Problem Chosen	2022	Team Control Number
B	ShuWei Cup Summary Sheet	2022101312870

Summary

In response to question 1

The problem of firepower allocation, using **multi-objective planning**, mainly establishes two models **firepower coverage model and position elapsed time model**, i.e. to ensure the maximum range of attack and the fastest speed of support for both sides. As there are many factors for different types of tank range, travel speed, gunpowder and geographical restrictions, the main factors are selected as guidelines to determine **the progressive hierarchical index system model** for firepower allocation.Simplify the model of red and blue position locations, and select 30 points with the greatest attack difficulty in the area where the attack nodes are gathered. Command positions are selected using **the Topsis multi-indicator preference method**, the indicator system is mainly from whether it is easy to develop firepower, whether it is easy to motivate, whether to improve the survivability of the three major aspects to determine the preferred indicators, and through the setting of indicators and the allocation of weights to make a comprehensive evaluation of the strengths and weaknesses of the program, to provide a basis for the decision to command the place, to determine the main four important indicators, different indicators are closely related to constitute an indicator class.

In response to question 2

Use **a multi-objective ant colony algorithm** to find the shortest route for each red and blue bike using the 30 nodes that have been identified as the most difficult to attack in the first problem. Considering the potential danger, it is not advisable for the vehicles to depart from the same starting point, so the command site and the prepared position are used as the starting point for the transport of supplies. Set at least the vehicles needed as variables, respectively, from the three starting points, will consider the vehicle travel distance and vehicle and personnel loss and other factors to **form a recursive hierarchy model**, the use of **AHP** will be the shortest path divided into suitable areas, and each area requires at least one vehicle and the nearest point from the three material points to divide the area.

In response to question 3

Combining the first two problems, we use **the ACO algorithm** to **plan the trajectory of the red side's UAVs** to find the optimal trajectory so as to effectively avoid the threats of radar, missiles, anti-aircraft guns, and atmosphere in space, and thus achieve a better attack; according to the **three retreat points** of the blue side, we use **the k-means model** to find the optimal retreat path; we collect and optimize the communication data, and through **the neural network model**, in the case of good communication, **each node is instructed by the general command**, and in the case of communication interruption, each node fights by itself and retreats towards the retreat node.

Keyword: Communications operations,MOP;Topsis,AHP,ACO,K-Means cluster analysis algorithm,Artificial neural networks algorithm,Material scheduling,Weapon distribution

Content

1. Introduction

Modern warfare with multi-dimensional combat space, multiple combat forces involved in the form of joint firepower strikes has become the norm, system operations in how to reasonably organize combat forces, arrange a variety of weapons, allocate different combat targets, and then achieve maximum results and minimum battle damage, and ultimately achieve the tactical objectives has been the concern of countries around the world. Intelligent firepower and command and control system in the information environment is based on the development of aviation firepower and command and control system, which is mutually compatible with the concept of information technology and networked operations to meet the military needs of modern warfare. Designing a set of scientific strategies for pre-war planning and assisting commanders in rational decision making has important theoretical and practical significance. This paper focuses on the joint firepower strike targets and the distribution of materiel.

2. Problem analysis

2.1 Data analysis

As can be seen by analyzing Annex 1, the annex gives the coordinates of the position points, the camp, the difficulty of the attack, and the length of each path. Considering it comprehensively, it is easy to find that the annex data can be roughly divided into two categories: aggregated class points and dispersed class points. In order to simplify the scale of the problem and improve the stability of the model, we adopt the research idea of aggregating local instead of overall, while scattered points are not considered.

By analyzing Annex 2, we can see that the annex gives detailed information about the weapons and equipment of both red and blue sides. Such as tank attack range, travel speed, etc. We fuzzy compare the two sets of data and synthesize several conclusions, such as: red side tanks generally move faster than blue side, red side artillery range is slightly higher than blue side, etc.

2.2 Analysis of question one

By analyzing Annex 1 and Annex 2, consider multiple factors such as weapon and equipment disparity and advantages and disadvantages points between red and blue sides, marching distance, etc. for reasonable weapon allocation deployment and quantity size distribution. Comprehensive and integrated existing model assumptions to find the optimal command points and alternative position points.

2.3 Analysis of question two

Based on the assumptions in question one, the existence of potential attack strategies on the enemy side and the problem of dispatching and allocating material transport vehicles in the non-supply mode need to be considered. And give reasonable results, such as the red and blue attack scenarios and the total number of workers versus the total number of vehicles.

2.4 Analysis of question three

Based on the assumptions of the first two questions, set the retreat node of the blue army, and comprehensively examine all factors to give the red side's attack plan and the blue side's retreat plan. At the same time, wartime communication as an important factor, consider the difference between the blue retreat plan in the case of good communication and communication failure.

3. Symbol and Assumptions

3. 1 Symbol Description

1. Only two factors are considered regarding firepower allocation: fire coverage and position elapsed time.
2. It is stipulated that each fire unit has and has only one attack target and that the number of fire units per target is not more than or exactly covered at one time.
3. A single supply of materiel is sufficient and easy to gather, and there is no shortage of materiel between types.
4. All supplies are transported in self-designated transport vehicles, and the total amount of transported supplies, including medical supplies, military supplies and daily supplies are uniformly considered as net weight loads, all divided among individual transport vehicles, and a single vehicle completes the entire transport.
5. Command, alternate transfer points are considered as material receiving and dispensing points. Vehicles depart from the distribution point, go through all positions one and only once, and return to the receiving and dispatching point by the same route after completion.
6. All transport roads comprehensive examination for the road, and drivers and vehicles are in normal, callable state.
7. To ensure the practicality, the vehicle transportation is not set in the repair and deployment. The implementation of 24-hour work, rest time in the middle of the journey is not counted in the consumption. To ensure safety, each vehicle is equipped with three drivers, taking turns to alternate driving and rest.
8. Only four external space threats are considered in the UAV trajectory planning.

9. Assume that the radar can scan the surrounding environment in all directions.
10. Assume that the UAV's fly at the same altitude and solve the UAV cluster's trajectory planning problem in two-dimensional space.
11. Assume that the set of starting and destination points in the trajectory planning belong to the planning space.

3.2 Fundamental assumptions

Variable symbol	Variable explanation
N	Firepower units
M	Position Points
e_{ij}	Fire coverage effect
X_{ij}	Fire coverage units
G1-G4	Consideration factors
S_{ij}	Business Rights Matrix
S1-S8	Shipping Solutions
U	Transportation Solution Score
D	Optimal Target
BN	Blue Team Transport Fleet
RN	Red Team Transport Fleet
Q	Comprehensive evaluation
Ci	Clustering Center
m	Iterative Dimension
SC	Contour factor

4. Model Establishment and Solving of Problem one

4.1Model Establishment

Regarding fire distribution only two factors are considered:fire coverage and position elapsed time.

1.Fire coverage model:

Let N fire units shoot M position points. The i-th fire unit (i=1,2,... ,N) fires at the j-th target (j=1,2,... ,M) for the effect of fire coverage is e_{ij} ,for the effect of fire coverage is X_{ij}. Denote as follows[1]:

$$X_{ij} \begin{cases} 1 & when\ the\ i-th\ fire\ until\ covers\ the\ j-th\ target \\ 0 & when\ the\ i-th\ fire\ until\ does\ notcovers\ the\ j-th\ target \end{cases} \quad (1)$$

To make the best effect, i.e., the maximum area of fire coverage, the objective function is set:

$$\max\gamma(x)=\sum_{i=1}^{m}\sum_{j=1}^{n} e_{ij} * X_{ij}$$

The corresponding constraint is expressed as follows.:

$$\sum_{j=1}^{k} X_{ij} = 1, (i = 1,2,\ldots, N)$$

$$\sum_{i=1}^{k} X_{ij} < N_j, (j = 1,2,\ldots, M)$$

Specify that each fire unit has and has only one attack target and that the number of fire units per target is not more than or exactly covered at one time.

2.Position elapsed time model.

With N fire units firing M position points, it is known that for three types of tanks, it is assumed that T1,T2,T3 denote the drive-to time for light, medium, and heavy tanks, respectively. Since the speed of all three types of tanks is different, we specify V1,V2,V3 to represent the speed of different types of tanks respectively. (V1>V2>V3). Therefore, the objective function is minimal.

$$\min\gamma(x)=\sum_{i=1}^{m}\sum_{j=1}^{n} T_{ij} * V_{ij} \quad (2)$$

Assume that the weights of the fire coverage model and the position elapsed time model are denoted as w1 and w2, respectively, so as to establish the optimal model representation of the allocation scheme problem as :

$$\text{Max}\vartheta(x)=w1f1+w2f2=\sum_{i=1}^{m}\sum_{j=1}^{n} e_{ij} * X_{ij}+\sum_{i=1}^{m}\sum_{j=1}^{n} T_{ij} * V_{ij} \quad (3)$$

According to the above model, the allocation of firepower resources between the red and blue teams can be solved for under the dual objective model that satisfies the maximum firepower coverage area and the minimum arrival time to the position. (See Appendix 2 for details)

3. Modeling of the selection of command positions.

Let there be n preferential indicators and m solutions to be preferred, and let the j-th indicator of the i-th solution take the value of x_{ij}, then it constitutes an evaluation matrix with m rows and n columns X=（x_{ij}）m*n.

In the preferential indicators of command sites, the larger the positive indicator the better, the smaller the negative indicator the better, and the moderate indicator is in an interval or a certain value is the best, then the selection range of command sites and reserve positions. Comparability between indicators can be standardized, and the linear transformation method is used in the model to determine the command and reserve positions[2].

$$x_j^* = \begin{cases} max_i\{x_{ij}\} & j\ is\ the\ positive\ index \\ jmax_i\left\{\dfrac{1}{|x_{ij}-r_0|}\right. & j\ is\ a\ moderate\ index \\ min_i\{x_{ij}\} & j\ is\ the\ inverse\ index \end{cases} \tag{4}$$

By x_j^*'s normalizing（x_{ij}）m*n, it is transformed into（y_{ij}）m*n:

$$y_{ij} = \begin{cases} x_{ij}/x_j^* & j\ is\ the\ positive\ index \\ \dfrac{|x_{ij}-r_0|}{x_j^*} & j\ is\ a\ moderate\ index \\ x_j^*/x_{ij} & j\ is\ the\ inverse\ index \\ 1 & when\ x_{ij}=r_0 \end{cases} \tag{5}$$

4.2Solving of the model

Firepower allocation.

