Fuzzy Systems and Data Mining IX
A.J. Tallón-Ballesteros and R. Beltrán-Barba (Eds.)

doi:10.3233/FAIA231070

Improvement of User Information Behavior in Online Medical Community Based on Reputation Incentive Game

Jianying Xiong[a,1] and Weilong Hu[b]
[a] *College of Computer Science, Jiangxi University of Chinese Medicine, China*
[b] *Hanlin Hangyu (Tianjin) Industrial Co.,Ltd, Tian Jin, China*

Abstract. Online medical communities can alleviate the imbalance of medical resources. However, the quality of information in the community varies and even contains false information. Online reputation can regulate user behavior and maintain online medical order. The research proposes a reputation reward and punishment model based on user behavior, which is used to guide users to regulate information behavior and improve the quality of medical information. The model rewards and punishes reputation according to the information release, forwarding, self-correction of information behavior and blocking of bad information. It also conducts game analysis on the interaction behavior of nodes in the community towards different quality medical information. By establishing a reputation incentive cooperation mechanism between nodes, information interaction between malicious nodes can be reduced. The experimental results show that the method can establish an incentive cooperation mechanism between nodes, and inhibit the dissemination of low-quality information.

Keywords. Online medical community, Trust, Reputation game, Reputation incentives, User behavior

1. Introduction

With the rapid development of mobile online communities and public health, online medical communities have emerged. Compared to traditional information services, the generation and dissemination of content in online communities are more complex. Medical information is different from other information. If users adopt it without discrimination, it not only threatens the network ecological environment, but also easily misleads users and affects their lives and health. As a result, many online medical websites have established reputation feedback mechanisms to reduce moral hazard issues caused by information asymmetry. For example, Chunyu Doctor and Good Doctor use patient feedback to calculate doctors' scores as service recommendation indicators. There are also some patient social networks that provide feedback on the information shared, such as MyHealthTeams, which is a chronic disease social networking website, and PatientsLikeMe, which is a patient diagnosis and treatment sharing platform.

Every node in the community is a key link in information dissemination, which can be the publisher, supervisor and blocker of content. From the perspective of network

[1] Corresponding Author, Jianying Xiong, Jiangxi UCM, China; E-mail: special8212@sohu.com

node autonomy, we can control the source of security problems and build a good network community ecology. The reputation of nodes in the open community is important network interpersonal relationships [1]. After evaluating the initial reputation, a reward and punishment mechanism is set up based on the node's information behavior to dynamically adjust the reputation. It can create constraints on the behavior of nodes and achieve better self-discipline [2]. In the process of information interaction, nodes need to consider the losses and benefits of themselves and others, so that the whole interaction process can become a game process. Therefore, game theory can be used to handle cooperation process of nodes in medical communities. The incentive strategy will guide nodes to make positive information behavior through the game, inhibit the spread of low-quality, bad and untrue information, and realize the autonomous mechanism of group prevention and control in medical communities [3].

Reputation is a method of establishing trust for strangers in online communities, and research on social network trust has a good foundation. The measurement of trust in online communities is currently mainly divided into global trust and local trust [4]. Global trust is also known as social reputation, and it can be seen as a cumulative social asset. There are many researches on different types of trust evaluation. For example, nodes obtain the global trust through the iteration of mutual satisfaction between adjacent nodes [5]. Some researchers show that the characteristics of users, information and media will affect the information dissemination, the propagation prediction of the trust of the integrated users is better than that of the general model [6]. In terms of improving the user participation of mobile group governance perception network, some researchers show that reputation can stimulate user participation. Reputation not only improves the efficiency of network task processing, but also reduces the processing cost [7]. Some researchers proposed to calculate user attitude through interaction experience, and evaluate the change law of interaction behavior pattern according to interaction time series, forming a comprehensive trust evaluation model for social network users [8]. A punishment mechanism is used to enhance the cooperative behavior of nodes in wireless ad hoc networks [9]. A trust driven model for network architecture software is proposed [10], which enables trust management and online evolution of trust relationship to be realized. Based on the law of trust, it aims to accumulate feedback of different information interactions to calculate the reputation of users, and then dynamically adjust the reputation of users through reputation rewards and punishments for different information behaviors. By simulating reputation gains games in different situations, the model can guide nodes to make reasonable interactions.

