

Retraction

Retracted: Earthquake Disaster Rescue Model Based on Complex Adaptive System Theory

Complexity

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] F. Chen, J. Liu, and J. Chen, "Earthquake Disaster Rescue Model Based on Complex Adaptive System Theory," *Complexity*, vol. 2021, Article ID 6655574, 12 pages, 2021.

Research Article

Earthquake Disaster Rescue Model Based on Complex Adaptive System Theory

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China is located in the intersection area of two seismic zones. Due to this special geographical location, earthquake disasters occur frequently in China. Earthquake emergency rescue work is one of the key construction works of disaster prevention and mitigation in China. This paper mainly studies the earthquake disaster rescue model based on the complex adaptive system theory and establishes the earthquake disaster rescue model by analyzing the complex adaptive system theory and combining the earthquake rescue process. In this paper, through the task allocation mechanism task, the disaster rescue task is divided into simple task and complex task, and the executive task subject is divided into single task subject and multitask subject. On the basis of considering the shortest emergency rescue time goal and the goal of maximizing the deployment utility of rescue team, the reasonable deployment of a rescue team is realized through a complex adaptive system, that is, the deployment utility of the rescue team is maximized. In this paper, the simulation experiment and comparison of the earthquake disaster rescue model based on the complex adaptive system theory are carried out. The experimental results show that the model used in this paper is better than the other two models in terms of algorithm convergence, rescue number, and overall score; in different scenarios, the relative survival probability of the model in this paper is 58.92%, 67.85%, and 77.46%, and the proportion of the wounded rescued is 66.31%, 76.45%, and 83.06%, which were higher than those of the other two models. The earthquake disaster rescue model based on the complex adaptive system theory proposed in this paper provides an effective theoretical basis and method system for postdisaster emergency rescue decision making and enhances and improves the emergency response ability to deal with large-scale geological disaster events.

1. Introduction

Large-scale earthquake disaster has become the focus and difficulty of research because of its wide influence range, huge population, serious economic loss, high uncertainty, derivation, and evolution. In recent years, large-scale earthquake disasters occur frequently in the world, which is a serious threat to the safety of human life and property. For example, the Wenchuan earthquake caused more than 80000 deaths and missing people and 370000 injured people. A total of 45 million people were affected, and more than 800 billion economic losses were caused. It can be seen that major geological disasters have a large influence range, a large number of affected population, and serious economic losses (including buildings, roads, cash crops, etc.), which

can have a serious impact on people's lives and even cause devastating consequences. In recent years, the occurrence of major earthquake disasters is more frequent, resulting in serious losses and difficult rescue, which is the focus and difficulty of emergency management research. Once a major earthquake disaster occurs, its loss and impact are immeasurable. It is necessary to strengthen the work of emergency rescue and response to major earthquake disasters. In the process of emergency rescue of major earthquake disasters, the core is the rescue of disaster victims, and the main participants are rescue teams. The effective deployment of rescue teams and the cooperation between rescue teams are important to guarantee to control the further deterioration of disaster situation and reduce casualties in disaster areas [1, 2].

Foreign experts and scholars have conducted a lot of research on emergency disaster rescue, and many research results are worth learning. Based on literature research and expert research, Baroni first selected the relevant important indicators to evaluate the priority and obtained the weight of these indicators through an analytic hierarchy process (AHP). Then, the spatial multicriteria decision analysis method was used for modeling in GIS to analyze the priority of disaster areas. Finally, the urban search and rescue operations were allocated based on this. But, his research is not applicable to earthquake disaster relief. Nakanishi et al. discussed the influence of the environment on each individual in pedestrian evacuation and proposed a social force evacuation model. In order to better describe the force of individual pedestrian evacuation, the model established three indicators including self-driving force, surrounding pedestrian influence, and surrounding obstacle influence. However, their conclusion is not supported by specific experimental data [3]. Gordon uses a mathematical model to establish an emergency plan and establishes an emergency decision support system of automatic response, which realizes the automatic decision making of the system through the interdependence and restriction relationship among the response tasks in the emergency plan. However, his contingency plan is not comprehensive enough.

Based on the theory of complex adaptive system, this paper establishes the earthquake disaster rescue model. By analyzing the task allocation mechanism and team deployment model, this paper studies the optimization method of emergency deployment decision making of a rescue team, which can effectively save the wounded and minimize the loss caused by the disaster, so as to realize the improvement of the emergency rescue effect in a real sense and provide a reliable basis for disaster relief and disaster reduction work.

2. Theoretical Basis of the Complex Adaptive System and Establishment of the Disaster Rescue Model

2.1. Complex Adaptive System Theory

2.1.1. Theoretical Basis of the Complex Adaptive System. The complex adaptive system is composed of adaptive agents, who constantly learn and accumulate experience in the process of interaction and accordingly change their own structure and behavior mode [4]. It is this kind of adaptive behavior that makes the subject and the environment constantly change, so that the system constantly evolves and becomes more complex. The theory of complex adaptive system includes two levels: a macrolevel and microlevel. The microlevel refers to that the adaptive subject constantly adjusts the behavior criterion according to the effect of behavior in the process of interaction with the environment to realize adaptive survival; the macrolevel refers to the system composed of adaptive subjects, which realizes adaptation, emergence, and differentiation in the process of interaction between the main body and the external environment iteration.

