

A Method of Emergency Volunteer Team Internal Participation in Rescue Decision-Making Considering Psychological Behavior

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Abstract A method for internal participation in rescue decision-making of emergency volunteer teams considering psychological behavior is proposed to address the time sequence of rescue tasks. Firstly, the problem of multi-tasking and multi-operation within the emergency volunteer team is described. Secondly, considering that task leaders are influenced by behavioral and psychological factors in the evaluation, the required time for the job is used as a reference point, and the expected time that volunteers can complete the job is used as an attribute value. The task leader's prospect satisfaction value for each volunteer is calculated based on prospect theory, and the perceived utility values of disappointment theory and regret theory are calculated to measure the task leader's satisfaction with each volunteer. Furthermore, a multilayer coded genetic algorithm is used to construct an optimization model for emergency volunteer decision-making with the objective of maximizing the satisfaction value. Finally, the feasibility and effectiveness of this method are illustrated by an example analysis. The result shows that the efficiency of rescue tasks can be improved through decision optimization within the volunteer team.

Keywords emergency volunteers; rescue task; multi-layer coding genetic algorithm; satisfaction value; psychological behavior

1 Introduction

In recent years, various major disaster events have occurred frequently, resulting in significant casualties and property damage. After a sudden disaster, emergency rescue work requires a lot of human and material resources. The practice has proven that emergency volunteers play an important role in emergencies^[1, 2].

Scholars at home and abroad have conducted a series of studies on volunteer decision-making in post-disaster rescue. Sampson^[3] compared the differences between volunteer labor decision-

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making and traditional labor decision-making based on cost structure, objective function, and constraints. In response to the volunteer job problem in humanitarian organization relief, Falasca and Zobel^[4] developed a multi-objective optimization model considering the ability and willingness of volunteers, and finally obtained the optimal volunteer job scheme. Considering the preferences and skills of volunteers, Garcia, et al.^[5] used mixed integer planning to assign volunteers to tasks in disaster situations. Lodree and Davis^[6] presented a case study of volunteer integration after a disaster, which is the first academic study to analyze volunteer integration data. Given that the arrival and departure times of volunteers are uncertain, Mayorga, et al.^[7] established a multi-server queuing system with random server arrivals and discontinuations and used a continuous-time Markov decision process to obtain the optimal volunteer decision scheme. For the volunteer decision problem in post-disaster rescue, Abualkhair, et al.^[8] utilized a heuristic strategy to assign volunteers to parallel queues and determined the most effective job strategy under various experimental conditions through a large number of experiments. Considering that the arrival and departure times of volunteers are random, Paret, et al.^[9] established a multi-server queuing model and used a Markov decision process to generate the optimal volunteer job scheme. To address the decision problem of social forces participating in post-disaster relief, Li, et al.^[10] proposed an optimal decision model and solution algorithm based on the principles of “acting according to ability and proximity”. Accounting for each volunteer’s preferences, Gordon and Erkut^[11] set up a goal-planning model and generated a personnel grouping scheme using a spreadsheet-based decision support tool. The contribution of these studies is mainly to solve the decision-making problems of individual volunteers, rather than volunteer teams.

In fact, many volunteers participate in relief efforts in small groups (e.g., families, sports teams, religious groups, etc.)^[12], and in difficult situations, volunteers tend to be more sustained in team-based relief efforts. When emergencies come, the relevant relief departments often give priority to volunteer teams rather than individual volunteers. To this end, Chen, et al.^[13] designed a model to solve the matching problem between volunteer teams and rescue tasks. The model not only improves the satisfaction of bilateral participants, but also avoids decision bias due to lack of information. However, it only solves the decision-making problem of the volunteer team and does not take into account the decision-making issues between volunteers within the team. Therefore, this paper proposes a multi-task and multi-operation decision optimization method within a team of emergency volunteers.

The prospect theory, first proposed by Kahneman and Tversky^[14] in 1979, is an integrated theory of psychology and behavioral science. First applied in economics, prospect theory has been extended to several fields in recent years, such as asset allocation^[15], health domain^[16, 17], portfolio insurance^[18], transportation management^[19, 20], multi-attribute decision-making^[21–24], and emergency decision-making^[25, 26]. In terms of decision-making, Chen, et al.^[27] proposed a multi-attribute matching decision method for the decision-making problem considering the psychological expectations and perceptions of matching subjects. Fan, et al.^[28] suggested a decision analysis method based on cumulative prospect theory by taking into account the psychological factors of decision-makers and using their expectations of each attribute as a reference point. Zhang, et al.^[29] presented a gray multi-index risk decision-making method based on prospect

