An Analysis of Word-of-Mouth Effects on Social Networks

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Abstract. In this paper, we discuss how the neighbors affect the decision of consumer behavior over diffusion of innovation. We suggest an agent-based model of diffusion and showed that on an online social network which have both of ”scale-free” and ”small world” properties, 1) the informative effect can cause a takeoff, but it is not sufficient to reach the completion of diffusion. 2) Meanwhile, the combination of the informative and normative effects can easily bring a takeoff before accelerating the diffusion and reaching the completion in the end. 3) The informative effect makes information propagate fast over a “scale-free” network, and so does the normative effect over a highly clustered network. The traits and the paths of information propagation actually differ.

Keywords: Social simulation, Agent-based model, Word-of-mouth, Diffusion process, Complex networks,

1 Introduction

Enterprise advertisement activities have taken up a one-way communication style in the past by which companies provide information to consumers. Information exchange among consumers has also been based on information exchange people close to them, such as friends and families. Consumers have been place in a position where they receive information from companies from only one side and they have been restricted from transmitting information back to companies. However, the appearance of the Internet has totally changed this situation. Costs of transmitting and receiving information have dramatically been reduced. For this reason, consumers have been able to convey their opinions or complaints back to companies by using email or through company websites. In addition, they have been able to exchange their opinions about product usability between themselves on electronic bulletin boards or social networking services (SNS).

On the other hand, companies have also been able to take a wide variety of advertisement strategies in addition to mass-media advertising that has previously been done, such as launching campaign websites, and viral marketing on the Internet services including SNS and Twitter. Trends (booms) that break out of unexpected movements or places are considered that word-of-mouth effects, which are interactions between consumers, have a significant influence when compared to running ordinary advertisements. Utilization of such word-of-mouth effects has been examined today. Evidently each advertisement through media has had a certain level of effect; however, the reaction mechanism of consumers on the Internet, especially where the word-of-mouth effects have had a significant influence, has not been clarified. This has brought difficulties in making decisions on sites.

Through this research, we show that there is limitation when treating consumer interactions such as word-of-mouth communication in an integrated fashion in diffusion. By doing so, we try to examine the mechanism by which the opinions of surrounding consumers affect one's own decision-making process.

2 Previous Research

Recently, based on agent-based models of diffusion, studies have been conducted in which networks, where consumer interaction is generated, were explicitly provided. Goldenberg et al. [1] discussed the role of a hub in a scale-free network by using ABS. In their model, the probability of change in consumer behavior, P, from rejection to adoption of a product is defined as follows by using the innovation exposure level (marketing effect), p, and the probability of information reception from other consumers (word-of-mouth effect), q.

$$P = 1 - (1 - p)(1 - q)^{\alpha(t)}$$

Here, α (t) indicates the number of those neighboring adopters. This probability of change in consumer behavior indicates the process of access to information taken in by consumers. This research utilizes the network data provided by Cyworld (SNS in Korea) as the consumer network model. Examining the role of the hub on this scale-free network, we showed that this hub can be separated into the innovator hub that actively adopts new products and the follower hub where the decision-making process of adopters could be affected by the market scale. Delre et al. made a study of diffusion in a small-world network by utilizing ABS, showing that the small-world feature of the network and consumer heterogeneity accelerate diffusion [2]. They adopted the threshold model in which the probability of change in consumer behavior (status transition) [3] increases in a discontinuous manner according to the percentage of neighboring adopters, in the consumer's decision-making process of accepting a product. Similarly, Watts et al. adopted the threshold model in which the probability of change in the consumer behavior generates according to the percentage of neighboring adopters [4]. Either of these models proposes a model in harmony with individual networks to be used, and it is impossible to explain the phenomenon of diffusion where each network is replaced. Delre et al. actually indicated that their own model cannot be applied to a scale-free network.

The threshold model adopted by Granovetter [3] separately presented those affected by the percentage of the neighboring adopters and the others affected by the number of the neighboring adopters. In his study, he considered that the influence level of neighboring adopters would be different between diffusion and word-of-mouth communication. In the research about diffusion, however, the difference in these influences is not separated, and the model of diffusion is directly utilized as the model of word-of-mouth communication.

3 Model Proposal

Similar to preceding research, we utilized the SI model, which is a kind of Susceptible Infectious Recovered model in epidemiology, in this research. In the SI model, consumers take the following two statuses: the susceptible status and the infected status. The default status of consumers is the susceptible status, and then their status changes to the infected status in a single direction by means of the decision-making model. The consumers that change to the infected status never return to the susceptible status. As a result, the number of adopters increases one-sidedly, with diffusion promoted.

