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Community Effect in Information Diffusion through Social Bookmarking Service

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Abstract The authors have proposed a new mechanism to foster Collaborative Information Gathering (CIG) in Social Bookmarking Service (SBS), which provides mutual awareness information about browsing behaviors. The paper describes an analysis on the effect of the mechanism on CIG in SBS. The CIG in SBS can be modeled as information diffusion as an extension of SIR model for epidemics. To evaluate the effectiveness of the mechanism, agent-based simulation based on the information diffusion model is conducted. The result shows that there is community effect that strong interaction between the users decreases diffusion time of bookmarks through SBS and the mutual awareness mechanism fosters community building in like-minded people by the community effect. Therefore the mutual awareness mechanism is effective for the CIG in SBS.

1. Introduction

Social Bookmarking Service (SBS) is a kind of social software to organize, share and discover useful information resources on the Internet by "bookmarking". SBS allows users to discover the potential bookmarks by browsing others' bookmark libraries through the social navigation function [10]. When a user of SBS discovers an interesting bookmark in others' library he/she can copy the bookmark in their own library. By this copying function bookmarks diffuse through SBS among like-minded people. SBS facilitates Collaborative Information Gathering (CIG) [3] through the social navigation function as an information diffusion process.

The authors have proposed a new navigation function called mutual awareness mechanism [7] to provide information about browsing behaviors; whose libraries are browsed by the user and who browsed the users' library. This mechanism increases the probability of revisiting others' bookmark libraries and fosters CIG in SBS. The feasibility of the mechanism to foster CIG in SBS is shown in the previous research [8].

To verify the effectiveness of the mechanism, it needs to understand what is the effect of the mutual awareness mechanism on information diffusion in SBS and how this mechanism to foster CIG in SBS. In order to explore these questions the authors propose two hypotheses:

- There is community effect that strong interaction between the users decreases diffusion time of bookmarks through SBS.
- The mutual awareness mechanism fosters community building among like-minded people by the community effect.

In real SBS it is very hard to verify the hypotheses because it takes long time to gather sufficient data and requires many people to participate. Therefore Agent-Based Simulation [2] is adopted as another way to verify these hypotheses for social phenomena in SBS.

The paper is organized as follows. Section 2 describes the mutual awareness mechanism in SBS. Section 3 explains the information diffusion model. Section 4 describes an experiment on community effect. Section 5 then presents another experiment on community building. Finally, section 6 provides conclusion.

2. Mutual Awareness Mechanism

Browsing others' libraries does not only leave footprint to a user whom was browsed, but also inform who may be the potential collaborator to the user as awareness information. We have proposed the mutual awareness mechanism to foster collaborative information gathering in SBS the mechanism is implemented as the Browsed Users list which is a navigation function of SBS as shown in Figure 1. The aim of this function is to provide information about browsing behaviors, i.e., whose library a user has browsed and who has browsed into the user's bookmark library. By aware of browsing behaviors of user self and others', the user may re-visit others' bookmark libraries that seem to be the like-minded people and discover useful bookmarks in others' libraries [9].

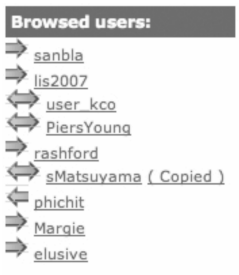

Figure 1. An example user interface for the Browsed Users list

The Browsed Users list is generated according to the browsing behaviors of the users as follows. When a user interacts with others by browsing into their library, the SBS 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 other's user-name in the Browsed Users list with *forward direction* displayed with ⇒. At the same time, the system will create the username with *backward direction* displayed with ⇐ in the Browsed Users list of other. The direction of browsing will be modified whether the pair of users has browsed into each other's library with *mutual direction* displayed with ⇔. When a user browses into others' libraries, the Browsed users list is updated by the following procedure.

Procedure check action user X => object Y
  For each 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 Y <= X

where X is a user to whom a Browsed Users list is provided, Y is a user whom was browsed by X.