theory for the multi-index risk decision-making problem. In the decision-making process^[30–32], typical psychological behaviors include disappointment theory and regret theory. To address the problem of uncertain decisions in which decision-makers have disappointing behavior, Bell^[33] proposed the disappointment theory. Disappointment theory^[34–38], as an important theory for studying typical psychological behaviors, has received the attention of many researchers and has yielded relatively rich research results. The regret theory was first proposed independently by Bell^[39], Loomes and Sugden^[40], respectively, and it is also an important theory of behavioral decision-making^[41–44]. Zhang, et al.^[45] presented a decision analysis method based on regret theory when considering the behavior of decision-makers. Lu^[46] put forward an emergency decision-making method based on regret theory to solve the problem of whether emergency plans have an impact on the evolution of emergency scenarios. Zhang^[47] proposed a method for selecting and adjusting emergency scenarios that considers regret and disappointment behaviors in response to the emergency decision-making problem. This paper calculates the task leader's satisfaction value for each volunteer based on the prospect theory, and calculates the perceived utility values of disappointment theory and regret theory, and uses the perceived utility to measure the satisfaction level of task managers with each volunteer. Further comparative analysis is conducted through prospect theory, regret theory, and disappointment theory. As the subject of evaluating the satisfaction value of volunteers, the task leader's evaluation is influenced by behavioral and psychological factors, so psychological behavior plays an important role in the decision-making process.

From the above literature, it is clear that the current research mainly focuses on the dispatch of scattered volunteers, with little emphasis on the dispatch of volunteer teams. This article studies how to coordinate work dispatch within volunteer teams and proposes a method of emergency volunteer team internal participation in rescue decision-making that considers psychological behavior.

The rest of the paper is organized as follows. Section 2 describes the problem of multi-tasking and multi-operation within a team of emergency volunteers and defines the associated notation. Section 3 proposes a method of decision optimization within a team of emergency volunteers to address this problem. This includes calculating the task leader's satisfaction value for each volunteer based on prospect theory, aiming at the maximum satisfaction value, and using the multi-layer coded genetic algorithm to construct a decision optimization model for emergency volunteers. Section 4 provides a case study for analysis, and Section 5 concludes the paper.

2 Description of the Problem

In emergency rescue, the issue of multiple tasks and multiple operations within the emergency volunteer team is proposed for operations where the rescue tasks have a time sequence.

2.1 Problem Formulation

Suppose a volunteer team agrees to accept requests for several rescue tasks, each with different jobs. As shown in Figure 1, the team has m volunteers to complete n tasks, and task B_j ($j = 1, 2, \dots, n$) has l_j jobs. The first job of task 1 is performed by volunteer A_1 , the second job of task 1 is performed by volunteer A_m , and the l th job of task 1 is performed by

volunteer A_2 . The three digits in Figure 1 represent the decision-making situation of volunteers, for example, 101 represents the first job of task 1. 201 can be performed by Volunteer 2 or Volunteer 3, but ultimately can only be performed by one volunteer. The research object of this paper is how to solve the optimal decision-making scheme for multi-tasking and multi-operation for volunteers with different rescue capabilities and different times available for participation.

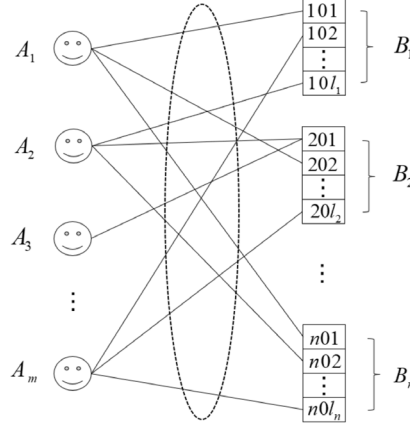


Figure 1 Multi-task and multi-job model within the volunteer team

2.2 Notations

The following symbols are used to indicate multi-tasking and multi-operation problems within a team of emergency volunteers:

$A = \{A_i | i = 1, 2, \dots, m\}$ denotes a collection of volunteers A_i .

$B = \{B_j | j = 1, 2, \dots, n\}$ denotes a collection of tasks B_j .

$C = \{C_k | k = 1, 2, \dots, l\}$ denotes a collection of jobs C_k .

$H = \{h_j^k | j = 1, 2, \dots, n, k = 1, 2, \dots, l\}$ represents the set of required times h_j^k for the jobs C_k in the task B_j .

$P = \{p_{ij}^k | i = 1, 2, \dots, m, j = 1, 2, \dots, n, k = 1, 2, \dots, l\}$ represents the set of expected time p_{ij}^k for the volunteer A_i to perform the jobs C_k in the task B_j .

$T = \{t_{ij}^k | i = 1, 2, \dots, m, j = 1, 2, \dots, n, k = 1, 2, \dots, l\}$ represents the set of actual time t_{ij}^k for the volunteer A_i to perform the jobs C_k in the task B_j .

$F = \{f_{ij}^k | i = 1, 2, \dots, m, j = 1, 2, \dots, n, k = 1, 2, \dots, l\}$ represents the set of completion time f_{ij}^k for the volunteer A_i to perform the jobs C_k in the task B_j .

$D = \{d_{ij}^k | i = 1, 2, \dots, m, j = 1, 2, \dots, n, k = 1, 2, \dots, l\}$ denotes the set of distances d_{ij}^k between h_j^k and p_{ij}^k .

$L = \{L(p_{ij}^k) | i = 1, 2, \dots, m, j = 1, 2, \dots, n, k = 1, 2, \dots, l\}$ denotes the set of profit and loss values $L(p_{ij}^k)$ of p_{ij}^k relative to h_j^k .

