Computer Fraud and Security
ISSN (online): 1873-7056

Agent Modeling and Simulation of Rumor Propagation Behavior Evolution in Social Network

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Abstract:

The spread of rumors in social networks shows greater concealment, subjectivity and aggression, is tend to be measured in the form of exponential functions. Based on the traditional model of infectious diseases, the social network rumor propagation model is investigated by differential equation. Then the simulation model via Anylogic is proposed by defining the agent of Internet users (USER), rumor maker (RM), and rumor breaker (RB) firstly. Then, the states of susceptible, exposed, infectious, mongering and recovered are defined in USER agent, at the same time the properties of transitions are set. A function of rumor_breakFUN to generates "rumor" message was defined. The rumor_breakFUN function is just to be executed at the beginning of experiment which indicates rumor maker immediately exit from social media platform after distributing rumor message. Then an influence function of the rumor break is defined in rumor breaker agent, which could be used to judge which Internet user is covered by the effect variable attach to the Internet user is set to true. The user's state conversion probability is changed when rumor breaker works on the user. At last, the changes among the five different states of the Internet users in the main agent are represented with different colors, and the changes of the number of users are shown in the time plot. The work theory analyzes the rumor propagation mechanism in the context of social networks. The simulation model reveals the transformation rate and number of social media users between different states under the condition of specific state transition parameters. It shows the influence mechanism of rumor dispeller in the process of rumor spreading. Through the analysis of the simulation model, the importance of the rumor breaking in time is discussed, and some suggestions on the problem of rumor management are proposed.

Keywords: social network, rumor propagation, differential equation, simulation model, rumor breaker

INTRODUCTION

The informal discourse space built by the new media network has significantly freed people's words, and the internet users have some degree of language, but it also results in the creation, transmission and impact of the rumors. Every rumor is related to environmental crisis, social unrest, lack of trust, etc., the main factor of the spread of rumors is the attention and the fuzzy degree of information[1]. Different people show different attention to the same event, and the same event is different for different people in chaos, so the effect of the rumor is different for each people, which requires concrete analysis based on different group characteristics.

"Complex group behavior is generated by multiple interactive and autonomous agent in coordination and mutual cooperation, and agent can be seen as the calculated entity hosting in complex dynamic environments, with ability to consciously perceive the information in the environment, act autonomously, and be able to implement a series of pre-setting goals or tasks." minsky said[2]. In recent years, the method of Agent based model (ABM) is applied to the research of online public opinion by scholars at home and abroad, but most works are based on analysis of historical events[3,4], but lack of prediction for future development trends in the perspective of research. In the study method, most of the research methods are based on the design of the macroscopic theoretical analysis or micro model design[5,6], but lack of the comprehensive research under the actual management requirements. The research strategy is also mainly static analysis, and lack of dynamic continuous observation and simulation[7].

Based on the internet group of the rumor spreading, the work studies the modeling methods and simulation models of the behavior of the internet users, reveals the development rules and influencing elements of the

rumor, explains the internal mechanism of the spread of the rumor, and propose some advice to support the prediction of the spread of rumors and the path.

AGENT BASED MODELING METHOD

The basic idea of the agent based modeling is each agent has different attribute and behavior ability, the behavior of all agents in the network reflects the evolution rule of event. the law of the individual and the group could be mined through modeling of the agent constructing the system, simulating the interaction of agents[8].

In the field of public opinion or rumour simulation, online organizations or personal users are generally defined as agent. Users' actions affect the development of the whole event, so the agent modeling is especially important. In order to find out the factors of affecting development of public opinion, the information published by the internet users is defined as a variable, then the variable is embedded into the relevant trust model based on the agent simulation. So the influence of different information intensity, information release time and information type are analyzed based on the model[9]. The research shows that information can change and even reverse public opinion. Borowskig presents an agent based dynamic simulation method, using four network topology, where the spread of the opinions of the masses is simulated through the interaction between public praise and mechanism of mass media or society, and furthermore the effect of relevant policies in social media are investigated[10]. Through the simulation model, the incentive strategy of opinion diffusion, the way of opinion communication and the best propagation effect in social media is analyzed. According to the simulation simulation of the group properties of internet users, opinion leaders and the rumor breakers, the comprehensive trust values of the opinion leader and the rumor breaker are calculated, which could be used to find the reliable information agent and identify the spammer to improve the efficiency of the rumor breaking[11]. Therefore, the ABM based methods can not only analyze the macroscopic process of public opinion evolution, but also reflect the influence of different agents on the evolution of public opinion in the system.