In order to arrive at the distribution scheme that covers the widest area of firepower under the constraints. The main considerations are the travel distance of different types of tanks and the firing distance of self-propelled guns as well as the travel speed, the time spent to reach each position point, the quantity of consumed artillery ammunition, and other factors. That is, we need to find a satisfactory solution for the allocation under multiple criteria. The following figure gives the model of the progressive hierarchical index system for firepower allocation.

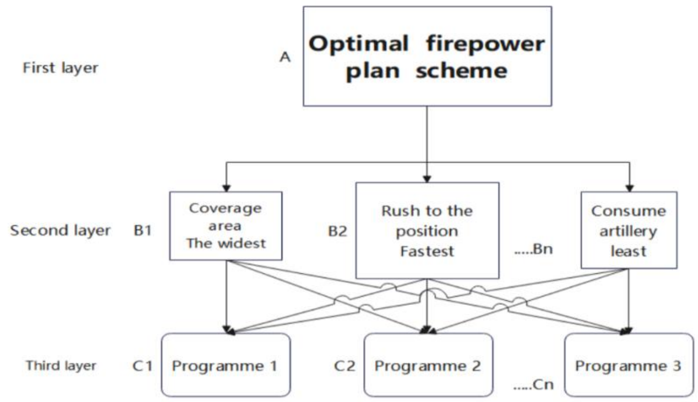

Figure 4-1:Fire power distribution progressive hierarchy model

Figure 4-2:The number of red and blue teams and the number of weapons and equipment gap

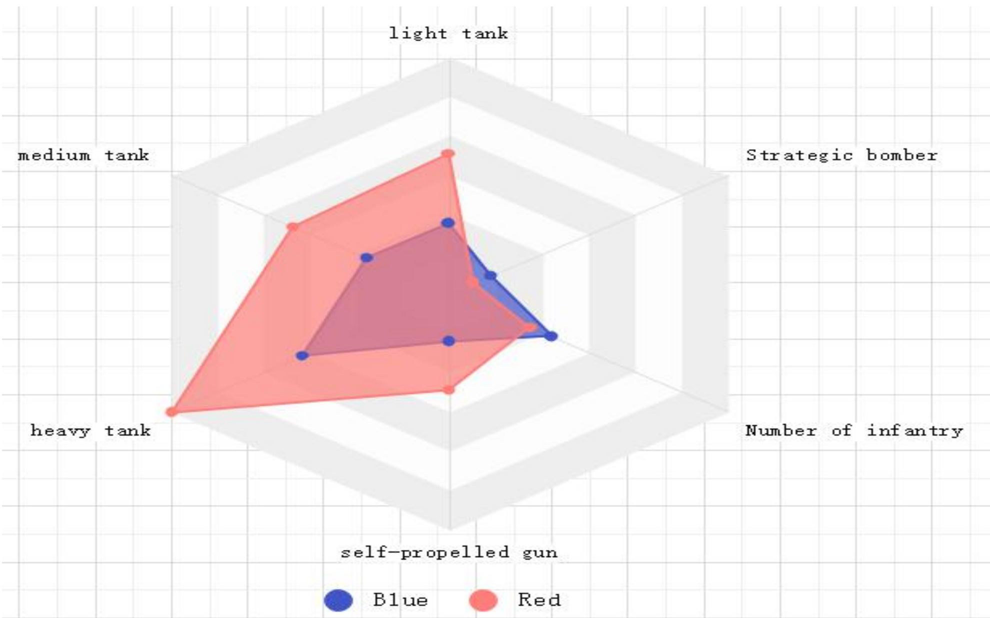

Figure 4-3:The number of red and blue teams and the number of weapons and equipment gap

From the above two charts, we can see that although Red has more infantry and drones than Blue, the number of tanks and artillery is close to a multiple less than Blue. Moreover, by comparing the difference in weapons, it is easy to find that Red's tanks move faster than Blue's and have better artillery range than Blue. These results will be conducive to the red side to better maneuver and adopt the tactics of interpenetrating tour, while for the blue side, the number of blue tanks determines that the blue side is more suitable for easing the red side's attack and defense.

According to the above model, the allocation of firepower resources between the red and blue teams can be solved for under the dual objective model of satisfying the maximum firepower coverage area and minimum arrival time to the position. (See Appendix 2 for details)

3.Selection of command positions.

After preprocessing the data, we decided to take the aggregated sparse points as the study object for the purpose of simplifying the problem and optimizing the model. As shown in Fig.

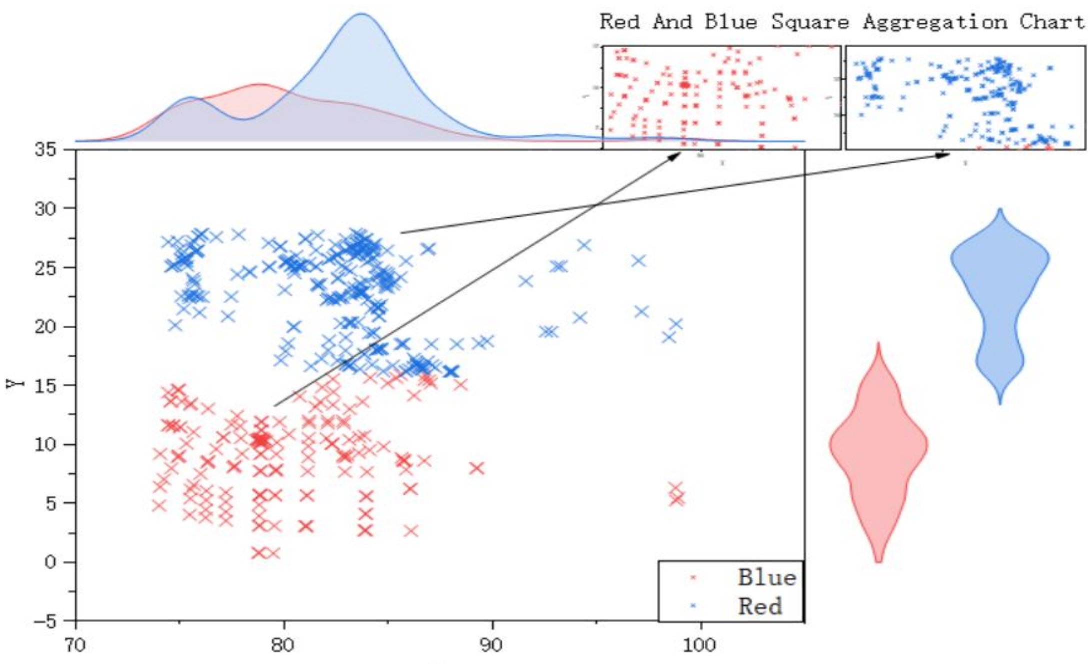

Figure 4-4：Red and blue position point deployment map

In ensuring that the red and blue sides of the formation of points of great difficulty to give priority to as a drop point. Select 30 points in the red and blue sides respectively (see Annex 1 for the location table) as indicators. As shown in the figure.

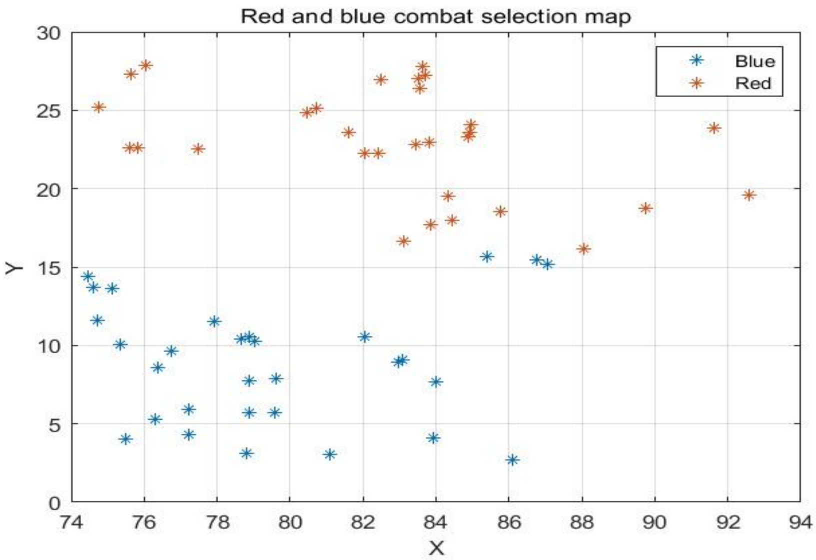

Figure 4-5:Red and blue position point selection chart

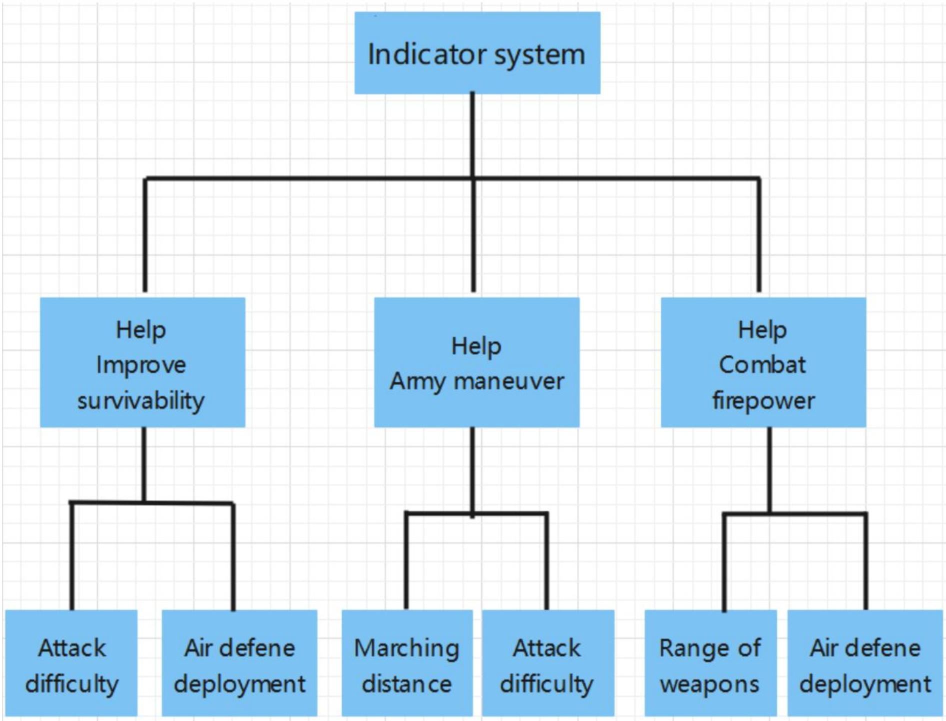

Figure 4-6:Multi-objective recursive hierarchical model diagram

The positions are selected, and the attack difficulty G1, air defense deployment G2, marching distance G3, and weapon range G4 are considered as factors using Topsis entropy method, and given weights, they are entered into the entropy weight matrix S_{ij}. Based on the literature search to determine expert scoring, we use G1, G4 as the first factor to be considered, and G2,G3 as auxiliary factors to be considered. The tuple where the consideration factors are located in the two groups of teams satisfying the red side and blue side is used as scenarios S1-S8[3].

