Hindawi
Mathematical Problems in Engineering
Volume 2023, Article ID 1604125, 7 pages
https://doi.org/10.1155/2023/1604125

Research Article

Simulation Study of Aviation Emergency Rescue Process Based on Application Scenario Features

Yichi Zhang

School of Civil Aviation, Zhengzhou University of Aeronautics, Zhengzhou, Henan 450000, China

Correspondence should be addressed to Yichi Zhang; zhangyichi330@zua.edu.cn

Received 4 June 2022; Revised 15 July 2022; Accepted 18 July 2022; Published 15 February 2023

Academic Editor: Naeem Jan

In the process of emergency relief material dispatching, most of the traditional algorithms for dispatching are for single rescue point and single material dispatching, which cannot solve the problem of multirescue emergency relief dispatching. The various supply and demand points for emergency relief materials and the multiple emergency relief material dispatching are utilized to create the multiobjective planning model, which is then used as the optimization objective to create the best material dispatching plan. Genetic algorithm (GA) is used to solve the optimal material dispatching scheme and symbolic coding; special pulse crossover operator and variational operator are used to ensure the quality of the solution. The experiment proves that the simulation method of the aviation emergency rescue process considering the application scenario characteristics is efficient in the emergency rescue process and can meet the application requirements of material dispatching in the process of civil emergency disaster relief.

1. Introduction

At the moment, the primary goal of the development of the domestic aerospace industry is to increase the safety of human life and property while simultaneously raising the level of economic construction and technology, as well as fully reflect the values of social and humanistic care and harmony, among other things. Aviation emergency rescue and dispatch has piqued the interest of many professionals and academics since it is a quick and efficient way of rescue that is not limited by distance. Due to its vast development area, emergency disaster relief scheduling has attracted the attention of numerous industry experts and received a great deal of attention [1–6].

It has been a long time since my country was regarded as one of those suffering from the most severe natural disasters in the entire world. More than 138 million individuals in my country were harmed by various natural disasters throughout the year 2020, with direct economic losses amounting to as much as 370.15 billion Chinese yuan (US$415 billion). Furthermore, it is impossible to ignore the annual losses suffered by my nation in the fields of public health, social security, and other public emergencies, as well as the effects of these losses. As a critical component of disaster relief efforts following disasters, aircraft emergency rescue has the qualities of rapid reaction time and strong on-site engagement capabilities, making it one of the most successful methods of reducing the loss of life and property during disasters. The need for aviation emergency rescue services is rising as my nation's system for aircraft emergency rescue keeps getting better [7–11].

The following are the materials dispatching methods currently in use in the domestic emergency rescue and disaster relief process:

(1) A civil aviation emergency rescue material scheduling method based on the hierarchical division behaviour state reorganization network algorithm. The method makes use of neural networks' incredible parallel processing power to complete the dispatching of emergency aid for civil aviation [12–16].

Despite the fact that this method is minimal in cost, it is time-consuming and computationally difficult, and it is unable to match the real-time requirements of disaster relief material distribution.

(2) Using the global optimal search capability of particles, a method based on the particle swarm algorithm is used to find the best route for distributing emergency relief supplies for civil aviation. It has the drawback of not being able to meet the actual needs of emergency disaster aid for multiple rescue points despite being a simple operation that is primarily intended for the dispatch of a single rescue point.

(3) A dispatching model is developed that is focused on providing the quickest possible emergency response time in order to meet the dispatching goal for civil aviation emergency relief materials. Despite the fact that this procedure is time-consuming, it is also expensive [17–19].

To address the aforementioned concerns, a simulation technique for the aviation emergency relief process is presented that takes into account the unique characteristics of the application situation. A multiobjective planning model is developed by utilizing multiple supply and demand points for emergency relief materials [20, 21], as well as multiple emergency relief material dispatching. The development of an ideal material dispatching method is then carried out using a GA, with this model serving as the objective function. Symbolic coding, unique crossover operators, and variational operators are employed to guarantee the achievement of the ideal material dispatching scheme. The results of this experiment demonstrated the effectiveness and capability of the optimization strategy for emergency relief material dispatching based on an enhanced GA to satisfy all application requirements for material dispatching throughout the disaster relief process.

The rest of the article is as follows: Section 2 discusses the principle of material dispatching in the emergency rescue process. Section 3 analyzes the proposed method. Section 4 explains the experiments and results analysis. Section 5 concludes an article.