2. Construction of Reputation Incentive Model

2.1. Working principle of reputation model

Each user can obtain initial reputation by authentication and personal information in online communities, such as patient communication website. In such a patient social network, each user is also a node. In order to focus on studying the impact of dynamic behavior on reputation, we do not consider the reputation brought by node identity here, but use social reputation (SR) to constrain the information behavior of nodes.

SR is a comprehensive evaluation of historical information behavior. The different feedback on information can affect their evaluation of *SR*. The posting and forwarding behaviors are all medical communities' interactions. The forwarding, liking and stepping

on behaviors given by other nodes are attitude feedback given after receiving information [11]. Three different types of behaviors are quantified as {1,0.5,-1}. The reputation value of the interaction node affects the validity of the score, and the interaction given by the node with high reputation is more valuable to enhance the reputation of the node. SR_j is the node reputation value of the j node's feedback, and fs_j is the quantitative score for the feedback of the j node. Therefore, the interaction degree of node i is weighted and accumulated by the reputation of medical communities. SR_i is calculated as formula (1), where j is the node with the interaction with i node, but except i node itself.

$$SR_i = \sum_{j=1}^{n}\left(\frac{SR_j}{\sum_{j=1}^{n} SR_j} * fs_j\right) \tag{1}$$

Reputation reward and punishment mechanism is used to motivate the information behavior of nodes, guide the nodes to adjust information behavior, and also is a positive expectation of node behavior. The information behavior of nodes will also be limited by reputation. As the figure 1, the system will set up the reputation-based user behavior permission mechanism RC, which can be divided into different levels G, and it can map different behavior permissions C, namely RC: G → C.

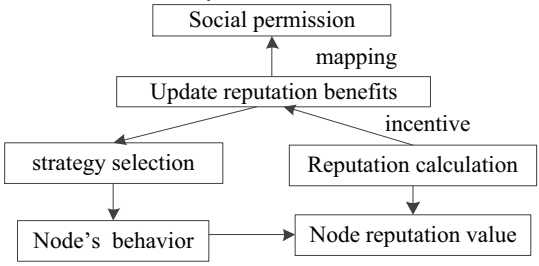

Figure 1. Game process based on reputation incentive

2.2. Reputation reward and punishment

The nodes with high reputation in medical communities will consciously maintain network stability and control negative information transmission in case of crisis, and actively maintain medical communities' security. If the initiative information strategy is guided by reputation reward and punishment, it can promote node autonomy more effectively. There are three dimensions in the mechanism, including content quality, information self-correction, and bad information transmission blocking. The reward and punishment coefficient can also be adjusted according to the platform experience.

The system rewards more punishment scenarios than rewards. Once bad behavior occurs, the reputation will decline faster, and the nodes will be more cautious about their information behavior. The reputation updating mechanism punishes and supervises the reputation behavior by time series, and adjusts the reputation value dynamically. In the process of adjustment, the higher reputation of users, the greater influence of each behavior in the medical communities. The reputation rewards and punishments are proportional to the reputation of nodes. Therefore, after increasing the reward and punishment coefficient, the calculation method of SR_i is shown in expression (2).

$$SR_i = SR_i * (1 + r) \tag{2}$$

2.3. Reputation game evolution of cooperation restrained by bad information

When using game theory to analyze medical communities' communication, the entities in the network are regarded as game participants with bounded rationality. The strategy

of the players is the action taken by the entity nodes. According to this idea, the basic formula of single-stage cooperative game of entity nodes in medical communities is given as follow.

