Research on COVID-19 Prevention and Control Model Based on Evolutionary Games

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ABSTRACT

In view of epidemic prevention costs and social benefits, an evolutionary game model of epidemic prevention and control strategies between government departments and local people was constructed based on evolutionary game theory to explore the influence of strategic behaviors between government departments and local people, and MATLAB was used to conduct systematic simulation of the game model. Studies have shown that local people will cooperate with government departments when they implement surveillance strategies. Reducing the cost of emergency epidemic prevention and improving the social benefits of epidemic prevention are conducive to the development of government departments towards the direction of supervision strategy, and local people towards the direction of active epidemic prevention strategy, so as to achieve effective epidemic prevention and control.

KEYWORDS
COVID-19, Evolutionary Game, Prevention and Control Model, System Simulation

INTRODUCTION

A public health emergency is an outbreak of a major infectious disease, a group disease of an unknown cause, a major food or occupation or any other event that seriously affects public health that causes (or may cause) serious damage to public health. The Corona Virus Disease 2019 outbreak at the end of 2019 is a major public health emergency. The virus is characterized by strong transmission capacity, wide range and high case fatality rate. It is an unprecedented challenge for all countries in the world and has brought certain impacts on the economy and development of all countries (Alankar et al., 2021). If the government and local people do not take timely measures to control the epidemic, it will cause very serious consequences to people’s health and the national economy. Therefore, the epidemic prevention measures of government departments and the active cooperation attitude of local people are of great significance to control the epidemic from the perspective of public health and safety as well as the stable development of the national economy.

Since the outbreak of novel Coronavirus, a number of researchers have studied the epidemic from clinical characteristics and bioinformatics. Abdel-Basset et al. (2020) presented a new hybrid approach...
based on threshold technology to overcome ISPs for COVID-19 chest X-ray images. Abdel-Basset et al. (2021) proposed an innovative semi-supervised less-shot segmentation (FSS) approach for effective segmentation of 2019-NCOV infections (FSS-2019-NCOV) from a small number of annotated lung CT scans. Dhiman et al. (2021) proposed a Novel Coronavirus infection patient X-ray recognition technology based on multi-objective optimization and deep learning for real-time classification of COVID-19 disease on X-ray chest images. Huang et al. (2020) investigated the reduction of lymphocyte subsets count in COVID-19 patients, and found that these studies met the reporting criteria for lymphocyte subsets count and disease severity of COVID-19. Yuen et al. (2020) highlighted nine of the most important research questions related to virus transmission, asymptomatic and presymptomatic virus shedding, diagnosis, treatment, vaccine development, virus origin, and virus pathogenesis. Zhang et al. (2020) used chemiluminescence analysis (CLIA) to detect IgG and IgM antibodies in COVID-19 patients, and found that severity of COVID-19 was associated with increased IgG response. Song et al. (2020) demonstrated that the characteristics of virological, epidemiological, clinical and managerial outcomes in patients with COVID-19 have been rapidly defined, but inflammatory and immune characteristics also need to be defined as they influence the pathogenesis and clinical expression of COVID-19. Noureddine et al. (2021) proposed that hydroxychloroquine derivatives showed significant efficacy against coronavirus-associated pneumonia. Gao et al. (2020) also pointed out that the chloroquine phosphate used in the multi-center clinical trial conducted in China was an old malaria drug with obvious efficacy and acceptable safety against COVID-19. The above research is mainly aimed at the biological science and medical research of COVID-19 virus, but the complex and changeable virus also needs to be studied at the technical level.

With the COVID-19 outbreak, research found that ML (Alimadadi et al., 2020) and AI (Vaishya et al., 2020) can integrate and analyze large-scale data on COVID-19 patients to better understand virus transmission patterns. So some scholars studied COVID-19 from the technical aspects of electronic learning, artificial intelligence and big data (Chang et al., 2021; Cho et al., 2021; Mehla et al., 2021). Singh et al. (2021) proposed to use computing infrastructure provided by cloud computing and fog computing to control pandemics such as COVID-19. Tai et al. (2021) initiated new research on XR and deep learning integration for IoMT implementation. Abdel-Basset et al. (2021) provided oversight for governments on how to adopt technology to reduce the impact of COVID-19 from an unprecedented implementation. Lalmuanawma et al. (2020) reviewed the important role of AI and ML in the screening, prediction, prediction, contact tracing and drug development of SARS-COV-2 and related outbreaks. Van et al. (2021) showed how the latest developments in ML and AI can address the five most important challenges of COVID-19. These studies provide references for the analysis of THE COVID-19 epidemic. However, it is not enough to study the COVID-19 epidemic from these technical aspects alone. It is also necessary to combine mathematical models to conduct quantitative research on the virus.