2. Principle of Material Dispatching in Emergency Rescue Process

As a result of previous experience with the implementation of emergency relief material dispatch in China, it has been determined that civil aviation emergency relief material dispatch should meet the following conditions.

It is crucial that emergency relief supplies are given as soon as possible after a tragedy. The emergency relief material dispatch procedures that are prepared must be activated as soon as possible, and the emergency relief dispatch tasks must be finished at the disaster site in a race against time. This is assuming that a catastrophic event occurs in a specific location.

The airline's emergency relief material reserves, which must be sufficient to fully support the entire process of emergency relief dispatching tasks until the disaster situation is alleviated, must be designed to work in a variety of harsh disaster environments, particularly in remote areas, and the airline's emergency relief material reserves must be designed to work in a variety of harsh disaster environments, especially in remote areas.

The service scope of emergency relief material sending should be broad, and various disaster relief actions should be carried out to the maximum extent possible, as indicated in the following mathematical model.

There are m civil aviation emergency relief supplies supply points by $s_1, s_2, \cdots, s_m$, generation table stores a total of p kinds of emergency relief materials, and $R_1, R_2, \cdots, R_p$ represents the number of emergency relief materials that emergency relief material dispatch is responsible for providing n emergency material demand points represented by $D_1, D_2, \cdots, D_n$.

Assume that the storage quantity of the kth emergency relief material at the first supply point can be expressed as $B_{ki}, 1 \le k, 1 \le i \le m$. The demand for the kth material at the j-th demand point can be expressed as $Q_{kJ}, 1 \le K \le P, 1 \le J \le n$. The delivery time from supply point s to demand point D_J can be expressed as $t_{ij}, 1 \le i \le m, 1 \le j \le n$. The goal of emergency dispatch is to be able to obtain a variety of material supply solutions from emergency relief material supply points, which can be calculated by calculating the value of x_{kjj}, x_{kjj} out of the supply point s_i, represented by D_J. The quantity of material supplied from the relief material demand point is represented by R_K. If $x_{kjj} \ge 0$, then the label $F_{kjj} = 1$, which can express a relief provided by the supply point represented by S_l for the demand point D_J, and vice versa, the label $F_{kjj} = 0, 1 \le i \le m, 1 \le j \le n, 1 \le k \le p$.

The following assumptions are made in order to solve the problem of emergency relief material deployment in civil aviation:

(1) The journey time of emergency relief supplies from the supply location to the demand point is constant, with the exception of unusual events that may occur during the transportation procedure

(2) The demand point does not need further emergency manufacturing or resupply because the supply point for emergency supplies has enough goods to meet the demand

(3) There is no association between the requests for different resources, and all emergency relief supplies are represented as integers

The optimization objectives and modeling of the disaster relief problem might be stated as follows:

$$\min w_1 \times \sum_k \sum_i \sum_j F_{kij} + w_2 \times \min \left\{F_{kij} \times t_{ij}\right\}, \tag{1}$$

$$\forall_j, \forall_k, \sum_i x_{kij} \ge Q_{kj}, \tag{2}$$

$$\forall_j, \forall_k, \sum_i x_{kij} \le B_{ki}, \tag{3}$$

$\sum_k \sum_i \sum_j F_{kij}$denotes the number of times that aviation emergency relief supplies are dispatched to rescue,

$\min\left\{F_{kij} \times t_{ij}\right\}$ denotes the time that aviation emergency relief supplies are dispatched to rescue, and the normalized weights of these two parts are expressed as w_1 and w_2, respectively, in equation (1). In this case, $\forall_j, \forall_k, \sum_i x_{kij} \geq Q_{kj}$ represents the quantity of emergency relief materials needed by the demand point for that particular sort of emergency relief material. Every relief supply point's real quantity of emergency items is represented by the number $\forall_j, \forall_k, \sum_i x_{kij} \leq B_{ki}$ in the equation.

We can describe the theory of dispatching emergency relief supplies for civil aviation, but the traditional algorithm is generally used for single rescue points and single materials, which is insufficient for meeting the actual needs of disaster relief.

