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Rumor Propagation Model on Complex Network with Repast Simulation Platform

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***Abstract*—Considering propagation characteristics of rumor on complex networks, this paper presents a rumor propagation model on complex network with Repast simulation platform. We introduce the structure and the main class library of Repast simulation platform. Then we build an efficient model based on the multi-agent modeling method. Through the model, we simulate the behavior of rumor propagation on scale-free network and calculate the propagation thresholds by corresponding dynamics equation. Theoretical analysis and simulation results show some basic rules and behavior characteristics of rumor propagation. Finally, we put forward some strategy and measures for prevention and control rumors.**

Keywords-rumor propagation; repast; complex networks; multi-agent modeling

I. INTRODUCTION

As a unique phenomenon in human society, rumor has greatly influenced people's life. The famous sociologist Karp Ferre ever said, "Rumor is the oldest of mass communication media."[1] Rumor refers to the spreading news that has not been approved or publicly reported by party or officially; even has been denied by relevant evidence or authority [2]. Generally speaking, rumor is information that unofficial, groundless and not confirmed.

Early research on rumor was mostly semantic classification and simple statistics, the rumor propagation model was yet based on the mathematical stochastic process method [3,4]. Therefore, the equations abstract out was hard to describe the real propagation process and difficult to find solution. Recently there has been a lot of research on rumor propagation by complex network theory [5,6]. The representative rumor propagation models established on small-world networks and scale-free networks include Potts model, Zanette model, Nekovee model, Moreno model and so on [7]. The above main models are to simulate rumor propagation process by differential equations which established by mean-field method. But unfortunately, mean-field method is only suitable for the overall forecast, so it is difficult to reflect the propagation process of small probability events and individual performance. Meanwhile, the solution of differential equation is sensitive to initial conditions extremely and relatively complex to calculate [8]. Therefore, the method is not very good to solve practical problems.

This paper presents a rumor propagation model on complex network with Repast simulation platform. We build an efficient model to simulate propagation process of rumor on complex network, such as social network and Internet, by means of multi-agent modeling and simulation method. Further, we analyze some basic rules and behavior characteristics of rumor propagation by using Repast simulation platform.

II. AGENT-BASED COMPLEX ADAPTIVE SYSTEM

The core idea of Complex Adaptive System (CAS) is that the whole system is composed of agents with adaptive behavior [9]. The theory and method of Multi-agent System

(MAS) are quite an efficient means to deal with complex system [10]. Agents can interact with environment and other agents, and change its own structure and behaviors through interact. Thus the whole system will evolved, furthermore, the whole system will emergence new structure, phenomenon and more complex behavior. In short, adaptability of agents builds complexity of system.

III. REPAST SIMULATION PLATFORM

Repast (The Recursive Porous Agent Simulation Toolkit) [11] was created at the University of Chicago. Repast is now managed by the non-profit volunteer Repast Organization for Architecture and Development (ROAD). It provides an easy-to-use, extensible and powerful simulation toolkit for social network simulation. Repast is a general simulation platform based on multi-agent now, because it has advantages such as powerful modeling ability, good man-machine interactivity, extensibility, and support for multiple programming languages, and so on. The latest version of Repast is Repast Simphony 2.X. Repast Simphony models can be developed in several different forms including the ReLogo dialect of Logo, point-and-click statecharts, Groovy, or Java, all of which can be fluidly interleaved. Repast Simphony has been successfully used in many application domains including social science, consumer products, supply chains, possible future hydrogen infrastructures, and ancient pedestrian traffic to name a few [12].

The core library classes of Repast Simphony include Analysis, Engine, GUI, Space, Network and Util, etc. Users can directly use the base class or subclass to construct their multi-agent simulation model, and through two typical internal mechanisms (Scheduling mechanism and Display mechanism) under the framework of Repast Simphony, they can acquire graphical observation and data collection of simulation process.