Table 4-1:Red Camp(S1-S4)

S	ID	X	Y	G1	G4
S1	6	76.041975	27.85373333	1	1
S2	8	75.655825	27.27536667	1	1
S3	108	83.860225	17.6948	1	0.6
S4	147	75.584325	22.61933333	1	0.9

Table 4-2:Blue Camp(S5-S8)

S	ID	X	Y	G1	G4
S5	134	75.340375	10.0837	0.99	1
S6	385	75.49475	4.042833333	0.98	0.4
S7	428	76.284125	5.285033333	0.98	0.5
S8	30	83.0695	9.070433333	0.97	0.9

The entropy values are given under different scenarios S by finding literature and combining expert scoring.

Table 4-3：Entropy power matrix S_{ij} diagram

Programs/indicator S	Air defense deployment G2	Marching distance G3
S1-S4	1/4	1/6
S5-S8	1/6	1/4

From the entropy weight matrixS_{ij}(i=1,2,...,8;j=1,2,...,8),the weights of the indicators were obtained as (to two decimal places):

W = {0.40,0.13,0.16,0.31}， using the ideal solution method will find the U and sort the table.

Table 4-4:Red team program score ranking table

Red Discriminate	S1	S2	S3	S4
U	0.8721	0.8662	0.7210	0.7719
Ranking	1	2	4	3

Table 4-4:Blue team program score ranking table

Blue Discriminate	S5	S6	S7	S8
U	0.8521	0.6982	0.7126	0.8110
Ranking	1	4	3	2

4.3 conclusion

For the red side, option 1 i.e. the point with ID=6 is suitable to be considered as a command position. ID=108,ID=147 is suitable to be considered as an alternative position.

For the blue side, option 5, the point with ID=134, is suitable to be considered as a command position. ID=385,ID=428 is suitable to be considered as an alternative position.

5.Model Establishment and Solving of Problem two

5.1Model Establishment

Ant colony algorithm under multiple objectives

Study the red and blue sides separately, and take the red side as an example. In the scatter diagram of 30 position points, assume that the transport vehicles from any location $X_i(i = 1,2,\ldots,30)$ That is, to ensure that the transport vehicle traverses all points and avoids points that have already been traversed, so that the total path is the shortest. Construct the basic shortest path model:

$$\text{Min } f(x) = \sum_i C_i X_i$$

$$\begin{cases} g_j(x) > 0 & j = 1,2,\ldots.,m \\ h_k(x) = 0 & k = 1,2,\ldots.,l \end{cases} \tag{6}$$

where the stipulation C_i is the weight of the i-th path, $g_j(x)$ and f(x) is the constraint.

"The effect of not considering the time window (time constraint) on the optimization algorithm under multiple objectives"

Considering each position point as N cities and transport vehicles as M ants, the set A is the set of nodes of all cities and $L_i(i \in 1,2,\ldots,n)$ denotes the distance between city i and city j; T_{ij} denotes the pheromone value in the path at a certain moment.

(1) Pheromone initialization

$T_{ij}(0)$ = const ----const is expressed as a constant

It is specified that each path has the same pheromone concentration at the initial moment

(2) State transfer rate criterion

At a certain point, each ant can independently select the next city that has not yet been visited and record the currently selected city in the prohibition table NoList.

$$P_{ij}(t) = \begin{cases} allowed = \{C - NoList\} \\ \dfrac{[T_{ij}(t)]^a * [n_{ij}(t)]^b}{\sum_{s \in allowed} [T_{ij}(t)]^a * [n_{ij}(t)]^b} \end{cases} \tag{7}$$

A denotes the degree of influence of pheromones on the path selection of ants; b denotes the degree of importance of the heuristic function.

(3) Pheromone updates

When all ants have completed a traversal of all cities, the information of each path node is updated.

$$\begin{cases} T_{ij}(t+n) = (1-\rho) * T_{ij}(t) + \Delta T_{ij}(t) \\ \Delta T_{ij}(t) = \sum_{k=t}^{m} \Delta T_{ij}^{k}(t) \end{cases} \tag{8}$$

$\Delta T_{ij}(t)$denotes the increment of pheromones on the path.

5.2Solving of the model

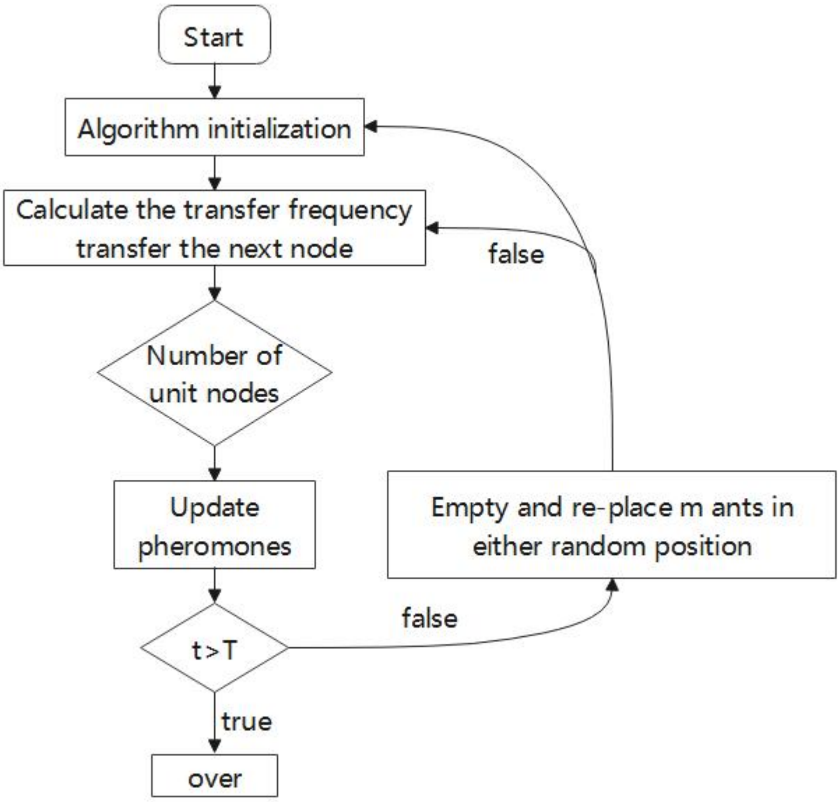

Figure 5-1:Flow chart of ant colony algorithm

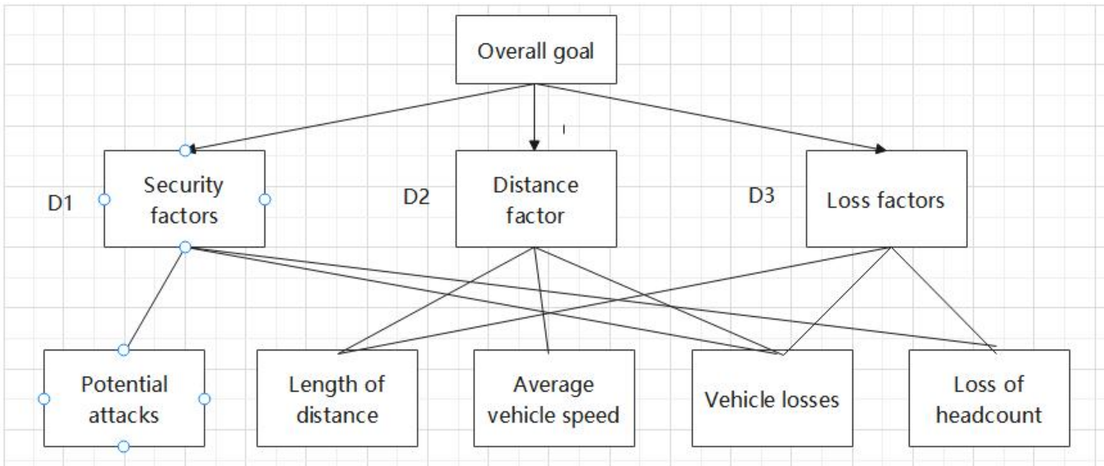

Figure 5-2:Recursive hierarchy model diagram

The relative importance of each factor is expressed by 1-9, and the judgment matrix is constructed[5-6].

Table 5-1:Judgment Matrix

D	D1	D2	D3	ŵ
D1	1	1/3	1/6	0.382
D2	3	1	1/5	0.843
D3	6	5	1	3.107

The individual factors of the judgment matrix were scored by experts according to the relevant literature. For objective D constructing each criterionD_i, the following$D - D_i$ consistency tests are thought to be performed.

The weight coefficients to be tested for each objective

$$w_i = \sqrt[n]{m_i}$$

m_i denotes the product of the factors in the i-th row and n is the size of the matrix.

Normalization process to obtain the maximum characteristic root:

Normalization process to obtain the maximum characteristic root

$$\lambda_{max} = \frac{1}{n} \sum_m^n \frac{(Aw_i)}{w_i} = 3.094 \tag{9}$$

Calculation of consistency index CI

$$\mathrm{CI} = \frac{\lambda_{max} - n}{\mathrm{n-1}} = 0.047 \tag{10}$$

Calculate the consistent type proportion CR

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} = 0.09 \tag{11}$$

Clearly, CR=0.09<0.1 passed the consistency test, i.e., the weight coefficients of this hierarchy are reasonable.

