. The mutual awareness function is designed to preserve the result of requirement and analysis, which provides the awareness information about browsing behaviors to the SBS users. A prototype SBS is developed to implement the mutual awareness function and to analyze the feasibility of the proposed design. Finally, the proposed design is evaluated by agent-based simulation based on an extension of the SIR model for epidemics to verify the validity of the design quantitatively. The results either from the case study or the agent-based simulation argue the effectiveness of the proposed mutual awareness function for fostering collaborative information gathering in SBS.

Although a number of researchers [1),29),34),41)] indicated that social software is the promising way for facilitating information sharing, it still left the challenge to develop more effective information system to support scientific communities. In the context of scientific communities, researches need the effective information system not only for facilitating their information gathering but also for their reference management and distributed collaboration. The research on social software should further study on supporting scientific research process by considering how to support reference management among people in the like-minded communities and contribute distributed collaboration among researchers in scientific communities.

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