Professor Holland proposed that the complex adaptive system includes four characteristics, aggregation, flow, nonlinearity, and diversity, and three mechanisms, identification, internal model, and building blocks [5]. Generally speaking, all the systems that meet the abovementioned seven basic points are complex adaptive systems and can be applied to solve related problems.

2.1.2. Complex Adaptive Subject. The complex adaptive system is composed of multiple individuals who actively and intelligently interact to realize the evolution and iteration of the system. Adaptation refers to the active and repeated interaction between the subject and the environment. The so-called subject refers to the active individuals in the system. The subjects aggregate into larger subjects and then form the system. Therefore, the subjects at different levels are also systems in different levels. When the adaptive agent plays an adaptive role, it follows the common model system rules [6, 7]:

(1) Executive system model

The executive system model is the “detector input + IF/THEN rule set + effector output” model. The detector filters the information in the surrounding environment, receives the useful stimulus, and transmits it to the subject, which reflects the agent’s ability to collect information. The IF/THEN rule set is a set of rules that define the subject. After receiving the information from the detector, the agent uses the rule set to process, continuously activate other rules, or directly activate the effector, reflecting the agent’s ability to analyze and process information. After the effector is activated, the subject takes corresponding actions to reflect the subject’s ability to cope with environmental changes.

(2) Credit assignment

When dealing with and applying rules, adaptive agents will comprehensively consider the environment and other agents and rank the roles of various rules. The assignment of this role is the trust degree. The competitiveness of a rule, that is, the trust degree, mainly depends on the past usefulness of the rule. In the process of adapting to the environment, the usefulness of various rules is changing and the trust degree is also changing. Therefore, the process of modifying rule trust strength based on experience and learning is credit assignment.

(3) Rule generation

The environment of the complex adaptive system is complex and changeable, and the adaptability of the main body is also changing. Any IF/THEN rule set is accumulated and evolved in adaptive activities. The existing rules with high success rate generate new rules by copying and reorganizing, thus enriching the rule set and increasing the fitness of the subject. The continuous emergence of new rules is an important source for the subject to adapt to the

environment and is also the main driving force of system evolution iteration.

2.1.3. Complex Adaptive System Model. The evolution process of the complex adaptive system is realized by the stimulation response model in the microlevel and the echo model in the macrolevel. The stimulus-response model is for adaptive agents, while the echo model is for complex adaptive systems. The model application of CAS has the characteristics of initiative, dynamic operability, and hierarchy. It studies the evolution process of CAS in a way that is more in line with the facts and combines qualitative and quantitative changes [8].

(1) *Stimulus-Response Model.* The stimulus-response model describes how the subject adapts, learns, and accumulates experience. The adaptive agent can respond to the stimulation of the surrounding environment and other agents by establishing the executive system model, credit allocation, and rule generation, thus evolving towards the highest point of adaptability in many directions.

(2) *Echo Model.* The echo model is based on the stimulus-response model, which simulates, describes, and studies the behavior of the whole complex adaptive system from a macroscopic perspective. In the echo model, in addition to defining topics, sites and resources are defined. The complex adaptive system is composed of several sites, which are connected with each other; each site has resource and environmental conditions to accommodate several main activities; the subject site carries out resource and information exchange. The basic model of the echo model can describe the resource exchange activities of adaptive agents at the same level and basically reflect the functional relationship and behavior mechanism between adaptive agents.

In the basic model, the agent is composed of a resource database, attack identifier, and defense identifier. The resource library processes and stores the acquired resources; it is the attack mark that actively establishes contact with other subjects to explore whether there are needed resources; the defense identification is used to accept the contact of other subjects, which is used to respond when receiving the contact of other subjects [9]. The basic model of the complex adaptive system is shown in Figure 1.

2.2. Overview of Earthquake Disaster Rescue Process

2.2.1. Disaster Emergency Rescue Process. Disaster emergency rescue refers to a series of means and countermeasures adopted by the government and other public organizations in the process of prevention, response, response, and recovery in the process of sudden and destructive emergency disasters. The purpose is to ensure the life safety of the people in the disaster area as much as possible, so as to minimize the loss caused by the disaster [10, 11]. The three core links of disaster emergency rescue process are “preparation before disaster,” “emergency in disaster,” and “recovery after disaster.”

