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UAV's Coverage Search Planning Algorithm Based on Action Combinations

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Abstract: The autonomous route planning in coverage search is an important subject of unmanned aerial vehicle (UAV) mission planning. Pre-planning is simple and feasible for the coverage search mission of single UAV in regular areas. As to the dynamic mission in complicated environment of multi-UAV, the route planning will encounter the difficulties of reasonable task distribution and the real-time environment changes which include the changes of the mission area, the detection of threat area, the interference of communication and so on. At this point, making the UAV to do real-time autonomous planning is necessary. However, it is hard to fulfil requirements of real-time, autonomous and efficient at the same time. According to a scalable knowledge base, this paper proposes a coverage search algorithm which is based on the mapping between the basic behavior combination and surroundings. A UAV's coverage search simulation model with random shapes is built with a discrete map to update the environment and the changes of the mission on time. Comparison of the simulation analysis and the dynamic programming shows that the method has amazing expandability and can change the search strategy feasibly. It is efficient, and the ratio of coverage redundancy can be decreased to 1.21. It also has the potentiality in real-time calculation, and the computing time can be shortened to about 2 s.
Key words: unmanned aerial vehicle (UAV), coverage search, action combinations, search strategy, dynamic programming
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0 Introduction

The autonomous route planning in coverage search can do works, including aerial mapping, regional pesticide spraying, disaster monitoring, targeted search, etc. In modern warfare, coverage search of unmanned aerial vehicle (UAV) has a natural advantage in information receiving and economic manufacturing for the low cost of casualties[1]. By its nature, aerial reconnaissance mission should make pre-planning, which can help UAV to fulfill task better. For static tasks without external risks or obstacles, pre-planning is simple and feasible, such as scanning paths method and center-edge rotation search method. In study of some articles[2-6], area coverage search problem is simplified into the method about how to reduce the frequency of turn and how to make routes shorter in scanning paths method. But conventional method of route planning is very predictable and easy to be informed by opponents, it is also difficult to finish a dynamic task, because it cannot distinguish the changes of the search area by real-time void. In mission distribution of multi-UAV cooperative path planning, region distribution and path planning have become an actual coupling problem[7]. Usually, the mission distribution in multi-UAV cooperative distribution is divided into two subsystems, including task allocation subsystem and track generation subsystem. Firstly, the track generation subsystem plans out the optimal paths that reach each task point, and provides the control input for the mission planning system. Then, the task allocation subsystem makes the best track combination[8]. However, coverage search is a range instead of the coordinates of each task point, which means the infinite continuous task points. Track generation subsystem is difficult to meet that demand.

If we want to make the real-time route planning better, the UAV's autonomy is required. UAV cluster is a kind of multi-UAV cooperation mode, which means that the UAV depends on the partial perception and interaction to decide the motion state autonomously[9]. The partial behaviors of single machine will make up the overall search behaviors of multi-UAV cooperative model. As to cluster, we must firstly solve the behavior strategy problem of single UAV. The requirement and difficulty lie in making the correct response to the

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complex environmental changes. In usual cluster task, the path planning strategy of single UAV is to propose a suitable cost function, such as search-graph method. Its cost function includes three parts: target return, time cost and cooperation cost. Another strategy is planning search routes and transfer routes after allocating tasks simply by clustering analysis[10]. What's more, an online updating algorithm for searching/attacking route-planning in a hostile environment uses an improved ant colony algorithm[11]. However, the efficiency of conventional search-graph method is not very well. Clustering analysis requires too high cognitive ability of global environment. Ant colony algorithm is difficult to response to dynamic changes of coverage area on time. Some solidified algorithms are difficult to extend, and they are also prone to defects. So a suitable frame planning algorithm to deal with the complicated dynamic environments is required.

Based on the concept of a scalable action combination frame, a real-time autonomous method of coverage search is proposed in this paper. And the method is enhanced by simplifying the model of the UAV's field of view (FoV) and the mapping concept between the environment and action combinations. The two algorithms are simulated with the program modeling. Compared with the original search method, the improved algorithm has strong expansibility and efficient autonomy and is more suitable for large-scale search. The coverage redundancy is reduced from 3.59 to 1.12 s, and the computation time of large area search is shortened to about 2 s, which means it has the potency to do real-time solution. Therefore, the application in action mapping strategy of combinations is developed to achieve a better effect of coverage search, and finally to achieve the autonomous coordination route planning for UAV.

1 Coverage Search Route Planning Algorithm for UAV

1.1 Action Mapping Search Model of Combinations in UAV Trajectory Planning

One of the most important aspects in UAV development is the improvement of UAVs' autonomous control-level. According to the description of 10-level autonomous control presented by the US Air Force Research Laboratory (AFRL), the level 4 requires to replan event-driven airborne track. But in the description of USA's flight control system (FCS) for autonomous levels, the level in the medium or above requires UAVs having capabilities in terms of limited real-time planning and environmental perception[12-13].

