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Study on optimal application of UAV identification of Merchant marine in Port Seal Control

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Abstract

Drone is widely used in various military fields such as port sealing and control tasks due to its many advantages, such as light quality, small size, strong overload capacity and not limited by geographical location. Therefore, it is of great significance to carry out the optimization and application of target identification based on UAV formation to complete the investigation tasks efficiently and safely. According to this application background, in order to determine the minimum number of UAVs required for merchant ship type identification tasks, this paper proposes a three-step solution model for merchant ship type identification task planning by constructing merchant ship cluster model, multi-object identification path optimization model and merchant ship type identification dynamic planning model. K-Means clustering algorithm is used to cluster merchant ships, Hamilton circle algorithm for optimal path planning, constantly dynamically update the global state, and finally get the minimum number of drones required is 4 and the flight route of this number of drones in each class..

Keywords

Target identification; dynamic planning model; K-Means clustering algorithm; shortest path optimization model.

1. Introduction

The port closure and control action is a key factor to maintain the daily order of the port, ensure the transportation of materials, and promote the smooth trade at home and abroad. In particular, the blockade and interception of prohibited materials such as nuclear raw materials, weapons and equipment is of great significance to ensure the safety of people's lives and property and maintain national security and stability. However, in order to achieve the effective sealing and control of the port, the first thing is to use the efficient and accurate identification of the port trading merchant ships in the form of UAV formation.

Port N is an important material transportation port for the blue side. Its external route is located in the fan area with the port as the center of the circle and the clockwise angle between 20 ° and 70 ° from the north direction. The merchant ship to Port N point to the center of the circle. In Figure 1, under the battle state, the red side decided to seal and control the N port.

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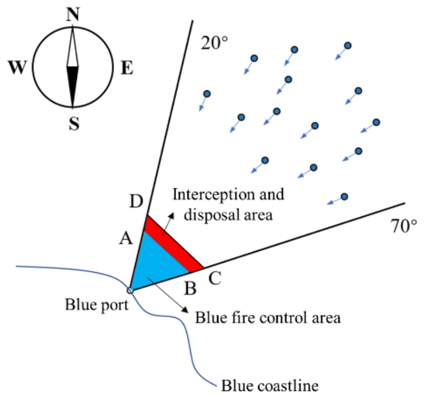

Figure 1: The port schematic diagram

The red containment action is carried out by drones, coast guard vessels and frigates. Merchant ship types can be divided into three categories according to the categories of transport materials. When merchant ships enter the interception and disposal area (ABCD), their types are first identified by drones, and then different disposal methods are adopted according to different types of merchant ships. Before the first merchant ship closest to the CD line, calculate the minimum number of drones required, and assign identification tasks for them to draw their flight routes.

In order to realize the final optimization of the number of UAVs, the K-Means algorithm combines the actual number of merchant ships and the given number of UAV speed is 3, then the initial position and Hamilton circle algorithm to find the shortest path; finally, the given interval, until the completion of the task, increase the class and repeat the iteration to reduce the minimum number of UAVs.

2. Establishment of a mathematical model

2.1. Description and description of the problems

The quantitative optimization problem of UAV is essentially a problem of multi-constrained path dynamic planning under the space-time sequence. According to the background, the navigation area, movement direction and movement speed, the red UAV lasts more than 30 hours, the cruise speed is 120 km/h, and the rotation radius can be found at 20-30km, reduce the height after 10km, identify the target detour at less than 2km, and the identification time is 10min. The identification results can be shared with other red units in real time.

Under the limit of the above conditions, the minimum number of drones required to complete the identification task of all merchant ships within the specified time is 8h according to the data calculation of Annex 2. The calculation can be obtained by MATLAB based on the trigonometric function relationship and will not be detailed here. Given the above constraints and assumptions, we decided to ignore the impact of UAV endurance and trajectory on its recognition process. The reasons are as follows: The time to complete the merchant ship identification mission is limited to 8h, which is negligible compared to the 30h of drone endurance time. At the same time, the trajectory of the UAV, but as a mass point with the merchant movement, in the actual identification height change, because the UAV is a rotation from high to low to high, the process affects the overall identification time, but the UAV identification time has been set at 10min, so considering the movement process is meaningless, the UAV reached 10min identification time will automatically leave, looking for the next target merchant ship according to certain identification rules.