3. The Proposed Method

Because the traditional algorithm for emergency relief material dispatching is primarily designed for single rescue point and single material dispatching, it is unable to meet the actual needs of emergency relief. To address this issue, we propose a simulation method for the aviation emergency relief process taking into account the application scenario characteristics, which is based on an improved GA, and which is intended to optimize the emergency relief material dispatching.

3.1. Development of a Paradigm for Multiobjective Planning. The multiobjective planning model plays a significant role in the optimization of the process of distributing emergency relief materials to the affected areas. It is built on a foundation of numerous civil aviation emergency relief material supply and demand locations, as well as multiple emergency relief material dispatching, with the aim of maximizing emergency relief dispatching efficiency while keeping costs to an absolute minimum. The following are the particular measures to take.

Let N be an emergency material supply point for the scheduling of aviation emergency relief materials, indicated by $A_1, A_2, \cdots, A_n$, m represents the requirements of emergency relief materials, and $C_1, C_2, \cdots, C_l$ represents the scope of the selection of emergency materials.

The emergency relief demand rate for the kth material at the j-th civil emergency relief material demand point on day t is

$$p_{ijk} = \frac{e_{ijk}}{r_{ijk}}. \tag{4}$$

In this equation, e_{ijk} denotes the amount of I emergency relief materials obtained from the j-th emergency material demand point on the t-th day, and r_{ijk} denotes the actual quantity of k materials required by the j-th aviation disaster relief emergency material demand point on the t-th day, $1 \leq i \leq m, 1 \leq k \leq l, t = 1, 2, 3, \cdots$.

After solving for $m \times 1$ emergency relief on tth day, it can be demonstrated that the average of the $m \times 1$ emergency relief need rate p_t may be used to calculate the total humanitarian assistance required on tth day by using the following equation:

$$p_t = \frac{\sum_j \sum_k e_{jkt}}{m \times 1}. \tag{5}$$

Calculating the whole transportation cost of the relief process on day t can be accomplished using the following equation:

$$c_t = \sum_k \sum_i \sum_j b_0 d_{ij} \left[\frac{e_{ijkt}}{a_k}\right]. \tag{6}$$

In the preceding equation, b_0 represents the unit transportation cost, d_{ij} represents the distance between the i-th emergency supply point and the j-th emergency demand point, e_{ijkt} represents the number of the kth material transported from the i-th emergency supply point to the j-th emergency demand point, and a_k represents the maximum load capacity of each aircraft to transport the k-th material are all given.

In the conventional state, aircraft transporting goods have a loading volume limit represented by v and a loading weight limit represented by M. In the unconventional state, aircraft transporting cargo has no loading volume limit. The critical density can be calculated with the help of the following equation:

$$P_0 = \frac{M}{V}. \tag{7}$$

According to the above equation, the complete capacity of each emergency relief dispatch transport aircraft for the l^{th} type of emergency relief materials varies depending on the type of emergency relief supplies.

$$a_k \begin{cases} \dfrac{v}{v_0}, \\ \\ \dfrac{M}{m_o}. \end{cases} \tag{8}$$

The density of emergency relief materials is represented by $p \leq p_0$ when referring to the unit material. V_0 denotes the volume of the unit material, and m_o represents the mass of the unit material.

The demand for the kth type of material at each emergency demand point should be proportional to the number of affected people present at the demand point, and the proportion of demand for the kth type of emergency relief material should be proportional to the proportion of affected people present at the demand point.

$$r_{jkt} = b_k \times q_{jt}. \tag{9}$$

In order to keep a lower bound on the relief rate of various materials, a lower bound based on the actual disaster situation should be set for each emergency material demand point in the optimization process of civil aviation emergency relief dispatch. When $p_{jkt} \geq p_o$ is present, po uses the lowest possible lower bound for relief dispatch.

If a single type of relief material is delivered by each emergency relief supply point to the corresponding demand point, the total amount of that relief material delivered by each emergency relief supply point cannot exceed the storage capacity of that emergency supply point for that emergency material, which is expressed as follows:

$$\sum_j e_{jkt} \le h_{jkt}, \tag{10}$$

and the objective function is as follows:

$$\begin{aligned} &\max\{p_t\},\\ &\min\{c_t\}. \end{aligned} \tag{11}$$

Finally, the multiobjective planning paradigm in civil aviation emergency relief material dispatching can be summarized by the following diagram:

$$S\cdot t\left\{\begin{array}{l} \sum_j e_{jkt} \le h_{jkt},\\ r_{jkt} = b_k \times q_{jt},\\ p_{jkt} = \dfrac{\sum_j e_{jkt}}{r_{jkt}},\\ p_t = \dfrac{\sum_j \sum_k e_{jkt}}{m\times 1},\\ i = 1,2,\cdots n,\\ j = 1,2,\cdots,m,\\ k = 1,2,\cdots,l. \end{array}\right\} \tag{12}$$