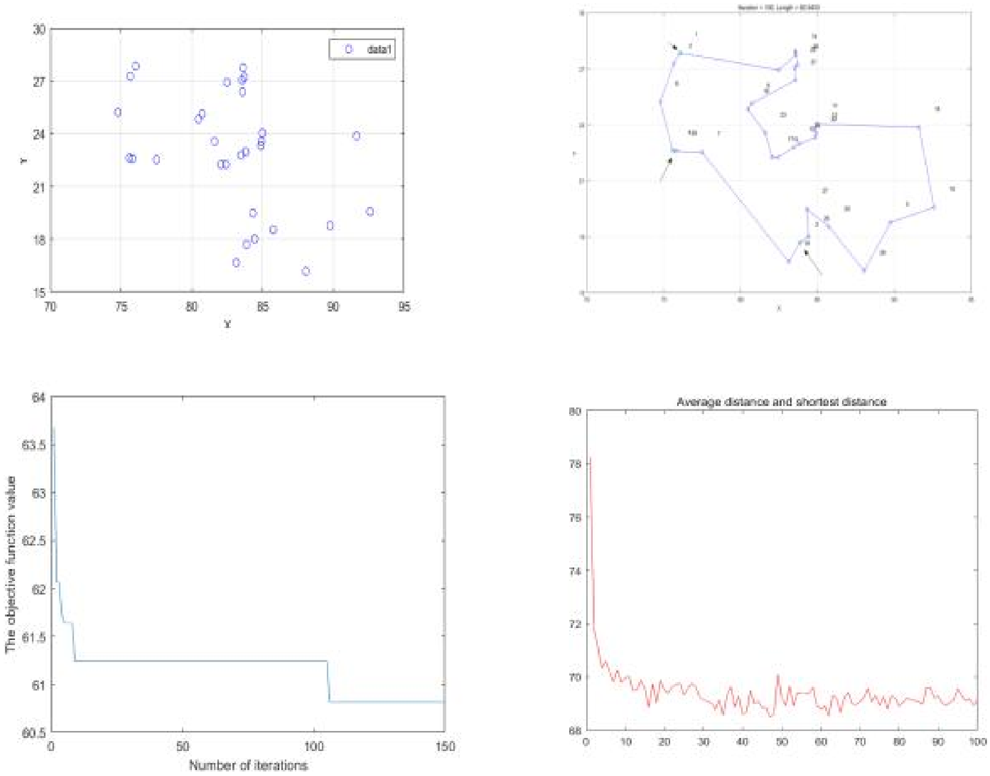

Figure 5-3:Red team scatter plot ---- ant colony algorithm results graph
The shortest path length is 61.2396

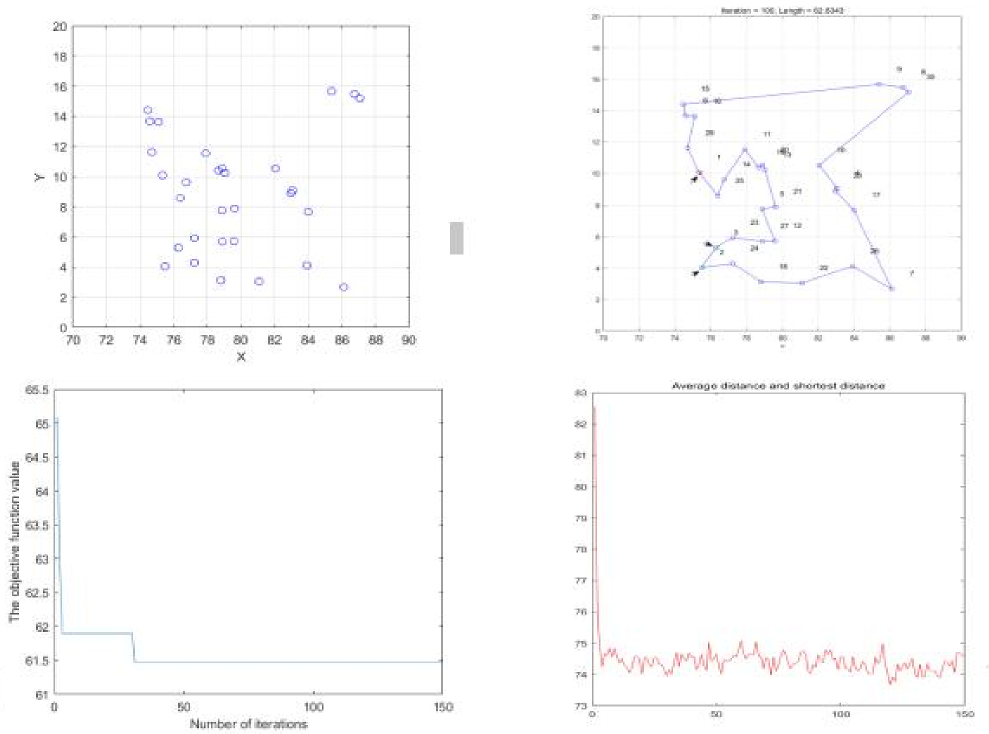

Figure 5-6:Blue team scatter plot ---- ant colony algorithm results graph
The shortest path length is 68.7824

5.3Conclusion

The combined results of the above model can be obtained, the optimal results of the red and blue team transportation vehicles are three each, the total number of thirty people.

Table 5-7:Blue team vehicle dispatch allocation

Transport truck	After the range	Total number of passing range points
BN1	(2)-(3)-(24)-....-(14)-(25)	12
BN2	(4)-(5)-(18)-....-(10)	10
BN3	(1)-(29)-(6)-...-(16)-(30)	8

Table 5-8:Red team vehicle dispatch allocation

Transport truck	After the range	Total number of passing range points
RN1	(4)-(29)-(7)-....-(19)	5
RN2	(3)-(25)-(20)-....-(10)	10
RN3	(2)-(1)-(14)-...-(26)-(12)	15

6. Model Establishment and Solving of Problem three

6.1.1Model Establishment

Red's offensive scenario modeling

Trajectory planning problem description

Assume that the planning space for the trajectory planning of UAV cluster operations is denoted as Ω， Assume that the trajectory of the UAV cluster has q starting points，Marked as S={S1,S2,S3,S4,...,Sq)，The drone cluster's trajectory has n destination points，Marked as D={D1，D2，. . . ，Dn}，The set of origin and destination points all belong to the planning space S，S ∈Ω，D∈Ω，Gis the number of tracks。Then the trajectory planning problem for a cluster of UAVs can be described as[8-9]：

L=[L1,L2,L3,L4,...LG],L∈Ω

Among as Lg={L_1^g，L_2^g， L_3^g，...,$L_{p_g}^g$},g=1，2，. . . ，G is the set of passing points on the gth UAV flight track, which is the track from the starting point to the destination point of the UAV, and， p_gG is the set of passing points on the gth UAV flight track, which is the track from the starting point to the destination point of the UAV.

Spatial modeling for trajectory planning

In order to solve the trajectory planning problem of UAV clusters effectively and simplify the complexity of the model, the trajectory planning problem of UAV clusters is solved in two dimensions assuming that the UAVs fly at the same altitude. Let the horizontal coordinate range of the planning space be $[X_{min},X_{max}]$，The range of vertical coordinates is$[Y_{min}, Y_{max}]$，Then the planning space is represented as：

$\Omega=\{(X,Y)|X_{min}<=X<=X_{max},Y_{min}<=Y<=Y_{max}\}$

Track external environment modeling

Synthesizing the characteristics of modern information warfare, this paper considers three main types of threats that pose the greatest threat to UAV cluster operations in the modern battlefield[10]:

1.Radar detection of drones;

2.Ground-based missile zone and anti-aircraft gun zone against UAVs;

3.Threats to UAV flight caused by harsh atmosphere.

（1）Radar Threat：

In this paper, we assume that the radar can scan the surrounding environment in all directions, then the probability of the target being detected by the radar$P_R(d_R)$can be expressed as:

$$P_R(d_R)=\begin{cases} 0, d_R > d_{Rmax} \\ 1/d_R^4 , d_{Rmax} \le d_R \le d_{Rmax} \\ 1 , d_R < d_{Rmax} \end{cases} \tag{12}$$

Among them，d_RIndicates the distance between the target and the radar，d_{Rmin} Indicates the distance between the target and the radar，d_{Rmax} Indicates the maximum distance of radar detection of the target。

（2）Missile Threat：

According to the working principle of missiles in practice, the threat damage zone of missiles is circular in two dimensions, and the damage of missiles in the damage zone is fatal to UAVs. Then the probability that the target is destroyed by the missile$P_E(d_E)$can be expressed as:

$$P_E(d_E)=\begin{cases} 0, d_E > d_{Emax} \\ 1/d_E^4 , d_{Rmin} \le d_E \le d_{Emax} \\ 1 , d_E < d_{Emin} \end{cases} \tag{13}$$

Among $d_E$the maximum damage distance of the missile damage area, d_{Emin} is the minimum damage distance of the damage area, the distance of the target from the missile is recorded as d_{Emax}.