Mathematical models (Adiga et al., 2020) have played an important role in the ongoing epidemic, and they have been used not only to inform public policy, but also to develop social distancing measures worldwide. For example, SIR model (Cooper et al., 2020; Calafiore et al., 2020), SIRD Model (Fernández-Villaverde et al., 2020; Chatterjee et al., 2021), SEIR model (Li et al., 2021), LSTM networks model (Chimmula et al., 2020), transmission dynamics (Samui et al., 2020; Ndaïrou et al., 2020), stochastic mathematical model (Chatterjee et al., 2020), interpretable mortality prediction model (Yan et al., 2020) were widely used in epidemic research. Mandal et al. (2020) studied the complete dynamic behavior of the model based on the basic regeneration number. They also performed sensitivity analyses of basic reproductive numbers to identify the most critical factors for disease control and determine optimal control. In order to study the impact of social distancing measures. Sardar et al. (2020) considered a new COVID-19 mathematical model combined with the locking effect. Although various mathematical models have been extensively used in the study of COVID-19, it was found that there were few studies on the political economy of government departments using mathematical models, and even fewer studies using game theory during the epidemic.
The game theory model can be used to better discuss the relationship between the epidemic prevention measures of government departments and the positive attitude of local people, so as to put forward effective epidemic prevention measures, prevent the outbreak of large-scale epidemic, stable social and economic development. However, if the general game theory is used, it often leads to the disconnection between theory and reality, and the underlying causes of many social phenomena are difficult to explain effectively. For the COVID-19 outbreak in 2019, due to the large number of interests involved, there is no completely rational person, so evolutionary game should be adopted for relevant analysis. Evolutionary game theory is built on the basis of imperfect rational human beings. Through continuous imitation, trial and error and learning, the original strategy is constantly adjusted and optimized, so as to find a stable strategy and make a more scientific explanation of related phenomena. Therefore, based on the evolutionary game theory of the hypothesis of finite theory, this paper adopts qualitative and quantitative comprehensive methods to build a game model between the government department strategy and the local people strategy, to explore the influence of the local people’s different decision-making behavior by the government department’s decision-making behavior.

MODEL CONSTRUCTION

Model Overview and Model Assumptions

As our country confronts the sudden outbreak of COVID-19. On the one hand, there is no doubt that the supervision measures taken by the government during the epidemic period have posed great challenges, due to the tight time, arduous task and a heavy workload of epidemic prevention and control, as well as the high level of social concern. On the other hand, local people in order to actively cooperate with the work of government departments also put forward higher requirements for local people’s emergency management ability. This paper uses evolutionary game theory to discuss the evolutionary game between government department strategy and local mass strategy during the epidemic. Suppose the model has two subjects, one is the government department, the other is the local masses.

Hypothesis 1: In the early days before the COVID-19 outbreak, government departments and local people knew little about COVID-19 and did not pay enough attention to epidemic. Suppose, when government departments adopt no supervision strategy and local people adopt passive epidemic prevention strategy, the utility profit and loss value of both sides of the game is 0.

Hypothesis 2: In the early stage of the outbreak, government departments generally have higher emergency management ability than local people due to Chinese political, economic, and cultural factors and previous experience in fighting against the epidemic, so that they give priority to epidemic control measures. When government departments supervise local people (cost: C1), the social benefits that can be obtained by delaying the large-scale outbreak of the epidemic are W. Local people know little about the epidemic and make passive epidemic prevention strategies, which will cause cost C3, and then cause their own loss (the loss is F), C1>C3.

Hypothesis 3: In the outbreak stage, government departments and local people realize the seriousness of the epidemic and cooperate to effectively control the outbreak. When the government departments implement supervision strategies, local people will cooperate with government departments to adopt active epidemic prevention strategies, resulting in C2 cost. Under the supervision of government departments, it can not only bring social benefits to the government (the social benefits are I), but also obtain its own benefits (the own benefits are H).

Hypothesis 4: If government departments relax their supervision over local people, it will be difficult to effectively control the epidemic, thus causing losses to the government departments themselves: V.