MODELING OF RUMOR PROPAGATION BEHAVIOR

The paper maps the internet users, rumor makers and rumor breakers into agents, analyzes the attributes of agents and actions in system, studies the relationship and interaction rules of internet users' groups with different categories, discusses the formation, behavior characteristics and influencing factors of the group of the people in the spread of the rumor, investigates the evolution of the spread of the rumors of the Internet rumors.

SEIMRB Conceptual Model Design

Based on works about agenda setting and sentiment analysis of internet users in public opinion propagation[12,13], the paper constructs an agent-based conceptual model considering the influencing factors of rumor breaker and rumor monger in the process of rumor spreading. Agenda setting theory points out that the media can influence the public's perception and judgment of an issue by continuously emphasizing its coverage[14]. Based on agenda setting theory, SEIMRB model designs the interaction rules between rumor makers, rumor refuters and Internet users, focusing on the mechanism and effect of the role of rumor breakers in the process of rumor spreading. When a specific event occurs, the Internet news and information source unit, which can represent the role of rumor breaker, will take actions according to the characteristics such as the emotion threshold of internet users and the theme of rumors set by it, guide the emotion of internet users, and improve the public opinion environment of online communities.

The social network platform includes the groups of rumor maker, rumor breaker and Internet user. The numbers of the rumor maker and the rumor breaker are fixed, which is denoted as RM and RB. The number of Internet users is named N. The rumor message posted by the rumor makers is delivered to the Internet users (susceptible state users), all of the Internet users are susceptible state at the initial time, after receiving rumor message the state of the Internet user becomes the exposed state. Because the Internet users are seen as rational information consumers, some of the exposed Internet users do not believe the rumor message, whose state is transferred to immune state; the others believe the rumor message is a truth, whose state is shifted to infection state. In the same way, only some of the infectious users, who believe the rumor message, propagate rumor message, whose state is change to monger state. Over time, under the influence of the independent rational judgment of the Internet public opinion and the interference of the rumor breaker, the infectious users and the mongering users

gradually realized the authenticity of the rumor message, their state is shifted to immune state, and eventually all the Internet users who believed the rumor message recognize the truth, no longer believe the rumor message, and no longer spread the rumor message. The model structure is shown in Figure 1.

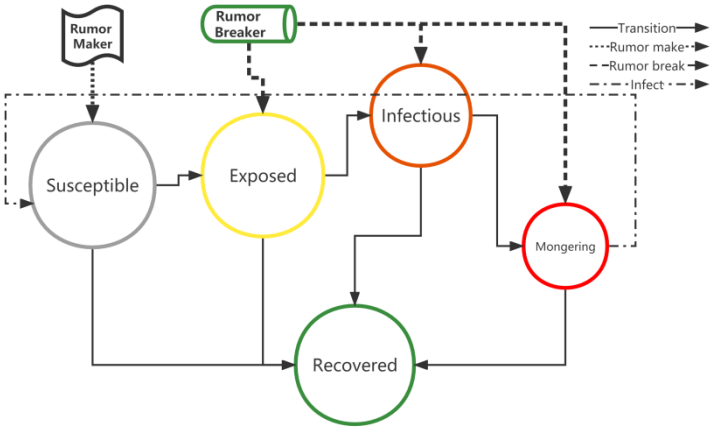

Figure 1. SEIMRB model structure

Model Hypothesis

(1) The number of Internet users is N., and the proportions of susceptible, exposed, infectious, mongering and recovered in total Internet users is S(t), E(t), I(t), M(t), R(t)) respectively, and there is S(t) + E(t) + I(t) + M(t) + R(t) = 1. Each user takes its final state as its status mark;

(2) Rumor makers just publish rumor message only once, which are equivalent to exiting from social media platform when they spread the rumor message;

(3) Unexposed Internet users are seen as recovered agent;

(4) Each agent who is mongering continues to spread rumor message;

(5) The exposed agent is immediately converted into one of the two states of infectious and recovered;

(6) The individual in the group of an infectious group can be converted into one of the state of mongering and recovered state, and the state of the infection can be maintained as well;

(7) Rumor message may spread to Internet users who have already learned about it;

(8) The agent who is recovered is immune, and may again contact the rumor message, but will not be infected again;

(9) The probabilities of converting the exposed to the infectious, the infectious to exposed, and increasing chance of transiting the exposed, the infectious, the mongering to the recovered are different.