$S = \{S(p_{ij}^k) | i = 1, 2, \dots, m, j = 1, 2, \dots, n, k = 1, 2, \dots, l\}$ denotes the set of prospect satisfaction values $S(p_{ij}^k)$ of the task leader towards volunteer when the volunteers A_i perform the jobs C_k in the task B_j .

$\bar{S} = \{\bar{S}(p_{ij}^k) | i = 1, 2, \dots, m, j = 1, 2, \dots, n, k = 1, 2, \dots, l\}$ denotes the set of prospect satisfaction values $S(p_{ij}^k)$ normalized to $\bar{S}(p_{ij}^k)$.

Hypothetical conditions:

- 1) At the same moment, one job of one task can be performed by only one volunteer.
- 2) At the same moment, a volunteer can only perform one job of one task.
- 3) Each job of each task is not allowed to be interrupted once it starts execution.
- 4) All tasks have the same priority among themselves.
- 5) Some tasks have sequential constraints on their jobs, while others have no sequential constraints on their jobs.

3 Decision-Making Method

A decision-making optimization method within an emergency volunteer team is proposed for the problem of multi-tasking and multi-operation within the emergency volunteer team. Calculate the satisfaction value of the task leader to each volunteer based on the required time for the job and the expected time that the volunteer can complete the job. A multi-layer coded genetic algorithm is used to construct an optimization model for emergency volunteer decision-making with the objective of maximizing the satisfaction value.

3.1 Solving Satisfaction Value Based on Prospect Theory

Prospect theory, as an integrated theory of psychology and behavioral sciences, can consider the influence of human behavioral and psychological factors in the decision-making process^[48]. As the subject of evaluating the satisfaction value of volunteers, the task leader's evaluation is influenced by behavioral and psychological factors. Therefore, in the problem of multi-tasking and multi-operation within emergency volunteer teams, it is not only of theoretical value but also of practical significance that the satisfaction value is solved by using prospect theory.

Using the required time h_j^k for the job as the reference point and the expected time p_{ij}^k that volunteers can complete the job as the attribute value. The size between the attribute value and the reference point is compared, and the profit and loss value of the attribute value p_{ij}^k relative to the reference point h_j^k is obtained by calculating the distance between the attribute value and the reference point. The specific calculation is as follows:

- 1) The size between the reference point h_j^k and the attribute value p_{ij}^k can be compared as follows:

$$x(p_{ij}^k) = (p_{ij}^{\text{low}} + p_{ij}^{\text{up}})/2, \quad i = 1, 2, \dots, m, \quad j = 1, 2, \dots, n, \quad k = 1, 2, \dots, l. \quad (1)$$

$$x(h_j^k) = (h_j^{\text{low}} + h_j^{\text{up}})/2, \quad j = 1, 2, \dots, n, \quad k = 1, 2, \dots, l. \quad (2)$$

When $x(p_{ij}^k) > x(h_j^k)$, $p_{ij}^k > h_j^k$. When $x(p_{ij}^k) < x(h_j^k)$, $p_{ij}^k < h_j^k$.

- 2) The distance between the reference point h_j^k and the attribute value p_{ij}^k can be calculated as follows:

$$d_{ij}^k = \sqrt{\frac{1}{2} [(p_{ij}^{\text{low}} - h_j^{\text{low}})^2 + (p_{ij}^{\text{up}} - h_j^{\text{up}})^2]}. \quad (3)$$

- 3) The profit and loss value of the attribute value p_{ij}^k relative to the reference point h_j^k can

be computed as follows:

$$L(p_{ij}^k) = \begin{cases} -d_{ij}^k, & p_{ij}^k \geq h_j^k, \\ d_{ij}^k, & p_{ij}^k < h_j^k, \end{cases}$$

$$i = 1, 2, \dots, m, \quad j = 1, 2, \dots, n, \quad k = 1, 2, \dots, l. \quad (4)$$

4) The prospect satisfaction value can be calculated as follows:

$$S(p_{ij}^k) = \begin{cases} -\lambda(-L(p_{ij}^k))^\beta, & p_{ij}^k \geq h_j^k, \\ L(p_{ij}^k)^\alpha, & p_{ij}^k < h_j^k, \end{cases}$$

$$i = 1, 2, \dots, m, \quad j = 1, 2, \dots, n, \quad k = 1, 2, \dots, l, \quad (5)$$

where $\lambda = 2.25, \alpha = \beta = 0.88$.