In each game stage, the reputation game between entities can be defined as triple D = (G, S, U). G is the set of entity nodes in the system, and is also the player of the game: $G_i = \{i, N_{-i}\}$. Where N_{-i} is the player of the game except entity node i. S is the strategy set of entity nodes participating in the game, $S = \{S_i, S_{-i}\}$. U is the income function of the player.

The revenue function U is the mapping from the policy set $S = \{S_i, S_{-i}\}$ to the reputation revenue R, that is, u: S → R. It is assumed that the benefits of nodes in medical communities are mainly personal reputation and additional benefits related to content promotion.

The game process of entity node cooperation can be described as follows: in the process of cooperation, entity node can be either the initiator of cooperation or the responder of cooperation. In the medical community's environment, the initiator's strategy is {Cooperation (publishing high-quality information), non-cooperation (Publishing bad information)}; The strategy of responders is {Cooperation (forwarding information) and non-cooperation (reporting information)}. It is supposed that there are no incentives in the medical community's environment, the dissemination income of the initiator's high-quality information and bad information is $\{p_1, p_2\}$; and the responder's high-quality information and bad information is $\{0, p_3\}$, such as water army behavior; There is no obvious punishment and incentive for the reported information in medical communities, and the income is 0. If there is no reputation punishment mechanism, the profit matrix of the game can be expressed as table 1.

Table 1. game income matrix under no credit incentive

	Initiator		
Responder		High quality information	Bad information
	Forward	$(0,p_1)$	(p_3,p_2)
	Accuse	(0,0)	(0,0)

It is assumed that all the entities participating in the interaction are rational and selfish. Without reputation punishment mechanism, as long as the $\{p_2, p_2\}$ revenue combination value is large enough, the initiator and responder are more likely to obtain benefits from the dissemination of bad information, so both parties will choose the one with greater benefits to publish and forward bad information. According to the reputation reward and punishment mechanism, for the initiator, the reputation incentive income of publishing information income is set to q, then the reputation income of publishing high-quality information and bad information is $\{q_1, -q_2\}$; The reported reputation gain is $\{0, -q_2\}$. For responders, the reputation gain of forwarding high-quality information and bad information is $\{0, -q_3\}$; The reputation gain of reporting behavior is $\{-q_4, q_5\}$. Therefore, after integrating reputation penalty, the income is the combination of reputation and propagation income, and income matrix as table 2.

If the initiator publishes the bad information and the responder forwards it under the condition of reputation rewards and punishments, their respective profits are $(-q_3 + p_3, -q_2 + p_2)$. If bad information is accused, the respective benefits are $(q_5, -q_2)$. As long as $U(q_5) > U(-q_3 + p_3)$, responders will choose to accuse the information. When the originator publishes high-quality information, the responder will not choose malicious report for the revenue relationship $U(-q_4) < U(0)$, so it is easier to choose forwarding. Therefore,

as long as the reward and punishment coefficient are set reasonably, the initiator and responder in medical communities will make the following strategies:

(1) Responders will choose to accuse bad information to gain reputation.

(2) Responders will not lose personal reputation to accuse high-quality information maliciously.

(3) The initiator is not willing to lose his reputation and publish bad information when there is no significant communication benefit.

(4) Sponsors are willing to publish high-quality information to gain Reputation.

Table 2. game income matrix under reputation reward and punishment incentive

	Initiator		
Responder		High quality information	Bad information
	Forward	$(0,q_1+p_1)$	$(-q_3+p_3,-q_2+p_2)$
	Accuse	$(-q_4,0)$	$(q_5,-q_2)$

3. Experiment

3.1. Simulation environment description

Because we hope to focus on observing the impact of behavior on reputation, we do not consider initial trust in the experiment and assume that there are already certain connections and interactions. In the experiment, a medical community with 4000 nodes is simulated, and the reputation value of each node is initialized to 0. Each node is randomly connected to 20% nodes in the community. Assuming that 50% of the connected nodes report the information, the information will be considered as bad information, the information will be verified and tagged, and the person who posts or posts will be punished for reputation, and the informant will be rewarded for reputation.