However, the final autonomous-planning is to make UAVs cooperating intelligently like humans, especially in the learning abilities. Chen et al.[14] proposed a 3D-path planning method based on independent learning frame, and its basic behavioral frame is shown in Fig. 1. When running online, UAVs retrieve the corresponding decision scheme in the repository according to the current environmental conditions and machine's state parameters. If the decision scheme is valid, it will be executed as the output of UAV behavior. If it is invalid, the basic path-planning algorithm will be executed and the results will be fed back to the knowledge base.

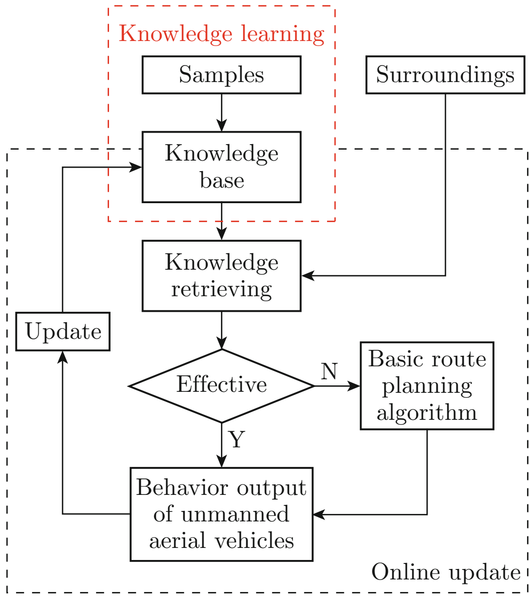


Fig. 1 Autonomous learning framework

The autonomous learning frame includes two main parts. One is how to learn and update the knowledge base independently. The other is how to work out the basic path-planning method when there is no corresponding knowledge. Nowadays, the artificial intelligence is still far from complete autonomy. So applying this retrieval frame might preset a knowledge base artificially. In practical applications, humans will intervene in updating knowledge base constantly. When the knowledge base is rich to a certain extent, its effect is very close to the effect of autonomous learning frame owing to great reductions of the online updating behavior. So this paper uses the frame, as shown in Fig. 2.

This paper proposes tree-like paths composed of the UAVs' basic behaviors as a strategy of knowledge base to calculate the merit function of each path combination. By contrast, we retrieve the optimal path. This operation is set up artificially. It is also static and non-updateable but can be modified offline. Thus, the basic frame of the conventional searching-graph scheme is formed.

Due to the complexity and dynamic of the battlefield environment, UAVs must independently detect, identify and combat targets, and even evaluate damage. It should be able to make appropriate adjustments quickly to the original mission plan according to the unexpected

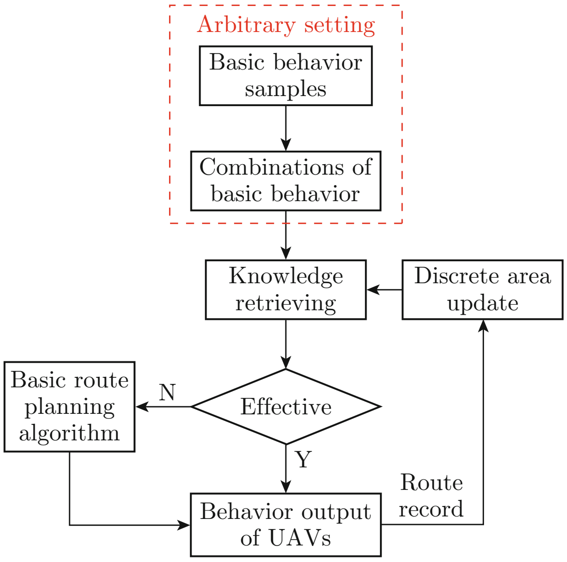


Fig. 2 Behavior flow diagram in UAVs' coverage search

situation. At the same time, new plans can be made to meet the requirements of current situation, environment and mission. Therefore, it requires that the cooperative combat-system of the drone clusters must be provided with some characteristics, such as autonomy, sensitivity, and sociality. In this paper, discrete maps are used to update the changes of environment and situation on time.

1.2 Discrete Maps' Model

In view of the classic hypothetical scenario, the initial map data in the dynamic programming is rough and approximate. During the search process, map data changes along with UAV's perception to the partial environment, or along with the search confirmation in the FoV. At first, the map data is discretized into a square grid[15-16], or a hexagonal grid[17] to adjust to the uncertain environment. In the square grid, the data that should be detected or not is stored. We can call it regional value. A two-dimensional (2D) function with the actual map coordinates (x, y) is set as

$$M^*(x,y)=\begin{cases}0, & (x,y)\ \text{not to be searched}\\ 1, & (x,y)\ \text{to be searched}\end{cases}. \tag{1}$$

In Eq. (1), "1" and "0" mean that each small grid should be detected or not, and the data will be applied in the cost estimation[18]. In each searching or mapping, UAVs search all square grids in the FoV.