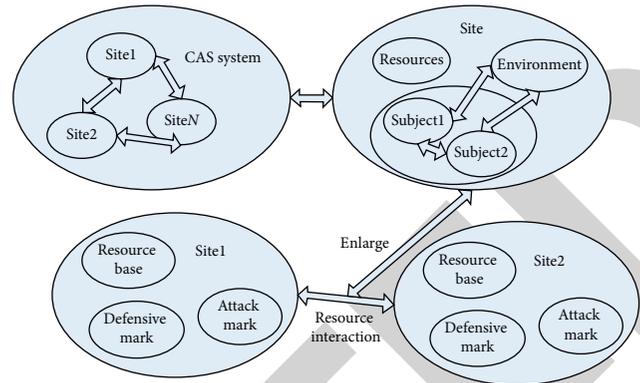


FIGURE 1: Basic model of the complex adaptive system.

(1) Predisaster preparation stage

The purpose of predisaster preparation is to ensure the necessary conditions and capabilities for post-disaster emergency rescue work. The main task is to take some organizational preparations and emergency support in advance for possible disaster events, so as to ensure the response and disposal in the first time after the occurrence of disasters and prevent the deterioration of disaster emergencies. The main work includes the distribution of emergency resources and the distribution of emergency materials emergency plan design, etc.

(2) Emergency stage in disaster

The emergency stage in disaster refers to the rescue measures taken after the occurrence of major geological disasters in order to prevent further expansion or deterioration of disaster events and minimize the loss or damage caused by disasters. The main research contents of the emergency stage include the demand forecast of emergency resources, the allocation of emergency resources, personnel search, and rescue and evacuation.

(3) Postdisaster recovery stage

Postdisaster recovery refers to the measures or actions taken to restore production, work, life, and ecological environment to the normal state as soon as possible after the impact of disaster events is controlled. At present, the research on the recovery stage mainly focuses on the assessment of emergency response capacity.

2.2.2. Task Allocation of Disaster Search and Rescue.

Most of the research studies on task allocation are related to work allocation and cooperation in a multirobot system [12]. In fact, the research of task allocation can also be applied to solve some similar problems in many other fields, such as UAV cooperation, RoboCup, assignment problem, and emergency rescue cooperation. The main factors of disaster search and rescue task allocation and classification are the complexity of the task and the function of the main body. The tasks to be completed are divided into simple tasks and

complex tasks according to their complexity. Simple tasks represent tasks that only need one agent to complete, and complex tasks represent tasks that need to be completed by multiple agents. According to the function, the subject of task execution is divided into single task subject and multitask subject. Single task subject means that the subject can execute at most one task at the same time, and multitask subject means that the subject can perform multiple tasks at the same time [13, 14].

(1) Single task subject- simple task

Task allocation in the context of single task subject and simple task is actually a classic assignment problem. Assuming that there are m single task agents a_i and n single agent tasks t_j , each agent can complete any task with corresponding cost c_{ij} and completion quality q_{ij} . The goal of the assignment model can be to minimize the total cost after allocation or to achieve the highest total completion quality or to maximize the allocation benefit (a comprehensive consideration of the total cost and completion quality). Suppose $m = n$; then, this is a balanced assignment problem.

$$\begin{aligned} \text{Maximize } Z &= \sum_{i=1}^m \sum_{j=1}^n x_{ij} u_{ij}, \\ \text{s.t. } \sum_{i=1}^m x_{ij} &= 1, \quad 1 \leq j \leq n, \\ \sum_{j=1}^n x_{ij} &= 1, \quad 1 \leq i \leq m. \end{aligned} \quad (1)$$

(2) Single task subject- complex task

Some of these problems can be transformed into set partitioning problems. Consider a nonempty set Y ; the set Y is divided into several nonempty subsets, these nonempty subsets have no intersection, and the union of the elements of these nonempty subsets is exactly equal to Y . If x is used to represent the set of nonempty subsets, there exists a utility function:

$$u: X \longrightarrow R^+. \quad (2)$$

Then, we need to find the set partition method X to maximize the utility. SPP is a NP hard problem, but on the other hand, many heuristic algorithms have been proposed to solve the problem.

(3) Multitask subject- simple task

This kind of problem is not very common in reality because it requires a single agent to perform multiple tasks at the same time, which only appears in a very few cases. However, the method to solve this kind of problem is similar to the single task subject complex task problem mentioned above. Some algorithms such as spp can be applied to these two models.

(4) Multitask subject- complex task

The task assignment problem can be transformed into the collection coverage problem. Set Y as a nonempty set. The elements in set Y can form several nonempty subsets, and these nonempty subsets can intersect. If X is used to represent the set of these nonempty subsets, then there is a cost function:

$$c: X \longrightarrow R^+. \quad (3)$$

Then, we need to find a subset of X that minimizes the cost, and the union of the elements in these subsets is exactly equal to Y . The SCP problem is also NP hard, but many scholars have proposed the algorithm to obtain the approximate solution.

2.3. Earthquake Disaster Rescue Deployment Model. After the occurrence of large-scale earthquake disaster, there are j disaster areas with scattered geographical locations and different disaster situations and i rescue points participate in the rescue. There are rescue teams with different numbers and abilities in each rescue point. For any disaster site, according to the disaster information we collected, we can know the type of rescue team that the disaster site needs the most. Therefore, the optimal deployment of rescue teams can be transformed into the problem of finding the most similar rescue teams. By calculating the similarity between rescue teams and selecting the rescue teams with high similarity for deployment, the emergency rescue effect is the best [15].