Hypothesis 5: The Probability of government departments choosing “supervision” strategy is p(0≤p≤1), and the probability of “no supervision” strategy is 1-p. The probability of local people choosing the “active epidemic prevention” strategy is q(0≤q≤1) and the probability of “passive epidemic
prevention” strategy is 1-q. Assuming $C_3 < C_2$, $(-C_2 + H) > (-C_3 - F)$, that is, $H + C_3 + F > C_2$, otherwise local people will not take active epidemic prevention strategies.

From above, table 1 can be obtained

**MODEL BUILDING**

According to the above hypothesis analysis and game matrix, the Nash equilibrium strategy of the above model is discussed in combination with the asymptotic stability analysis of evolutionary equilibrium strategy, and the replication dynamic equation, so as to analyze the evolution process of both sides of the two games.

This is a 2×2 asymmetric game, in which player 1 is the government and player 2 is the local masses. The expected benefit of player 1 adopting the “supervision” strategy is $U_{1e}$, and the expected benefit of the “no supervision” strategy is $U_{1d}$, and the average expected benefit is $U_1$:

$$U_{1e} = q(W - C_1 + I) + (1 - q)(W - C_1) = qI + W - C_1$$

$$U_{1d} = q(-V) + (1 - q)0 = -qV$$

$$U_1 = pU_{1e} + (1 - p)U_{1d} = pq(I + V) + p(W - C_1) - qV$$

The expected benefit of the “active epidemic prevention” strategy of Player 2 is $U_{2e}$, and the expected benefit of the “passive epidemic prevention” strategy is $U_{2d}$, and the average expected benefit is $U_2$:

$$U_{2e} = p(-C_2 + H) + (1 - p)(-C_2) = pH - C_2$$

$$U_{2d} = p(-C_3 - F) + (1 - P)0 = -p(C_3 + F)$$

| Local people | The government department | Active prevention (q) | Negative epidemic prevention (1-q) |
|--------------|----------------------------|-----------------------|-----------------------------------|
| Supervision (p) | W - C_1 + I, -C_2 + H | -W - C_1, -C_3 - F |
| No supervision (1-p) | -V, -C_1 | 0, 0 |
\[ U_2 = qU_{2e} + (1 - q)U_{2d} = pq(H + C_3 + F) - P(C_3 + F) - C_2q \] (6)

The dynamic replication equation is applied to the two game sides respectively. The dynamic replication equation of game side 1 is:

\[ \frac{dp}{dt} = p(U_{1e} - U_1) = p(1 - p)(qI + W - C_1 + qV) = F(p) \] (7)

The dynamic replication equation of game side 2 is:

\[ \frac{dq}{dt} = q(U_{2e} - U_2) = q(1 - q)(pH - C_2 + pC_3 + pF) = G(q) \] (8)

**EVOLUTIONARY GAME THEORY ANALYSIS**

Progressive Stability Analysis of Government Sector Strategy

1. When \( q = \frac{c_1 - w}{I + V} \), \( \frac{dp}{dt} \) is always 0, all p’s are stable;

2. If \( q = \frac{c_1 - w}{I + V} \) and \( \frac{dp}{dt} = 0 \), \( P^* = 0 \) and \( P^* = 1 \) are two stable states of P. The derivative of the replication dynamic equation chosen by the government department’s strategy to P can be obtained as follows:

\[ \frac{dF(P)}{dP} = (1 - 2p)(qI + W - C_1 + qV) \]

According to the stability theorem of the differential equation, only when \( \frac{dF(P)}{dP} < 0 \), the P value obtained is in a stable evolutionary state. Assuming that \( I + V > 0 \) and \( C_1 - W > 0 \), so \( \frac{c_1 - w}{I + V} > 0 \), the following two cases are discussed:

a. When \( \frac{c_1 - w}{I + V} > 1 \), and \( 0 \leq q \leq 1 \), \( q < \frac{c_1 - w}{I + V} \) is always valid, and \( P^* = 0 \) is an evolutionary stable strategy. It starts before the outbreak, the government’s action strategy is to adopt a “no supervision” strategy. In this case, the income of government departments implementing supervision strategies is always less than that of government departments not implementing supervision strategies. Therefore, no matter what strategies local people adopt, government departments will adopt non-supervision strategies, that is, non-implementation of supervision strategies is a pure strategy of government departments.

b. When \( 0 < \frac{c_1 - w}{I + V} < 1 \), the analysis is further divided into two situations:

When \( q > \frac{c_1 - w}{I + V} \), \( P^* = 1 \) is the evolutionary stability strategy;

When \( q < \frac{c_1 - w}{I + V} \), \( P^* = 0 \) is the evolutionary stability strategy.
At this time, the behavior of government departments will be affected by the behavior of local people. When local people tend to implement active epidemic prevention strategy, government departments tend to implement supervision strategy. While local people tend to implement passive epidemic prevention strategies, government departments tend to implement unsupervised strategies.