After being discretized, the equation is

$$M_{k,j}=\iint_{S_{\text{unit}}} M^*\mathrm{d}x\mathrm{d}y>0, \tag{2}$$

where S_{unit} shows the square grid centered on the coordinates (kc, jc). Here, c is the side length of the grid; k and j are the ordinal numbers, and they are based on the position of the discretized square. So $M_{k,j}$ is the logical value of matrix used to judge whether the area S_{unit} should be detected or not.

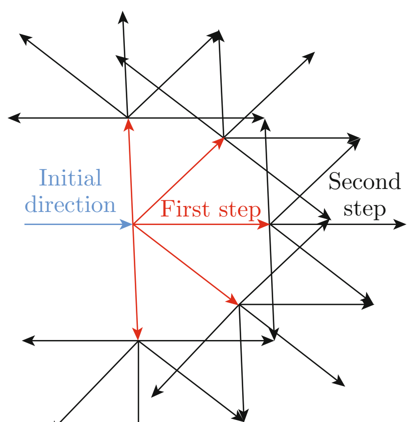
1.3 Basic Motion Combination Model for UAV

Considering the model of scanning, the basic behavior can be simplified as simply actions in 2D space[19-21]. In the search-graph modeling and simulation, the basic behavior is set as: turning left 90°, turning right 90°, turning left 45°, turning right 45° and going straight.

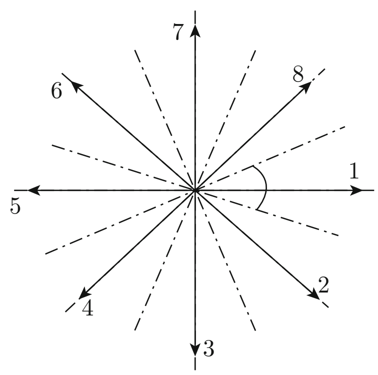
The number of combinations increases exponentially along with the increase of the steps. If 5-step mode is taken into account, there are total 55 kinds of combinations. Each kind of combinations passes through 5 steps, and the grid area swept by the step i is marked as the area S_i which includes many S_{unit}. At each step, the UAV is simplified to have two basic attributes including position and direction. And the machine can perceive if every grid in the nearby area is pending-search area.

Greedy algorithm cannot find search point far away in limited steps. An arrival method having wider range in Fig. 3 finds the nearest search point on the whole map, and confirms the position according to the following equation:

$$D_{\text{dire}}=P_{\text{posi}}-P_{\text{aim}}, \tag{3}$$



(a) Two-step combinations



(b) Basic directions

Fig. 3 Basic behavior

where $P_{\rm posi}$ is position of the UAV, $P_{\rm aim}$ is the nearest search point, and $D_{\rm dire}$ is the relative position. For a discretized map of square, $D_{\rm dire}$ should be divided into 4 or 8 directions, as shown in Fig. 3(b). We choose 8-direction scheme to show the turn of UAV. As shown in Fig. 3(b), the four judgment lines are

$$\left.\begin{aligned} -ax+y>0 \\ bx-y>0 \\ bx+y>0 \\ ax+y>0 \end{aligned}\right\}, \tag{4}$$

where $a=\tan 22.5°$, $b=\tan 67.5°$. We can get a target direction from 8 directions by Eq. (4) and summarize it as the following equation whose form is not unique:

$$r=(2c_1-1)(c_2+c_3+c_4-4)+9c_1, \tag{5}$$

where $c_i\,(i=1,2,3,4)$ is the logical value and means one of the 8 relative directions. Comparing the direction r with the present direction, we get actual directions and times of turning and carry on corresponding combinations according to the basic behaviors. In this way, the UAV can approach the existing target direction. When reaching in a certain range, the UAV can trigger an effective retrieval mechanism to start the search around the target.

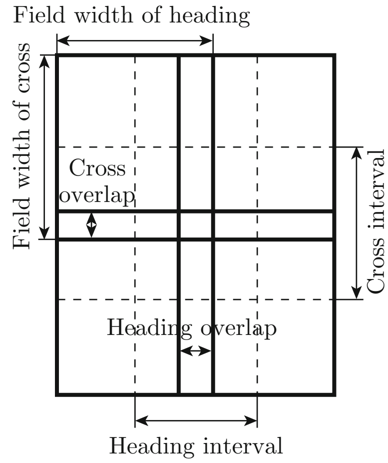
1.4 Model of FoV

FoV is a key factor in the actual mapping of UAVs. It determines the heading interval $b_{\rm h}$ and the cross interval $b_{\rm c}$. It is shown in Fig. 4(a) and the logic is