According to the actual situation of emergency rescue after a large-scale earthquake disaster, the following assumptions are given: each rescue team may include four types of personnel, namely, armed police officers and soldiers, doctors, nurses, and volunteers; the number of rescue teams required by the disaster site is highly related to the population size and the number of survivors; the road condition and corresponding geographic location information are obtained through GIS.

Once a large-scale earthquake disaster occurs, it often causes damage to the road network in the disaster area. Combined with the internationally accepted definition of the 72 hour golden rescue period after the disaster, in order to shorten the rescue time, the helicopter is also used as an emergency transport tool [16]. The parameter t_{ikj} represents the transportation time from the k -type transport vehicle in the rescue point i to the disaster site j under the condition of road network damage. Considering the characteristics of the transport vehicle, it is discussed in the following situations:

- (1) The transport tool $k \in H.$, in the rescue point, is transported by a helicopter. At this time, the transportation time is not affected by the road conditions; therefore, $t_{ikj} = t_{ikj}^n$.
- (2) The means of transport $k \in E.$, in the rescue point, that is, road transportation, is adopted. At this time, the transportation time will be affected by the road conditions. According to the road damage degree λ_{ij} , it can be divided into the following situations:

- (1) When $\lambda_{ij} = 0$, the road is not damaged and the transportation time is not affected, $t_{ikj} = t_{ikj}^n$.
- (2) When $0 < \lambda_{ij} < \alpha$, it means that the road has been damaged but can pass and the transportation time is affected. At this time, $t_{ikj} = t_{ikj}^n (1 + l\lambda_{ij})$.
- (3) When $\alpha \leq \lambda_{ij} \leq 1$, it means that the road is damaged and cannot be passable, but can be repaired. At this time, the transportation time is $t_{ikj} = t_{ikj}^n (1 + l\lambda_{ij}) + t_{ij}^r$.
- (4) When $\lambda_{ij} = 1$, it means that the road is damaged and cannot be repaired in a short time, so the route is not feasible and the transportation time is $t_{ikj} = +\infty$.

To sum up, the parameter t_{ikj} can be expressed as follows:

$$t_{ikj} = \begin{cases} t_{ikj}^n, & k \in H. \text{ or } k \in E. \text{ and } \lambda_{ij} = 0, \\ t_{ikj}^n (1 + l\lambda_{ij}), & k \in E. \text{ and } 0 < \lambda_{ij} < \alpha, \\ t_{ikj}^n (1 + l\lambda_{ij}) + t_{ij}^r, & k \in E. \text{ and } \alpha \leq \lambda_{ij} < 1, \\ +\infty, & k \in E. \text{ and } \lambda_{ij} = 1. \end{cases} \quad (4)$$

Based on the abovementioned analysis, this paper establishes a rescue team deployment model to solve the contradiction between the disaster severity and the complexity of the rescue team in the process of large-scale earthquake disaster rescue team deployment, effectively depict the difference between the rescue team and disaster site, and realize the personalized deployment of the rescue team.

After the occurrence of a large-scale earthquake disaster, the earlier the rescue team arrives in the disaster area, the more we will be able to reduce casualties and property losses. In addition, the rescue team is different from the emergency

materials, and the same rescue team deployed to different disaster areas has different effects [17, 18]. Therefore, the reasonable deployment of a large-scale earthquake disaster rescue team must consider both timely and efficient objectives, that is, to deploy the most suitable rescue team to the disaster site in the shortest time.

- (1) Shortest time target of emergency rescue

The time the rescue team arrives in the disaster area will directly affect the rescue effect. Therefore, the shortest emergency rescue time target is an important objective function in the deployment model of a large-scale geological disaster rescue team. This paper uses the time when all rescue teams arrive at the disaster area to measure [19]. Since the rescue vehicles in each rescue point can be parallel, the maximum rescue transportation time is taken as the minimum.

- (2) Goal of maximizing the effectiveness of rescue team deployment

The difference between the rescue team and the disaster site leads to the different effects of the same rescue team deployed to different disaster areas. Therefore, in the process of emergency deployment, we should strive to make the best use of the talents of the people and make the best use of the personnel. In this paper, the complex adaptive system is used to realize the reasonable deployment of rescue teams, that is, to maximize the effectiveness of the deployment of rescue teams.