5) In order to eliminate the influence of different magnitudes on the calculation results, the prospect satisfaction values $S(p_{ij}^k)$ can be normalized as follows:

$$\bar{S}(p_{ij}^k) = \frac{S(p_{ij}^k) - \min(S(p_{ij}^k))}{\max(S(p_{ij}^k)) - \min(S(p_{ij}^k))},$$

$$i = 1, 2, \dots, m, \quad j = 1, 2, \dots, n, \quad k = 1, 2, \dots, l. \quad (6)$$

3.2 Constructing Decision-Making Optimization Model

When volunteers perform job C_k in the task B_j , the goal is to maximize the prospect satisfaction value of the task leader for each volunteer, so the objective function can be expressed as follows:

$$\max \{ \bar{S}(p_{1j}^k), \bar{S}(p_{2j}^k), \dots, \bar{S}(p_{mj}^k) \},$$

$$j = 1, 2, \dots, n, \quad k = 1, 2, \dots, l. \quad (7)$$

The constraints can be represented as follows:

$$f_{ij}^k - f_{ij}^{k-1} \geq t_{ij}^k,$$

$$i = 1, 2, \dots, m, \quad j = 1, 2, \dots, n, \quad k = 1, 2, \dots, l. \quad (8)$$

$$f_{ie}^g - f_{ij}^k \geq t_{ie}^g,$$

$$i = 1, 2, \dots, m, \quad j = 1, 2, \dots, n, \quad k = 1, 2, \dots, l. \quad (9)$$

$$f_{ij}^k \geq t_{ij}^k,$$

$$i = 1, 2, \dots, m, \quad j = 1, 2, \dots, n, \quad k = 1, 2, \dots, l. \quad (10)$$

f_{ij}^k represents the completion time for the volunteer A_i to perform the jobs C_k in the task B_j , t_{ij}^k represents actual time for the volunteer A_i to perform the jobs C_k in the task B_j . Eq. (8) indicates that when jobs of the same task have sequential constraints, job C_k in the task B_j must be started after job C_{k-1} is completed. Eq. (9) indicates that volunteer A_i can only start executing job C_g in the task B_e after executing job C_k in the task B_j . Eq. (10) represents that the completion time of any job cannot be less than its execution time.

3.3 Solving Decision-Making Optimization Model

Genetic algorithms, also known as GA (Genetic Algorithms), were proposed by Professor Holland of the University of Michigan in the United States, as a parallel stochastic search optimization method based on the genetic mechanism of nature and biological evolution^[49]. Generally, the genetic algorithm converts the value of the objective function into the fitness value of the chromosome, and the fitness value of the chromosome in this paper is the maximum prospective satisfaction value of the task leader for each volunteer. The genetic algorithm is an iterative process, each iteration will make the fitness of individuals in the population bigger and bigger, and finally gradually approach the approximate optimal solution of the problem. Therefore, in this paper, genetic algorithm is used to solve the volunteer decision problem.

The main operations of the genetic algorithm include selection, crossover, and mutation. Since these several operations give the genetic algorithm the ability to keep moving towards the goal, however, these operations are probabilistic and as the search progresses more good individuals are generated, gradually approaching the optimal solution of the problem^[49]. In this article, a multilayer coded genetic algorithm is used to solve the volunteer decision problem in the following steps:

1) Individual code

The chromosome coding method adopts integer coding, the coding of this chromosome mainly consists of two parts. The first layer is the order of execution of all tasks, and the second layer is the volunteer serial number corresponding to each job of the task. As shown in Figure 2, this individual expresses the order of execution of two tasks that are both performed twice corresponding to three volunteers. Among them, the first four digits indicate the execution order of tasks, which is task 2 \rightarrow task 1 \rightarrow task 1 \rightarrow task 2 in order. Five to eight digits indicate volunteers, which is volunteer 3 \rightarrow volunteer 1 \rightarrow volunteer 2 \rightarrow volunteer 1 in order.

2	1	1	2	3	1	2	1
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Figure 2 Chromosome structure

2) Adaptation value

In this paper, the chromosome adaptation value based on multi-level coding genetic algorithm is the maximum prospect satisfaction value of the task leader for each volunteer. The adaptation value is calculated as follows:

$$fit = \max\{\overline{S}(p_{1j}^k), \overline{S}(p_{2j}^k), \dots, \overline{S}(p_{mj}^k)\},$$

$$j = 1, 2, \dots, n, k = 1, 2, \dots, l. \quad (11)$$

3) Select operation

The selection operation adopts the roulette wheel method (i.e., the proportional method of adaptation), and the selection is made according to the probability of individual adaptation values. The higher the adaptation value, the greater the probability of being selected. The larger the prospect satisfaction value in this paper, the more likely the volunteer is to be selected.

4) Crossover operation

The crossover operation is performed by randomly selecting two chromosomes from the population and then randomly choosing the crossover position for the crossover. The operation is as follows: If the crossover position is 5, the crossover will be performed from the initial position to the crossover position. The schematic diagram of individual exchange crossover is shown in Figure 3.

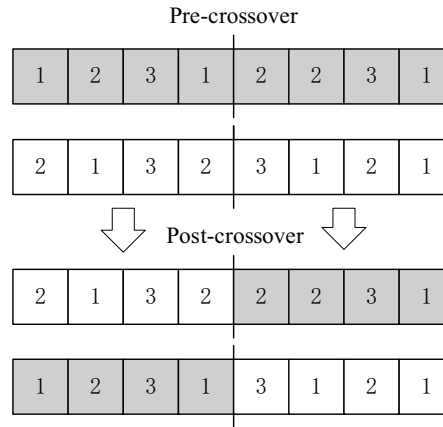


Figure 3 Schematic diagram of individual exchange and crossover

5) Mutation operation

The mutation operation was performed by randomly selecting mutant individuals from the population, selecting two positions for each individual and swapping the corresponding volunteer serial numbers, as shown below, with crossover positions 2 and 4. The schematic diagram of individual variation is shown in Figure 4.