Symbolic Specification

N: the total number of user on social networking platform;

S: which means Internet users are susceptible, s(t) represents the proportion of the number of susceptible people in the total number of Internet users at time t, and the initial value of s(0) is 1.

E: which means the exposed users, who has heard of the rumor message, e(t) represents the proportion of the number of exposed users in the total number of Internet users at time t, and the initial value of e(0) is 0.

I: which means the infectious users, who believe the rumor message, i(t) indicates the proportion of the number of infected persons to the total number of Internet users at time t, and the initial value of i(0) is 0.

M: refers to the Internet users who spread the rumor message, m(t) represents the proportion of the number of communicators in the total number of Internet users at time t, and the initial value was 0, denoted as m(0).

R: which is the users who in recovered state, such user know which is rumor message, r(t) represents the proportion of the number of immunized persons in the total number of Internet users at time t, and the initial value is 0, named r(0).

RM: which means the number of the rumor maker, and it is fixed at some value, the default value of it is 1.

RB: which is the number of the rumor breaker, and it is fixed, which has the default value, 1, he is always recovered.

λRM: The number of people who can be exposed to the rumor message by some one rumor propagating.

λUSER: Number of users (value) that can be contacted by each spreader in a unit time (day).

α: The rate of infection when a susceptible user comes into contact with a monger and becomes exposed, among λ contact users, a total of λs(t) users are susceptible, then the average value of newly exposed users per spreader within a unit time (day) is αλs(t);

β: The probability of an exposed person becoming infected in a unit time (day), then $\frac{1}{\beta}$ is the average incubation period of the exposed person;

γ_M: the probability that an infectious user will become a monger in a unit time (day), then $\frac{1}{\gamma_M}$ is the average incubation period of an infected person;

γ_R: the probability that an infectious user will become recovered in a unit time (day), $0 \le \gamma_M + \gamma_R \le 1$;

μ: the conversion rate/recovery probability of a monger transits to recovered per unit time (day), then, the average transmission period is $\frac{1}{\mu}$;

$\theta_{EI}, \theta_{IM}, \theta_{IR}, \theta_{MR}$ represent the average coefficient of the conversion from exposed users to infectious user, from infectious user to mongering user, from infectious user to recovered user, from mongering user to recovered user respectively, then the probability of conversion from exposed to immune is $1 - \theta_{EI}$, The value range of each parameter is[1,10].

The Spread of Rumors among Internet Users

According to the transition between different states of social media platform users and the model, the number of susceptible people can be assumed to be:

$$S(t+\Delta t)N - S(t)N = -\alpha\lambda\Delta t\, S(t)(M(t)N + RM) \quad (1)$$

$$S(t+\Delta t) - S(t) = -\alpha\lambda\Delta t\, S(t)\left(M(t) + \frac{RM}{N}\right) \quad (2)$$

$$\frac{dS}{dt} = -\alpha\lambda S(t)(M(t) + \frac{RM}{N}) \quad (3)$$

The number of exposed people changes is:

$$E(t+\Delta t)N - E(t)N = \alpha\lambda\Delta t\, S(t)(M(t)N + RM) - \frac{\beta}{\theta_{EI}}\Delta t E(t)N \quad (4)$$

$$E(t+\Delta t) - E(t) = \alpha\lambda\Delta t\, S(t)\left(M(t) + \frac{RM}{N}\right) - \frac{\beta}{\theta_{EI}}\Delta t E(t) \quad (5)$$

$$\frac{dE}{dt} = \alpha\lambda S(t)\left(M(t) + \frac{RM}{N}\right) - \frac{\beta}{\theta_{EI}}E(t) \quad (6)$$

The number of infected people is changed:

$$I(t+\Delta t)N - I(t)N = \frac{\beta}{\theta_{EI}}\Delta t E(t)N - \gamma_R\theta_{IR}\Delta t I(t)N - \frac{\gamma_M}{\theta_{IM}}\Delta t I(t)N \quad (7)$$

$$I(t+\Delta t) - I(t) = \frac{\beta}{\theta_{EI}}\Delta t E(t) - \gamma_R\theta_{IR}\Delta t I(t) - \frac{\gamma_M}{\theta_{IM}}\Delta t I(t) \quad (8)$$

$$\frac{dI}{dt} = \frac{\beta}{\theta_{EI}}E(t) - \gamma_R\theta_{IR}I(t) - \frac{\gamma_M}{\theta_{IM}}I(t) \quad (9)$$

