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An Information Propagation Model for Instant Messaging Based on Small-world Networks

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Abstract: Nowadays, people prefer to transmit information through instant messaging system, due to its unique efficiency and convenience. Sometimes a certain message propagates quickly among people and many people will wonder how it propagates in the instant messaging system. In this article, an information propagation model for instant messaging is constructed based on small-world networks, to obtain the law of information propagation in instant messaging network. Then we can solve the problem how the information propagates in the instant messaging system based on the law. Each participant in instant messaging network that is regarded as a node in this model has four states: Hasn't received the message; has received the message but hasn't opened it yet; has opened the message but hasn't retransmitted it yet; has already opened the message and has retransmitted the message. And the transformation probabilities among them are set initially. We change the number of participants' friends and the number of their circles of friends and use MATLAB to simulate this process to see how the information propagates. We find that the above two factors have a very big impact on the information propagating in the instant messaging system: If participants have more friends or join in more circles of friends, the message will be propagated more widely and quickly. Thus, we successfully find two influencing factors of the information propagating in the instant messaging system. And we can also find how they influence propagating.

Key words: Instant messaging, information propagation, MATLAB, small-word networks, propagation law

INTRODUCTION

In recent years, people have been very interested in how information propagates, in order to continuously find better communicating methods (Herbsleb *et al*., 2002). With the innovative development of the internet, the communication can't be independent from it. Among the network communication systems, instant messaging systems have quickly come into our lives due to their efficiency and convenience, such as MSN, Skype and so on. Users on the same IM (Instant Messaging) system can communicate, transmit files or make a video call synchronously, based on Internet. IM also supports group chat, which means not only it support point to point communication but also lots of users can communicate with each other at the same time (Grinter and Palen, 2002).

The small-world conception was firstly proposed in (Milgram, 1967) where six degrees of separation were observed in friendship graphs (Milgram, 1967). When a small number of edges are added to a network randomly, the diameter of it will drop rapidly. Networks constructed in this way have small-world properties, so they are called small-world networks. The small-world network is just like a circle contains lots of people which communicate with each other occasionally. In recent years, small-world networks model is widely used and substantiated when researching on the propagation law of information and virus, such as discussing on virus propagation law (Hu *et al*., 2004), human brain networks (Liao *et al*., 2011) and online social networks (Kumar *et al*., 2010).

After analyzing these models, it is obvious that current information propagation models of instant messaging can be improved and particularly a problem that there are too many states in it can also be conquered. Then a new information propagation model for instant messaging based on small-world networks can be obtained. In this model, each node is supposed to have four states, when a message is propagated into this model, the number of nodes is recorded constantly in each state by changing some parameters. Finally the features of information propagation in it can be directly

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found: In an instant messaging network, both the number of participants' friends and the number of their circles of friends can deeply affect information propagation.

SMALL-WORLD NETWORKS

In Watts and Strogatz (1998) proposed a conception of "small-world networks" and constructed the WS model (Watts and Strogatz, 1998). It considers a regular circle network with N nodes. Each node is connected to its K adjacent nodes, K/2 on the left and K/2 on the right. K represents each node's degree and is an even number. Following this definition, original connections of each node are broken with the probability P and they are reconnected to other nodes in the case that no one has self-connection and no one is connected to other same nodes.

In the WS model, when P = 0, it represents an absolutely regular network. When P = 1, it represents an absolutely random network. By changing P, the transition from absolutely regular network to absolutely random network can be made, as shown in Fig. 1.

The average shortest path means the average of the shortest path between each two nodes in a network. It can represent the distance between each two nodes in a network (Rubinov and Sporns, 2010). The clustering coefficient means the clustering level of all nodes in a network (Newman, 2009). Both WS model and NW model have features of a smaller shortest path and a bigger clustering coefficient.

However it may produce solitary nodes in WS model. To solve this problem, Newman and Watts constructed the NW model (Newman and Watts, 1999). In this model, nodes are only reconnected but original connections aren't broken. In this method, a module without solitary nodes can be constructed (Lu and Guo, 2012).

