Research on Site Selection and Algorithm of Military Logistics Center

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Abstract. As an important link in the guarantee, military logistics is becoming a hot topic. The paper briefly describes the general situation, summarizes the characteristics of military logistics and the research significance of military logistics center. It systematically analyzes the siting model and method of military logistics center, and gives two siting models of military logistics center. According to the special needs of military logistics, the paper establish the location model of military logistics center and simulation algorithm. On this basis, it carry out the experiment to verify the model, in which the results show that the model has a wide range of application and high precision.

1. Introduction
The location selection model of military logistics center is mainly designed for military logistics at ordinary times. In general, it is mainly to meet the daily needs of military users, such as training and support, without special requirements for time and other factors.[1] At this time, military benefits are mainly to ensure service quality and improve economic benefits. This model aims to establish a reasonable logistics center on the premise of fully meeting the needs of military users, and optimize the distribution on this basis to reduce the cost of military logistics support.[2]

2. The Model of Logistics Center
It is planned to set up a logistics center with limited capacity. There are a total of users to be served, and the service demand of each user is a constant value. And the following conditions shall be specified:[3]

• (a) The total amount of each logistics center shall not exceed the capacity of each logistics center;
• (b) More users than logistics centers: \( n > m \).
• (c) A logistics center can serve multiple users, but a user can only assign services to one logistics center.

The parameters used in the model are explained as follows:
Symbolic convention:
• \( i \): the serial number of the logistics center;
• \( j \): the serial number of the user;
• \( m \): the total number of logistics centers;
\( n \): the total number of users;
\( F_i = (x_i, y_i) \): the location of the logistics center on the two-dimensional geographic coordinate plane;
\( C_j = (u_j, v_j) \): the user's position on the two-dimensional geographic coordinate plane;
\( a_i \): the capacity of the \( i \)th logistics center;
\( b_j \): the quantity demanded by the \( j \)th user;
\( d(F_i, C_j) \): the Euclidian distance between the \( i \)th logistics center and the \( j \)th user.

\[
d(F_i, C_j) = \sqrt{(x_i-u_j)^2 + (y_i-v_j)^2}
\]

The decision variable:
\( z_{ij} \) is a 0-1 discrete decision variable, which represents the service demand distribution relationship between the user and the logistics center. If \( z_{ij} = 1 \), it means that the \( j \)th user will be provided by the assigned logistics center; if \( z_{ij} = 0 \), it means that the second user will be provided by the assigned logistics center. Thus, the following optimization objective function can be obtained:

\[
\min f(F, z) = \sum_{i=1}^{m} \sum_{j=1}^{n} d(F_i, C_j) \cdot z_{ij} 
\]

s.t. \( g_i(z) = \sum_{j=1}^{n} b_j z_{ij} \leq a_i, i = 1, 2, ..., m \) (2)
\( g_j(z) = \sum_{i=1}^{m} z_{ij} = 1, j = 1, 2, ..., n \) (3)
\( z_{ij} = 0 \text{ or } 1, i = 1, 2, ..., m; j = 1, 2, ..., n \) (4)

In which, equation (1) is an objective function, constraint (2) ensures that the total amount of services of each logistics center cannot exceed its own capacity, constraint (3) ensures that a user can only assign one logistics center service, constraint (4) represents the service demand distribution relationship between the \( j \)th user and the \( i \)th logistics center.

3. Improved Genetic Algorithm Combined With Lagrange Relaxation

The above models are non-convex and non-smooth mixed integer nonlinear programming models with complex constraints, belonging to the P-hard problem.

The location selection model of logistics center is optimized based on an improved genetic algorithm, in which the fitness function is closely related to the distribution of demand corresponding to each logistics center, and the sub-problem of service demand distribution for the specific location of logistics center is solved by Lagrange relaxation method. The genetic operator adopts the hybridization mode of linear convex combination, the variation mode of strong and weak, and the evolutionary \( \mu + \lambda \) selection mode, so as to effectively avoid the premature phenomenon of the algorithm and prevent it from converging to the local optimal solution quickly.

3.1. Coding

The location of the logistics center is a continuous variable, and the real floating point value is used for chromosome coding. Assuming that the \( k \) chromosome as follows:

\[
v_k = [(x_1^k, y_1^k), (x_2^k, y_2^k), ..., (x_i^k, y_i^k), ..., (x_m^k, y_m^k)]
\]

In which, \((x_i^k, y_i^k)\) is the location of the \( i \)th logistics center on the \( k \)th chromosome.