The number of communicators is:

$$M(t+\Delta t)N - M(t)N = \frac{\gamma_M}{\theta_{IM}}\Delta t I(t)N - \mu\theta_{MR}\Delta t M(t)N \quad (10)$$

$$M(t+\Delta t) - M(t) = \frac{\gamma_M}{\theta_{IM}}\Delta t I(t) - \mu\theta_{MR}\Delta t M(t) \quad (11)$$

$$\frac{dM}{dt} = \frac{\gamma_M}{\theta_{IM}}\mathrm{I(t)} - \mu\theta_{MR}\mathrm{M(t)} \tag{12}$$

The number of immune populations changed:

$$R(\mathrm{t}+\Delta\mathrm{t})\mathrm{N} - \mathrm{R(t)N} = \gamma_R\theta_{IR}\Delta\mathrm{tI(t)N} + \mu\theta_{MR}\Delta\mathrm{tM(t)N} \tag{13}$$

$$R(\mathrm{t}+\Delta\mathrm{t}) - \mathrm{R(t)} = \gamma_R\theta_{IR}\Delta\mathrm{tI(t)} + \mu\theta_{MR}\Delta\mathrm{tM(t)} \tag{14}$$

$$\frac{dR}{dt} = \gamma_R\theta_{IR}\mathrm{I(t)} + \mu\theta_{MR}\mathrm{M(t)} \tag{15}$$

The model of the differential equation is:

$$\begin{cases} \frac{dS}{dt} = -\alpha\lambda S(\mathrm{t})(\mathrm{M(t)} + \frac{\mathrm{RM}}{\mathrm{N}}) \\ \frac{dE}{dt} = \alpha\lambda S(\mathrm{t})\left(\mathrm{M(t)} + \frac{\mathrm{RM}}{\mathrm{N}}\right) - \frac{\beta}{\theta_{EI}}\mathrm{E(t)} \\ \frac{dI}{dt} = \frac{\beta}{\theta_{EI}}\mathrm{E(t)} - \gamma_R\theta_{IR}\mathrm{I(t)} - \frac{\gamma_M}{\theta_{IM}}\mathrm{I(t)} \\ \frac{dM}{dt} = \frac{\gamma_M}{\theta_{IM}}\mathrm{I(t)} - \mu\theta_{MR}\mathrm{M(t)} \\ \frac{dR}{dt} = \gamma_R\theta_{IR}\mathrm{I(t)} + \mu\theta_{MR}\mathrm{M(t)} \end{cases} \tag{16}$$

Note: the initial values of the susceptible and the mongering are $S_0 = N$ and $I_0 = 0$ respectively, SEIMRB model is following,

$$\begin{cases} \frac{dS}{dt} = -\alpha\lambda S(\mathrm{t})(\mathrm{M(t)} + \frac{\mathrm{RM}}{\mathrm{N}}), S(0) = N \\ \frac{dE}{dt} = \alpha\lambda S(\mathrm{t})\left(\mathrm{M(t)} + \frac{\mathrm{RM}}{\mathrm{N}}\right) - \frac{\beta}{\theta_{EI}}\mathrm{E(t)}, E(0) = 0 \\ \frac{dI}{dt} = \frac{\beta}{\theta_{EI}}\mathrm{E(t)} - \gamma_R\theta_{IR}\mathrm{I(t)} - \frac{\gamma_M}{\theta_{IM}}\mathrm{I(t)}, I(0) = 0 \\ \frac{dM}{dt} = \frac{\gamma_M}{\theta_{IM}}\mathrm{I(t)} - \mu\theta_{MR}\mathrm{M(t)}, M(0) = 0 \\ \frac{dR}{dt} = \gamma_R\theta_{IR}\mathrm{I(t)} + \mu\theta_{MR}\mathrm{M(t)}, R(0) = 0 \end{cases} \tag{17}$$

And, $\mathrm{S(0)} + \mathrm{E(0)} + \mathrm{I(0)} + M(0) + R(0) = 1$.

Note: the period of propagation is the total number divided by the number of people who have been transmitted per day, the daily migration rate isμ, $\frac{1}{\mu}$ is the average spread period of the rumor message.

Note: $б = \frac{\lambda}{\mu}$, is the effective contact number of each rumor spreader during a transmission period, which is called the contact number. Then $\frac{1}{б} = \frac{\mu}{\lambda}$, which is called the relative transmission rate.