On this basis, the deployment model of the rescue team based on the complex adaptive system is constructed as follows:

$$\text{Min } Z_1 = \max_{j \in J} \left\{ \max_{i \in I} \left\{ \max_{k \in K_i} t_{ikj} \left(2 \left\lceil \frac{(\sum_{p \in P_i} y_{ikpj} * n_{ip})}{q_k} \right\rceil - 1 \right) \right\} \right\}, \quad (5)$$

$$\text{Max } Z_2 = \sum_{j \in J} \sum_{i \in I} \sum_{k \in K_i} \sum_{p \in P_i} e_{ipj} y_{ikpj}, \quad (6)$$

$$\text{s.t. } \sum_{j \in J} \sum_{k \in K_i} \sum_{p \in P_i} y_{ikpj} \leq s_i, \quad i \in I, \quad (7)$$

$$\sum_{i \in I} \sum_{k \in K_i} \sum_{p \in P_i} y_{ikpj} \leq d_j, \quad j \in J, \quad (8)$$

$$\sum_{k \in K_i} \sum_{j \in J} y_{ikpj} = 1, \quad i \in I, p \in P_i, \quad (9)$$

$$\sum_{i \in I} \sum_{k \in K_i} \sum_{p \in P_i} \sum_{j \in J} c_p y_{ikpj} + \sum_{i \in I} \sum_{k \in K_i} \sum_{j \in J} 2c_{ikj} \left\lceil \frac{(\sum_{p \in P_i} y_{ikpj}) * n_{ip}}{q_k} \right\rceil \leq C_0, \quad (10)$$

$$\sum_{i \in I} \sum_{k \in K_i} \sum_{p \in P_i} \sum_{j \in J} y_{ikpj} > \varphi, \quad (11)$$

$$y_{ikpj} \in \{0, 1\}, \quad i \in I, j \in J, p \in P_i, \quad (12)$$

$$t_{ikj} = \begin{cases} t_{ikj}^n, & k \in H. \text{ or } k \in E. \text{ and } \lambda_{ij} = 0, \\ t_{ikj}^n(1 + \lambda_{ij}), & k \in E. \text{ and } 0 < \lambda_{ij} < \alpha, \\ t_{ikj}^n(1 + \lambda_{ij}) + t_{ij}^r, & k \in E. \text{ and } \alpha \leq \lambda_{ij} < 1, \\ +\infty, & k \in E. \text{ and } \lambda_{ij} = 1. \end{cases} \quad (13)$$

Formulas (7) to (13) are the constraints of the model, where formula (7) indicates that the deployment quantity of rescue teams does not exceed the available quantity; formula (8) indicates that the deployment quantity of rescue teams does not exceed the demand of the disaster stricken area; formula (9) indicates that each rescue team can only be deployed to one disaster site no matter what transportation mode is used; and formula (10) represents the constraint of available rescue cost at the initial stage after the disaster, which reflects the possible financial constraints in the early postdisaster period, and the emergency manager can adjust the parameter C_0 according to the actual situation; formula (11) indicates that at least 0 rescue teams should be deployed to participate in the rescue work, and φ is a constant greater than 1; equation (12) is a decision variable, indicating whether to deploy rescue teams; and equation (13) represents the transportation time from the rescue point to the disaster site when the road network is damaged.

3. Rescue Model Simulation Experiment Based on the Complex Adaptive System Theory

3.1. Comparison Objects. This paper establishes an earthquake disaster rescue model based on the theory of complex adaptive systems. In order to verify the performance and effectiveness of this model, it is first compared with other rescue models and then compared with the rescue model based on the *F*-Max-Sum algorithm. *F*-Max-Sum is also a distributed algorithm, which is improved on the basis of Max-Sum algorithm. It is suitable for solving similar dynamic task allocation problems and has excellent performance [20, 21]. At present, the Max-Sum algorithm and the *F*-Max-Sum algorithm are used for task allocation in disaster environments, as well as for the allocation of spectrum resources and cloud resources. The *F*-Max-Sum algorithm first converts the problem to be solved into the expression form of a factor graph and iterates the value of information transfer between variable nodes and function nodes in the factor graph until it converges or iterates a certain number of times.

3.2. Experimental Parameter Setting. This paper uses *R* and Netlogo software to calculate and simulate. It is assumed that the disaster area is a circular area with a radius of 150 m, and

a certain number of wounded are scattered in several burial sites. The simulation step size ticks are in minutes. When there are no survivors on the scene, the simulation ends. The longest simulation cycle is 72 hours.

Combined with the statistical results of earthquake casualties in recent years, assuming the specific distribution of the injury degree of landslide disaster under different scenarios, as shown in Table 1, in the “extremely serious” scenario, the proportion of wounded death is 35%, the proportion of serious injury is 30%, the proportion of minor injury is 20%, and the proportion of no injury is 15%.

The input variables include the number of wounded in each mask point n_s-U (1,3); the injury degree v_{si} of each wounded person is given the initial number according to Table 1; and the burying condition of each buried point is $v_{\text{rubble}}-N(120,30)$; the results show that the search speed is 3 m/min; the radius shown is $s_r = 3$ m; and the rescue speed is $S_{\text{rubble}} = 0.5$; when there is a buried point in the search radius, the simulation rescue team can find it with a certain probability, assuming the probability of $\text{prob} = 20\%$; the cooperation range s_c is 40 m.