**Asymptotic Stability Analysis of Local Masses**

1. when \( p = \frac{C_3}{H + C_3 + F} \), \( \frac{dq}{dt} \) is always 0, all q’s are stable;

2. when \( p = \frac{C_3}{H + C_3 + F} \), let \( \frac{dq}{dt} = 0 \), \( q^* = 0, q^* = 1 \) are two stable states. The derivative of the replication dynamic equation of local mass strategy selection with respect to q can be obtained: \( \frac{dG(q)}{dq} = \frac{(1 - 2q)(PH - C_2 + PC_3 + PF)}{q(H + C_3 + F)} \). According to the stability theorem of differential equations, only when \( \frac{dG(q)}{dq} < 0 \), the q value obtained is the evolutionary stable state. The following two cases are discussed:

   a. If \( \frac{C_2}{H + C_3 + F} > 1 \), \( 0 < P < 1 \), \( P < \frac{C_2}{H + C_3 + F} \) is always constant, and \( q^* = 0 \) is the evolutionary stability strategy. At this time, local people will adopt passive epidemic prevention strategy, no matter what government departments adopt, because the benefits of active epidemic prevention are smaller than those of passive epidemic prevention.

   b. When \( 0 < \frac{C_2}{H + C_3 + F} < 1 \), the analysis is divided into two conditions:

   When \( p > \frac{C_2}{H + C_3 + F} \), \( q^* = 1 \) is the evolutionary stability strategy;

   When \( p < \frac{C_2}{H + C_3 + F} \), \( q^* = 0 \) is the evolutionary stability strategy.

At this time, the behavior of local people will be affected by the behavior of government departments. If the government departments tend to implement supervision strategy, the local people tend to implement active epidemic prevention strategy. Local governments, on the other hand, tend to adopt passive epidemic prevention strategies.

**Progressive Stability Analysis of Government Departments and Local Mass Strategies**

Dynamic replication equation (7) and (8) are used to describe the progressive stability analysis of the government department and the local mass strategy system, and the Jacobian matrix can be obtained as follows:

\[
J = \begin{bmatrix}
a_{11} & a_{12} \\
a_{21} & a_{22}
\end{bmatrix} = \begin{bmatrix}
(1 - 2p)(qI + W - C_1 + qv) & P(1 - P)(I + V) \\
q\left(1 - q\right)(H + C_3 + F) & (1 - 2q)(PH + PC_3 + PF - C_2)
\end{bmatrix}
\]

(9)

According to the equation (9), when \( p^* = 0,1, \frac{C_2}{H + C_3 + F} \), the supervision strategy adopted by
when \( q^* = 0.1 \), the active epidemic prevention strategy adopted by local people is stable;

equation:

\[
\text{det} (J) = a_{11}a_{22} - a_{12}a_{21} > 0
\]

\[
\text{tr} (J) = a_{11} + a_{22} < 0
\]

According to Equation (10), the stability of the five equilibrium points can be judged.

From Table 2, figure 1 can be obtained. As shown in figure 1, in the evolutionary game between the government departments and the local mass strategy system, there are two evolutionary stable points among five equilibrium points, namely point A (0,0) and point C (1,1). In the dynamic replication evolutionary game of this game, when the initial situation falls in region I, it converges to the point A (0,0) of evolutionarily stable strategy. Government departments did not realize the seriousness of COVID-19 in the early days before the COVID-19 outbreak. The reason why government departments adopted the strategy of no supervision is that the national emergency response measures to prevent and defuse major risks need to bear a high cost of supervision and epidemic prevention \( C_1 \). Because the cost \( C_2 \) of active epidemic prevention by local people is higher than that of passive epidemic prevention, local people will take passive epidemic prevention actions.

When the initial condition falls in region III, it converges to the evolutionary stable strategy (1,1). In the early stage of the Corona Virus Disease 2019 outbreak, the government will take immediate action...
to monitor local people. If local people cooperate with government departments to implement active epidemic prevention actions to effectively control large-scale outbreaks of the epidemic, local people will not only gain their own benefits $H$, but also bring some benefits $I$ for government departments. If local people do not cooperate with the work of government departments to adopt passive epidemic prevention, it will cause their own loss (the loss is $F$, and $(-C_2 +H) > (-C_1-F)$, so local people will not choose passive epidemic prevention strategy, but convergence to active epidemic prevention strategy.