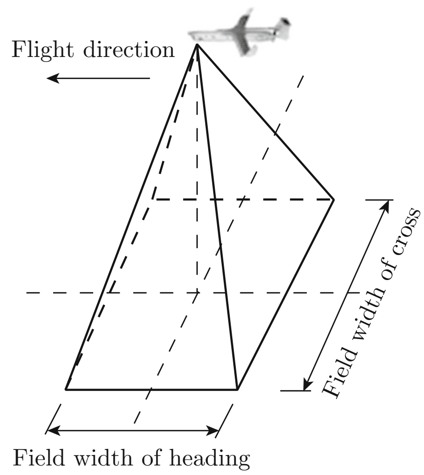
$$\left.\begin{aligned} b_{\rm h}=(1-p_{\rm h})L_{\rm h} \\ b_{\rm c}=(1-p_{\rm c})L_{\rm c} \end{aligned}\right\}, \tag{6}$$

where, $L_{\rm h}$ and $L_{\rm c}$ represent the widths of the heading and cross FoVs, respectively; $p_{\rm h}$ and $p_{\rm c}$ are the overlap-rates of the heading and cross FoVs, respectively. The width of the FoV is up to the camera angle of view (AoV) and the flight altitude of UAV. The camera AoV and the flight altitude are related to the pixel-precision that the mapping or searching requires[22], as shown in Fig. 4(b).

In order to simplify the model of search range, the active search area is a rectangle smaller than the flight FoV. The length of the rectangle is the distance marched along the flying direction plus half of the heading interval, and the width is the cross interval. For convenience, the distance marched along the flying direction is selected as the heading interval. The area scanned in the step i is marked as S_i. To simplify the search area, we convert S_i into the divided squares of corresponding positions from the search area, and then calculate it in a way that only the integer is retained to ensure that all positions are searched. As shown in Fig. 5, each asterisk represents a discrete square.



(a) Overlapping



(b) FoV

Fig. 4 The sketch of UAV's FoV and overlapping

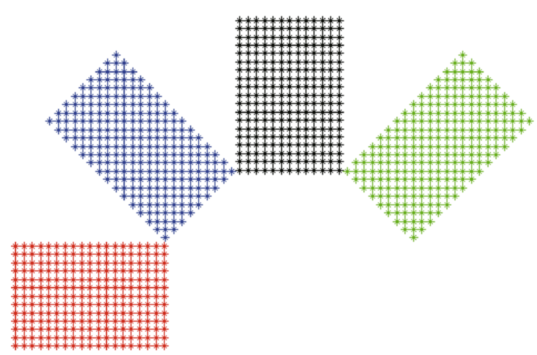


Fig. 5 FoV of UAV's four-direction search

1.5 Search-Graph Algorithm Based on Action Combinations and Cost Function

Based on the above model, its cost function is used to include the target profit and the behavior cost (time cost). If it is multi-aircraft cooperative task, the synergistic profit also needs to be included. In this paper, we ignore the synergistic profit. The behavior cost is the same in cause of each isometric step in the following models. Thus, the cost function only focuses on the objective gain, which is called the merit function. The path search is based on the calculation of the merit function. The function is

$$F = \sum_{i=1}^{n} w_i P_i, \tag{7}$$

where w_i is the weight coefficient of the step i in the behavior combination, P_i is the search area of the step i, and n is the number of steps. This is a greedy algorithm. The base of calculation is

$$P_i = \iint_{S_i} M^* \mathrm{d}x\mathrm{d}y = \sum_{k,j \in S_i} M_{k,j}. \tag{8}$$

The basis of the search lies in comparing the calculated values in the merit function. If the calculated values made by different combinations are the same, it can be based on other characteristics to do further judgement, such as the number of turns or orders. Steps of program simulation are described as follows.

1. Data initialization
   The length of the discrete grid, c; machines' initial position, P_{posi}; initial direction; $i = 1$; calculation of the FoV including b_h and b_c, based on Eq. (6)
2. Discrete map, based on Eq. (2)
   Calculation of the position matrix in search FoV shown in Fig. 5
3. While $\exists\, M_{k,j} > 0$ in the whole map
   Get all positions' logical values, $\mathrm{Pmap}_{k,j}$, in the nth step.
   If $\exists\, M_{k,j} > 0$ in the nth step
      Calculate all the merit functions in the nth step by Eqs. (7) and (8).
      Compare merit functions, and select the appropriate combination.
   Else
      Select the nearest point on the map as the goal.
      Determine steering with the composite behavior, according to Eqs. (4) and (5).
   End
   Update UAV's position and direction.
   Update the discrete map search part, and dynamic updated part.

End

1.6 Mapping Improved Retrieval Algorithm

Noriega and Anderson[23] divided the problem into multi-point coverage problem (actually a generalized assignment problem) and travelling salesman problem (TSP). They transformed the problems into binary optimal function. The problem of multi-point coverage discretizes the pending-search area in the shape of irregular quadrilateral to each discrete point firstly. The discrete point represents an area of 200 m × 200 m. As shown in Fig. 6, the FoV of single UAV covers an area of 7 × 7 discrete points. So the problem is how many waypoints (center of the FoV) we need can completely cover the search area at least.