IV. RUMOR PROPAGATION MODEL ON COMPLEX NETWORK

This paper introduces rumor acceptability function $A(k)$ denotes the acceptable degree of k degree nodes for rumors. The relationship between rumor acceptability function and propagation rate is

$$\lambda(k) = CA(k) \tag{1}$$

where C is a constant, $\lambda(k)$ denotes the acceptability of k degree nodes for rumors, and that is the ability of rumor propagation on this node. Different degrees have the corresponding different values of rumor acceptability function, leading to each nodes in network have different propagation rates.

The average propagation rate is

$$\lambda = \sum_k \lambda(k)P(k) = C\sum_k A(k)P(k) = C\langle A(k)\rangle \tag{2}$$

where $\langle A(k)\rangle = \sum_k A(k)P(k)$ denotes the average mathematical expectation of $A(k)$.

The total number of population is N, they are classified into three types: Ignorants (they still not heard rumors); Spreaders (they spread rumors); Stiflers (they heard rumors ever, now be immune to this rumor, won't be infected and won't spread rumors). The rules of rumor propagation are as follows: when a Spreader contact to a Ignorant, the Ignorant become the Spreader with probability $\lambda(k)$, Spreaders gradually lose interest in rumors and then do not have desire to spread rumors or know the truth of the rumors by outside influences, at this time the Spreader become the Stifler with probability δ.

We establish rumor propagation model on scale-free network:

$$\begin{cases} \dfrac{dI_k(t)}{dt} = -CkA(k)I_k(t)\Theta(t) \\ \dfrac{dS_k(t)}{dt} = CkA(k)I_k(t)\Theta(t) - \delta S_k(t) \\ \dfrac{dR_k(t)}{dt} = \delta S_k(t) \end{cases} \tag{3}$$

where $I_k(t)$, $S_k(t)$, $R_k(t)$ denote the proportion of Ignorants, Spreaders and Stiflers in nodes with k degree respectively. They meet normalization conditions

$$I_k(t) + S_k(t) + R_k(t) = 1 \tag{4}$$

V. MODEL BASED ON REPAST SIMULATION PLATFORM

We build the prototype of model on Repast Simphony using Java language, and mainly realize three classes: <Model>, <Agent> and <Space>.

<Model> is used in the implementation of simulation process. <Model> inherits abstract class <SimModelImpl> and implement some methods mainly including [buildModel], [buildSchedule] and [buildDisplay]. First, we generate the topological structure of complex network, and then create agent object and space object. In the end, we simulate rumor propagation process that is Ignorant agents become Spreader agents and become Stifler agents according to the rules of propagation.

<Agent> is used in each agent location in the space and calculation of agent life value. By setting different $\lambda(k)$ and δ, we can change the propagation rate.When rumors spread ended, the Spreaders is 0, at this time, the system reach steady state. The ratio of Stiflers reflect the Influence degree of the rumor spread.

<Space> is used in container for the model. In the space, the agent location and the space position relate to each other. Space and some display classes in the GUI library cooperating to realize the visualization of space and agents.

As shown in Fig.1 and Fig.2, there were a small number of Spreaders and a lot of Ignorants in network when the initial time similar to actual situation. Along with the advancement of time, the number of Spreaders increase very soon, it get to the top and back soon until zero. In the final steady state, there are a lot of Stiflers and a little of Ignorants, no Spreaders, therefore rumors die.

