PATH PLANNING FOR MULTI HELICOPTER COORDINATED RESCUE

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Abstract

The coordinated search of multi helicopter is required in the relief of the severe nature disasters for improving the rescue efficiency. The path planning is one of the most important things during the pre-flight preparation. For several helicopters with many targets, it is difficult to find the best route manually. In this paper, the fitness value was introduced to assess multi helicopter with multi rescue missions. Then the path-planning problem for multi helicopter was solved based on genetic algorithm. Simulation results show that the method works well.

1 General Introduction

The helicopters always play an irreplaceable role in the search and rescue missions (SRM) during the various nature disasters. Helicopters maybe the only available tools to the disaster survey, search, supply and rescue. When more than one helicopters are involved in the search and rescue mission, particularly for different types of helicopters with different performance and different detection equipment, there should be effective coordination mission planning to take fully advantages of all helicopters and complete the mission efficiently. For the multi-helicopter and multi-target search problems, most current studies focus on the surveillance coordination of military UAVs mission planning. For example, Hutchision divided the surveillance area into several partitions with the same size, then allocate the targets of a partition to one UAV, and establish independent TSP model, using simulated annealing algorithm to optimize single UAV reconnaissance target sequence[1]. Ryan takes UAV reconnaissance mission planning problem as a multi-traveling salesman problem with time window, and use the Tabu search algorithm to solve it. Most existing studies generally assumed that each aircraft could reach all targets[2] [3]. But in the real SRM especially in mountain area, there are exiting the facts that different types of helicopters with different kinds of tasks. No study is reported on this topic. This paper studied the problem of route planning for multi helicopters in the multi task types SRM.

2 Multi Helicopters Routes Planning Description

Multi helicopter SRM route planning problem can be described as: there are n different types of helicopters that need to cover m target points. The question is how to plan the routes for helicopters so that all targets are covered and the total time consumed is the shortest[4] [5].

The feasibility of the helicopter to the task refers to the level of the match of the target type and the helicopter performance. The calculation of the feasibility should take several viable into account, including the type of the task (such as searching, airdrop, remote sensing, photography, etc.) and the critical level, the geographic characteristics of the target area, the performance of the helicopter (range, altitude and load capacity etc.) and the distance between the target and the base or airfield.

3 Tasks Allocation of Helicopters

In the feasible degree assessing, due to the different nature of various factors, some factors are quantifiable like the distance, some are qualitative factors, like the task type and the performance of the helicopter. For the quantitative factors, threshold should be considered, and quantify the factors in sections to avoid the affection of difference between the factors on the assessment[5] . The main factors discussed in this paper and their method of quantify method are as follows:

1). The distance between the base and the target, according to the performance of common helicopters, 0~1000km range is divided equally spaced by 50km, value from 21 to 1. $f_d = \lambda d$,in which the λ is the limiting factor, represented by 0-1 function. For the target located beyond the range , $\lambda = 0$, means that the helicopter cannot reach the target.

2). The geographic information, including the altitude of the target, clearance condition ,terrain and so on. In the case of altitude, the range of 0~5000m divided by 500m, represented by λH ,which also including the threshold to avoid the allocation of target above the limit to the helicopter. The clearance condition is the qualitative factor, so assume 0 means that the condition of clearance is poor that all helicopters are unable to land; 1 for the general condition that the pilot takes the decision; 2 for the good condition. In the case of terrain, 0 for the steep terrain that helicopters are unable to land, 1 for the general condition and 2 for the flat terrain.

3). Type of task, including remote sensing photography, target search, airdrop mission and rescue personnel, according to the critical level of the tasks valued as 1,2,3,4. The chain score method is used to determine the weight of each factor mentioned above. This method can determine the ratio of weight between two factors. i.e $\mu_{k-1,k}$, $\mu_{k-2,k-1}, \ldots, \mu_{1,2}$ are the ratio weight between f_{k-1} and f_k , f_{k-2} and f_{k-1} , … f_1 and f_2。 assume $\omega_k^* = 1$,then

$$\omega_k^* = \mu_{k,k+1}\omega_{k+1}^*, (k = n-1, n-2, \ldots, 1) \qquad (1)$$

$$\omega_k = \frac{\omega_k^*}{\sum_{t=1}^{n} \omega_t^*} \qquad (2)$$

The weights of factors mentioned are as follows:

Table1 weight of the task type

Factor k	weight		
	$\mu_{k-1,k}$	ω_k^*	ωK
Distance	1	1	0.2295
Altitude	1	1	0.2295
Clearance	0.9	0.9	0.2065
Terrain	0.9	0.81	0.1673
Task type	0.8	0.648	0.1080

For example, a target located at a place 100km from the base, 2000m from sea level, the clearance and terrain condition are normal. And the mission is a rescue mission. The chain score method is used to determine the weight of each facto, the feasible value is 6.0978r. This method can determine the ratio of weight between two factors. A feasible value matrix $V_{s\times t}$ can be acquired, in which s is the number of helicopters, t is the number of target, and V_{st} is the feasible value for helicopter s to target s.