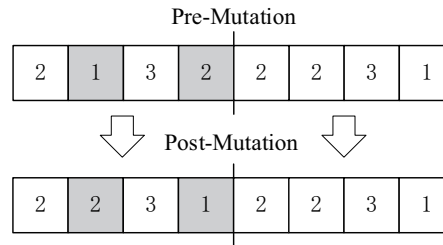


Figure 4 Schematic diagram of individual variation

4 Simulation Analysis

The method proposed in this paper is illustrated by an arithmetic example analysis using a typhoon disaster as an example. Suppose that after a typhoon disaster occurs in a certain place, 10 volunteers of a volunteer team need to complete 8 tasks such as accident rescue, personnel rescue and order maintenance. Among them, task 1 and task 5 go through 7 jobs, task 2, task 6 and task 7 go through 10 jobs, task 3 and task 8 go through 8 jobs and 8 jobs in task 8 are unordered, and task 4 goes through 9 jobs.

The volunteers available for each job are shown in Table 1. The content of the first row and the first column is $\{2, 3, 4\}$, indicating that the volunteers available for the first job of task 1 are volunteers 2, 3, and 4. The content of the second row and the second column is 7, indicating that the volunteer available for the second job of task 2 is Volunteer 7. The choice of volunteers varies depending on the occupation, age and gender of the volunteers.

The required time for each job is shown in Table 2. The content of the first row and the first column is $[9, 10]$, indicating that the required time for the first job of task 1 is 9 to 10 hours, where $[9, 10]$ represents the interval. The content of the second row and the second column is $[2, 5]$, indicating that the required time for the second job of task 2 is 2 to 5 hours.

The expected time for each volunteer is shown in Table 3. The content of the first row and the first column is $(9, [1, 10], [2, 9])$, which means that the volunteers available for the first job of task 1 are volunteers 2, 3, and 4, and the time to select volunteer 2 is 9 hours, the time to select volunteer 3 is 1 to 10 hours, and the time to select volunteer 4 is 2 to 9 hours. The content of the second row and the second column is $[1, 5]$, indicating that the time available

Table 1 Optional volunteers for jobs

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8
Job 1	$\{2, 3, 4\}$	8	2	$\{3, 5, 7, 9\}$	6	9	6	$\{7, 9\}$
Job 2	1	7	$\{2, 4, 7\}$	8	8	$\{3, 8\}$	5	1
Job 3	6	$\{5, 6\}$	5	$\{4, 6\}$	$\{2, 4, 9\}$	$\{2, 4\}$	5	1
Job 4	$\{3, 8\}$	4	1	3	9	7	$\{4, 7\}$	$\{3, 6\}$
Job 5	$\{4, 8\}$	7	2	2	1	8	$\{2, 3\}$	6
Job 6	9	$\{1, 4\}$	4	8	$\{4, 6\}$	$\{2, 5, 8\}$	3	$\{5, 8\}$
Job 7	6	$\{4, 5\}$	$\{1, 6\}$	3	4	9	$\{3, 7\}$	$\{1, 3\}$
Job 8		4	$\{2, 5\}$	$\{2, 4, 7, 8, 9\}$		$\{1, 9\}$	5	10
Job 9		$\{2, 6, 9\}$		$\{5, 9\}$		9	$\{2, 5\}$	
Job 10		$\{3, 7\}$				$\{1, 6\}$	10	

Table 2 Required time for each job

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8
Job 1	$[9, 10]$	$[4, 9]$	$[2, 6]$	$[3, 5]$	$[5, 6]$	$[6, 8]$	$[7, 9]$	$[8, 8]$
Job 2	$[2, 6]$	$[2, 5]$	$[5, 9]$	$[1, 4]$	$[4, 5]$	$[5, 6]$	$[6, 8]$	$[7, 8]$
Job 3	$[1, 8]$	$[8, 9]$	$[2, 3]$	$[4, 5]$	$[5, 7]$	$[4, 7]$	$[7, 9]$	$[2, 4]$
Job 4	$[5, 6]$	$[3, 8]$	$[2, 5]$	$[3, 4]$	$[4, 6]$	$[2, 6]$	$[7, 7]$	$[3, 9]$
Job 5	$[6, 10]$	$[7, 8]$	$[4, 6]$	$[6, 7]$	$[3, 5]$	$[3, 5]$	$[6, 7]$	$[2, 8]$
Job 6	$[4, 5]$	$[1, 9]$	$[6, 8]$	$[3, 9]$	$[6, 7]$	$[7, 9]$	$[7, 8]$	$[8, 9]$
Job 7	$[3, 6]$	$[6, 7]$	$[2, 7]$	$[3, 8]$	$[4, 5]$	$[6, 8]$	$[5, 7]$	$[7, 8]$
Job 8		$[9, 10]$	$[4, 9]$	$[5, 6]$		$[6, 6]$	$[1, 7]$	$[7, 9]$
Job 9		$[2, 3]$		$[7, 8]$		$[7, 9]$	$[6, 8]$	
Job 10		$[6, 7]$				$[6, 9]$	$[8, 9]$	