For that reason, to achieve the final optimization of the number of drones, it is divided into three steps: the first step, Clustering of merchant populations by the K-Means algorithm, During the period, the given class is 3, Assign one UAV to each category; the second step, Given the initial position of various drones combined with the Hamilton circle algorithm to find the shortest path; the third step, Global clustering updates given interval, Until the task is completed, After the end time does not meet the constraint requirements, add the class and repeat the iteration, Meet the requirements, reduce the class start iteration, This yields the minimum number of drones needed.

2.2. The Establishment of the mathematical model

According to the above analysis, this problem belongs to the multi-constrained merchant ship path dynamic planning problem under the space-time sequence. The minimum number of UAVs is required to identify all merchant ship types under all constraints being met. The objective function, decision variables, and constraints are shown below.

Objective function:

$$\min N = f(A_i),\quad i \in (1, N) \tag{1}$$

Where, N represents the number of drones and A_i represents the UAV decision variable group completing the merchant ship identification mission.

Decision variable:

$$A_i = \{S_{i0}, S_i\} \tag{2}$$

Where, A_i is a binary group, S_{i0} notes the starting position of the i-th UAV, S_i is the flight path for the i-th UAV.

Constraint condition:

Constraints of UAV and merchant vessel, namely:

$$\begin{cases} y_i \le x_i \cdot \tan\theta_2 \\ y_i \ge x_i \cdot \tan\theta_1 \\ y_i \ge \mathrm{k}x_i + x_c(\tan\theta_1 \text{-k}) \\ \mathrm{k}=\dfrac{x_c \cdot \tan\theta_1 \text{ - } x_d \cdot \tan\theta_2}{x_c - x_d} \end{cases} \tag{3}$$

Among them: (x_i, y_i) is the right angle coordinate system coordinates of UAV and merchant ship, for merchant ship, $i \in (1,84)$, for UAV, $i \in (1, N)$ and θ_1、θ_2 is the included angle between BC and ad lines and X axis, the specific position range is shown in Figure 2.

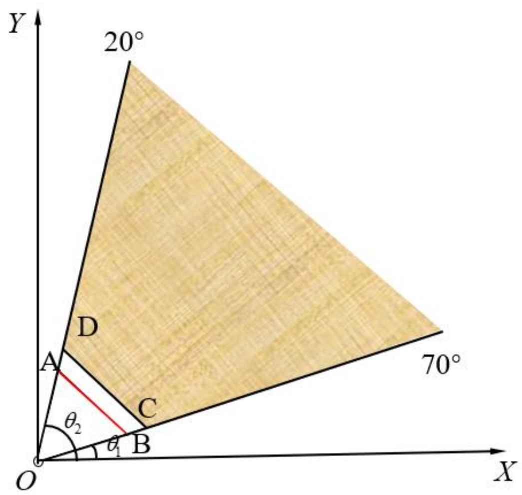

Figure 2: Position range diagram in the right-angle coordinate system

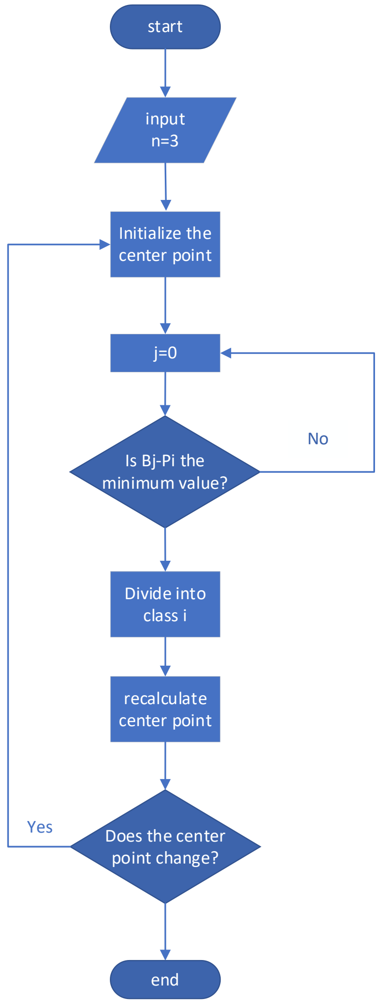

Figure 3: Thinking flow chart of the K-Means algorithm

The direction of merchant ships point to the center of N port, namely:

$$\theta_j = \arctan\frac{y_j}{x_j},\ j \in (1,84) \tag{4}$$

Where, θ_j is the angle of the movement direction of the j merchant ship and the X axis.

The mission time of all drones is no more than hours, that is:

$$\forall i \in (1, N),\quad \mathrm{t}_i \le 8.41h \tag{5}$$

Where, t_i is the mission time for the i-th UAV.

UAV cruise speed of 120 km/h:

$$\forall i \in (1, N),\quad v_i = 120 km/h \tag{6}$$

Where, v_i is the speed of the i-th drone.

The UAV identification time of each merchant ship type is 10 minutes, namely:

$$\forall i \in (1, N),\quad \mathrm{t}_{\mathrm{is}} = 10\,\mathrm{min} \tag{7}$$

Where, t_{is} is the identification time of the i-th UAV to the merchant ship.

The identification scope of the UAV shall not exceed 30km, namely:

$$\forall i \in (1, N),\quad \mathrm{R}_i \le 30\mathrm{km} \tag{8}$$

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Where, R_i is the identification range of the i-th UAV.

3. The Solution of the mathematical model

3.1. Merchant ship clustering model

Based on the K-Means algorithm[1], program the merchant ship clustering model with Matlab software as follows:

(1) Based on the actual number of merchant ships and UAV speed, given the number of required classes n=3, randomly initialize the respective center points P_i of the 3 classes (The central point is the point equal to the length of the merchant ship vector);

(2) Calculate the distance from each merchant ship particle B_j to the center point, and the merchant ship is divided into which category according to which center point it is close;

(3) Reccalculate the central point of each category as the new central point;

(4) Repeat the above 3 steps until the center point of the class does not change.

The idea flow chart is shown in Fig3.

3.2. Multi-objective recognition order optimization solution model

Based on the Hamilton-circle algorithm[2], optimization model of UAV identification path using Matlab [3], programming the solution for the following steps:

(1) First, specify the initial position of the UAV as the nearest merchant ship to the CD line in each class. From this point, the first Hamilton circle is obtained by passing through each merchant ship node and only once;

(2) Modify the Hamilton circle obtained in the previous step to get a new Hamilton circle with small rights, and repeat the improvement until there is no change in the Hamilton circle.

The principle of improvement is as follows:

For 1≤m<m+1<n≤k, a new Hamilton circle is constructed, as obtained by combining the edge inversion between J_m and J_n in L:

$$L_{mn} = J_1 J_2 \ldots J_m J_n J_{n-1} J_{n-2} \ldots J_{m+1} J_{n+1} J_{n+2} \ldots J_k J_1 \tag{9}$$

When $\omega(J_m J_n) + \omega(J_{m+1} J_{n+1}) < \omega(J_m J_{m+1}) + \omega(J_n J_{n+1})$ standing, it means that the improved circle can be replaced, the principle as shown in Figure 4.