Assignment problem is used to solve the problem that assign different tasks to different workers, since the ability and work efficiency of different workers are always not the same. The goal of assignment problem is to maximize the overall profit considering the different abilities of objects. Tasks of different targets assigned to helicopters can be described as:

$$\max S = \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}x_{ij} \qquad (3)$$

$$s.t.\begin{cases} \sum_{i=1}^{n} x_{ij} = 1, j = 1,2,\ldots,m \\ \sum_{j=1}^{m} x_{ij} = 1, i = 1,2,\ldots,m \end{cases}$$

In which c_{ij} is the feasible value, n is the number of helicopters and m is the number of targets. x_{ij} is the decision variable,

$$x_{ij} = \begin{cases} 1 & \textit{helicopter } i \textit{ is assigned to } j \\ 0 & \textit{helicopter } i \textit{ is not assigned to } j \end{cases} \quad (4)$$

In the multi task assignment problem, one helicopter may take several tasks, then dummy variables can be added to make the problem balance and then solved with the Hungarian algorithm[6].

4 Route Planning Based on Genetic Algorithm

After the tasks are assigned, a proper route for each helicopter with different tasks should be planned. Helicopters start from base are supposed to pass through each targets in sequence and should not pass the same target twice and return the base in the shortest time. Described as following: for set of infinite number of targets $C=\{C_1,C_2,\dots,C_n\}$, distance between targets are $D(C_1,C_2)\in\mathbb{Z}^*$, find a target sequence $\{C_{I(1)},C_{I(2)},\dots,C_{I(n)}\}$ with the condition of the minimum of total distance as $\min\sum_{i=1}^{n-1}\{D(C_{I(i)},C_{I(i+1)})+D(C_{I(n)},C_{I(1)})\}$, in which $I(1),I(2),\dots,I(n)$ are all-permutations of 1,2,…, n.

These problems can be treated as traveling salesman problem (TSP problem) with the complexity of $O(n!)$. Since the TSP problem is a NP-hard problem, in this paper the genetic algorithm with integer encoding is introduced to solve the problem. In order to avoid the replication of target, crossover operator is designed corresponded.

5 Submission Dates

Assuming the assigned 9 SRM points named as from 1 to 9 are shown in fig.1, the distance between those points is shown in table 2.

Table2 distance between targets (km)

SRM point	1	2	3	4	5
1	0.00	9.31	20.00	31.20	36.30
2	9.31	0.00	11.46	21.95	27.80
3	20.00	11.46	0.00	12.30	24.06
4	31.20	21.95	12.30	0.00	16.33
5	36.30	27.80	24.06	16.33	0.00
6	18.37	12.43	17.90	21.97	19.50
7	32.49	25.44	25.78	22.24	9.28
8	30.93	29.50	36.80	39.18	29.62
9	28.96	30.21	39.49	44.17	36.88
SRM point	6	7	8	9	
1	18.37	32.49	30.93	28.96	
2	12.43	25.44	29.50	30.21	
3	17.90	25.78	36.80	39.49	
4	21.97	22.24	39.18	44.17	
5	19.50	9.28	29.62	36.88	
6	0.00	14.18	18.90	22.40	
7	14.18	0.00	20.38	27.88	
8	18.90	20.38	0.00	8.67	
9	22.40	27.88	8.67	0.00	

Encode the gene as the sequence of the targets. Randomly arrange the integer from 1-9 as one gene in the initial population. The distance between targets is D_{ij}, the fitness is $1/\sum D_{ij}$. The size of the population is 50 and the maximum number of iterations is 2000. The crossover probability is 0.25, and the mutation probability is 0.01. The initial population is generated randomly. After 185 iterations, the optimal solution has stabilized with the total distance of 128.5km. And the optimal route is shown in fig.1

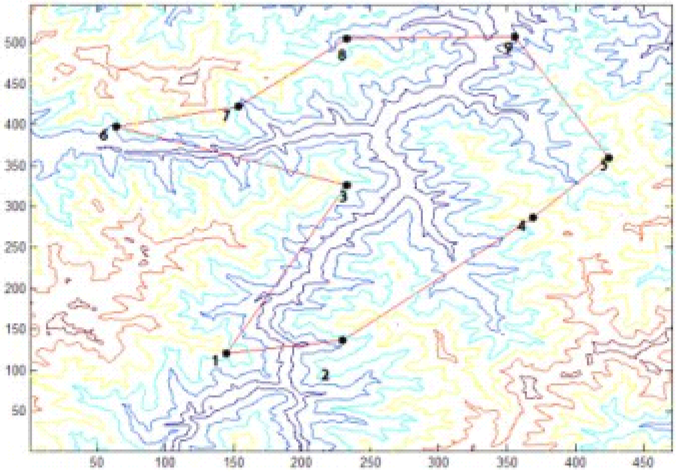

Figure 1. The optimal traversal route(in 100 meters)

6 Conclusions and Outlook

The route planning problem of more than one helicopter with multi target problem is decomposed into two problems, which are assignment problem and traversed problem. Through the feasible value assess method and the assignment problem, tasks are assigned to each helicopter. Then the route planning is achieved in genetic algorithm with proper fitness value. The research is arose during the earthquake rescue in China 2008, and real life, a clear target task types and the requirement of helicopter performance, more accurate assessment of feasible value and proper distribution of helicopters are the directions of the future research.

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