IMPLEMENTATION BASED ON ANYLOGIC SOFTWARE MODEL

In the paper, the model is named SEIMRB model, and the model time is set to the day. The SEIMRB model contains the Internet user, the rumor maker, the rumor breaker three agent group, which is named as USER, RM, RB respectively, the animation effect is none, the agent body is initially empty. Specify the values of initial parameters such as, λRM, λUSER, α, β, γ_M, μ, θ_{EI}, θ_{IM}, θ_{IR} in the Main agent.

Design of Agent

Social network user

In the user agent, a state with five states of the susceptible state, the exposed state, the infectious state, the mongering state, the recovered state is created. See Figure 2. A circle is dragged from the user agent dashboard to the center of the agent, its radius is 5, and its color is pink. The circle represents the individual of the agent. A variable is dragged from dashboard to the agent, named rbworksVAR, which represents the effect of the rumor breaking.

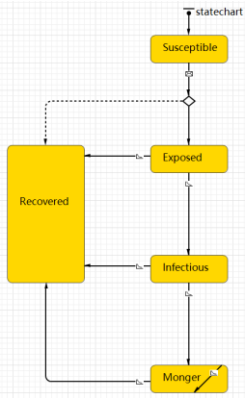

Figure 2. User intelligence status diagram

In the user agent group, the transit from the susceptible state to exposed state is message transit, where a branch structure is following, one susceptible user will change to the exposed state at rate of α when it receives s rumor message, at (1-α) probability to the recovered state. The transit trigger condition of the rest transit between any states possible is set to the rate. There is a self-transit in the state of the mongering state, which action attribute is set to release the rumor message.

The transit rate is set to different values based on the variable rbworksvar, for example, the transit rate from the exposed state to the infectious state has two potential values based on rbworksVAR: pow (main.βI, main.θEI) and main.βI which is set in the model rate attribute with equation of rbworksVAR: pow(main.βI, main.θEI):main.βI.

Rumor maker agent

A function of send_rumorFUN in the rumor maker agent is created, which simulates the rumor maker spreading rumor message in the initial state of online rumor spreading. The function is triggered by the event of send_rumorEVT, which trigger type is set to "Timeout", and mode is "Occurs once".

Rumor breaker agent

In the SEIMRB model, each rumor breaker just influence the Internet users with certain distance. Transit rate corresponding the Internet user who is covered by rumor breaker will be changed by rbworksVAR. SEIMRB model defines a function rumor_breakFUN to find the Internet users within the distance, the function is triggered by an event rumor_breakEVT on the fifth day.

Main agent

In the main agent, an initialization function, ini_mainFUN, is defined to generate the specified number of Internet users, rumor makers, and rumor breakers, which is triggered by an initialization event, iniEVT.

In order to show the subsequent data changes, the statistical attribute of the uSERs object in the main agent is set to count the number of Internet users in different states. For example, a statistics object in the statistics attribute of the uSERs object could be added to count the number of Internet users, which type is set to "Count", "Condition" attribute is set to item. statechart. isStateActive (USER. Susceptible).

Presentation

Internet users and rumor breaker are shown in main agent in the model. The space type is set to continuous, the layout type is set to random, the network type is set to small world network. The "width" and "Height" in Space and network are set to 1060 and 760 pixels respectively.

A time plot is added to presentation area, statistics information are add in the time plot. And "Data update" attribute in time window is set as "update data automatically". The total number of people in the model is set as the total number of specific monitoring objects in a city, and its value is 2000. Refer to the research results of relevant scholars[15-17], λ_{RM} and λ_{USER} are set to 6.α=0.3, β=0.14, γ_M=0.071, μ=0.5, θ_{EI}=2, θ_{IM}=2, θ_{IR} = 0.5, θ_{MR} = 0.5.The execution result is shown in Figure 3.

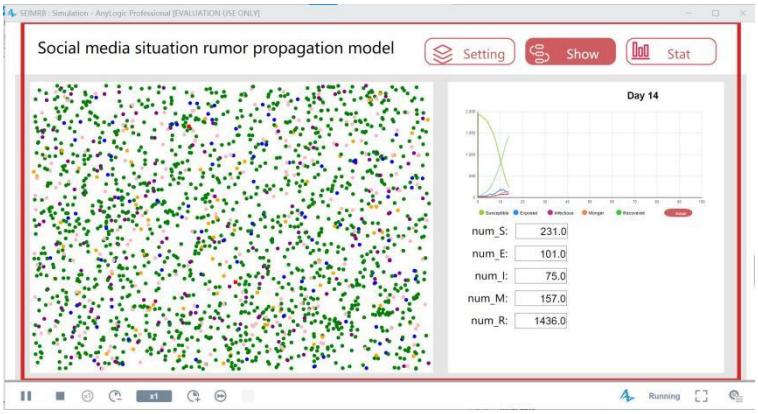

Figure 3. Model execution process example

ANALYSE

As an unproven information, the rumor message would cause some degree of disruption to society when it is propagated on social media platform over and over again, which are shown in several aspects.