3.1 Decision-making Model that Considers Informative Effect and Normative Effect

As a decision-making model for consumers, this model defines the probability of transiting from the susceptible status to the infected status. In this model, the probability of status transition of a consumer, i, is P_i. Consumers with a high probability of status transition easily change their behavior.

In this research, it is supposed that the informative effect and the normative effect affect the change in consumer behavior. The informative effect indicates the possibility of access to information by means of searching, which is considered to be the influence exerted by the number of neighboring adopters (number-of-exposure rule). On the other hand, the normative effect indicates the possibility of communication in a highly-clustered relationship, which is the influence provided by the percentage of the neighboring adopters (proportion-of-households-threshold rule).

Based on this concept, the probability of change in behavior, Pi, is defined below.

$$P_i = \alpha x_i + (1 - \alpha) y_i,$$

$$x_i = \begin{cases} 1 \ (N_{i,adopted} \geq \xi) \\ 0 \ (\text{otherwise}) \end{cases}$$

$$y_i = \begin{cases} 1 \ \left(\dfrac{N_{i,adopted}}{N_{i,neighbor}} \geq \varphi \right) \\ 0 \ \ (\text{otherwise}) \end{cases}$$

In this equation, x_i and y_i are the variables that indicate the informative effect and the normative effect, respectively. $N_{i,neighbor}$ and $N_{i,adopted}$ indicate the number of neighboring consumers of the consumer i and the number of the neighboring adopters, respectively. ξ is the threshold of the informative effect, while a change in behavior is more likely to occur where the number of neighboring adopters exceeds this threshold. Similarly, φ is the threshold of the normative effect, and change in behavior also is more likely to occur when the percentage of the neighboring adopters exceeds this threshold. α is the weight to the informative effect and the normative effect.

3.2 Network of Interactions among Consumers

Upon performing simulation experiments, a network that connects each consumer together was formed. The consumer agents located on the end of each branch of this network interact together.

The previous studies have confirmed that human-relationship networks on the Internet are scale-free and highly clustered networks [5][6]; however, it is impossible to generate such networks by using the existing mathematical models. For this reason, the network desired in this research was formed by synthesizing each network generated by using the WS model and the BA model. First, the regular network with the degree of 4 (Table 1: Regular) was generated and the scale-free network (Table 1: ScaleFree) was generated by using the BA model. With these networks, the network ScaleFreeC was created by obtaining the logical sum of the corresponding link of each network and then overlapping these two networks. The process of diffusion on the created network, ScaleFreeC, was observed. Table 1 shows the characteristics of each network (the average degree, the average reach distance, and the cluster coefficient).

Table 1: Networks

Network	Generation method	Average degree	Average path length	Clustering coefficient
ScaleFreeC	ScaleFree+Regular	5.998	4.24	0.216
Regular	WS [2k=4, p=0.0]	4.000	125.38	0.400
ScaleFree	BA	1.998	7.50	0.000

4 Simulation

The influences of the informative effect and the normative effect on diffusion in online human-relationship networks were examined.

Here, based on the three conditions, “with only the informative effect,” “with only the normative effect,” and “with both the informative effect and the normative effect,” the following three cases of the probability for change in behavior were defined:

1. The case where only the informative effect provides the influence for change in behavior

$$P_i = \alpha x_i$$

2. The case where only the normative effect provides the influence for change in behavior

$$P_i = \alpha y_i$$

3. The case where both the informative effect and the normative effect provide the influence for change in behavior

$$P_i = \alpha x_i + (1 - \alpha_i) y_i$$

We confirmed what kind of influence would be provided to the diffusion process when the probability of change in behavior was defined as above.

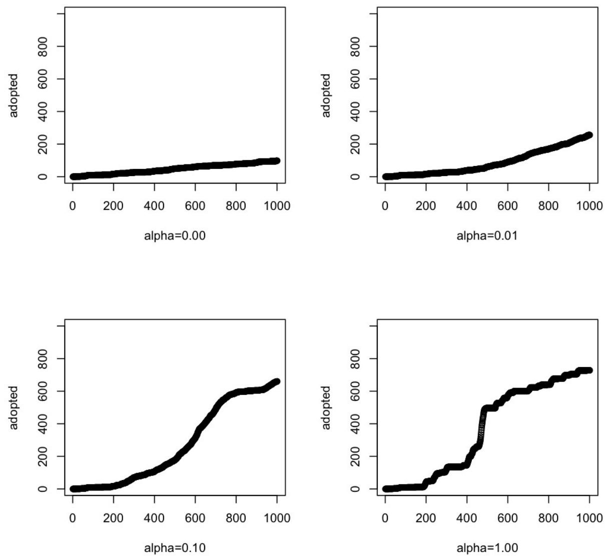

Fig.1 Diffusion process (informative only)