（3）Anti-aircraft gun threat：

The actual attack range of the anti-aircraft gun approximates a cone centered on the turret, which can be considered as a circular area in the flight plane of the UAV. The

mathematical model for the anti-aircraft gun threat in this paper is as follows：
Set the minimum strike radius of the strike area d_{Vmin} , Maximum strike radius d_{Vmaax} 。 Probability of target being hit by anti-aircraft guns P_V (d_V) can be approximated as:

$$P_V(d_V)=\begin{cases} 0, d_V > d_{Vmax} \\ 1/d_V^4 , d_{Vmin} \leq d_V \leq d_{Vmax} \\ 1 , d_V < d_{Vmin} \end{cases} \quad (14)$$

Among indicates the distance between the target and the anti-aircraft gun.
In this paper the atmospheric restriction region of the vehicle is approximated in three dimensions as a diagonal column type, then the atmospheric influence region in the plane where the UAV flight height of the vehicle is located is approximated as a circle. The corresponding mathematical model is as follows：
Assumptions d_{Cmax} Indicates the maximum radius of the atmospheric confinement area，d_{Cmin} Indicates the minimum radius of the area inaccessible to the vehicle。Let the distance of the vehicle from the center of the atmospheric limit be d_C， Then the probability of atmospheric confinement of the vehicle $P_C(d_C)$can be expressed as:

$$P_C(d_C)=\begin{cases} 0, d_C > d_{Cmax} \\ 1/d_C^4 , d_{Vmin} \leq d_C \leq d_{Cmax} \\ 1 , d_C < d_{Cmin} \end{cases} \quad (15)$$

Comprehensive cost model for drones
The combined cost of a UAV cluster is the combination of resource cost and threat cost during the flight of the UAV from the starting point to the destination point. The goal of the trajectory planning is to ensure that the UAV cluster finds multiple trajectories with the shortest distance and the least time while meeting the combined UAV cost and mission requirements. In this paper, the resource cost mainly considers the fuel consumption during the flight. In summary, the combined cost of the total trajectory can be expressed as[11]:

$$W=\sum_{g=1}^{G} W_g \quad (16)$$

$$Wg=\sum \delta_o W_o(g)+\delta_R W_R(g)+\delta_E W_E(g)+\delta_V W_V(g)+\delta_C W_C(g)$$

Among them，W Indicates that the purpose of UAV cluster trajectory planning is to minimize the combined cost of the UAV cluster， can be expressed as min{W}。

$W_g$denotes the combined cost of the g-th track， Wo(g)is the cost of fuel consumption

for the g-th track； W_R(g)is the radar threat cost for the area passed by the g-th track； W_E(g)Missile threat cost for the area passed by the g-th track； W_V(g)Flak threat cost for the area passed by the g-th track；W_C(g)is the atmospheric threat proxy for the area passed by the g-th track;δ_O,δ_R,δ_E,δ_V,δ_C ∈ [0， 1]， indicating the importance of each threat and cost, respectively. And $\delta_O + \delta_R + \delta_E + \delta_V + \delta_C$=1

The blue retreat scheme model was established

Initially specify the number of clustering centersC_i(1≤i≤3)is 3， That is, the three retreat points of the blue side. Based on the similarity of the distance between the position points and the cluster center distance, the Euclidean distance from the position points to the cluster center is calculated, and the nearest center point is found, and the position points are assigned to that for the cluster.

Euclidean formula：

$$d(x, C_i) = \sqrt{\sum_{j=1}^{m} (x_j - C_{i_j})^2} \tag{17}$$

SC Calculation formula:

$$SC = \frac{1}{N}\sum_{i=1}^{N} SC(d_i(x, C_i)) \tag{18}$$

6.1.2Solving of the model

Red's attack plan：

The coordinates of the four vertices of the planning space are (70, 0), (97, 0), (0, 27) and (97, 27). The coordinates of the starting point are (85,27) and the destination point is (86,3). The parameters of the ant colony algorithm are set as follows: the maximum number of ants is 20, the initial pheromone concentration is 3, the pheromone increasing intensity factor is 1, the importance of the pheromone is 1, the importance of the heuristic factor is 0.5, and 200 iterations are performed. The parameters of the radar threat are set as follows:： k_R=4， d_{Rmin}=3km,d_{Rmax}=120km；The parameters of the missile threat are set as follows：k_E=4，d_{Emin}=3.5 km，d_{Emax}=4 km； The anti-aircraft gun threat parameters are set as follows： k_V=3， d_{Vmin}=3km， d_{Vmax}=6 km；Atmospheric threat point parameters are set as follows：k_C=2， d_{Cmin}=2 km， d_{Cmax}=2 km。The weights of each threat cost sum are set as follows： δ_R=0.3， δ_E=0.2， δ_V=0.2， δ_C=0.2， δ_O=0． 1.

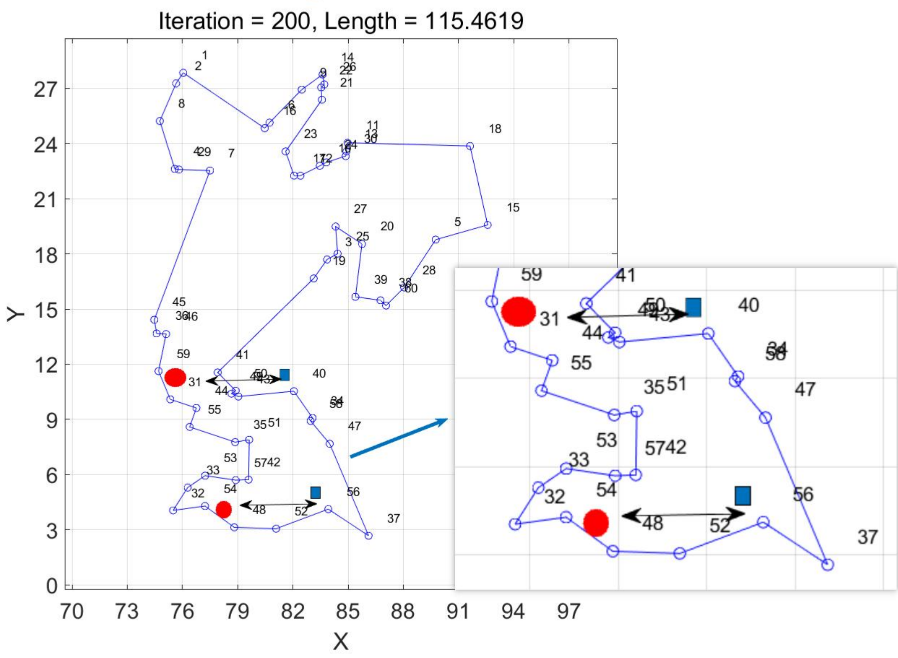

Figure 6-1:ACO Algorithms for planning trajectories

Table 6-1:External Space Threat Table

Threat Points	Number	Coordinates	Threat Points	Number	Coordinates
Missile Threat Point	1	[76.12,10.89]	Radar threat points	2	[83.22,5.42]
Anti-aircraft gun threat points	3	[78.45,3.69]	Atmospheric threat points	4	[81.56,11.12]

From the data in the table, the planned trajectory length is 115.4619 km. from the trajectory planning results in Figure 2.1, it can be seen that the ACO algorithm for trajectory planning can effectively avoid the threats in space and plan the optimal UAV flight trajectory from the starting point to the destination point.

Blue retreat scenario.

Where, x is the number of position points, is the ith cluster center, m is the iteration dimension

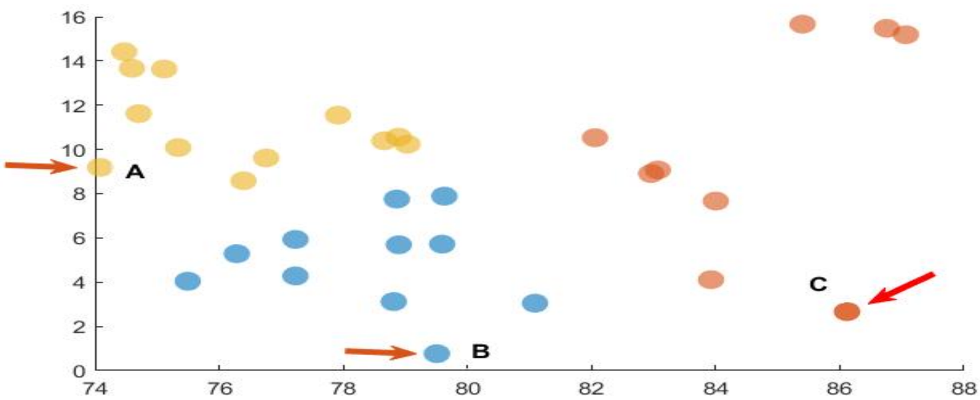

Figure 6-2:Cluster analysis under the blue team retreat area map

As shown in the figure, according to the retreat point [140,37,378], the figure is marked ABC, that is, we can know the optimal retreat plan of the blue team

Table 6-2:Blue team optimal retreat plan

Retreat point	Interval range	Number of retreat positions
A	[74-80,8,15]	11
B	[75-81.5,0-8.3]	10
C	[81-88,2-17]	9

The number of clusters is：3 SC:0.53065'1.

6.2Model Establishment

6.2.1Communication data optimization

Modeling in case of good communication

A. Acquisition of communication data

Each node in the communication mode completes one communication data acquisition and sends the data to the sink system in various ways to complete one communication data acquisition. Define the parameter c as the probability of a node transmitting data to the mobile sink during communication data acquisition, defined as follows:

$$C=\begin{cases} 0, & D<r \\ D/R, & r<D<R-r \\ 1, & D>=R-r \end{cases} \quad (19)$$

Among them: D denotes is the distance from the communication node to the center of the network area, and R and r denote the radius of the maximum and minimum range of communication coverage, respectively. Let T be the total number of data collected by the communication network, then the total number of ship communication

The total number of data collection can be expressed as :

$$T_m = \mathrm{T}\times\mathrm{C} \quad (20)$$
$$T_s = \mathrm{T}\times T_m$$

Among them: T is the total number of data acquisition, Tm and Ts are the number of static data acquisition and dynamic data acquisition respectively, and the calculation result of the number of communication data acquisition can be derived by substituting the calculation result of equation (1) into equation (2)

and the corresponding number of communication data acquisition results are derived.

Therefore, the initial collected communication data need to be normalized and converted, and the specific processing can be expressed as follows.

$$x^{*}=\text{x-u}/\delta \quad (3)$$

B.Determining data fuzzy clustering cluster centers

In the selection process of data fuzzy clustering cluster centroids, the node generates a random value in the range of 0 to 1. Then the value is compared with the threshold value in equation (4), and if the random number is smaller, the node is selected as the cluster center.

$$T_{(xi)}= \text{P/1-P}\times[\eta \bmod(1/\text{P})] ,\text{Xi}\in \text{G} \quad (21)$$

C.Extraction of communication data features using artificial neural networks

The collected ship communication data are used as samples and the data features are extracted by constructing a neural network. The designed network structure also includes gain 1, gain 2 and reset modules, as shown in Fig. 1.