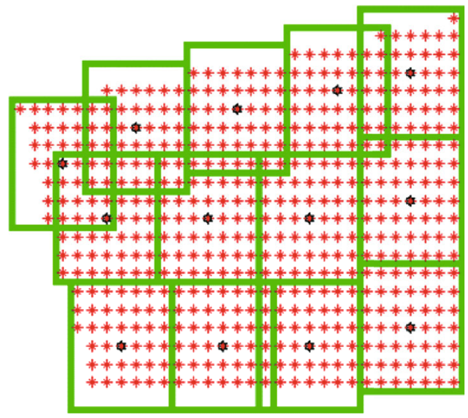


Fig. 6 Optimization results about route point number

When we use the binary optimal function of the generalized task distribution to solve the problem, the actual operand rises exponentially with the numbers of waypoints. Solution of Ref. [23] only solves the problem with about 30 waypoints. In fact, under the situation that the search task area is structured and larger than the FoV of the UAV, the number of waypoints is huge. So, we can expect that the results of multi-point coverage optimization will tend to be structured, especially inside the search task area. In the case of large number of waypoints, it is undoubtedly feasible to simplify and regularize the pending-search points. The operand is reduced greatly.

Based on the above rule, this paper simplifies the form of discrete maps to improve the rule. We approximate the size of the UAV's FoV to a square whose length is the cross internal. The whole map is discretized into lots of squares with the same size. The coordinates (x, y) are the actual coordinates in the discrete maps. After being discretized, the logic is

$$\left.\begin{aligned} &\tilde{M}_{k,j} = \iint_{S_i} M^* \mathrm{d}x\mathrm{d}y > 0 \\ &S_i = S_{\mathrm{unit}} \end{aligned}\right\}. \tag{9}$$

In Eq. (9), S_i shows the square which centers on the coordinates (kc, jc) with a length of $c = b_\mathrm{c}$. The difference from Eq. (2) is that S_i also represents an FoV. We consider the search mode of the UAV as scanning search. Its basic behavior can be simplified as a left turn, a right turn and a straight move in 2D space. In the process of improving the simulation, the basic behaviors include three kinds: turning left 90°, turning right 90°, and moving straight, as shown in Fig. 7.

Accordingly, the merit function should be simplified. We abandon the reference of merit function and directly establish the mapping from the external environments to the basic behavior. So we make use of the retrieval to distinguish the environmental conditions within two-step arrival on the map and retrieve the basic behavior combinations corresponding to the environmental conditions, as shown in Fig. 8. Then, mapping priority is required. Different mapping libraries are run during performing different tasks. Multiple mapping libraries can also be stored in one algorithm. Mapping libraries can be changed by using the command of mode conversion or situational trigger.

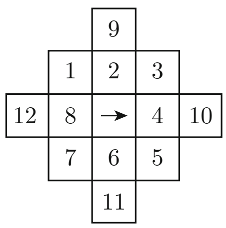


Fig. 7 Position number in two-step arrival

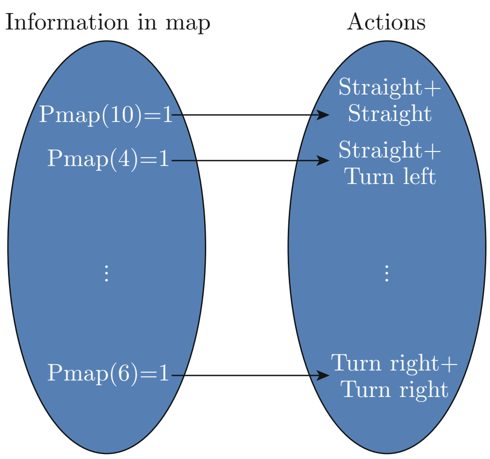


Fig. 8 The sketch of retrieving mapping

2 Simulation Analysis and Discussion

The simulation scenario assumes that when the UAV performs the coverage search task, the covered area is rectangle. But the task is dynamic and must update on time. The information shown by the map not only includes the part updated in the usual search, but also includes the part updated in cause of the dynamic environments. It means that $M_{k,j}$ in Eq. (2) can update on time. With the search-graph model or the direct mapping model, the UAV has the ability to convert the analysis of partial environments to actions. Based on the search-frame in Fig. 2, UAV can automatically cover the search area.

2.1 Simulation Analysis of Search Graph Algorithm Based on Action Combinations

Simulation settings are as follows: ① discrete maps are in the red area, as shown in Figs. 9 and 10, where each point means a 40 m × 40 m area; ② FoV of UAV is defined with a cross interval of 260 m, and the mode is scanning; ③ the basic behaviors of UAV are turning left 90°, turning left 45°, moving straight, turning right 45° and turning right 90° with a step length of about 520 m; ④ combinations of the n-step ($n = 5$) basic behaviors are built; ⑤ the merit function that can judge the behavior combinations is good or not is established with a weight coefficient of 1.