In the process of emergency relief resource scheduling optimization, the multiobjective planning model is integrated into an optimization objective. It can be expressed by the following equation:

$$S\cdot t\left\{\begin{array}{l} p = \sum_j w_j \times p_j,\\ e_{jkt} = a_k \times n_{jkt},\\ r_{jkt} = b_k \times q_{jt},\\ p_{jkt} = \dfrac{\sum_j e_{jkt}}{r_{jkt}},\\ i = 1,2,\cdots,n,\\ j = 1,2,\cdots,m,\\ k = 1,2,\cdots l. \end{array}\right\} \tag{13}$$

In summary, we can describe the process of developing a multiobjective planning model for the optimization of emergency relief material dispatching, which serves as an effective foundation for the completion of the optimization of emergency relief material dispatching after it has been established.

3.2. Actualization of the Civil Emergency Relief Material Dispatching Process. As part of the process of optimizing emergency relief material dispatching, a multiobjective planning model is developed, which is then translated into an optimization goal for the purpose of designing the most efficient material dispatching strategy. The ideal material dispatching strategy is identified and solved using an enhanced GA. The algorithm is the last step in optimizing emergency relief material dispatching, and it uses symbolic coding, special crossover operators, and variational operators to ensure a high-quality solution. The specific actions that must be taken are as follows:

Pretend you have tempx_{kij}, which represents the quantity of emergency supplies k currently provided by aviation disaster relief emergency supply point i for demand

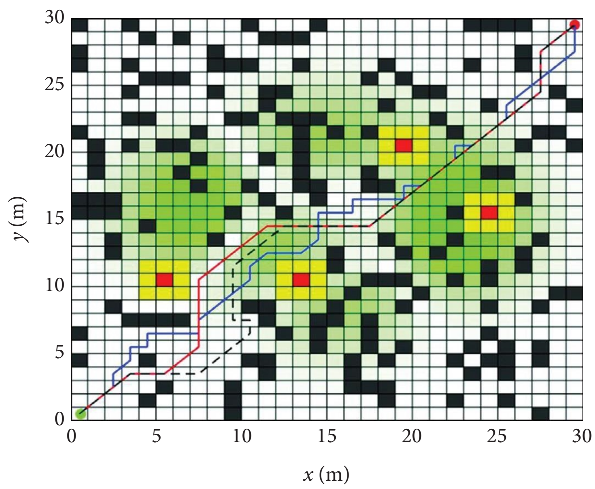

Figure 1: Optimal rescue route.