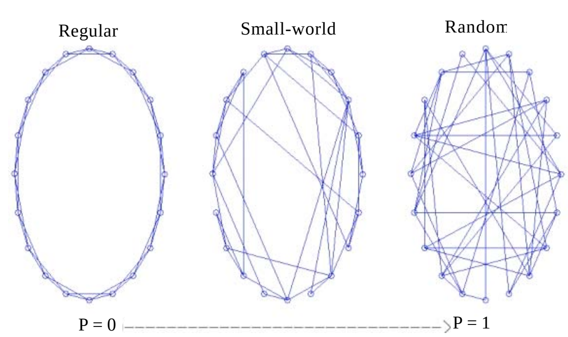

Fig. 1: Regular networks, small-world networks and random networks in WS model

Each participant in instant messaging network is not only a disseminator but also a recipient. Once a lot of messages are sent out, they will be propagated so fast that people can't imagine. Meanwhile, the connection between nodes isn't limited by distance in it. Lots of people can receive the same messages at the same time by the so-called "group-propagation". So this network with a smaller shortest path and a bigger clustering coefficient is a typical small-world network. Considering the situation that participants may neither have friends nor propagate the message, which means solitary nodes may exists. WS model is used as the basic model in this article.

INFORMATION PROPAGATION MODEL OF INSTANT MESSAGING

The information propagation model of instant messaging is based on WS model. It has all features of WS model. Once a node in this model receives a message, it will make an irreversible state change with a certain probability. Moreover, by changing K and P in this model, in a certain time, the change of density in each state can be observed. And then the law of information propagation can be obtained.

INTRODUCTION OF PROTOTYPE

It assumes that there are N participants in instant messaging network. When a message is propagated into this network, at first, there will be a small number of participants receive it. As the participants who have known it, they can propagate it freely. Because each participant has different attitude and view towards this message, they generally will take different actions to it. If a participant who has received this message isn't interested in it, he will not open it. If a participant who has opened it thinks it not necessary to tell others, he will not retransmit it. Only when a participant is not only interested in the message but also wants to share it with others, he/she will retransmit it. When a message is being retransmitted, if a receiver has received or opened it, the message will not be retransmitted to him successfully. And we also assume that the number of a participant's friends means the number of participants that this participant connects with. If it assumes that several adjacent participants are in a same circle of friends, the number of a participant's circles of friends means the number of circles of friends that each participant's friends participate in.

According to these assumptions, an instant messaging network can be easily constructed. The law of information propagation is tried to be obtained, by changing the number of participants' friends and the number of their circles of friends.

MODEL CONSTRUCTION

According to the process mentioned above, WS model is used as a basic model to construct an information propagation model for instant messaging. It supposes that there are N nodes in this network, each of which represents a participant. When a message is propagated in this network, each node has 4 states: First, state S0 which hasn't received the message; second, state S1 which has received the message but hasn't opened it yet; third, state S2 which has opened the message but hasn't retransmitted it yet; and last, state S3 which has already opened the message and also has retransmitted the message. Each node opens the message with the probability P1, which means each node changes from S1 to S2 with the probability P1. And each node retransmits the message with the probability P2, which means each node changes from S2 to S3 with the probability P2, as Fig. 2 shows.

Here, it assumes that each node can be in S1 with the probability P0 initially and the other nodes are in S0. Actually there are N*P0 nodes have received the message, at the initial moment. Blue nodes are used to represent nodes in S0, red nodes are used to represent nodes in S1, green nodes are used to represent nodes in S2 and black nodes are used to represent nodes in S3. As Fig. 3 shows, it is the distribution of initial states of all nodes. If the node is in S0, it only can change to S1. If the node is in S1, it only can change to S2. If the node is in S2, it only can change to S3. If the node is in S3, it only can retransmit the message to the node which is connected with it and is in S0. If a node connected with it but isn't in S0, we consider this node has already received the message.