In the figure above, B (1,0) and D (0,1) are unstable points, while E is the saddle point. When the initial situation falls in two regions II and IV, the saddle point E changes with the change of related costs and social benefits, and most possibilities converge to the evolutionarily stable strategy (0,0) or (1,1). This means that the long-term strategy adjustment will lead government departments to adopt monitoring policies, which will lead local people to adopt active epidemic prevention strategies. It starts before the outbreak, local people adopted passive epidemic prevention strategies when government departments did not supervise. However, with the development of the epidemic, both government departments and local people do not take epidemic prevention measures, and the large-scale outbreak of the epidemic will cause huge losses to the country and society. Therefore, government departments and local people still tend to cooperate with each other, that is, government departments adopt supervision strategy, while local people adopt active epidemic prevention strategy, which finally converges to evolutionary stability strategy (1,1). Hence, (1,1) is the only perfect equilibrium path. When the relevant epidemic prevention costs and social benefits are adjusted, the saddle point will change and the strategy will develop in the same direction as the expected strategy.
RESULTS AND DISCUSSION

According to the conclusions of the evolutionary game model, numerical simulation is carried out with Matlab to verify the results.

Case 1: make $C_1 = 8, W = 5, I = 3, V = 2, C_2 = 6, H = 6, F = 10, C_3 = 4$, can calculate $q_1 = 0.6, p_1 = 0.2$. Assuming $q = 0.7 > q_1$, figure 2 can be obtained, that is, $p \rightarrow 1$. In the outbreak stage, when local people take active epidemic prevention, government departments tend to adopt supervision strategy. Assuming $q = 0.4 < q_1$, figure 3 can be obtained, that is, $p \rightarrow 0$. It starts before the outbreak, when local people adopt passive epidemic prevention, government departments tend to not supervise the strategy.

Assuming $p = 0.6 > p_1$, figure 4 can be obtained: that is, $q \rightarrow 1$ indicates that local people tend to adopt active epidemic prevention strategies when government departments adopt supervision strategies at the outbreak stage. Assuming $p = 0.1 < p_1$, figure 5 can be obtained: that is, $q \rightarrow 0$, local people tend to adopt passive epidemic prevention strategy when government departments adopt no supervision strategy in the early days before the COVID-19 outbreak.

The practical meaning of this simulation process is that in the early stage of the outbreak, government departments fully realized the urgency and importance of epidemic prevention and control,
and immediately took epidemic prevention measures to supervise local people. It is also necessary to show local people their attitude and determination to strictly supervise the epidemic prevention and control, so that local people will actively cooperate with the actions of government departments and take active epidemic prevention measures to control the epidemic in a timely and effective manner. If government relaxes its supervision over local people during critical periods, it will incur higher costs for local people to take active epidemic prevention measures, which will further influence local people to take passive epidemic prevention measures.

Case 2: Assume that the cost of emergency containment is reduced and the social benefits of containment are increased. $C_1 = 6, W = 8, I = 5, V = 2, C_2 = 4, H = 8, F = 5, C_3 = 2$, when, can calculate $q_2 = -0.286, p_2 = 0.133$, it is concluded that figure 6 (a, b, c, d).

As shown in Figure 6 (a, b, c, d), when the cost of emergency epidemic prevention is reduced for government departments and local people and the social benefits of epidemic prevention are improved through mutual cooperation, the final result is that government departments adopt supervision strategy and local people adopt active epidemic prevention strategy. The practical implications of this simulation process are: in the face of the sudden COVID-19 outbreak, the cost of epidemic prevention and control directly reflects the ability of government departments to deal with major emergencies, and also reflects the level of emergency management of government departments. If government departments respond quickly and deal with major emergencies in a timely manner, they have a high level of emergency management. Government departments are bound to lead local people to improve the level of emergency management, in the face of major emergencies local people also have better handling capacity. In this way, both sides can reduce the social losses caused by COVID-19 and improve social benefits.
Therefore, in this evolutionary game model, the following conclusions can be drawn: First of all, in the early stage of the outbreak, government departments should take immediate actions to set up relevant working groups of local people in time and carry out the work of fighting the epidemic quickly. At the same time, it is necessary to supervise the work carried out by local people, and give full play to the role of government departments’ dedication and dedication to encourage local people to cooperate with the supervision of government departments in the most active manner. Secondly, as the epidemic is characterized by heavy tasks and heavy workload, government departments are required to quickly improve their ability of emergency management and drive local people to quickly improve their ability of emergency management. In this way, the efficiency of epidemic prevention and control work can be effectively improved, the cost of emergency management and supervision of government departments and local people can be reduced, and the social benefits can be maximized to promote the efficient implementation of epidemic prevention and control measures. Finally, the fight against the epidemic is an unprecedented major battle, so local people must quickly enhance the awareness of emergency management, and actively cooperate with the Party and government departments of the epidemic prevention work. The task of fighting the epidemic is arduous and the working environment is special. There is no doubt that we should strengthen contacts between government departments and local people to share information, and respond to the epidemic in a scientific and rational way.
Figure 5. Evolution of local masses