3.2. Initial population

For each chromosome in the population, the initial locations of the \( m \) logistics center are randomly generated within the square area containing all user locations. If the \( j \)th user is set \( C_j = (u_j, v_j) (j = 1, \cdots, n) \), the square area it contains can be determined by the following formula:

\[
x_{min} = \min \{u_j | j = 1, \cdots, n\}; \quad x_{max} = \max \{u_j | j = 1, \cdots, n\};
\]
\[ y_{\min} = \min \{ v_i | i = 1, \ldots, n \}; \quad y_{\max} = \max \{ v_i | i = 1, \ldots, n \} \]

When the population is initialized, for the \( k \) chromosome \( v_k (k = 1, 2, \ldots, n) \), each of its components \((x_i^k, y_i^k)\) must satisfy: \( x_i^k \) randomly generated in \([x_{\min}, x_{\max}]\), \( y_i^k \) randomly generated \([y_{\min}, y_{\max}]\).

3.3. Fitness Evaluation

For a given chromosome \( v_k \), the location of the logistics center is fixed, so the sum of the optimal allocation of Euclidian distance can be considered as the \( v_k \) fitness. The fitness function of chromosomes \( v_k \) as follows:

\[ F_i(t) = \frac{1}{f(F, x)} = \frac{1}{\sum_{i=1}^{m} \sum_{j=1}^{n} d(F_i, C_i) z_{ij}} \quad (6) \]

3.4. Lagrange relaxation method

Lagrange multiplier is \( \mu_i \), and it relax capacity constraint \( g_{ij}(z) = \sum_{j=1}^{n} b_j z_{ij} \leq a_i \), and then the Lagrange relaxation problem after transformation as follows:

\[ \min L(z; \mu_1, \mu_2, \ldots, \mu_l) = \sum_{i=1}^{m} \sum_{j=1}^{n} d(F_i, C_i) z_{ij} + \sum_{i=1}^{m} \mu_i (a_i - \sum_{j=1}^{n} b_j z_{ij}) \quad (7) \]

\[ \text{s.t. } g_{m+j}(z) = \sum_{j=1}^{n} z_{ij} = 1, j = 1, 2, ..., n \quad (8) \]

\[ z_{ij} = 0 \text{ or } 1, i = 1, 2, ..., m; j = 1, 2, ..., n \quad (9) \]

Because of the good separability of the Lagrange relaxation problem, it can be transformed into \( n \) independent subproblem, in which each subproblem is to solve the problem of choosing the minimum value from the \( m \) real value, thus completing the calculation of the fitness function.[9-10]

3.5. Genetic operator. Hybridization adopts the hybridization mode of linear convex combination

Let the two father chromosomes \( v_1 \), \( v_2 \) as follows:

\[ v_1 = [(x_1^1, y_1^1), (x_1^2, y_1^2), \ldots, (x_m^1, y_m^1)] \quad (10) \]
\[ v_2 = [(x_1^2, y_1^2), (x_2^2, y_2^2), \ldots, (x_m^2, y_m^2)] \quad (11) \]

Then the offspring they produce are determined by the following formula:

\[ x_i^1 = \alpha \cdot x_i^1 + (1 - \alpha) \cdot x_i^2 \quad (12) \]
\[ y_i^1 = \alpha \cdot y_i^1 + (1 + \alpha) \cdot y_i^2 \quad (13) \]
\[ x_i^2 = (1 - \alpha) \cdot x_i^1 + \alpha \cdot x_i^2 + (1 - \alpha) \cdot y_i^1 + \alpha \cdot y_i^2 \quad (14) \]

The two ways of variation are weak variation and strong variation. Weak variation is the addition of a small random disturbance to the father's chromosome to produce offspring, while strong variation is the re-generation of offspring in the same way as the initial population. Let the progeny chromosomes be denoted as

\[ \tilde{v} = \{ v + \delta, \text{Strong variation} \} \quad (15) \]

In which, \( \delta = [\delta_1, \delta_2, \ldots, \delta_2m-1, \delta_2m] \) is the random number distributed over \(( -\alpha, \alpha ) (i = 1, 2, \ldots, 2m) \), and \( \alpha \) is a very small positive number; \( \theta = [(\theta_1^x, \theta_1^y), (\theta_2^x, \theta_2^y), \ldots, (\theta_m^x, \theta_m^y)] \) \( \theta_i^x \) is the random number in \([x_{\min}, x_{\max}]\), \( \theta_i^y \) is the random number in \([y_{\min}, y_{\max}]\).