(1) It affects the ecological balance of public opinion and causes group anxiety. Rumor message in the Internet environment will disturb the ecological balance of public opinion in the way of viral spread. With the rapid development of information in China, the tentacles of rumor will extend to every information transmission hub. When rumor message is mixed in the normal information interaction, the balance of public opinion will be broken, and more and more deviant remarks will stimulate the public psychology and cause group anxiety.

(2) Destroying the social trust system and intensify social conflicts. At the beginning, rumor is often generated because the public is eager to know about the information asymmetry, but the official does not respond to it, and gossip is spread everywhere, which increases the public's distrust of the society, especially in the face of public crisis events, and easily stimulates social contradictions.

(3) Disturbing the normal social order and cause social panic. In the face of rumors of different articles, the public can't judge and choose information only by personal subjective emotions, so that the public is easily caught by rumor message of a bad talk, and most of the rumor messages contain the content of social unrest and panic, and if the public is left by these bad words, the normal social order will be disturbed.

It is essential to eliminate the uncertainty of information. But the reality is that "rumors precede the fact". Therefore, effective containment of the negative impact of rumors requires the joint efforts of all parties.

First of all, from the government view, it is necessary to further improve the information release mechanism, use computer technology to collect, classify and analyze massive information, quickly focus on keywords, predict and prevent the potential spread of rumors, and establish a network prevention and control system for rumors. The government should also play a leading role in the prevention and control system, coordinate various departments, and communicate with each other in all aspects from monitoring, collection, sorting to analysis and prevention and control, so as to form a smooth channel for rapid feedback and support.

In addition, the government must realize that although rumors themselves are untrue, they are also the expression of the real feelings of the public. In refuting rumors, the government should cautiously use warning and suppression to avoid standing on the opposite side of the public. Especially in the face of sudden crisis, it should pay attention to strengthen the psychological counseling of the public.

Secondly, the media, especially social media, should establish a sense of social responsibility and consciously play the role of information "gatekeeper". On the one hand, objective and true information should be provided to the public quickly to create a healthy information dissemination environment. On the other hand, we should actively promote the mainstream social values, guide the public with correct public opinion, and correct the audiovisual.

Finally, from the public view, the public in the information age may be both the receiver of rumors and the spreader of rumors. "Audience" has become a key link to determine whether rumors can have bad effects. If the audience can improve their media literacy, their ability to recognize and use media, and their ability to distinguish media information, then the rumor "stops at the wise" will eventually come true. In addition to mobilizing the public's own subjective initiative, education and publicity in the objective environment are also very necessary to cultivate the public's rational and critical attitude in the face of rumors.

CONCLUSION

The work analyzes the mechanism of rumor information transmission in the context of social media through differential equation model, reveals the changes in the number of netizens in different states in the process of rumor information transmission, and better simulates the situation of rumor information transmission. Since we cannot solve the exact analytical solution of the differential equation, the simulation model of rumor propagation is constructed by Anylogic software. Visualization is used to show the whole process of rumor information transmission life cycle, and it can be used to simulate the rumor information spreading process under different social media situations by setting different transition parameters. Our work could be used to provide quantitative decision-making reference information for specific social network platform supervision activities.

The shortcomings of this work are mainly reflected in the fact that the parameters in the Anylogic simulation model are the simulated data constructed by the project research team according to the epidemic transmission data, which usage is limited. This study also did not carry out sensitivity analysis and other studies on rumor information propagation mechanism with different parameter combinations. It fails to fully analyze the difference of rumor information transmission process under different parameter combinations.

In the future, Parameter Variation and Sensitivity Analysis experiments of Anylogic software will be used to further verify the impact of different parameters on rumor propagation. On the other hand, the values of relevant important parameters in real scenarios are calculated based on real data, analyze the rule of rumor propagation under this parameter, and provide decision-making reference for social media network rumor management.

ACKNOWLEDGEMENT

This work was supported in part by the Philosophy and Social Science planning project of Anhui Province Under Grant No. AHSKF2021D31.

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