Table 3 Expected time for each volunteer to complete the job

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8
Job 1	9, [1, 10], [2, 9]	[3, 8]	[2, 3]	[3, 6], [3, 5], [3, 4], [3, 8]	[4, 5]	[5, 7]	[7, 9]	[7, 8], [8, 9]
Job 2	[5, 6]	[1, 5]	[2, 9], [2, 8], [2, 7]	[3, 5]	[3, 5]	[1, 6], [5, 6]	[6, 8]	[2, 7]
Job 3	[3, 9]	[7, 9], [5, 9]	[3, 6]	[3, 4], [3, 8]	5, 6, [4, 5]	[5, 6], [6, 9]	[6, 7]	[1, 8]
Job 4	[4, 9], [3, 10]	[3, 9]	[2, 9]	[3, 6]	[4, 5]	[5, 8]	[5, 7], 7	[5, 8], [7, 8]
Job 5	[3, 4], [3, 7]	[6, 9]	[2, 4]	[3, 8]	[4, 7]	[5, 10]	[5, 7], [6, 7]	[6, 9]
Job 6	[4, 5]	[4, 9], [6, 10]	[1, 8]	[3, 4]	[4, 5], [4, 8]	[6, 7], [5, 8], [5, 9]	[6, 7]	[4, 8], [1, 8]
Job 7	[5, 7]	[4, 10], [1, 8]	[1, 4], [2, 9]	[3, 9]	[4, 6]	[5, 7]	[6, 8], [5, 7]	[7, 8], [3, 8]
Job 8		[3, 9]	[2, 7], [3, 9]	[3, 8], [4, 9], [3, 5], [3, 9], [3, 7]		[5, 6], [3, 8]	[6, 7]	[3, 9]
Job 9		[3, 4], [1, 7], [2, 8]		[3, 6], [3, 10]		[2, 7]	[3, 7], [6, 7]	
Job 10		[1, 8], [1, 6]				[5, 8], [1, 6]	[4, 8]	

for volunteer 7 in the second job of task 2 is 1 to 5 hours. Due to the influence of volunteers' personality, ability and specialty and other factors, the time for each volunteer to perform the task is different.

4.1 Solving Process

According to the above Eqs. (1)~(6), the satisfaction values of task leaders for each volunteer were found out, as shown in Table 4. The content of the first row and the first column is {0.17, 0.35, 0.31}, which means that the volunteers available for the first job of task 1 are volunteers 2, 3, and 4, and the satisfaction value for volunteer 2 is 0.17, for volunteer 3 is 0.35, and for volunteer 4 is 0.31. The content of the second row and the second column is 0.26, indicating that the satisfaction value of volunteer 7 for the second job of task 2 is 0.26.

The basic parameters of the algorithm are as follows: The number of populations is 40, the maximum number of iterations is 50, the crossover probability is 0.8, and the variation probability is 0.6.

The changing trend of population fitness values based on prospect theory is shown in Figure 5.

Table 4 Satisfaction values of task leaders to each volunteer

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8
Job 1	{0.17, 0.35, 0.31}	0.14	0.21	{0.09, 0.11, 0.15, 0.04}	0.15	0.14	0.11	{0.14, 0.1}
Job 2	0.02	0.26	{0.19, 0.16, 0.14}	0.11	0.18	{0.27, 0.06}	0.07	0.28
Job 3	0.05	{0.15, 0.2}	0.06	{0.16, 0.04}	{0.17, 0.07, 0.18}	{0.07, 0.06}	0.17	0.04
Job 4	{0.04, 0.02}	0.07	0.03	0.07	0.14	0.03	{0.16, 0.09}	{0.05, 0.04}
Job 5	{0.17, 0.23}	0.08	0.2	0.19	0.06	0.02	{0.13, 0.09}	0.04
Job 6	0.11	{0.04, 0.04}	0.25	0.26	{0.2, 0.16}	{0.17, 0.16, 0.17}	0.14	{0.22, 0.31}
Job 7	0.05	{0.05, 0.26}	{0.21, 0.06}	0.06	0.08	0.14	{0.07, 0.09}	{0.1, 0.22}
Job 8		0.28	{0.19, 0.13}	{0.05, 0.04, 0.18, 0.03, 0.17}		{0.13, 0.21}	0.01	0.22
Job 9		{0.09, 0.05, 0.02}		{0.24, 0.24}		0.26	{0.2, 0.12}	
Job 10		{0.26, 0.26}				{0.14, 0.28}	0.22	

It can be seen from Figure 5: As the number of iterations increases, the envelope of the population fitness values tends to stabilize. After 50 iterations, the fitness value of the population tends to 1.9. The change of population mean tends to be stable in the 12th generation, which indicates that the multilayer coded genetic algorithm can effectively solve the scheduling problem of volunteers and rescue tasks.

The Gantt chart of volunteer decision-making based on prospect theory is shown in Figure 6.

The three digits in Figure 6 represent the decision-making situation of the volunteers, for example, 401 indicates the first job of task 4. The row from top to bottom of the matrix in the figure shows the order in which each volunteer performs the task. For instance, the second row indicates the order in which the 9th volunteer performs the task, and 601 indicates the first job of task 6.