In order to verify the impact of reputation on the transmission process, SIR model of infectious disease model is used to simulate the process of information transmission [12]. There are three states of user groups in SIR model: uninfected state S(susceptible), infected state I (infected) and immune state R (recovered), which correspond to users who do not receive information, users who transmit information and users who are not interested in information. In traditional SIR model, we add connection state C (connected), which indicates that it is connected with the spreading node of infection. The dynamic process of SIR propagation is improved as shown in (3).

$$\begin{cases} \frac{dC(t)}{dt} = \gamma C(t) \\ \frac{dS(t)}{dt} = -\lambda S(t)I(t) \\ \frac{dI(t)}{dt} = \lambda S(t)I(t) - \mu I(t) \\ \frac{dR(t)}{dt} = \mu I(t) \end{cases} \tag{3}$$

According to the SIR model, iff the number of infected nodes is NI_t and the number of iterations is t, the cumulative total number of infected nodes NI is shown in (4).

$$NI = \sum_{t=1}^{T} NI_t \tag{4}$$

The experimental rules are as follows:

(1) In each time step, the receiving point is the node connected by all infection points.

(2) The infected nodes are infected by probability λ to infect the integrity and connected nodes in the susceptible state, the malicious nodes will be infected directly; After the infection, the node forwards the information for the next iteration.

(3) The susceptible integrity node will accuse bad information with probability p. After the infection, the integrity node will lose interest in spreading with probability μ, and become an immune node, then accuse bad information;

(4) The contact between immune node and infected node will not produce transmission behavior.

(5) When all nodes in the whole network receive bad information or the information is successful be accused, the propagation ends.

In the whole propagation process, the total number of participants n remains unchanged, so S(t) + R (t) + I (t) = n. In SIR model, λ is the probability of infection, μ is immune probability. However, in the model of add the connect nodes, γ Is the connectivity probability.

3.2. Comparison of communication effects under different models

In the simulation experiment, the relevant parameters need to be set after many times of debugging. After 100 times of debugging, the simulation parameters are set as: infection rate λ= 1, recovery rate μ = 5, t = 10 iterations. Under the scenario of any single propagation source, 10% malicious nodes in the community spread bad information. The experimental results in Fig. 2 and Fig. 3 show the number variation curves of four types nodes with time t in NER (No Encourage Reputation) model and ER (Encourage Reputation), including the total number of connected nodes (C), susceptible nodes(S), infected nodes (I) and recovered nodes (R).

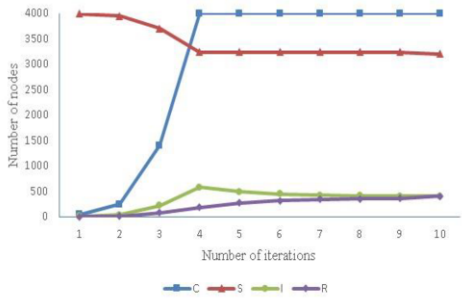

Figure 2. Number of different nodes in of NER

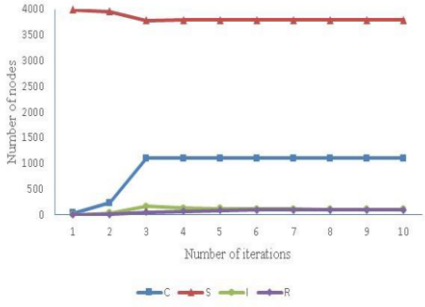

Figure 3. Number of different nodes in ER

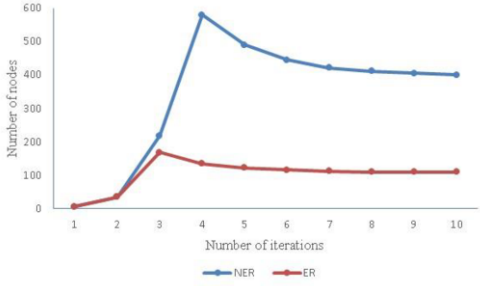

Figure 4. Number of infected nodes in different model

The experimental results show that, compared with the case of no reputation reward and punishment game, the number of nodes receiving bad information in ER model will