Figure 6 (a). Evolution of government departments
Figure 6. (b). Evolution of government departments

Figure 6. (c). Evolution of local masses
CONCLUSION

While COVID-19 is still spreading around the world, China’s great success in epidemic prevention and control seems to be due to the effectiveness of China’s anti-epidemic measures. In fact, it is due to the cooperation between Chinese government departments and local people. This paper constructs a game model between government department strategy and local mass strategy based on the evolutionary game theory of the hypothesis of finite theory person to discuss the influence of different decision-making behaviors of local masses by government department. By analyzing the gradual stability of the government department strategy and the local mass strategy respectively, it can be concluded that there are five dynamic replication equilibrium points in the system evolution. Then, the stability of five equilibrium points is judged, and two evolutionary stable strategies (ESS) of the model are obtained.

Use Matlab to verify the evolutionary game model. It starts before the outbreak, local people tend to adopt passive epidemic prevention strategy when government departments adopt no supervision strategy. In the outbreak stage, local people tend to take active epidemic prevention strategies when government departments take surveillance strategies. When reducing the cost of emergency epidemic prevention, and improving the social benefits of epidemic prevention, the final result is that government departments implement monitoring strategies and local people implement active epidemic prevention strategies to achieve early control of the epidemic situation.

Based on China’s epidemic prevention experience, it can be summarized as follows: First of all, Fever clinics in China have played a very important role in the response to the epidemic. Patients with fever must go to fever clinics to seek medical treatment, which can achieve “early detection of
patients”. Second, it is possible to “diagnose patients quickly” with sufficient reagents. Third, because China can isolate confirmed and suspected patients through legal means, it has achieved “early isolation of confirmed and suspected patients” and blocked the source of infection. Finally, treatment as soon as possible can prevent the disease from worsening in patients with mild COVID-19, reduce mortality, and prevent the re-transmission of novel coronavirus in patients with mild COVID-19. The COVID-19 pandemic has posed a huge challenge to the economies of countries around the world, and economic development can only be boosted if the epidemic is effectively brought under control. Rapid diagnosis and isolation of COVID-19 patients is therefore critical to containing the spread of the outbreak and its global impact on the world’s health, society and digital economy.

There are some shortcomings in our research, including: some assumptions are too idealistic, and factors are not considered comprehensively when constructing the evolutionary game model between government departments and local masses. However, the fact that there are more interests at stake during COVID-19 requires a more holistic consideration. These are all things we need to improve on, and these challenges become our goals for the future.

In the future, we will try to use deep learning to build a more comprehensive model and apply it to practical cases. The difference between deep learning and traditional shallow learning lies in the following: First, deep learning emphasizes the depth of model structure, which usually has 5, 6 or even 10 layers of hidden nodes. Secondly, deep learning makes clear the importance of feature learning. In other words, the feature representation of the sample in the original space is transformed into a new feature space through layer by layer feature transformation, so as to make classification or prediction easier. Compared with the method of constructing features by artificial rules, using big data to learn features can better depict the rich internal information of data. Therefore, deep learning will be a good method in future research.

FUNDING AGENCY

Open Access Funding for this article has been covered by the authors of this manuscript.

ACKNOWLEDGMENT

The author would like to thank all the knowledgeable editors, editing teachers and reviewers for their suggestions and revisions to earlier versions of this article. With the help of all the teachers, the logic of this article became more reasonable and the expression became clearer, which greatly improved the level of this article.

This work was financially supported by the science and Technology Research Project of Jiangxi Education Department: theoretical Model of risk transfer and Applied Research on quality improvement of the Project (Project number: GJJ180610).
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