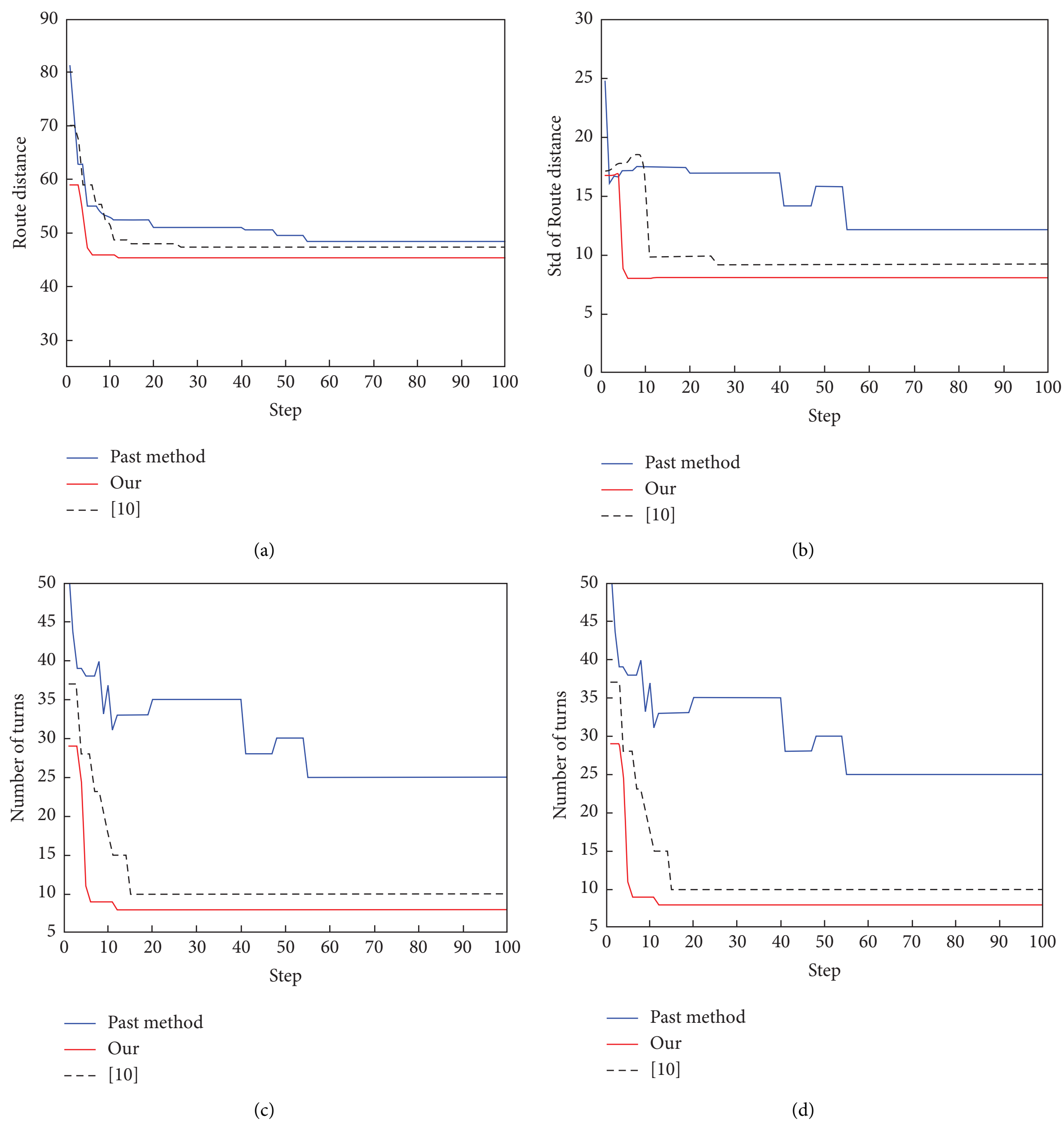

Figure 2: Comprehensive index comparison: (a) route distance, (b) standard of route distance, (c) number of turns, and (d) comprehensive index.

point j, and tempB_{kij}, which represents the remaining reserve quantity of civil aviation disaster relief emergency supply point k (initial quantity of temp$B_{kij} = B_{kij}$).

(1) During the disaster relief dispatch optimization process, determine whether there is an unequal distribution of relief supplies at the relief demand point, and if there is, ensure that j satisfies the condition.

$$k\sum_{i=1}^{m} \text{temp}x_{kij} \leq Q_{IJ}. \tag{14}$$

If not, turn to (4), otherwise, choose J arbitrarily and turn to (2).

(2) Analyze whether there is an unbalanced distribution of relief supplies at the relief demand points represented by J. If so, make k satisfy

$$\sum_{i=1}^{m} \text{temp}x_{kij} \leq Q_{IJ}. \tag{15}$$

If not, turn (1), and vice versa, choose k arbitrarily and turn (3).

(3) In the optimization process of aviation disaster relief resource dispatching, analyze whether there exists a current reserve of relief materials represented by h at the supply point greater than 0. If so, make i satisfy that

$$\sum_{i=1}^{m} \text{temp}B_{kij} \leq Q_{I}. \tag{16}$$

If not, the solution fails and exits, and vice versa, arbitrarily picks j and generates

$$0 \sim \min\left(\text{temp}B_{ki}, Q_{ki} - \sum_{i=1}^{m} \text{temp}x_{kij}\right). \tag{17}$$

In the disaster relief resource scheduling process, the random number rm represents the number of emergency relief supplies k distributed by aircraft for rescue point j of i to be satisfied by

$$\begin{aligned} \text{temp}x_{kij} &= \text{temp}x_{kij} + rm, \\ \text{temp}B_{ki} &= \text{temp}B_{ki} - rm. \end{aligned} \tag{18}$$

(4) In the process of scheduling optimization, let $x_{kij} = tempx_{kij}$, and if $x_{kij} \geq 0$, then $F_{kij} = 1$; otherwise, $F_{kij} = 0$.