be less than that in traditional NER model, and will soon tend to balance. The main reason is that more nodes will accuse bad information after the reputation game in the fast iterative propagation, which blocks the information propagation. And it also prevents other nodes from receiving information in the later propagation network. Under different models, the number of susceptible nodes in ER model will only be infected at the initial stage. With the blocking and disclosure of bad information, the number of infected nodes and recovery nodes will be lower.

Figure 4 is the comparison results of all infected nodes in the community. In NER model, there will be a rapid propagation peak, causing more node infection. In ER model, there will be more blocking behavior of nodes in the community at the propagation peak, resulting in a rapid decline of infected nodes.

4. Summary

Reasonable reputation mechanism in online medical communities can regulate node information behavior. And experiments have shown that the ER model can effectively promote the formation of relationships between nodes, and suppress the dissemination of low-quality information. The study analyzes reputation rewards and punishments from a dynamic game perspective, which helps enrich the research on knowledge sharing and dissemination mechanisms and network trustworthiness. The next step in the research will be to study more intelligent agents and their behavior rules, and analyze the dynamic evolution process of reputation in multiple stages.

References

[1] Popescul, D. , & Georgescu, M. . Social networks security in universities: challenges and solutions. Annals of the Alexandru Ioan Cuza University - Economics, 2015,62(s1):53-63.

[2] Jazaieri H , Logli Allison M , Campos B , et al. Content, structure, and dynamics of personal reputation: The role of trust and status potential within social networks. Group Processes & Intergroup Relations, 2019.22(7):964-983

[3] Jaramillo, Juan Jose , and R. Srikant . "A game theory based reputation mechanism to incentivize cooperation in wireless ad hoc networks." *Ad Hoc Networks*8.4(2010):416-429.

[4] Urena R, Chiclana F, Carrasco R A, et al. Leveraging Users' Trust and Reputation in Social Networks. Procedia Computer Science, 2019: 162, (12):955-962.

[5] Raj, E. D. , & Babu, L. D. D. An enhanced trust prediction strategy for online social networks using probabilistic reputation features. Neurocomputing, 2016, 219(1) :412-421.

[6] Yu, Y. , Jia, Z. , Tao, W. , Xue, B. , & Lee, C. An efficient trust evaluation scheme for node behavior detection in the internet of things. Wireless Personal Communications An International Journal, 2017, 93(2) :571-587.

[7] Srinivasan, A. , & Naseera, S. Trust and location based service in mobile social networks – a survey. Multiagent and Grid Systems,2018,14(3):263-282.

[8] Liu Y.H, Jin X.L, &Shen H.W. Towards early identification of online rumors based on long short-term memory networks. Information Processing & Management, 2019, 56(4):1457-1467.

[9] Kareva, I. , Morin, B. , & Karev, G. Preventing the tragedy of the commons through punishment of over-consumers and encouragement of under-consumers. Bull Math Biol, 2013, 75(4):565-588.

[10] Mughal, B. K. , S. Hameed , and G. M. Shaikh . "A Centralized Reputation Management Scheme for Isolating Malicious Controller(s) in Distributed Software-Defined Networks." International Journal of Advanced Computer science and Applications 7.12(2017):368.

[11] Shen, Y. , et al. "Dynamic socialized Gaussian process models for human behavior prediction in a health social network." *Knowledge and Information Systems*49.2(2016):455-479.

[12] Siqing, S. , Mengni, L. , & Xiaobo, X. Analysis of the key influencing factors of haze information dissemination behavior and motivation in wechat. *Interlending & document supply,* 2017, *45*(1):21-29.