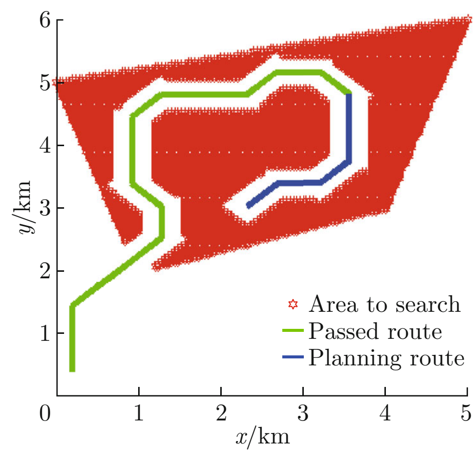


Fig. 9 The sketch of dynamic program based on cost function

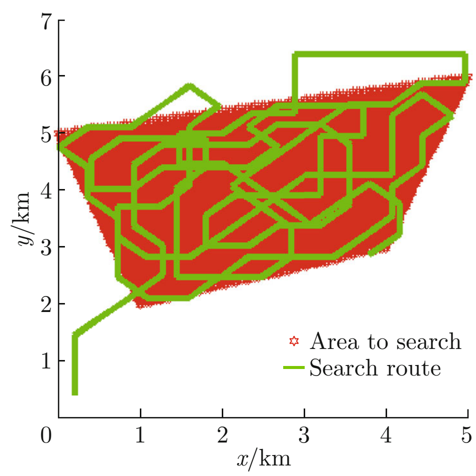


Fig. 10 The result of dynamic program based on cost function

Because each time of the calculation refers to 3 125 path parameters as well as a wide range of map data updates, each time of iteration needs to account a very long time. Thus, the amount of calculation is relatively huge and the speed of calculating is relatively slow. After running for a while, the effect is shown in Fig. 9, where the red asterisk is the pending-search area and the blank is the searched or pre-determined non-target area. The original search area is an irregular quadrilateral. After finishing running, it is shown in Fig. 10, where the red asterisk is the pending-search area and the blank is the pre-determined non-target area. After the search, all the points have been scanned and the task is reached. But the shape of the track is not regular. Also, repeated search is more serious. The process of calculation is time-consuming. It is unsuitable for searching in large scale and monitoring tasks on time.

2.2 Simulation Analysis of Improved Mapping Algorithm

2.2.1 *Improved Algorithm Simulation About Spiral Search*

Since simplifying the FoV and abandoning the merit function, we directly get the route by the knowledge base and search, as shown in Fig. 11. In this simulation, there are four items. ① Each point represents an area of 2 km × 2 km on the map. ② Define the FoV of UAV by simplifying the view to one grid whose size is also 2 km × 2 km. ③ The basic behaviors of UAV include turning left 90°, turning right 90° and moving straight with a step length of 2 km. ④ Build combinations of the 2-step basic behaviors.

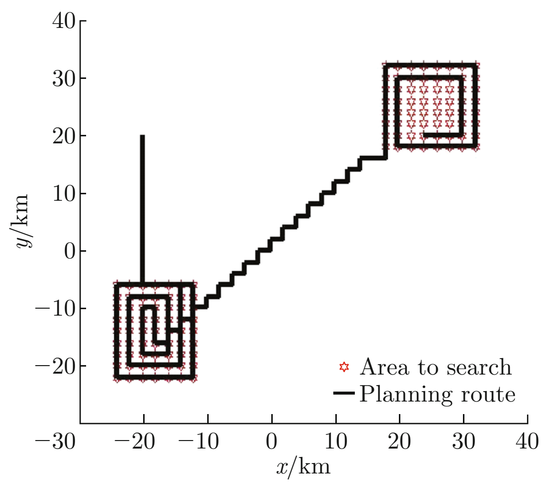


Fig. 11 The program result in the improved algorithm simulation about spiral search

We abandon the merit function and make use of the retrieval to retrieve the positions where UAV can reach within 2 steps on the map. Then, we correspond the positions to the combinations. It means a strategy that can correspond the distribution of pending-search points to a combination of actions. The details are described as follows:

(1) Find the values corresponded to the position Nos. 1—7 (Fig. 7) with the right direction.

(2) Set the priority. To move straight as far as possible, we set 3 steps. If there is a pending-search point in the position No. 1 or No. 2, which means the position No. 1 or No. 2 has a positive value, then turn left; if not, turn to search Nos. 3—5. If there is a positive value in the position Nos. 3—5, go towards the point No. 4. If there is a positive value in the position Nos. 6 and 7, turn right.

After simplification, we can see that the calculation accelerates. Also, it can achieve the effect that the searched curve is from outside to inside and the task can be completed well. However, transferring routes between the two search areas also expose the shortcomings of the combinations of the three-directions' vertical strategy. Therefore, transferring routes need to be further advanced.