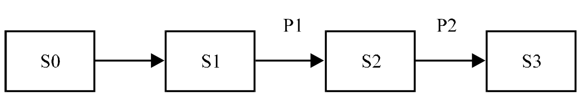

Fig. 2: State transition of each node

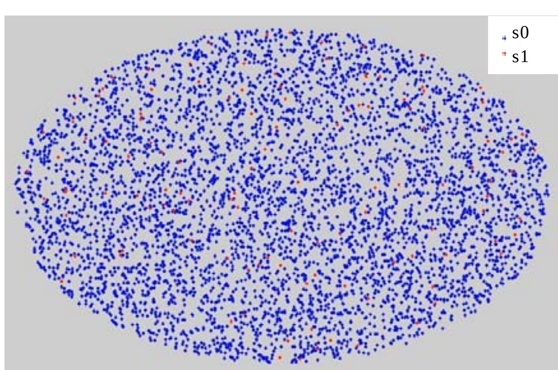

Fig. 3: Distribution of initial states: 2% nodes in S1, the other nodes in S0

In this model, it can be inferred that the node number in each states change with K and P. Specific conclusions can be substantiated by MATLAB imitating.

MATLAB IMITATING

These densities are supposed: Density ρ0 which represents the ratio of nodes in S0 to total nodes N; density ρ1 which represents the ratio of nodes in S1 to total nodes N; density ρ2 which represents the ratio of nodes in S2 to total nodes N; density ρ3 which represents the ratio of nodes in S3 to total nodes N.

Time T is also assumed when the number of nodes in each state is stable and won't change any more.

Time T, the influence of K on each density: K is the degree of each node. It virtually means the number of every participant's friends. When K increases, participants will have more friends. According to the experience, if a participant has more friends, he may propagate it to more people and that means the message may be propagated more widely. Whether the inference is true, we will verify it by MATLAB imitating. At particular time T, N = 5000, P = 0.4, P0 = 0.02, P1 = 0.6, P2 = 0.2, each density changes with K from 0 to 12 is imitated shown as Fig. 4.

It can be easily found that with the increase of K, the density ρ0 decreases. When K> = 6, it decreases to 0. It exactly accords with the propagation law of instant

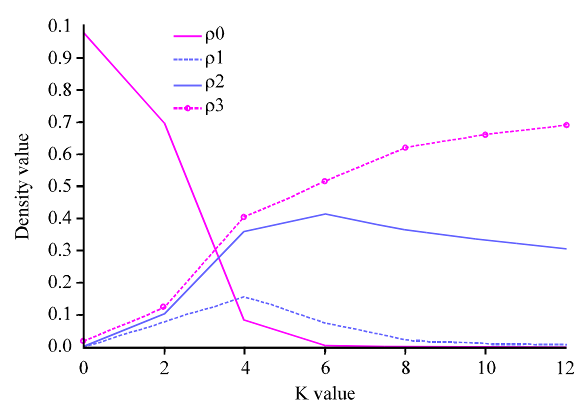

Fig. 4: Changes of ρ0, ρ1, ρ2, ρ3 with K increasing from 0 to 12 at time T

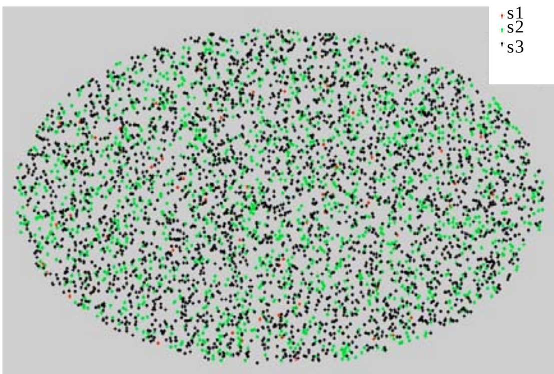

Fig. 5: When K = 12, the distribution of states: 68% nodes in S3, 30% nodes in S2, 2% nodes in S1, 0% nodes in S0

messaging network. The increasing K means the increasing number of participants' friends. When K> = 6, all participants will receive the message and there is none participants in S0. The density ρ1 increases initially, then decreases. When K = 4, the number of participants that has received the message but hasn't opened it, is maximum. That is to say, when each participant has four friends, there are most people in S1. The density ρ2 increases quickly at first and then increases stably, finally it decreases gradually. When K< = 4, the number of participants who has retransmitted the message after they opened it increases quickly. When K>4 and K<6, it increases a little. When K> = 6, it decreases gradually. With the increase of K, the density ρ3 increases all along. It can find that when K< = 4, as the increase of K, each density changes obviously. But when K>4, each of them changes stably. From there, a conclusion can be made that K greatly impacts the densities, when K< = 4. And when K>4, the influence is not very great.