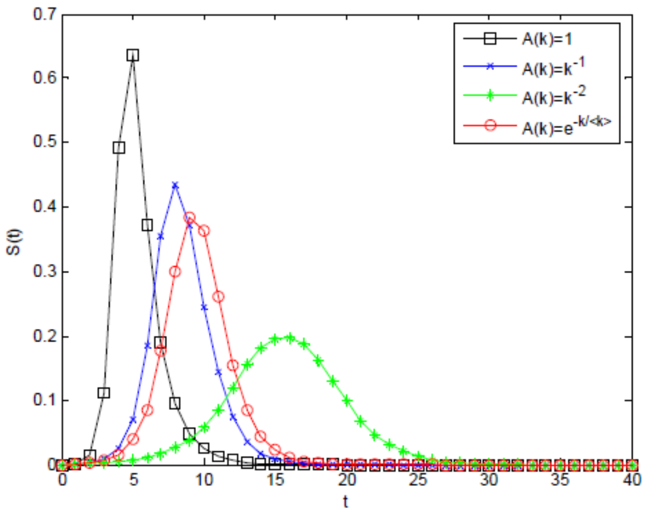

Figure 1. The relationship between the number of Spreaders $S(t)$ and time t

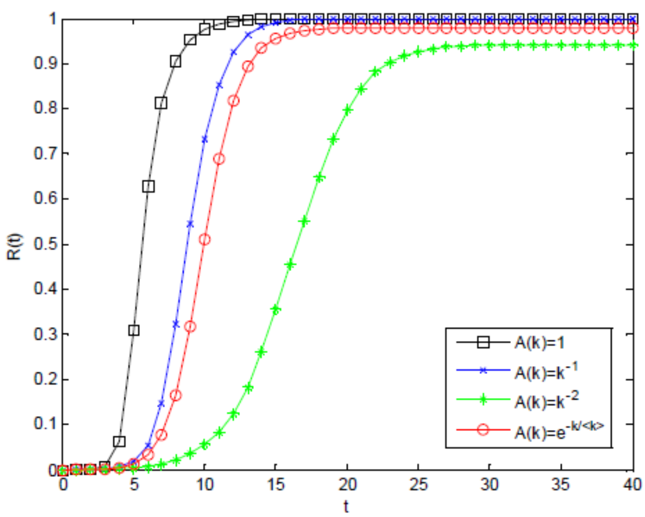

Figure 2. The relationship between the number of Stiflers $R(t)$ and time t

By solving equations and simulation, the propagation threshold is

$$\lambda_c = \frac{\langle k \rangle \langle A(k) \rangle}{\langle k^2 A(k) \rangle} \quad (5)$$

When propagation rate $\lambda < \lambda_c$, rumors will not propagate but gradually demise; when propagation rate $\lambda \geq \lambda_c$, rumors will be large-scale propagate on networks.

As shown in Fig.3, rumor acceptability function make the propagation threshold increased significantly in scale-free network, this means that different levels of resistance for rumors will have important influence to propagation threshold. That is the positive propagation threshold can restrain the outbreak of rumors and reduce the propagation scale.

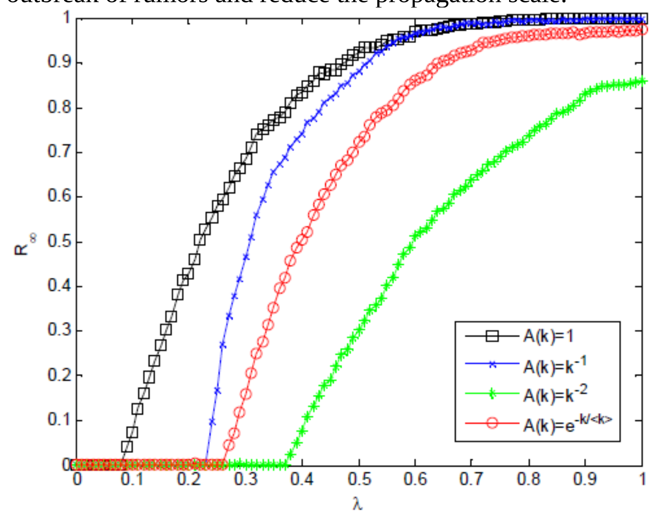

Figure 3. The relationship between the number of Stiflers in steady state R_∞ and propagation rate λ

VI. Summary

In summary, this paper presents a rumor propagation model on complex network. Through Repast simulation platform, we realize rumor propagation model framework and modeling process. With individual as an agent in the process of rumor propagation, define the attribute of each agent and the agent's behavior between rules, this paper study some basic rules and behavior characteristics of rumor propagation by using Repast simulation platform. The theoretical analysis and experimental results show that there are positive propagation threshold and different change of spread speed and propagation threshold for different rumor acceptability functions. Therefore we can appropriate select rumor acceptability function in the real-world networks to change the propagation rates and then effective restrain rumor propagation. Through the theoretical and experimental analysis, it is proved that this method is significant both to theory and practice.

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