3. Information Diffusion Model

3.1 Related Work

A number of researches on information diffusion model that explains how information spread from individual to individual are based upon an epidemiological model on social network [4,11,14,15]. The basic similarity between the diffusion of information among people and the spread of infectious disease between the individual themselves is that both are processes in which given a contact something is communicated. The results of these researches suggest that the way of information spread is affected by the topology of the social networks [14]. The result also suggests that information frequently propagates among the like-minded people because individuals with similar characteristics tend to associate with one another [11]. A well-known epidemiological SIR model [13] can be used for the basis to understand the information diffusion.

The SIR model computes the theoretical number of people infected with a contagious illness in a closed population over time. It is a basic model for simulating the phenomenon of virus infection among the population. Figure 2 shows a general SIR state transfer diagram. There are three primary states of individual with respect to the spread of disease: *Susceptible*, *Infectious*, and *Recovered*. The symbol r denotes the transfer rate for S to I, whereas α is the transfer rate for I to R. 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 [6].

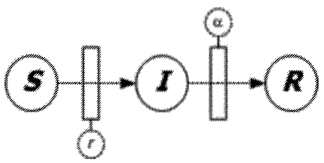

Figure 2. A general SIR state transfer diagram

The SIR model is selected to model the information diffusion in SBS since it is able to explain aggregate diffusion dynamics in term of individual transmissibility. It allows for derive macro level from micro level on individual decision-making [1]. In case of information diffusion in SBS, the state transition is applied only from S to I and uses the transfer rate r since people visits and copies the interesting bookmark from the like-minded people and tend to never release the copied bookmark from his library.

3.2 Information Diffusion through SBS

Since SBS allows people to browse others' bookmark libraries and copy interesting bookmarks of others into individual own library, it contributes the spread of bookmarks among like-minded people. In some cases, the chance of finding the interesting bookmarks comes from

re-visiting the bookmark libraries of the like-minded people rather than filter the bookmarks from the system [9]. A bookmark can propagate from one to others by browsing and copying actions. Figure 3 depicts a scenario of information diffusion through SBS. It shows that bookmark #1 is propagated from User 1 to User 3 through User 2 as their collaborative activity.

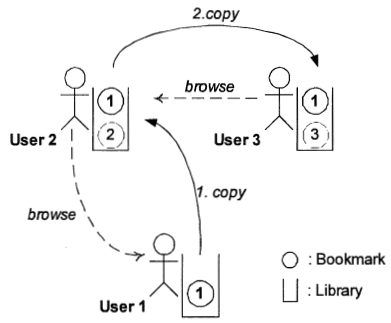

Figure 3. Information diffusion through SBS

3.3 Agent Based Model of SBS

There are two actions related to information diffusion through SBS: browsing others' bookmark libraries with a basic contacting action and copying bookmarks from others' library. The state transfer from S to I occurs as a result of these actions. The transfer rate r in the SIR model is assumed to depend on the probability of copying action between the like-minded people.

The general users' behaviors used in the agent-based simulation are specified as the following rules:

1. Each agent browses others' libraries and copies a bookmark
2. An agent gathers bookmarks of a specific topic
3. An agent contacts frequently the like-minded people

The simulation model in figure 4 describes the influence of the Browsed Users list on users' behavior. In the simulation model it is assumed that the nodes are the users of SBS and each links between two nodes represents the browsing action between two users. The users contact with linked people at an influence rate which is the additional visiting rate due to the mutual awareness mechanism from their Browsed Users list. The users contact with others people who are not in Browsed Users list randomly.

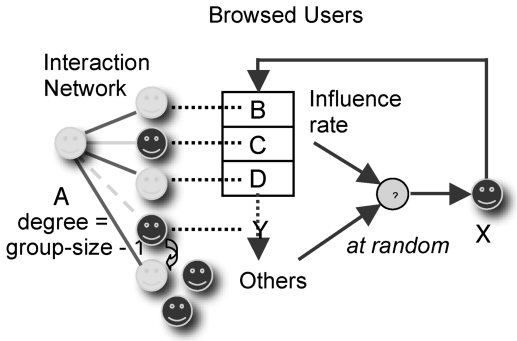

Figure 4. The simulation model

4. Experiment on Community Effect

4.1 Objective

The experiment was performed to verify the first hypothesis that "there is community effect that strong interaction between the users decreases diffusion time of bookmarks through SBS".