4. Simulation Results and Performance Comparison of Different Rescue Models

4.1. Performance Comparison of Different Rescue Models. As shown in Table 2 and Figure 2, the algorithm in the model used in this paper converges after 40 hours of running the simulation program, while the *f*-max-sum model converges after 50 hours. The simulation results show that the convergence speed of the model algorithm in this paper is faster than that of the other two model algorithms. The reason is that, firstly, the model algorithm in this paper does not blindly process all the perceived information, but only selects the information that has an impact on the assistance task. Secondly, it uses the screened information to predict the relevant state and formulate the cooperation strategy, which can quickly find the convergence path after interference, so as to improve the rescue efficiency.

As shown in Table 3 and Figure 3, it can be seen that, after 72 hours, the rescue number of the model in this paper reached 138, higher than that of the other two models. The number of rescuers in this model is higher than that of the other two models because the cooperation information obtained is more comprehensive, which improves the accuracy of the prediction results, and uses action evaluation

TABLE 1: Distribution of the injury degree under different disaster scenarios.

Degree of injury- disaster scenario	Extremely serious (%)	Serious (%)	Ordinary (%)
Death	35	25	15
Serious injury	30	20	20
Minor wound	20	35	25
No injuries	15	20	40

TABLE 2: Comparison of convergence of different model algorithms.

Path length	10 H	20 H	30 H	40 H	50 H	72 H
This paper	34	23	14	9	9	9
Other model	38	30	23	16	12	9
<i>F</i> -max-sum model	37	25	19	14	9	9

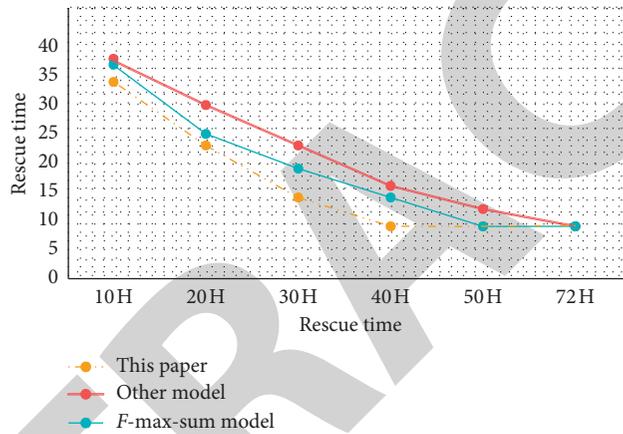


FIGURE 2: Comparison of convergence of different model algorithms.

and trigger class to realize the dynamic adjustment of the cooperation strategy to help the task to be completed smoothly. *F*-max-sum model algorithm reduces the efficiency of cooperation due to the high complexity of information processing algorithm, and it is difficult to get the optimal cooperation strategy, which leads to low rescue efficiency.

As shown in Table 4 and Figure 4, the overall scores of the three models in the simulation experiment within 72 hours are shown. Among them, the score of the model proposed in this paper is the highest among the three models after 72 hours, reaching 98. The scores of the other two models are 80 and 84, respectively. When the simulation program runs for about 40 hours, the scores of the three models are the closest. The results in Table 4 and Figure 4 further show that the performance of the proposed model is better than that of other models.

4.2. Comparison of Simulation Results of Different Rescue Models. As shown in Table 5 and Figure 5, the simulation results of the rescue model in this paper are compared with those of the other two models, and some indexes of the former are better than those of the latter two. The results

show that compared with other models, the performance of this model is not inferior, and some indicators are better than the other two models. One of the biggest advantages of this model is the low complexity of the calculation process. In the iterative process of *f*-max-sum algorithm, function nodes need to traverse the various combinations of surrounding variable nodes, which will consume a lot of time, especially when the cooperation set is large, that is, there are more rescue teams to be deployed around the rescue task. In addition, *f*-max-sum was originally designed for the cooperation between devices with computing functions, such as robots and sensors. It has adaptability problems when it is directly applied to the cooperation between rescue teams on the disaster scene (Tables 6 and 7).

As shown in Figures 6 and 7, the average situation of the relative production probability and the proportion of the wounded rescued in the earthquake disaster rescue based on the complex adaptive system within about 2000 simulation steps in three different scenarios after 100 simulation times are shown. It can be seen that, in the initial stage of rescue, the relative survival probability decreases rapidly. With the development of rescue work, the decline speed of relative survival probability slows down after about 300 minutes. In the early stage of rescue, the average survival probability

TABLE 3: Comparison of rescue numbers of different models.