2.2.2 *Improved Algorithm Simulation About Zigzag Search*

Also, we directly get the route by the knowledge base and search. But it is more complicated. So, it is a strategy that we search all the positions within 2 steps and correspond the positions to the combinations. In the mapping of the knowledge base search and combinations of basic actions, we change the order of the priority. As shown in Fig. 12, there are four items in this simulation. ① Each point represents an area of 2 km × 2 km on the discrete map, and the figures on it represent the pending-search area or not, where "1" means yes while "0" is no. ② Define the FoV of UAV by simplifying the view to one grid whose size is 2 km × 2 km. ③ The basic behaviors of UAV include turning left 90°, turning right 90° and moving straight with a step length of about 2 km (one grid). ④ Build combinations of the n-step basic behaviors ($n = 1$ or 2, n will change with the searching results).

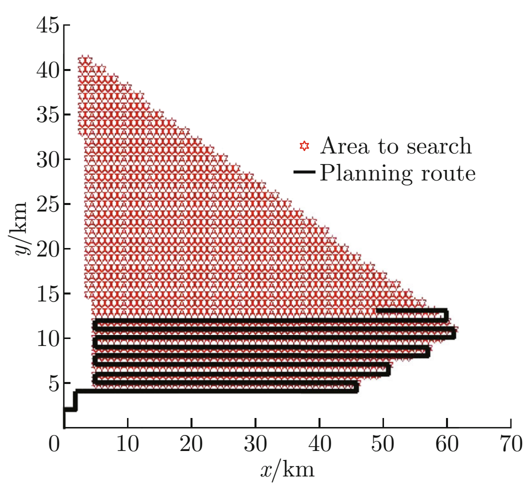


Fig. 12 The program result in the improved algorithm simulation about zigzag search

There are 10 kinds of combinations in this simulation: {[0,0]; [0]; [0]; [0]; [−1, −1]; [1,1]; [−1]; [1]; [1]; [−1]}. The ten combinations correspond to the positions of Nos. 10, 4, 5, 3, 1, 7, 9, 11, 6 and 2, as shown in Fig. 7, in the order of the priority that whether the pending-search points exist.

In the ten combinations, [0] represents moving straight, [−1] shows turning left 90°, and [1] means turning right 90°; [0, 0] means moving forward with 2 steps, [−1, −1] shows turning left with 2 steps continuously, and [1,1] shows turning right with 2 steps continuously.

The goal of zigzag search can be achieved by advancing the priority of the continuous turn. After further adjustment including adjusting the combinations of actions and priority, it is easy to find that the advantages of zigzag search lie in being flexible to adjust the paths needed by actions.

2.2.3 *Multi-UAV Route Planning Based on Improved Algorithm of Knowledge Base Search*

We get 3-UAV version of the algorithm in use of improving the simulation. In this version, the UAV with a minimum number of step sizes always has the priority to choosing the path and updating maps due to the changes of the step sizes in the iterative process of each path. Thus, the iterative steps of 3-UAV can get the synchronous growth. As shown in Fig. 13, it is the effect of the improved program about 3-UAV route planning (starting from different points to 800 steps). In Fig. 13(a), the starting points of 3 machines are in x axis (20, 40, 60 km). In Fig. 13(b), the starting points of three machines are in x axis (44, 40, 48 km). In Fig. 13(c), the starting points of 3 machines are in x axis (40, 40, 40 km). In Fig. 13(d), the starting points of 3 machines are in y axis (2, 2, 4 km).

The effect of automatically dividing areas is acceptable, as shown in Fig. 13. However, the program does not get the optimal route and just provides an approximate track about regional division. Although there is a small part of pending-search points located at the edge left when the search completes, the positions of these points are relatively concentrated and easy to handle.