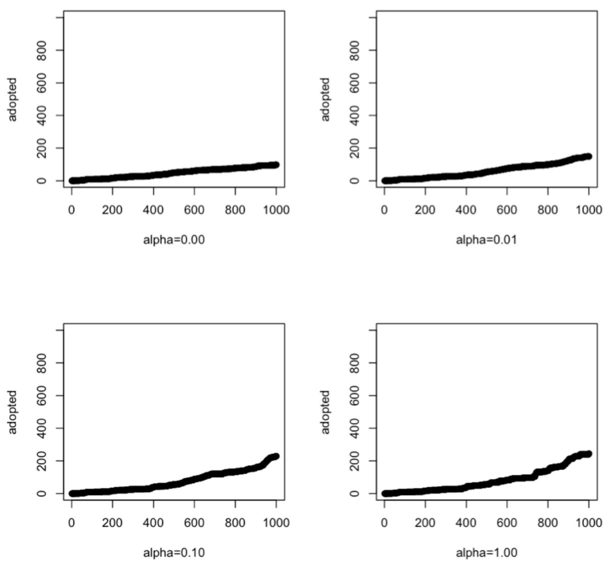

Fig.2 Diffusion process (normative only)

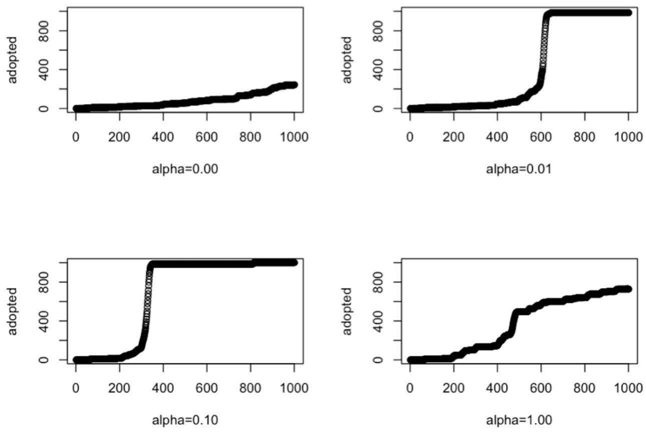

Fig.3 Diffusion process (both)

Figures 1, 2, and 3 respectively show the differences in diffusion where the parameter α was varied based on each of the probability functions of status transitions described above. In the case of only the informative effect, although takeoff occurs, diffusion does not reach completion by the specified time (Fig. 1). In the case of only the normative effect, only a slight takeoff occurs (Fig. 2). In contrast, where both of the effects are mixed, diffusion rapidly reaches completion from the takeoff (Fig. 3).

5 Discussion

In the previous section the proposed model was implemented and the conditions of the diffusion (information propagation) process were also clarified, especially under the circumstance where only a small quantity of advertisements exists, based on the simulation performed. With the simulation results discussed, the findings of the studies of consumer activity show the following points. 1) The existing research on diffusion adopted either of the following models to be treated as the word-of-mouth model: the informative effect, in which the number of the neighboring adopters affects change in consumer behavior, and the normative effect, in which the percentage of the neighboring adopters affect change in consumer behavior. However, the characteristics of information propagation of each model are different, thus they are identifiable. 2) In the scale-free and highly clustered network that is in harmony with the actual consumer networks, the informative effect and the normative effect trace the different paths when diffusing. 3) The type of communication (interactions) among consumers includes the information-seeking type and the self-contained type. The information propagation paths provided by these communication types correspond to the propagation path of the informative effect and that of the normative effect, respectively.

6 Conclusion

In this paper we proposed the agent-based diffusion model, and the simulation we performed indicated that there are different paths by which the informative effect and the normative effect convey information. The informative effect indicates the exploratory action of gaining information, whereas the normative effect indicates the imitation effect that works on how consumers feel and try to keep up other consumers, network externalities, and explanations from society. The traits and the paths of information propagation actually differ. Therefore, there is limitation when treating either of these two effects as the word-of-mouth effect, just as done by the previous studies on word-of-mouth communication by using simulation. This paper also showed that it is inadequate to think that opinion leaders, connected with numerous other consumers, only adopt a product and transmit the information of usability impressions to other consumers in order to trigger diffusion on online human-relationship networks. Rather, diffusion is promoted entirely by active communication among non-opinion leaders, which have received such information from opinion leaders.

7 References

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