It use the method \( \mu + \lambda \) to choice. This is a deterministic selection process that selects the best chromosome from the parent \( (\mu) \) and the child \( (\lambda) \), and prohibits the selection of the same chromosome from the population. If less than \( \mu \) one result is selected, it is made up at random in the same way that individuals of the population were originally generated. This method can effectively
avoid the premature phenomenon of genetic algorithm and prevent it from converging to the local optimal solution quickly.

4. Case Analysis

According to the data of a military logistics center, there are 20 grass-roots troop users, and the locations of 3 logistics centers need to be determined. The position of each user and its material demand are given in the following table. Taking into account the requirements of national defense and military, the coordinates in the table are the relative geographical coordinates after processing. The maximum material capacity of the three logistics centers is $a_1 = 500, a_2 = 500, a_3 = 400$, and the numerical value after standardized treatment, which it does not represent the actual capacity value. It shows as Table 1.

Table 1. The geographical location and material requirements of grass-roots units

| j | (u_j, v_j) | b_j | j | (u_j, v_j) | b_j | j | (u_j, v_j) | b_j |
|---|------------|-----|---|------------|-----|---|------------|-----|
| 1 | (700, 264) | 30  | 6 | (386, 198) | 70  | 11| (318, 138) | 60  | 16| (814, 198) | 50  |
| 2 | (166, 295) | 90  | 7 | (496, 368) | 90  | 12| (414, 138) | 20  | 17| (690, 300) | 80  |
| 3 | (378, 332) | 90  | 8 | (682, 240) | 90  | 13| (682, 297) | 40  | 18| (72, 540)   | 60  |
| 4 | (398, 152) | 60  | 9 | (175, 118) | 40  | 14| (281, 226) | 60  | 19| (705, 518) | 80  |
| 5 | (214, 276) | 70  | 10| (544, 242) | 70  | 15| (127, 576) | 100 | 20| (484, 652) | 90  |

The parameters of genetic algorithm: the population number is 20, the maximum evolutionary algebra is 200, the hybrid rate is 0.8, the mutation rate is 0.2. In accordance with the location allocation model and the solution programming idea, the program was run for 50 times in Matlab7.1, and the average value of the results was used to obtain the globally optimal logistics center address, and the relationship between logistics center and user demand allocation was also obtained. The optimization results are shown in the Table 2.

Table 2. Best logistics center location and user distribution

| No | Address $(x_i, y_i)$ | Assigned Troop Users | Actual Capacity Condition | Maximum limiting Capacity |
|----|---------------------|----------------------|--------------------------|--------------------------|
| 1  | (210, 351)          | 2,5,6,9,14,15,18    | 490                      | 500                      |
| 2  | (545, 152)          | 1,3,4,8,10,11,12,16 | 470                      | 500                      |
| 3  | (618, 407)          | 7,13,17,19,20       | 380                      | 400                      |

In terms of the processing method of solving the results, we adopt the method of calculating the average value of 50 runs. After 50 runs of genetic algorithm, the final average objective function value is 4223. Compared with the results obtained in each run, it is found that the fluctuation of each result is very small. It can be verified that increasing the number of program runs can further improve the stability and accuracy of the results, but more than 50 runs have little improvement on the results, so it is reasonable to take the result of 50 runs as the result of the global optimal solution.

5. Conclusions

The data results show the specific location of the logistics center and the distribution of users, proving that the model and algorithm we proposed under normal conditions can achieve the optimization goal of site selection and establishment of multiple logistics centers on a continuous plane. In the debugging of the program, Lagrange relaxation method plays a very good role, it simplifies the complex fitness function calculation problem into an independent sub-problem, greatly improving the
calculation time. Comparing the results of each run, the fluctuation in the average is small. It can be seen that the model and its optimization algorithm have high stability and effectiveness.

Acknowledgments
This research was financially supported by the Independent Innovation Project of Army Academy of Armored Force.

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