Number of rescuers	10 H	20 H	30 H	40 H	50 H	72 H
This paper	28	40	77	101	130	138
Other model	18	43	71	106	120	123
<i>F</i> -max-sum model	19	37	60	108	124	126

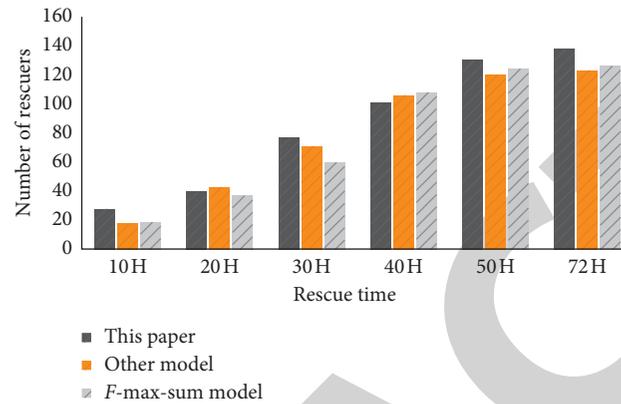


FIGURE 3: Comparison of rescue numbers of different models.

TABLE 4: Comparison of overall scores of three models.

Overall score	10 H	20 H	30 H	40 H	50 H	72 H
This paper	24	33	56	72	91	98
Other model	19	37	49	76	80	80
<i>F</i> -max-sum model	16	38	51	75	81	84

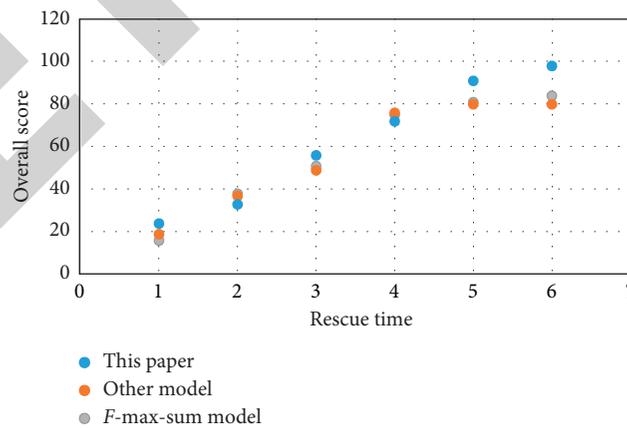


FIGURE 4: Comparison of overall scores of three models.

TABLE 5: Comparison of simulation results of three rescue schemes.

		Relative survival probability (%)	Proportion of wounded rescued (%)	Average rescue time (min)
Extremely serious	This model	58.92	66.31	523.1
	<i>F</i> -max-sum model	54.38	62.48	541.6
	Other model	48.74	59.18	584.2
Serious	This model	67.85	76.45	596.1
	<i>F</i> -max-sum model	65.17	74.21	610.7
	Other model	61.94	70.94	645.6
Ordinary	This model	77.46	83.06	631.3
	<i>F</i> -max-sum model	74.37	83.53	659.7
	Other model	71.25	82.17	684.6

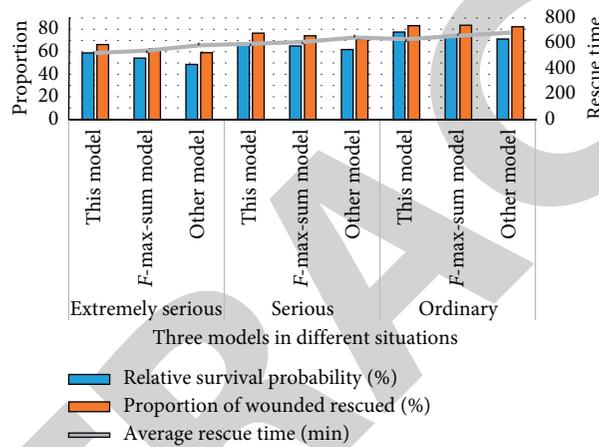


FIGURE 5: Comparison of simulation results of three rescue schemes.

TABLE 6: Changes of survival rate in different situations.

	1	501	1001	1501	2001
Extremely serious	1	0.57	0.56	0.55	0.54
Serious	1	0.7	0.7	0.69	0.68
Ordinary	1	0.83	0.8	0.78	0.76

TABLE 7: Proportion of wounded rescued in different situations.

	1	501	1001	1501	2001
Extremely serious	0.42	0.67	0.83	0.98	1
Serious	0.42	0.66	0.82	0.9	0.93
Ordinary	0.42	0.65	0.81	0.83	0.85

decreases faster, mainly because of the existence of seriously injured trapped people. However, the survival probability of such wounded people drops very fast, about 300 minutes. After that, the seriously injured died or were rescued and only slightly injured or not injured persons were left on the whole scene, and the average survival probability of the wounded decreased slowly.

4.3. *Frequency of Earthquakes in Recent Years.* We have made statistics on the frequency of earthquakes with magnitude 5 and above in recent years and also the property and life damage caused by them, as shown in Table 8.