Each layer of recognition neuron j has a vector of real values corresponding to it, which for a class of input patterns is equivalent to a stored sample pattern. Each neuron takes as its input the output of the comparison layer of its weight vector. The output of the deterministic layer neuron can be expressed by the following equation：

$$net_i=\sum_{i=1}^{M} bijci \tag{22}$$

D. Implementing fuzzy clustering of naval communication data

To measure the affiliation between the feature extraction results of the ship communication data and the data at the center of the data fuzzy clusters, the affiliation measure can be expressed as：

$$d(xi,xj)=\sqrt{\sum_{k=1}^{p} (xik-xjk)^2} \tag{23}$$

Among them：xik and xjk denote the kth eigenvalue of the i-th data point and the j-th clustering center, respectively.If the final calculated value is higher than 0.9, it means that the data has a high affiliation with the cluster center and can be classified into the cluster center, otherwise it means that the data does not belong to the cluster center. By updating the similarity measure and categorization of all the ship communication data, the fuzzy clustering result of the ship communication data is finally obtained.

6.2.2Solving of the model

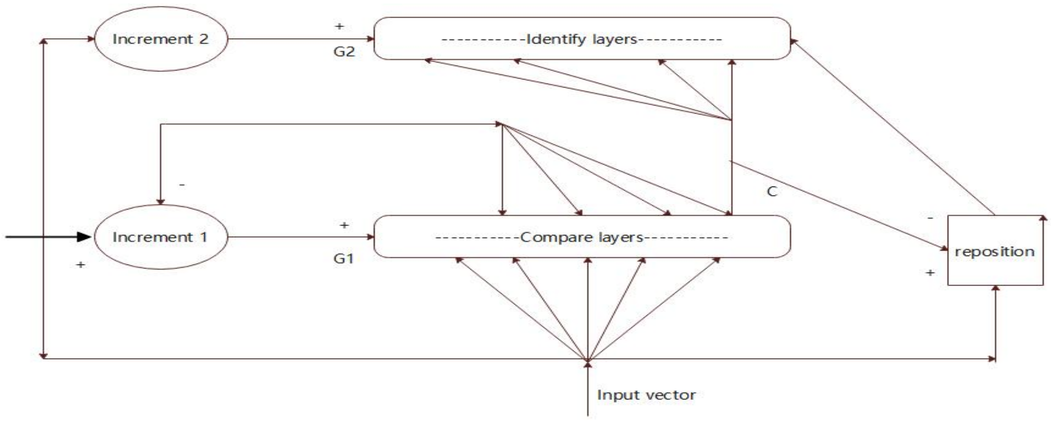

Figure 6-3:Artificial neural network structure diagram

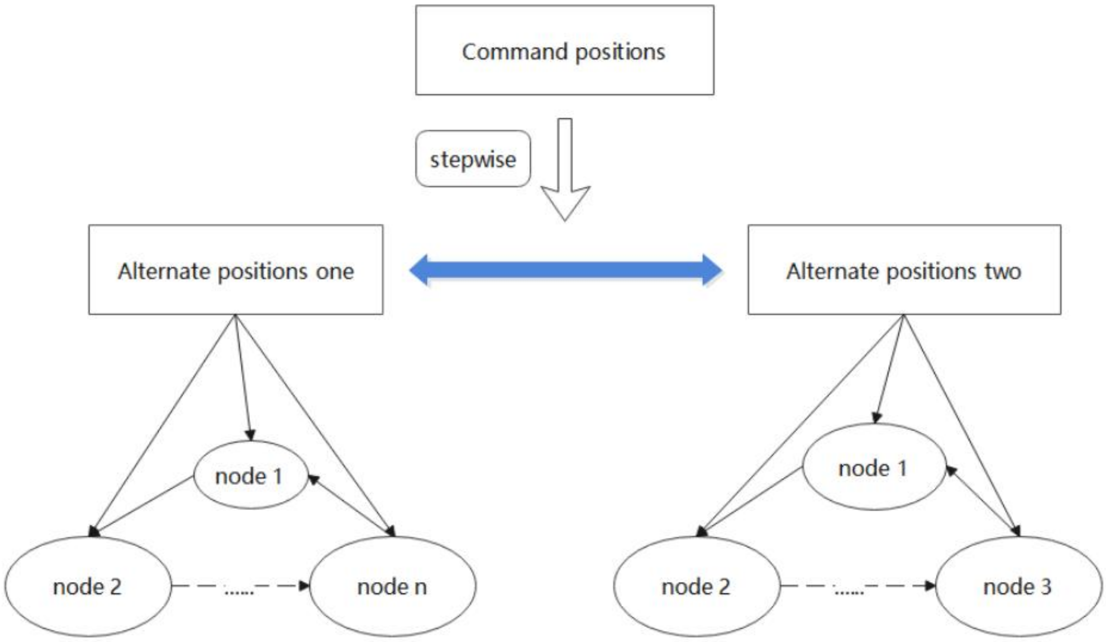

Figure 6-4:Blue Team Retreat Neural Network Model Architecture

Using the integration idea, the neural model is trained when the communication is good, as shown in the following figure：

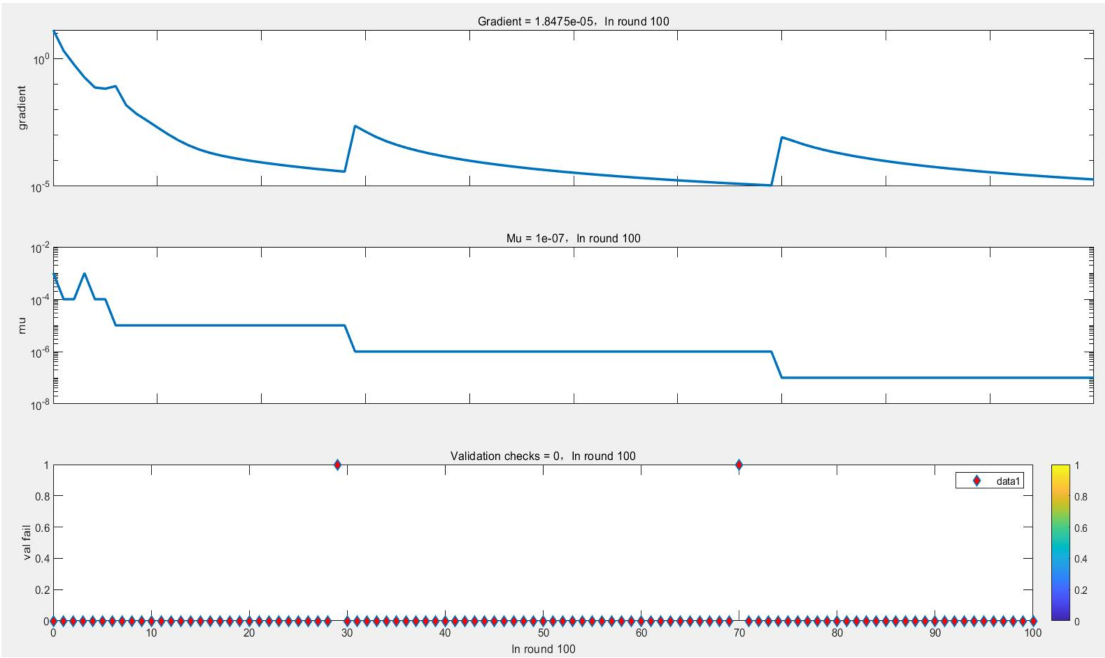

Figure 6-5:Neural network model training diagram

When communication is interrupted, its position command model structure changes to the following diagram：

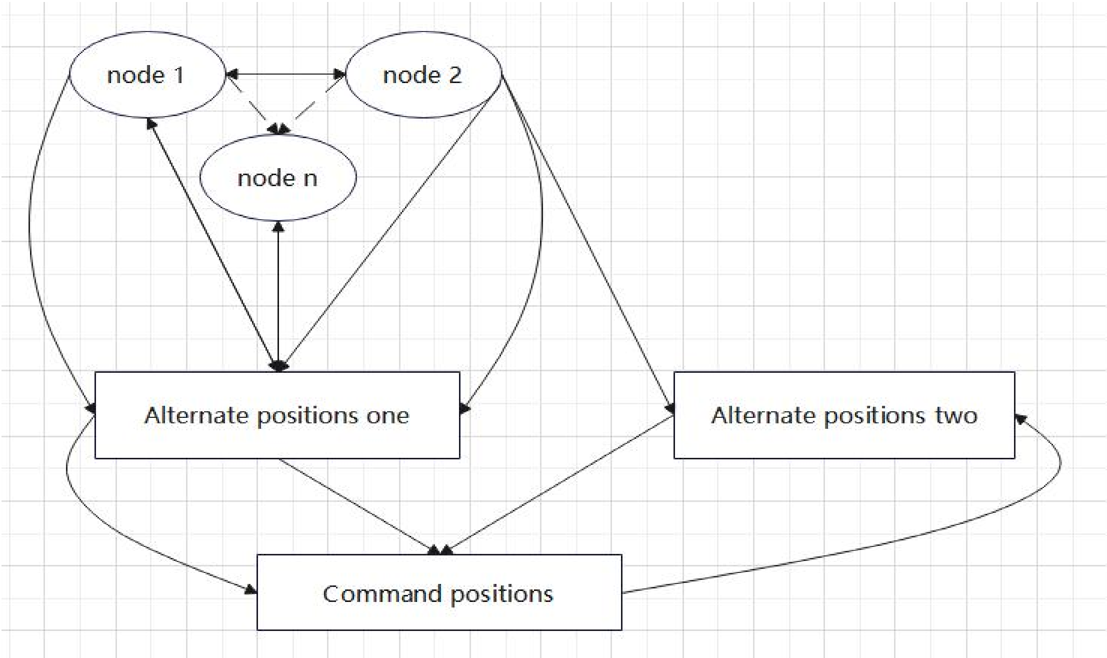

Figure 6-6:Neural network model under communication interruption

The neural network model was tested, and the model was basically stable under communication interruption