4.2 Method

NetLogo version 4.0.2 [12] has been used as a software tool for the agent-based simulation due to its usability and extendibility. NetLogo is a multi-agent programming and modeling environment which can be used across a wide range of disciplines for simulating complex phenomena. The developed simulation program is based on sample models of NetLogo; Virus model and Small World model. A user interface of the simulation program is shown in Figure 5.

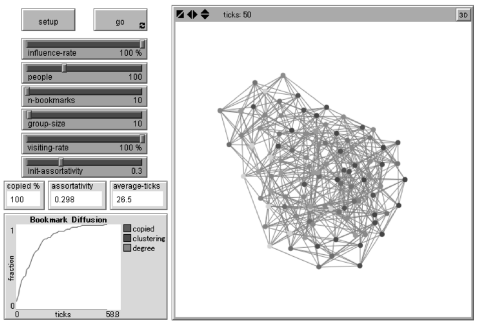

Figure 5. The simulation interface in the NetLogo environment

The interaction network is created by generating a complete graph for a community with

specified number of people and then replaced a link in the community with a link to an agent in other community randomly until the assortativity reaches the specified value. The community is defined as a group of like-minded people. In the simulation it is assumed that just a user of each community carries an original bookmark and a user copies only a bookmark of a specific topic identified with "tag". The assortativity which is the fraction of links in a community is defined by the equation (1),

$$Assortativity = \frac{I}{I+O} \qquad (1)$$

where, I and O are the inner and outer links in a community of the interaction network respectively.

A number of settings are allowed for modification in the interface. Table 1 shows the parameters and the used values in the simulation. The parameters are determined by the sensitivity analysis to validate the simulation. The most important elements that affect the characteristics of information dissemination through SBS are the number of people, the number of communities, the group size, visiting rate, the number of bookmarks and influence rate. The probability of browsing others' library is not constant in time. It is common experience that some users are more frequent than others. As a consequence in more realistic scenarios, the visiting rate depends on users' personal characteristics. The number of people considered here is fixed. In real SBS, it will not be close. The number of bookmarks considered here is only one for each community.

Table 1. Parameters of the simulation

Parameter	*Description*	*Value*
people	the number of agents	100
n-bookmarks	the number of bookmarks	2-20
group-size	the size of the group	5-40
visiting-rate	the rate of visiting others' library in a tick	100%
init-assortativity	the initial assortativity in a community	0-1
influence-rate	additional visiting-rate due to awareness	100%

The controlled parameters in the simulation are group-size, init-assortativity and influence-rate. Group-size is the number of people in the same community. Init-assortativity is the initial fraction of the number of inner links in a community of the interaction network, which remains constant in time. Another controlled parameter, influence-rate is the additional visiting rate that reflects the influence of awareness mechanism. It provides the awareness between two agents by increasing the probabilities of revisiting others' libraries.

The observed quantity of the simulation is diffusion time of bookmarks. The diffusion time is defined as the time for all agents to complete gathering all bookmarks in the same community. It is measured for each community for up to 100% copied bookmark.

4.3 Result

Figure 6 shows the diffusion time for different number of group sizes with 50% influence rate and 95% confidence interval. The data has been taken 10 times and then the average diffusion time is calculated. The settings selected to run the experiment with parameters are shown in table 1. The result shows the diffusion time explicitly decreases according to the increase of the assortativity. The result also suggests that the diffusion time is lower for all groups in case of the highest value of the assortativity. It implies that the strong interaction between users in a community decreases the diffusion time.