Anyway the result accords with the propagation law: If participants have more friends, there will be more people retransmit the message and it will be propagated quickly. The result of distribution of states of all nodes is imitated, when K = 12, 68% Nodes are in S3, 30% Nodes are in S2, 2% Nodes are in S1, 0% Nodes are in S0, shown as Fig. 5.

Time T, the influence of P on each density: P is the probability of breaking original connections and reconnecting them. It supposes several adjacent participants are in a same circle of friends. When P increases, participants will join in more circles of friends and the message will be propagated more widely and speedily. At particular time T, N = 5000, K = 4, P0 = 0.02, P1 = 0.6, P2 = 0.2, each density changes with P from 0 to 0.4 is imitated, shown as Fig. 6.

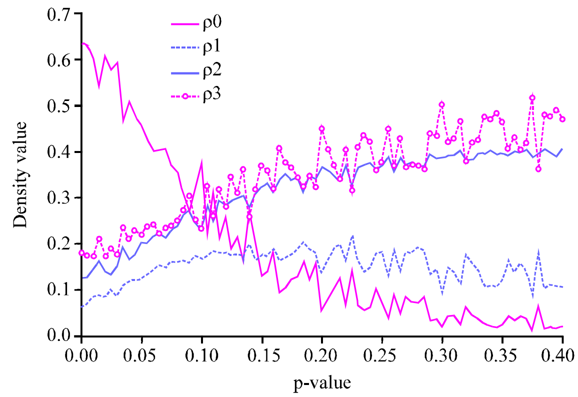

Fig. 6: Changes of ρ0, ρ1, ρ2, ρ3 with P increasing from 0 to 0.4 at time T

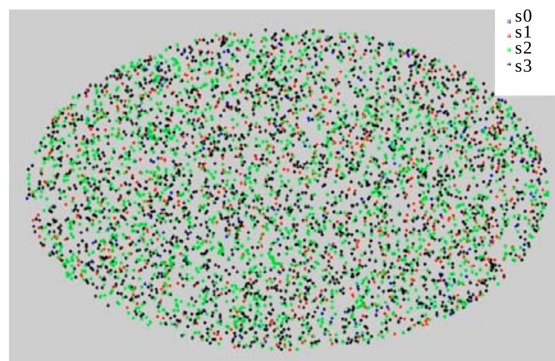

Fig. 7: When P = 0.4, the distribution of states: 48% nodes in S3, 40% nodes in S2, 10% nodes in S1, 0.2% nodes in S0

It can be easily found that with the increase of P, the density ρ0 decreases, finally it closes to 0. The increasing of P means participants will join in more circles of friends and the message will be propagated to a large number of different circles. The densityρ1 changes stably. It means the number of participants in S1 which has received the message but hasn't opened it doesn't change much. In other words, P can't change the number of participants in S1 much. With the increase of P, the density ρ2 and ρ3 increase, too. But not all people will retransmit the message, so the changes of S2 and S3 are similar.

Namely, it also accords with the propagation law: if participants join in more circles of friends, the message will be propagated more widely and more people will receive the message.

The result of distribution of states of all nodes is imitated, when P = 0.4, 48% Nodes are in S3, 40% Nodes are in S2, 10% Nodes are in S1, 0.2% Nodes are in S0, shown as Fig. 7.

CONCLUSION

The instant messaging tools have been widely used in people's daily life. This article successfully imitates an information propagation model of instant message based on small-world network and it conquers a problem that there are too many states in the current model. Meanwhile it obtains the propagation law of instant messaging network. It says: The participants' number of friends and the number of their circles of friends have a very great influence on information propagation in instant messaging network. If participants have more friends and participants join in more circles of friends, the message will be propagated more widely and speedily. How to apply this model to other information propagation model is the next problem that we are working on.

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