4. Experiments and Results Analysis

Experiments were carried out in Matlab's GA toolbox as a simulation platform in order to illustrate the usefulness of the improved GA-based optimization strategy for emergency relief material dispatching.

Run the revised GA for a different experiment and compare the outcomes with those of the current experiment using the experimental data in the experimental database for multiobjective optimization. The outcomes are shown in Figure 1 for the population size of 290, the number of iterations of 99, the crossover rate of 0.7, the variation rate of 0.02, and the weights of 5 and 1, respectively. On the basis of Figure 1, it can be shown that the modified GA's optimal scheduling scheme is essentially consistent with the experimental data.

Figure 1 depicts the starting point of the environment. It is decided on the parameter settings based on the comparison between empirical and experimental simulation results. Using the same environment model, the improved GA, the algorithm described in literature [10], and the standard GA were all simulated in parallel. Rescue paths generated by three distinct algorithms are depicted in Figure 1. Figure 1: Rescue routes determined by three different methods.

As illustrated in Figure 2, various experimental simulations were carried out in order to evaluate the superiority of the revised algorithm's performance.

By comparing the experimental results of the three algorithms, including path length, path height mean square deviation, and number of turns, it can be seen that the path calculated by the algorithm of this paper is significantly better than the path calculated by the traditional GA and the path calculated by the algorithm of literature [10]. It can be observed that the path calculated by the algorithm of this study is much better than the path computed by the conventional GA by comparing the comprehensive indexes of the three algorithms. Also of note is that the technique described in this research has significantly increased the speed with which the algorithm converges, reduced the number of stable iterations, and improved the search ability of the algorithm. On the stability front, the indicators computed by the algorithm in this paper for numerous trials fluctuate less than those calculated by the algorithm in literature [10] and the standard ant colony algorithm, indicating that the algorithm in this article is substantially more stable.

5. Conclusion

An aviation emergency relief process simulation algorithm is proposed that takes application scenario characteristics into account in order to address the issue that traditional emergency relief material dispatching algorithms are primarily designed for single rescue point and single material dispatching, which does not adequately address the actual needs of emergency relief. Specifically, an improved GA is applied to the optimization of emergency relief material dispatching. By incorporating multiple supply and demand points for emergency relief materials, as well as multiple emergency relief material dispatching, a multiobjective planning model is formed, and the multiobjective planning model is used as the optimization objective for designing the optimal material dispatching scheme; the optimal material dispatching scheme is solved using a GA; symbolic coding, a special crossover operator, and a variational operator are used to ensure that t the final stage of optimization is complete. In this experiment, it was shown that the optimization strategy for distributing emergency relief supplies, which is based on an enhanced GA, is effective and able to satisfy the application needs for distributing emergency relief supplies.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] Z. Xia and W. Pan, "Research on the Algorithm of Aviation Emergency Rescue under Major Disasters," *Applied Mechanics and Materials*, vol. 236, pp. 315–320, 2012.

[2] Q. Shao, C. Xu, and Y. Zhu, "Multi-helicopter search and rescue route planning based on strategy optimization algorithm," *International Journal of Pattern Recognition and Artificial Intelligence*, vol. 33, no. 01, Article ID 1950002, 2019.

[3] R. Wang, W. Pan, and R. Jie, *Research on Multi-Objective Model of Resource Scheduling Based on General Aviation Emergency Rescue*, DEStech Transactions on Computer Science and Engineering, (cmsam), 2018.

[4] N. Lu and L. Zhang, "Research on the Layout of General Aviation Emergency Rescue Spots Based on P-Median Model," in *Proceedings of the 2017 International Conference on Financial Management, Education and Social Science*, London, UK, 2017.

[5] B. Hu, F. Pan, and Y. Zhang, "Research on selection of general aviation rescue airports[C]//Journal of physics: conference series," *Journal of Physics: Conference Series*, vol. 1910, no. 1, Article ID 12023, 2021.