It can be seen from Figure 8 that, in recent years, the global threat of earthquakes has been more serious. On average, there are about 5 earthquakes of magnitude 7 or

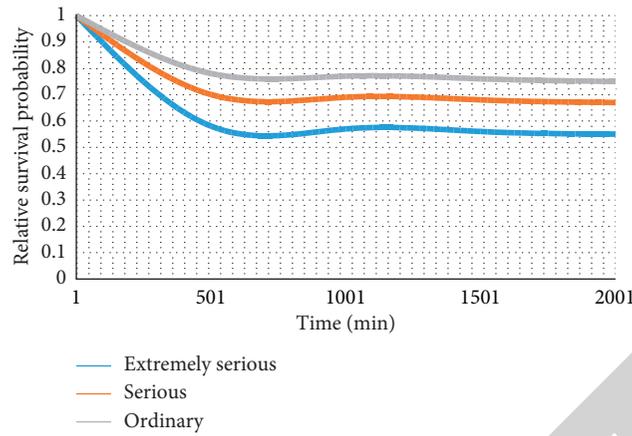


FIGURE 6: Changes of survival rate in different situations.

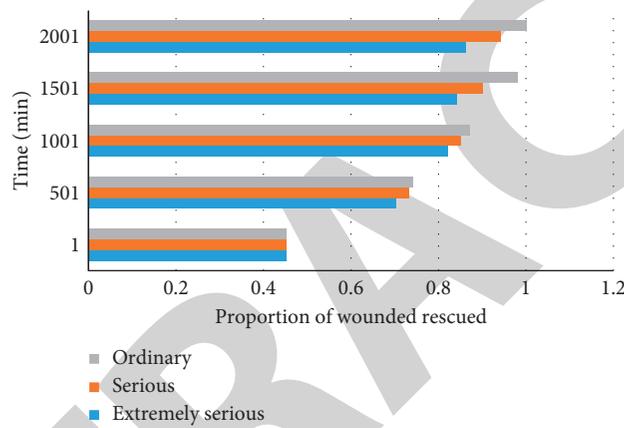


FIGURE 7: Proportion of wounded rescued in different situations.

TABLE 8: Number of earthquakes worldwide.

	Level 3	Level 4	Level 5	Level 6	Level 7
2015	165	53	18	16	7
2016	177	42	24	14	5
2017	162	47	26	17	3
2018	159	41	22	15	9
2019	163	39	15	14	6

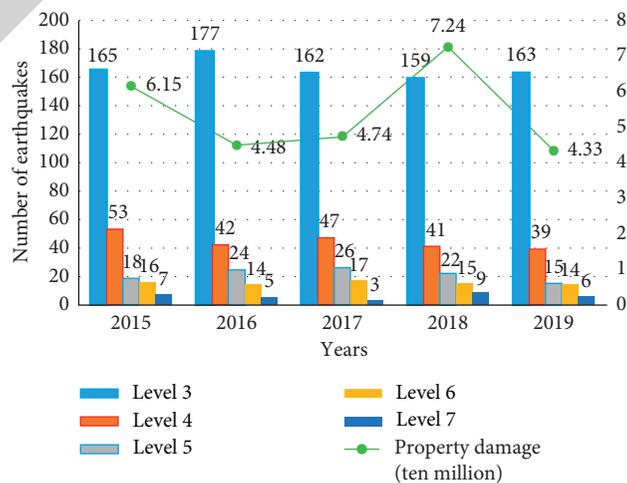


FIGURE 8: Number of earthquakes and losses.

above each year. The remaining small earthquakes are even harder to count. The property losses caused by earthquakes are as high as tens of millions each year. This also shows that the earthquake relief system proposed in this article is particularly necessary.

5. Conclusions

The frequent occurrence of major earthquake disasters is an urgent problem faced by all countries in the world. The traditional emergency management and emergency response decision making focus on the dispatching and distribution of relief materials, ignoring the role of human beings. In fact, in the process of disaster relief, the rescue team is the main body of participation. Under the background of frequent occurrence and increasingly serious impact of major earthquake disasters, it is not only of important theoretical value to carry out the research on search and rescue model to deal with such disasters but also has a strong practical significance for guiding the emergency rescue work after disasters and improving the effectiveness of the rescue decision-making scheme.

The main research content of this paper is an earthquake disaster rescue model based on the theory of complex adaptive systems. Aiming at the contradiction between the severity of large-scale earthquake disasters and the complexity of rescue teams, an earthquake disaster rescue model based on complex adaptive systems is established. The model considers the two goals of timeliness and efficiency, deploys the most suitable rescue team to the disaster site in the shortest time, and better describes the needs of large-scale geological disaster emergency rescue decision making. In the context of large-scale earthquake disasters, the research content of this paper solves many difficulties faced in the deployment of rescue teams and improves the efficiency of emergency rescue work. It provides an effective solution tool for postdisaster emergency rescue decision making and improves the emergency response capability for large-scale geological disasters.

Although this paper has carried on the beneficial exploratory research on the optimization deployment and decision making of a large-scale earthquake disaster rescue team and has achieved certain innovative results, there are still many work that need further study, mainly including the following: in the future, we will study the demand quantity of the rescue team in a disaster area by the tensor decomposition and filling method; pay attention to the data collection of rescue cases, according to the model proposed by relevant scholars, and use limited data to correct the model parameters, so as to improve the applicability of the model to the actual situation.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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