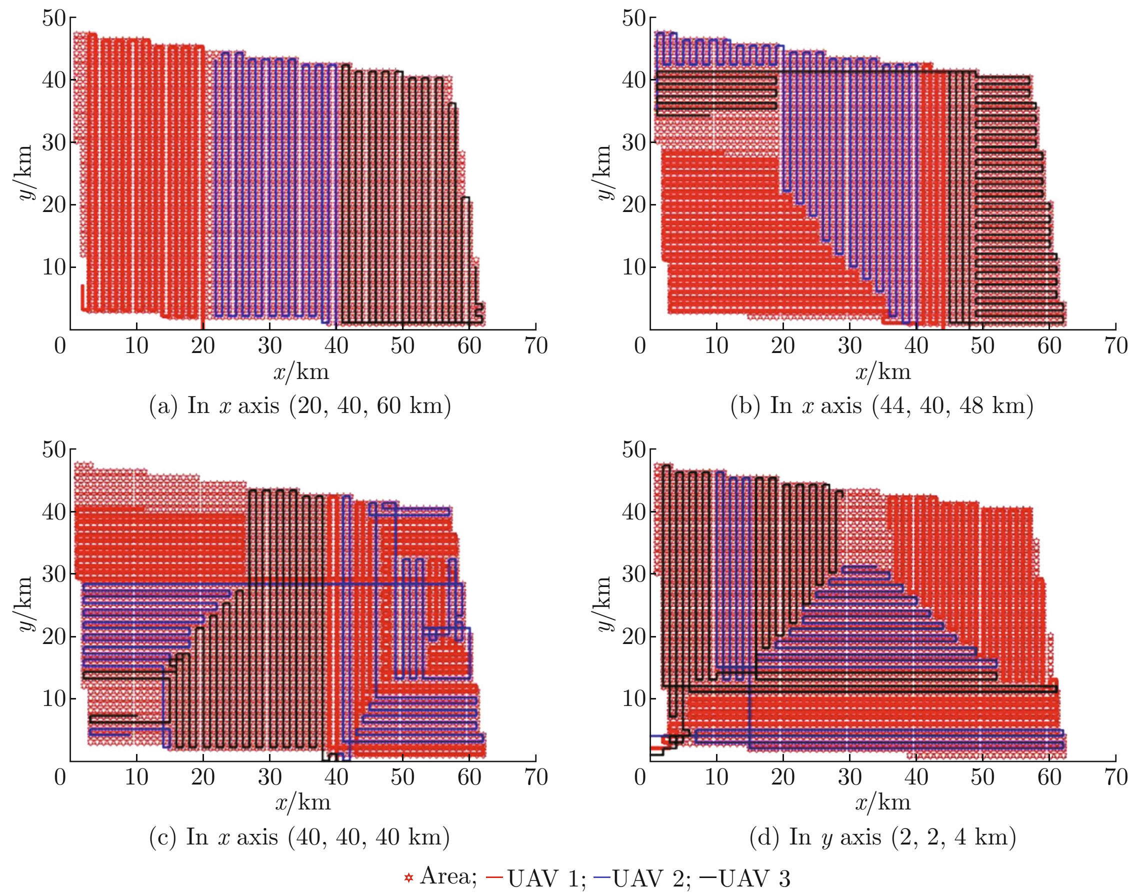


Fig. 13 The improved program of 3-UAV simulation from different starting points to 800 steps

2.3 Results of Simulation

After analysis, it is found that the conventional search-graph retrieval scheme performs slowly because it needs to calculate 5 steps (3 125 combinations) at the same time. But the improved scheme has only 2 steps, more than a dozen combinations. Comparing Fig. 10 and Fig. 13, we can get the following conclusions. The more abundant the knowledge base is, the better the search completes. Action-mapping search is more suitable to be applied in large area. In the search with a large range of areas, the action-mapping scheme can divide the search areas autonomously and perfectly without the prior division. It is suitable for multi-UAV to complete the task.

Actually, the number of waypoints is huge under the situation that the search task area is structured and larger than the FoV of UAV. So the results of multi-point coverage optimization tend to be structured, especially inside the task area. In the case of large number of waypoints, it is undoubtedly feasible to simplify and regularize the pending-search points. Also, the operand can be reduced greatly and the search time is shortened to about 2 s. What's more, the ratio of coverage redundancy (ratio of the swept area to the area to be searched) can be decreased to 1.21.

Table 1 shows the comparison of two schemes.

Table 1 Comparison of two schemes

Scheme	Search area/km^2	FoV/km^2	Last step	Redundancy ratio	Computing time/s
Cost function program	$7\,541 \times 0.04^2$	224×0.04^2	121	3.59	> 72 (long)
Improved program (Fig. 13(c))	2 474	1	921×3	1.21	2.29 (short)

3 Conclusion

This paper raises a developable and autonomous algorithm applied in large-scale coverage search of UAV, so as to solve the problem with the changes of dynamic environments in the actual search. In this method, the UAV can sense differences from changes of dynamic environments and plan for differences efficiently on time when it is in a battlefield with small range.

Comparing the improved scheme of action combinations with the search-graph, we find the speed of operating improved. Three-direction strategies of combinations show well in search routes, but limit the transferring routes obviously. If we need to complete a more suitable search route, it is effective to enrich strategies of knowledge base. This paper discusses the advantages of action combinations in knowledge base. The advantages of applying the mapping library are as follows:

(1) Making mission routes based on the mapping or changing the routes autonomously on time according to partial sense can make UAV have efficient autonomy and strong vitality. Also, the probability of completing tasks is considerable.

(2) Different UAVs can be equipped with different mapping libraries according to the requirements of different missions. It can make UAVs more flexible and professional.

(3) The same UAV with the same mission can also be equipped with different mapping libraries. Then, it can increase the unpredictability of mission routes and the survival rate of UAVs.

(4) The content of the mapping library can continue to be enriched due to actual experience. So the whole model is likely to evolve continuously and can also be extended from single mode to multi-UAV cluster mode.

(5) In the future, combinations of UAV with different mapping libraries will make the weakness that is easy to be predicted different due to single UAV. Thus, it can reduce the coefficient of danger in respect of overall tactics and can promote the fighting capacity greatly.

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