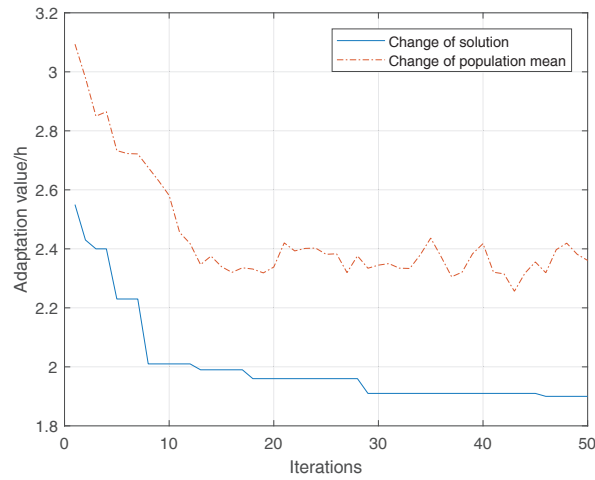


Figure 5 Variation of population fitness values based on prospect theory

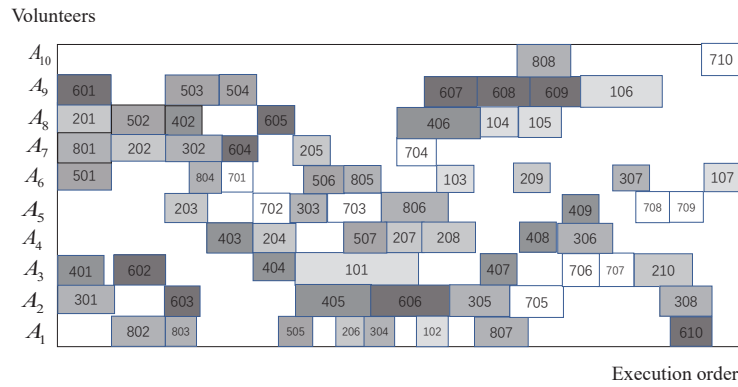


Figure 6 Gantt chart of volunteer decision-making based on prospect theory

4.2 Comparison and Analysis

In the decision-making process, typical psychological behaviors include disappointment theory and regret theory. The disappointment theory was first proposed by Bell^[33]. The basic idea of disappointment theory is that the decision-maker will compare the actual decision result with the expectation, and when the actual decision result is smaller than the expectation, the decision-maker will feel disappointed. On the contrary, it will feel pleasure. Regret theory was first put forward independently by Bell^[39], Loomes and Sugden^[40], respectively. The basic idea of regret theory is that decision-makers will compare their actual situation with the one they might have been in, and when they find that choosing other alternative options would result in better results, decision-makers will feel regret. Conversely, they will feel happy. The following is a comparative analysis between prospect theory and these two theories.

The changing trend of population fitness values based on disappointment theory is shown in Figure 7.

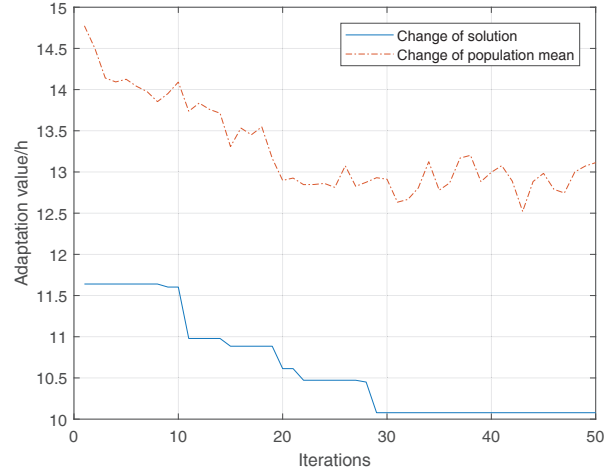


Figure 7 Variation of population fitness values based on disappointment theory

It can be seen from Figure 7: As the number of iterations increases, the envelope of the population fitness values tends to stabilize. After 50 iterations, the fitness value of the population tends to 10.1. The change of population mean tends to be stable in the 22nd generation.

The changing trend of population fitness values based on regret theory is shown in Figure 8.

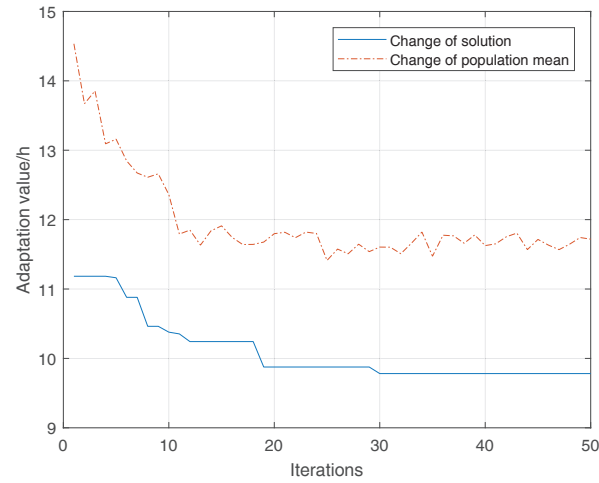


Figure 8 Variation of population fitness values based on regret theory

It can be seen from Figure 8: As the number of iterations increases, the envelope of the population fitness values tends to stabilize. After 50 iterations, the fitness value of the population tends to 9.9. The change of population mean tends to be stable in the 16th generation.