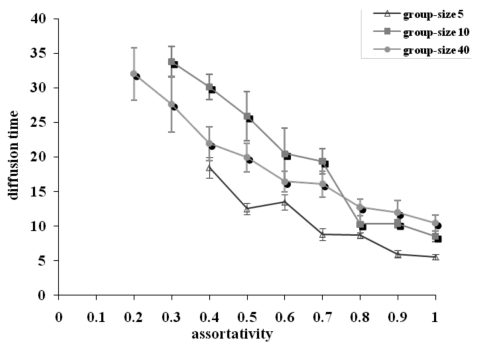

Figure 6. Diffusion time for different group sizes

Figure 7 shows the reduction ratio of diffusion time which is calculated by the difference of diffusion time between influence rate 0% and 100% for different group sizes. The data has been

taken for different assortativity 0.3, 0.5, 0.8, and 1 with 0% influence rate when the group size is 5. The diffusion time has been noted for each condition 10 times and then average diffusion time has been calculated. The same experiment is then executed for other group sizes. This procedure is then repeated for 100% influence rate and then reduction ratio has been calculated. The result shows that the reduction ratio turns to negative when the group size increases.

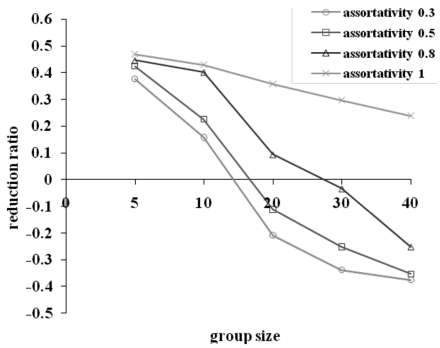

Figure 7. Reduction ratio of diffusion time for different group sizes

4.4 Discussion

The results of the diffusion time for different group sizes confirm the community effect in information diffusion among the like-minded people. It indicates that the strong interaction between users in a community fosters the time for information diffusion of gathering bookmarks among like-minded people since the diffusion time decreases with the increases of the assortativity. The reduction ratio of diffusion time for different group sizes presents that there is significant community effect in information diffusion exists for small groups.

5. Experiment on Community Building

5.1 Objective

In order to analyze that how mutual awareness mechanism fosters community building, a preliminary experiment using agent-based simulation is conducted to verify the second hypothesis.

5.2 Method

The simulation model has been developed from the above described model of the community effect. It is developed by repeating the simulation of the community effect for a bookmark randomly assigned to an agent.

The users browse others' library at the influence of the Browsed Users list, which is provided by mutual awareness function. Browsed Users list has limited length, so if it overflows the oldest entry is removed and the link to the user is replaced with the link to another user randomly. The browsed user is put in the top of the list.

The parameters that are identified for the model are max-browsed-users and simulation turns. Max-browsed-users is the maximum length of Browsed Users list. The simulation-turns is the maximum turns of the simulation. It is the number of turns which are measured by repeating the simulation of the community effect.

To verify the hypothesis the average of the assortativity due to the influence of the mutual awareness mechanism is observed for all communities for the simulation turns.

5.3 Result

The result is shown in figure 8 for group size 10 and the maximum browsed users 8. From the result it is apparent that the assortativity reaches at its highest value which fosters community building for small group size. It also suggests that the diffusion time decreases according to the increases of the assortativity.

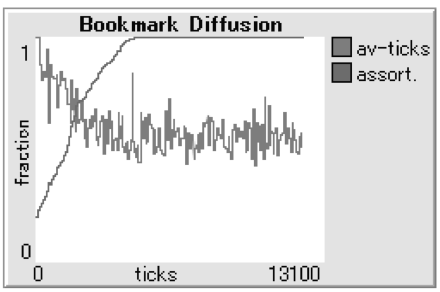

Figure 8. The assortativity for mutual awareness

5.4 Discussion

The result implies that the mutual awareness mechanism fosters community building among like-minded people by the community effect in SBS due to the influence of the Browsed Users list through browsing behaviors of users which provides the second hypothesis. The result also

indicates that the mechanism affects the information diffusion by decreasing the diffusion time of bookmarks as collaborative information gathering in SBS.

6. Conclusion

The results of the simulation can be summarized as:

- There is community effect in information diffusion through SBS for small groups i.e., strong interaction in a community decreases the diffusion time.
- The mutual awareness mechanism fosters community building by the community effect.
- Therefore the mutual awareness mechanism is effective for CIG in SBS.

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