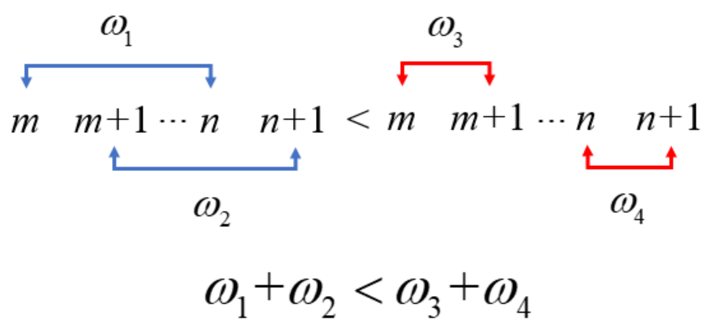

Figure 4: Schematic diagram of the Hamilton circle improvement

3.3. Dynamic programming and solution model for merchant ship type identification

Based on the dynamic planning method, the diffusion-like phenomenon caused by the inconsistent merchant ship velocity is solved[4], Dynamic updates of classes at 1h intervals, thus reclustering to achieve the minimum number of UAV planned[5][6]. The steps are as follows:

(1) Determine the current classes and numbers of merchant ships and unmanned aerial vehicles;

(2) The various status variables S_k are obtained at the present stage ;

(3) Define the decision variable X_k, The decision determines the status of stage k+1;

(4) Get the state transfer equation $S_{k+1}=T_k(S_k, X_k)$;

(5) Determine the index function.

3.4. Solution results

(1) Minimum drone results required

When the given class is the initial value of n=3.

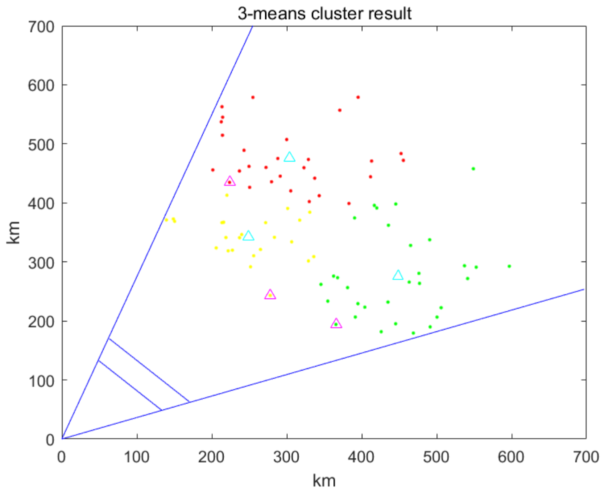

Figure 5: UAV clustering effect at n = 3

When the given class is the initial value of n=4.

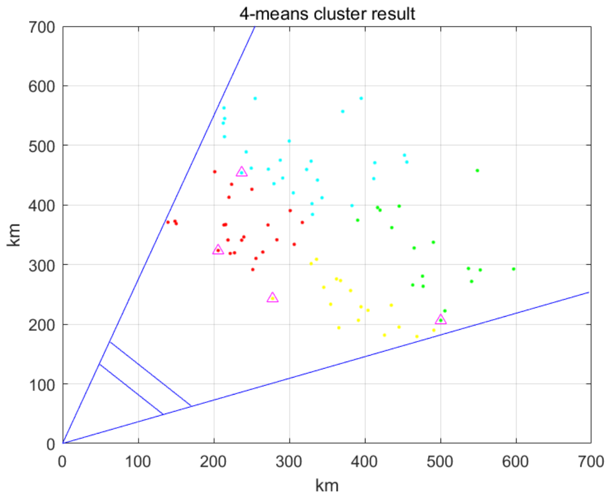

Figure 6: UAV clustering effect at n = 4

(2) UAV flight road map

Flight trajectory diagram of 3 drones:

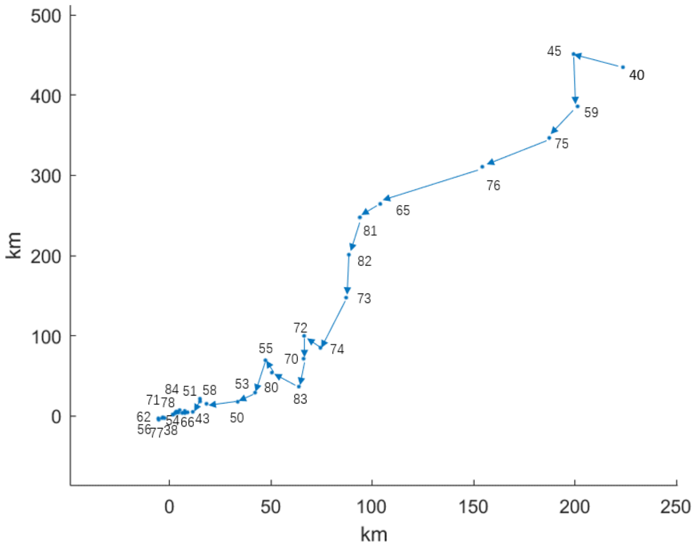

Figure 7: Path of the first UAV at n = 3

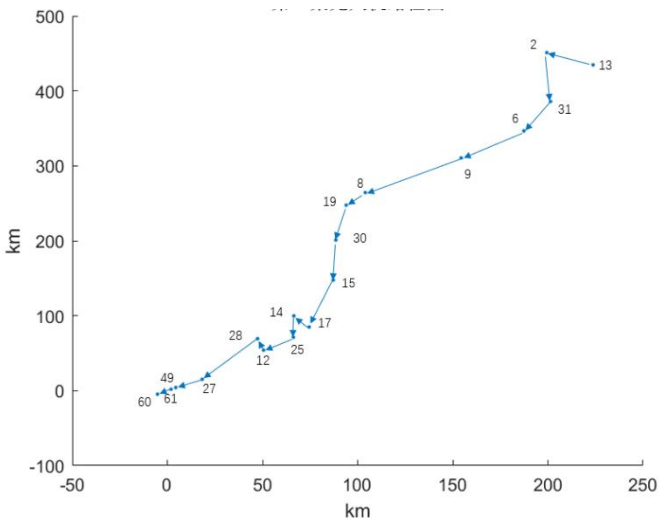

Figure 8: Path of the second UAV at n = 3

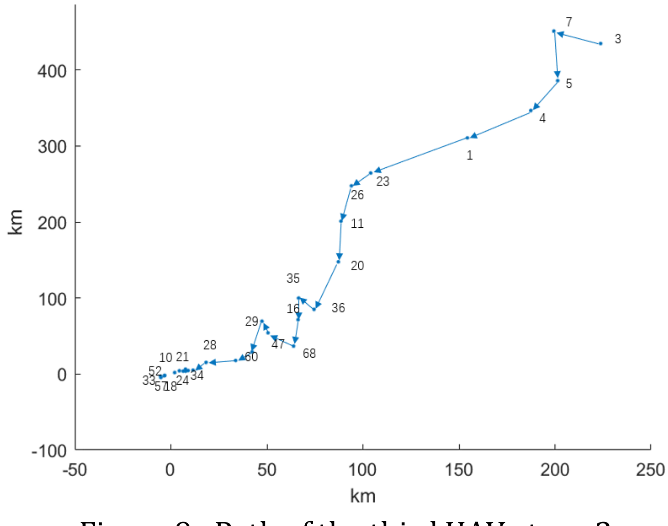

Figure 9: Path of the third UAV at n = 3

Flight trajectory diagram of 4 drones increased at 4:00:

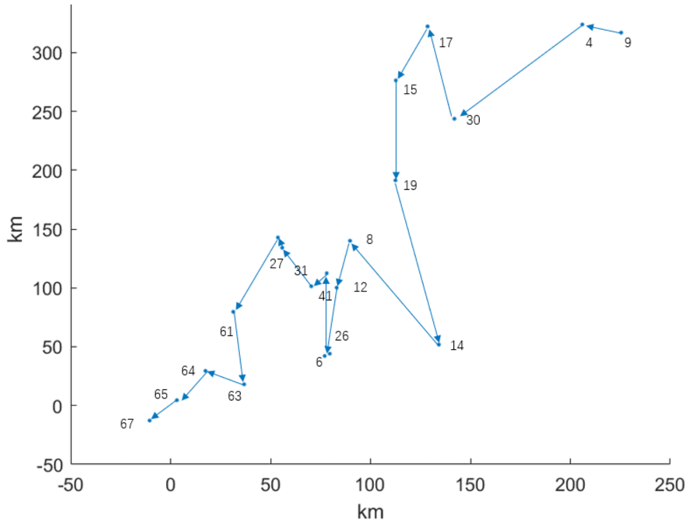

Figure 10: Path of the first UAV at 10 n=4

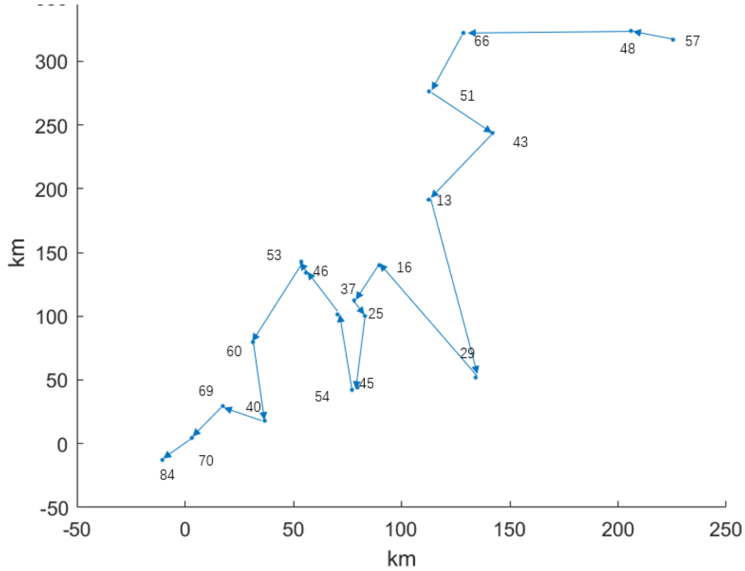

Figure 11: Path of the second UAV at n = 4

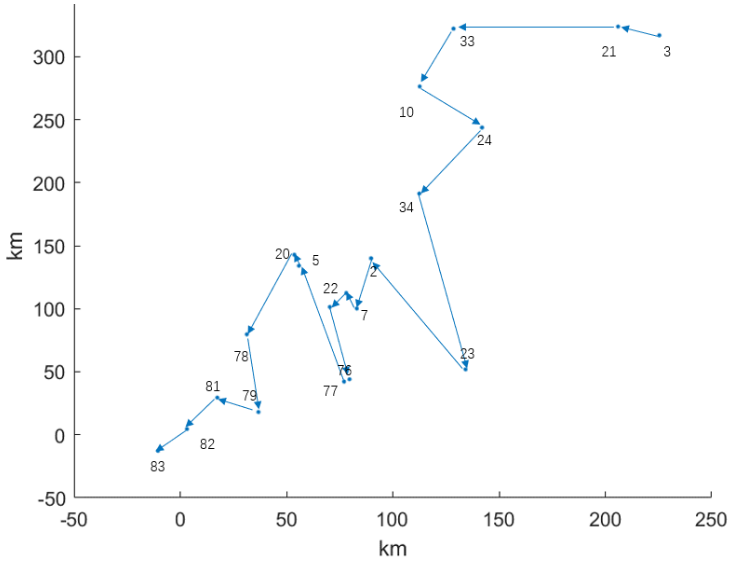

Figure 12: Path of the third UAV at n=4

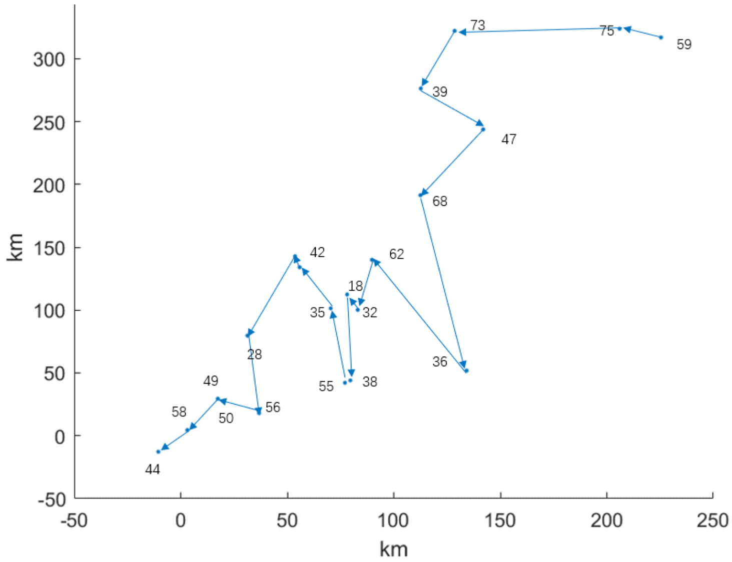

Figure 13: Path of the fourth UAV at n=4

3.5. Results analysis

As shown in Figure 5, when the initial value is set to three UAVs to perform the identification task, each UAV can first be assigned to some tasks with relatively concentrated initial position. The product blue triangle marks the cluster center of K-means cluster. However, because the speed direction of the merchant ship is pointed to the port, the nearest position to the blockade CD is selected as the initial identification point. For drone mission, planning for each drone flight route, and every 1h at the center of drones to cluster, thus planning the drone flight path, as shown in Figure 7-9 for the task of the three drone route, by their route can be seen when sending three drone mission, each drone assigned to more tasks and task concentrated in a fan area. From the first known merchant ship at CD line for 8h, update the relative position every 1min, and judge the movement status, every 1h, to complete an iteration, set each iteration after the number of undetected ships N, in our calculation, when the iteration after 9, time has passed 9h, but the number of undetected ships is not reduced to 0, indicating that 3 drones cannot complete the task within the specified time.

As shown in FIG. 6, when four UAVs are set to perform the identification task, the task pressure of each UAV is partially reduced and the task distribution is relatively dispersed, so the UAV is also easier to complete the identification task, as shown in FIG. 10-13. During the calculation, when the iteration runs up to the 8th time, N =0, and the iteration ends. This shows that the task completion time is less than 8h, meeting the background requirement of 8 h, and the reliability of the present question model is proved.

4. Conclusion