[6] S. Lv, Q. Zhang, and L. Wang, "P-3.2: VR Air rescue immersive simulation system," *SID Symposium Digest of Technical Papers*, vol. 52, no. S2, pp. 717–720, 2021.

[7] H. Bin, P. Fang, and Q. Xiaoxia, "Research on trajectory prediction algorithm for low-altitude emergency rescue aircraft," *Journal of Physics: Conference Series*, vol. 1510, no. 1, Article ID 12018, 2020.

[8] H. Liu, P. Zhang, and H. Wu, "A model of airport emergency rescue path planning based on hierarchical optimized Dijkstra algorithm," *Rev. Téc. Ing. Univ. Zulia.,* vol. 39, no. 7, pp. 261–268, 2016.

[9] Q. Yu, L. Cai, and X. Tan, "Airport emergency rescue model establishment and performance analysis using colored petri nets and CPN tools," *International Journal of Aerospace Engineering*, vol. 2018, pp. 1–8, 2018.

[10] M. Zhang, H. Yu, J. Yu, and Y. Zhang, "Dispatching Plan Based on Route Optimization Model Considering Random Wind for Aviation Emergency rescue," *Mathematical Problems in Engineering*, vol. 2016, Article ID 1395701, 2016.

[11] L. Jiang, L. Wang, Z. Li, and S. Zhao, "Aviation medical simulation training based on interactive technology," in *Proceedings of the 2021 IEEE 4th international conference on computer and communication engineering technology (CCET)*, pp. 387–391, Beijing, China, August 2021.

[12] Z. Xia and W. Pan, "Researches on the Coordinated Rescue of Multi-Helicopters Based on Feasibility Matrix and Track Planning," in *Proceedings of the 2nd International Conference on Computer Science and Electronics Engineering (ICCSEE 2013)*, pp. 181–184, Paris, France, March 2013.

[13] B. Hu, F. Pan, and L. Wang, "A scheduling algorithm for medical emergency rescue aircraft trajectory based on hybrid estimation and intent inference," *Journal of Combinatorial Optimization*, vol. 37, no. 1, pp. 40–61, 2019.

[14] E. Rippel, A. Bar-Gill, and N. Shimkin, "Fast graph-search algorithms for general-aviation flight trajectory generation," *Journal of Guidance, Control, and Dynamics*, vol. 28, no. 4, pp. 801–811, 2005.

[15] Y. Su, H. Yu, X. Sun, and L. Gao, "A target detection method with morphological knowledge for high-spatial resolution remote sensing image applying for search and rescue in aviation disaster," *International Society for Optics and Photonics*, vol. 9260, Article ID 926022, 2014.

[16] L. Binbin and H. Songchen, "Modeling and Simulation of Civil Aviation Disaster Relief Logistics within Multiairport Network," in *Proceedings of the 2019 6th International Conference on Frontiers of Industrial Engineering (ICFIE)*, pp. 48–55, London, UK, September 2019.

[17] S. Yigang, F. Jie, and Z. Hongying, "Research on the shortest path algorithm of vehicles dispatch in airport emergency rescue," in *Proceedings of the 2011 third international conference on intelligent human-machine systems and cybernetics*, pp. 107–110, Hangzhou, China, August 2011.

[18] H. Xu, X. Zhu, and J. Wan, "Airport Fire Emergency Rescue Virtual Drill Platform Based on Virtual Reality Technique," in *Proceedings of the 2019 IEEE 1st International Conference on Civil Aviation Safety and Information Technology (ICCASIT)*, pp. 63–66, Kunming, China, October 2019.

[19] C. Xin, X. Guo, and D. Fan, "Application research of ground shortest path based on GIS in the Emergency Rescue Information Management System for airport airside," in *Proceedings of the 2011 Second International Conference on Mechanic Automation and Control Engineering*, pp. 5632–5635, Hohhot, China, July 2011.

[20] M. Tang, M. Hu, H. Zhang, and L. Zhou, "Research on multi unmanned aerial vehicles emergency task planning method based on discrete multi-objective TLBO algorithm," *Sustainability*, vol. 14, no. 5, p. 2555, 2022.

[21] Z. Ding, X. Xu, S. Jiang, J. Yan, and Y. Han, "Emergency logistics scheduling with multiple supply-demand points based on grey interval," *Journal of Safety Science and Resilience*, vol. 3, no. 2, pp. 179–188, 2022.