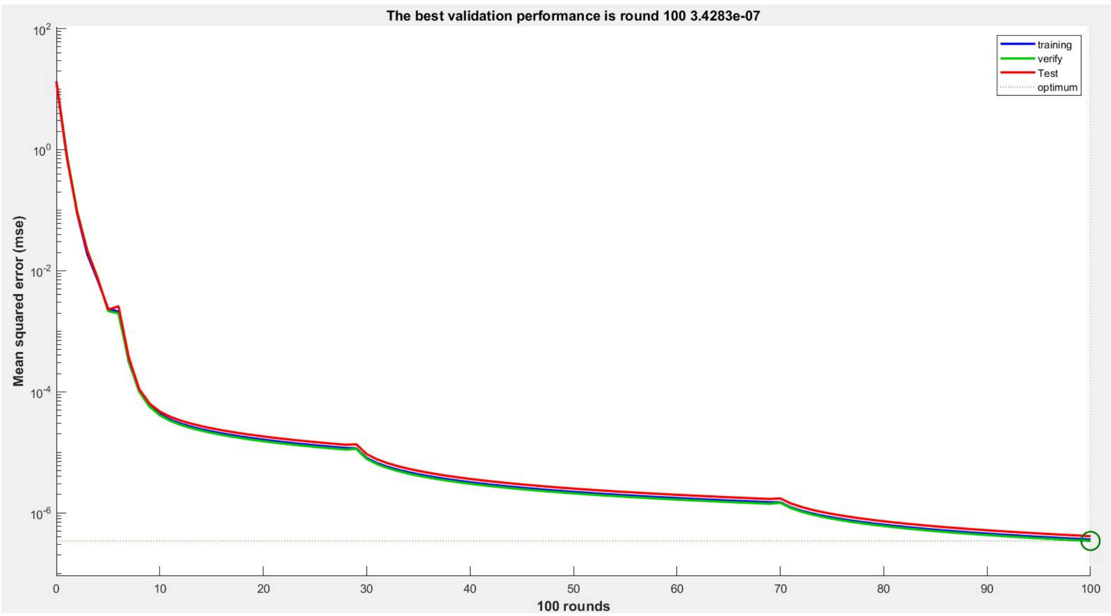

Figure 6-7:Neural network training results graph

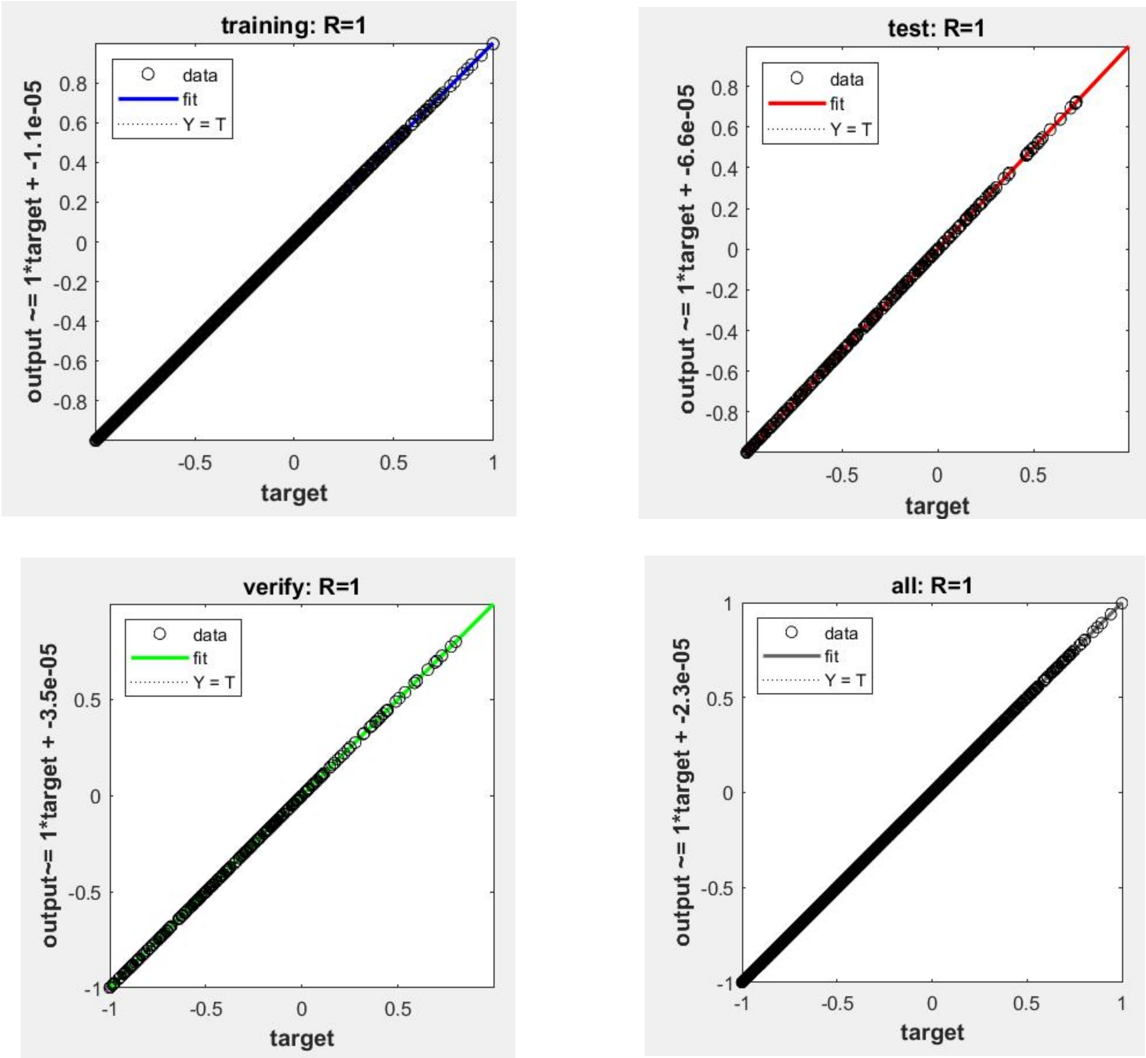

Figure 6-8:Model fit diagram

6.3Conclusion

According to the UAV model planning, the red side attack route plan is shown above, and the optimal flight shortest attack route is derived under the comprehensive consideration of avoiding the threat of missiles, anti-aircraft guns, radar, and atmosphere. Through the cluster analysis method, the blue side will be divided into three categories according to the respective block retreat as the optimal. When the communication is good, human neural network is constructed for training, and when the communication is interrupted, information is passed between each node to retreat according to the training result of good communication, thus reverberating the command position.The difference between communication interruption and good communication mainly lies in.

1. when the communication is good, the blue army according to the command and temporary command, the orderly cluster analysis method, belonging to which cluster

class that to which class retreat. And when communication is interrupted, the blue army position points in accordance with the results of the former neural network training to retreat, and always reflect to the command and other position nodes.

2. When the communication is good, the blue army retreat route to the shortest and fastest, by the red team sneak attack and artillery attack probability is the smallest route. In the event of a communication breakdown, the loss of the UAV leads to a certain local deviation for the Blues.

7. Strengths and Weakness

7.1For the question 1

The Topsis method avoids the subjectivity of data, does not require an objective function, and can well characterize the combined impact of multiple impact indicators to better achieve the allocation of fire resources to both red and blue. However, there may be too many indicators, and it is not sure how many indicators are suitable for the selection of the number of indicators to be able to well portray the influence strength of the indicators. Multi-objective planning fully takes into account the multi-objective nature of the decision variables, giving full play to the respective roles of the planner and the decision maker, and then selecting the optimal solution for this fire resource allocation problem.

7.2For the question 2

Each individual in the ant colony algorithm can change the surrounding environment by releasing pheromones, and each individual can perceive the real-time changes of the surrounding environment, and the individuals communicate with each other indirectly through the environment. Moreover, the heuristic probabilistic search method is not easy to fall into the local optimum, and it is easy to find the global best line. In the hierarchical analysis method, from establishing the hierarchical model to giving the pairwise comparison matrix, the human subjective factor has a great influence on the whole process, which makes the results difficult to be accepted by all decision makers. Of course adopting the approach of expert group judgment is one way to overcome this drawback.

7.3For the question 3

K-means method is simple, efficient, fast convergence, and good clustering when the clusters are close to Gaussian distributed, but the mean value must be defined, K is given in advance, and the value of K affects the clustering effect and has a large impact on the outliers. Neural network model in the classification of high accuracy, parallel distribution processing ability, distribution storage and learning ability, can fully approximate the complex nonlinear relationship. However, the neural network requires a large number of parameters and cannot observe the learning process between them, and the output results are difficult to interpret, which will affect the credibility and acceptability of the results; the learning time is too long and may not even achieve the learning purpose.

References

[1] Wenzhong Huang, Ai Lingyun, PengBo. Preferential selection method of artillery positions based on entropy power and ideal solution method[J]. Ship Electronics Engineering,2010,30(8):39-41

[2] Xingguo Fan, Li Jie, Di Liu. Exploration on the optimization of production, deployment and transportation of wartime general-purpose materials[J]. Logistics Technology,2006(6):84-86.

[3] Tang JL, Zhang D, Wang MY, et al. Improved chained multiple swarm genetic algorithm for air defense fire task allocation[J]. Journal of Harbin Institute of Technology,2022,54(6):19-27.

[4]Lingling Yin,Jianfeng Su. Exploration of vehicle scheduling problem of multiple distribution centers based on ant colony algorithm[J]. Journal of Jiujiang College (Natural Science Edition), 2020, vol. 35(3): 40-42.

[5] Huaye Zhang, Design and implementation of parallel algorithm for path planning based on Hopfield network [D]. South China University of Technology,2016.

[6]Ruimei Wang,Xiaona Zhang, GongSong Zhang. AHP-based UAV material transportation model[J]. Science and Technology Information,2020,18(5):60-62.

[7] Cheng Yu, Wei Cheng, Bindi You, et al. An ant colony-based multi-objective optimization algorithm for space-based early warning[J]. Journal of Harbin Engineering University,2021,42(10):1428-1438.

[8] Su Xue. Research on the trajectory planning and mission assignment technology for UAV cluster operations [D]. Heilongjiang:Harbin Engineering University,2018.

[9] Yujiao Zhang, Huang Rui, Fuquan Zhang. Research on nearest neighbor propagation clustering algorithm based on colony optimization[J]. Computer Science,2022,49(5):165-169.

[10] Luo Fan. Neural network-based chaotic communication optimization research [D]. Sichuan:University of Electronic Science and Technology, 2021.