As can be seen from Figure 5, Figure 7 and Figure 8, the change of population mean based on prospect theory tends to be stable in the 12th generation, the change of population mean based on disappointment theory tends to be stable in the 22nd generation, and the change of population mean based on regret theory tends to be stable in the 16th generation. It shows that

the population fitness value based on the prospect theory converges faster, which can optimally solve the decision-making problems within the volunteer team.

The Gantt chart of volunteer decision-making based on disappointment theory is shown in Figure 9.

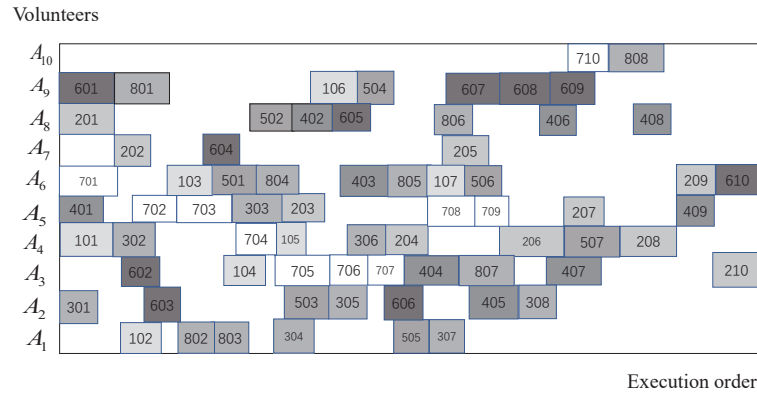


Figure 9 Gantt chart of volunteer decision-making based on disappointment theory

The matrix in Figure 9 represents the order in which each volunteer performs the tasks from top to bottom of each row. For example, the third row represents the order in which the 8th volunteer performs the task, and 201 indicates the first job of task 2.

The Gantt chart of volunteer decision-making based on regret theory is shown in Figure 10.

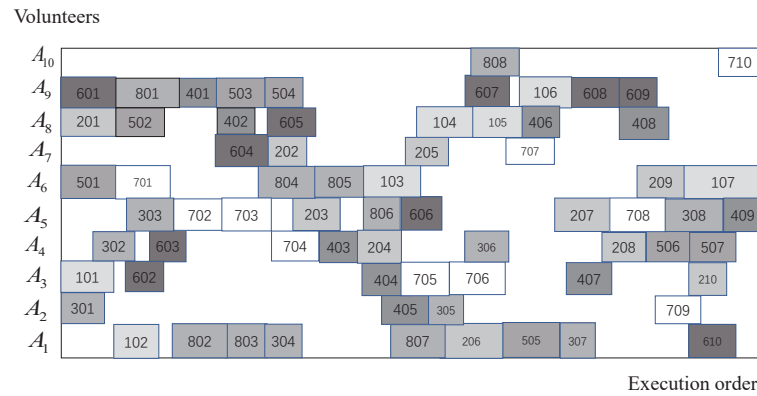


Figure 10 Gantt chart of volunteer decision-making based on regret theory

The row from top to bottom of the matrix in Figure 10 shows the order in which each volunteer performs the task. For instance, the fifth row stands for the order in which the 6th volunteer performs the task, and 501 indicates the first job of task 5.

5 Conclusions

This paper proposed an approach for the emergency volunteer team to participate in rescue decision-making within the team, considering psychological behavior, in response to the problem of decision-making within the volunteer team and the operational situation where rescue

tasks have a time sequence. Considering that task leaders are influenced by behavioral and psychological factors in the evaluation, the required time for the job is used as a reference point, and the expected time that volunteers can complete the job is used as an attribute value. The task leader's prospect satisfaction value for each volunteer is calculated based on prospect theory, and the perceived utility values of disappointment theory and regret theory are calculated to measure the task leader's satisfaction with each volunteer.

The proposed method has several advantages. First, this article studies how to coordinate task dispatch within volunteer teams and proposes an optimization method for multi-task and multi-operation decision-making within emergency volunteer teams. Second, the model was solved by a multilayer coded genetic algorithm, and the feasibility and effectiveness of the method were illustrated by the analysis of arithmetic examples, providing theoretical guidance for the rescue work. Third, it can be seen from Figure 5, Figure 7 and Figure 8 that the population fitness value based on the prospect theory converges faster, which can optimally solve the decision-making problems within the volunteer team.

Although the results obtained in this study are promising and reveal the potential of the proposed emergency volunteer team's internal participation in rescue decision-making, the limitations should be noted. First, the data in this article is hypothetical, not real data. Second, the comparative analysis section did not provide more quantitative results. Finally, the study aims to maximize the satisfaction of the task leader with the volunteers to achieve the decision-making of the volunteer team, without considering the two-way choice between the volunteer team and the rescue task. Therefore, further research is needed in the future.

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