Port closure and control action is an important action to safeguard national security interests and ensure social security and stability. According to the problem setting requirements and the original data provided in the attachment, this paper has basically completed the modeling, solution, analysis and discussion of the optimization problem of UAV identification of merchant ship type. The main conclusions are summarized as follows:

For multi-constraint path planning problems, With the minimum number of UAVs required to complete the merchant ship type identification mission as the global optimization target, Through the specific construction of merchant ship cluster model, multi-target identification path optimization model, and dynamic planning model of merchant ship type identification model, A three-step solution model for merchant ship type identification task planning is presented, Merchant ship clustering using the K-Means clustering algorithm, The Hamilton-

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circle algorithm performs the optimal path planning, Dynamic dynamically update the global state, Finally, the minimum number of drones required for the problem one is 4 and the optimal flight route of that number of drones in each class, The optimal flight roadmap of 10-13 is shown.

Acknowledgements

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References

[1] Liu Jingming, Han Lichuan, Hou Liwen. A K-mean clustering algorithm based on the particle population [J].System Engineering Theory and Practice, 2005 (06): 54-58.
[2] Zhang Hongwei, Pan Xiaogang, Xiao Long. A joint combat force model solution method [J].Defense Technology, 2019,40 (05): 112-116.
[3] Lai Yuxia, Liu Jianping, Yang Guoxing. A K-mean clustering analysis based on the genetic algorithm [J].Computer Engineering, 2008 (20): 200-202.
[4] Noble, Sun Chuan. Force development problem research [J].Command, control and Simulation, 2006 (05): 22-23 + 32.
[5] Li Zhigang, Wu Cangpu. Two-tier planning model for the force deployment optimization problem [J].Journal of Beijing Institute of Technology, 1997 (03): 268-272.
[6] Qiu Qianjun, Hao Lingjun, Zhang Fuxing, Li Liang. Multi-objective function unmanned underwater navigation track planning under multiple constraints [J].Command, Control and Simulation, 2020,42 (05): 7-12.