[11] Xiaosong Lu, Fuzzy clustering algorithm for naval communication data based on artificial neural network[J]. Ship Science and Technology,2021,43(24):91-93.

Appendix

First question matlab code:

Topsis:

```
[n,m]=size(x);
x(:,1)=x(:,1)/100;
x(:,3)=(1./x(:,3))*100;
x(:,4)=(1./x(:,4))*100;
x(:,7)=(1./x(:,7))*100;
zh=zeros(1,m);
d1=zeros(1,n);
d2=zeros(1,n);
c=zeros(1,n);
for i=1:m
for j=1:n
zh(i)=zh(i)+x(j,i)^2;
end
end
for i=1:m
for j=1:n
x(j,i)=x(j,i)/sqrt( zh(i));
end
end
xx=min(x);
dd=max(x);
for i=1:n
for j=1:m
d1(i)=d1(i)+(x(i,j)-xx(j))^2;
end
d1(i)=sqrt(d1(i));
end
for i=1:n
for j=1:m
d2(i)=d2(i)+(x(i,j)-dd(j))^2;
end
d2(i)=sqrt(d2(i));
end
for i=1:n
c(i)=d1(i)/(d2(i)+d1(i));
end
```

Second question matlab code

2.1 Analytic Hierarchy Process

```
W=[1 0.3 0.17;3 1 0.2;6 5 1]
O=input('O=');
[c,n]=size(O);
[V,W]=eig(O);%Find the feature vector and feature value
tempNum=W(1,1);
pos=1;
for h=1:n
if W(h,h)>tempNum
tempNum=W(h,h);
pos=h;
end
end
w=abs(V(:,pos));
w=w/sum(w);
t=W(pos,pos);
disp('The criterion layer feature vector w=');disp(w);disp('The maximum feature
root t= of the criterion layer');disp(t);
%The following are the consistency tests
CI=(t-n)/(n-1);RI=[0 0 0.52 0.89 1.12 1.26 1.36 1.41 1.46 1.49 1.52 1.54 1.56
1.58 1.59 1.60 1.61 1.615 1.62 1.63];
CR=CI/RI(n);
if CR<0.10
disp('TRUE!');
disp('CI=');disp(CI);
disp('CR=');disp(CR);
else disp('FALSE');
end
```

2 .2 Blue And Red Ant Colony Optimization

```
% TSP (ACO)
% Generate the map
N_cities = 30; N_ants = 50; N_iter = 100;
plot(cities(:, 1), cities(:, 2), 'bo');
xticks([70: 2: 90]); yticks([0: 2: 20]);
xlabel('X'); ylabel('Y'); grid on;
axis equal; axis([70, 90, 0, 20]); getframe;
% Calculate distances
D = zeros(N_cities, N_cities);
for i = 1 : N_cities
for j = 1 : N_cities
```

```
x = cities(i, 1) - cities(j, 1);
y = cities(i, 2) - cities(j, 2);
D(i, j) = sqrt(x * x + y * y);
end
end
% Prepare memory tables
Tau = zeros(N_cities, N_cities); % pheromone matrix
Route_best = zeros(N_cities, 1); % Best TSP trajectory
Length_best = zeros(N_iter, 1); % Best TSP length
Length_avg = zeros(N_iter, 1); % Average TSP length
% The main loop
for iter = 1 : N_iter
beta = 5 * rand(N_ants, 1) .^ 0.6;
alpha = 3 - rand(N_ants, 1) .* min(3, 2 + beta / 3);
% Generate TSP trajectories
Table = zeros(N_ants, N_cities);
for i = 1 : N_ants
Table(i, 1) = unidrnd(N_cities);
cities_index = 1 : N_cities;
for j = 2 : N_cities
has_visited = Table(i, 1 : (j - 1));
allow_index = ~ismember(cities_index, has_visited);
allow_cities = cities_index(allow_index);
P = zeros(length(allow_cities), 1);
for k = 1 : length(allow_cities)
tau = Tau(has_visited(end), allow_cities(k)) + 0.01;
dist = D(has_visited(end), allow_cities(k));
P(k) = tau ^ alpha(i) / dist ^ beta(i);
end
P = P / sum(P); Pc = cumsum(P);
target_index = find(Pc >= rand);
target_city = allow_cities(target_index(1));
Table(i, j) = target_city;
end
end
% Calculate TSP lengths
Length = zeros(N_ants, 1);
for i = 1 : N_ants
TSP = [Table(i, :), Table(i, 1)];
for j = 1 : N_cities
dist = D(TSP(j), TSP(j + 1));
Length(i) = Length(i) + dist;
end
end
```

```
Length_avg(iter) = mean(Length);
[min_Length, min_index] = min(Length);
if iter == 1 || min_Length < Length_best(iter - 1)
Length_best(iter) = min_Length;
Route_best = Table(min_index, :);
else
Length_best(iter) = Length_best(iter - 1);
Table = [Table; Route_best];
Length = [Length; Length_best(iter)];
end
% Update Tau matrix (pheromones)
Delta_Tau = zeros(N_cities, N_cities);
[Len, index] = sort(Length);
vol = max(0.1, 0.5 * (1 - (iter - 1) / 15));
pcnt = max(0.2, vol); n_ants = floor(N_ants * pcnt);
for i = 1 : n_ants
TSP = [Table(index(i), :), Table(index(i), 1)];
tau = Len(1) / Len(i) * (1 - (i - 0.5) / n_ants);
for j = 1 : N_cities
x = TSP(j); y = TSP(j + 1);
Delta_Tau(x, y) = Delta_Tau(x, y) + tau;
end
end
Delta_Tau = (Delta_Tau + transpose(Delta_Tau)) / n_ants * 2;
Tau = Tau * (1 - vol) + Delta_Tau * vol;
% Plot currently best TSP
TSP = [Route_best, Route_best(1)];
plot(cities(TSP, 1), cities(TSP, 2), 'bo-');
xticks([70:2:90]); yticks([0: 2: 20]);
xlabel('X'); ylabel('Y'); grid on;
axis equal; axis([70,90,0,20]);
title(['Iteration = ',num2str(iter),', Length =
',num2str(Length_best(iter))]);
getframe;
end
% Print standardized TSP and label the cities
TSP = Route_best; i = find(TSP == 1);
TSP = [TSP(i : end), TSP(1 : i - 1)];
if TSP(2) > TSP(end)
TSP = [TSP(1), TSP(end : -1 : 2)];
end
for i = 1 : N_cities
x = cities(i, 1); y = cities(i, 2);
text(x + 1, y + 1, num2str(i));
```

```
end
disp(['Min TSP Length = ', num2str(Length_best(end))]);
```

Third question matlab code

3.1 The blue team has a better retreat plan

```
subplot(2,1,2) %Draw sub-diagrams
cluster_num=3; %Define the number of classifications as 3
[index_km,center_km]=kmeans(data,cluster_num) ;%MATLAB k-means
a=unique(index_km); %Find out the number of sorts
C=cell(1,length(a));
for i=1:length(a)
C(1,i)={find(index_km==a(i))};
end
for j=1:cluster_num
data_get=data(C{1,j},:);
scatter(data_get(:,1),data_get(:,2),100,'filled','MarkerFaceAlpha',.6,'Mark
erEdgeAlpha',.9);
hold on
end
hold on
sc_k=mean(silhouette(data,index_km));
```

3.2 Neural network retreat

```
load data
inputnum=2;
hiddennum=5;
outputnum=1;
input_train=input(1:1900,:)';
input_test=input(1901:2000,:)';
output_train=output(1:1900)';
output_test=output(1901:2000)';
[inputn,inputps]=mapminmax(input_train);
[outputn,outputps]=mapminmax(output_train);

net=newff(inputn,outputn,hiddennum);
maxgen=100;
sizepop=30;
Vmax=1;
Vmin=-1;
popmax=5;
```

```
popmin=-5;
for i=1:sizepop
pop(i,:)=5*rands(1,21);
V(i,:)=rands(1,21);
fitness(i)=fun(pop(i,:),inputnum,hiddennum,outputnum,net,inputn,outputn);
end
[bestfitness bestindex]=min(fitness);
zbest=pop(bestindex,:);
gbest=pop;
fitnessgbest=fitness;
fitnesszbest=bestfitness;
for i=1:maxgen
i;
for j=1:sizepop
V(j,:) = V(j,:) + c1*rand*(gbest(j,:) - pop(j,:)) + c2*rand*(zbest - pop(j,:));
V(j,find(V(j,:)>Vmax))=Vmax;
V(j,find(V(j,:)<Vmin))=Vmin;
pop(j,:)=pop(j,:)+0.2*V(j,:);
pop(j,find(pop(j,:)>popmax))=popmax;
pop(j,find(pop(j,:)<popmin))=popmin;
pos=unidrnd(21);
if rand>0.95
pop(j,pos)=5*rands(1,1);
end
fitness(j)=fun(pop(j,:),inputnum,hiddennum,outputnum,net,inputn,outputn);
end
for j=1:sizepop
if fitness(j) < fitnessgbest(j)
gbest(j,:) = pop(j,:);
fitnessgbest(j) = fitness(j);
end
if fitness(j) < fitnesszbest
zbest = pop(j,:);
fitnesszbest = fitness(j);
end
end
yy(i)=fitnesszbest;
end
x=zbest;
w1=x(1:inputnum*hiddennum);
B1=x(inputnum*hiddennum+1:inputnum*hiddennum+hiddennum);
w2=x(inputnum*hiddennum+hiddennum+1:inputnum*hiddennum+hiddennum+hiddennum*
outputnum);
```

```
B2=x(inputnum*hiddennum+hiddennum+hiddennum*outputnum+1:inputnum*hiddennum+
hiddennum+hiddennum*outputnum+outputnum);
net.iw{1,1}=reshape(w1,hiddennum,inputnum);
net.lw{2,1}=reshape(w2,outputnum,hiddennum);
net.b{1}=reshape(B1,hiddennum,1);
net.b{2}=B2;
net.trainParam.epochs=100;
net.trainParam.lr=0.1;
%net.trainParam.goal=0.00001;
[net,per2]=train(net,inputn,outputn);
inputn_test=mapminmax('apply',input_test,inputps);
an=sim(net,inputn_test);
test_simu=mapminmax('reverse',an,outputps);
error=test_simu-output_test
```