A Novel Optimal Route Planning Based on Ramp Lowest Point Search Method for Unmanned Aerial Vehicle

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***Abstract*—The research area of unmanned aerial vehicles (UAVs) is getting popular recently. However, how to find the optimal path is still an unsolved issue. In this paper, a novel optimal route planning based on ramp lowest point search method (RLPS) is proposed to find the route from any point in the space to the target. By applying the RLPS method, the path from the starting point to the end point will be planned automatically without complicated calculations. The proposed method will not only achieve self-correct function but also provide the shortest and optimal path.**

I. INTRODUCTION

Route planning technology has been applied on many applications, such as robotics, unmanned aerial vehicles (UAVs), missiles, road network planning, logistics and even routing issues in the field of communications, etc. In general, any shortest-path problem that can be abstracted to a dotted-line network model, can be resolved using route planning algorithm.

In order to find the optimal path to reach the target, route planning must take into account the length of the journey and avoid the obstacles. Moreover, the unnecessary detours or collisions also need to be avoid so that the flight duration or financial losses can be reduced. In the past decades, many optimal route planning algorithms have been proposed [1-3]. The gradient descent method find a local minimum solution of a function using gradient descent, one takes steps proportional to the negative of the gradient of the function at the current point [1]. However, this method take lots of computation time to find the path. Moreover, it generates many zigzags path if the problems is poor conditioned convex. The artificial potential field (APF) method assumed that the vehicle moves in the abstract artificial field [2]. Moreover, it is assumed that the target attract the moving object and obstacles create repulsion. The vehicle moves along the force of the total potential field. If the sum of the force is zero, the vehicle will be stagnant and cause route planning failed [3]. In this paper, a novel ramp lowest point search (RLPS) method is proposed to solve the above-mentioned drawbacks. The proposed method is divided into two parts: map model generation and path routing. In map model generation, it only needs a simple calculation to generate a plane. During the path routing, according to the map model and the starting position, the optimal path can be calculated automatically.

II. PROPOSED RLPS METHOD

In general, there are two kinds of route planning methods: static planning and dynamic planning. In static planning, environmental information is collected and build before route planning. In dynamic planning, the environmental information is collected in real-time during route planning. The proposed RLPS method is belong to static planning. The flow chart of the proposed method is shown in Fig. 1.

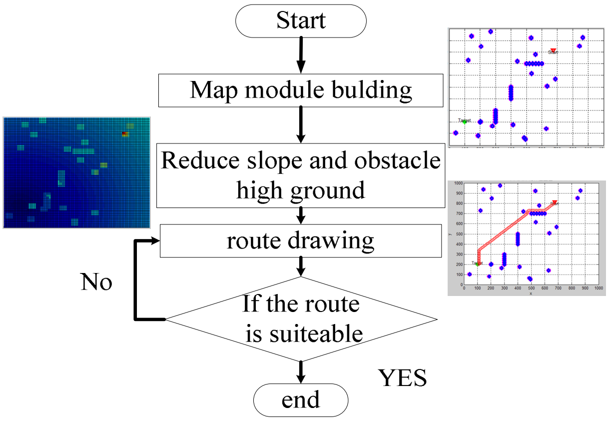
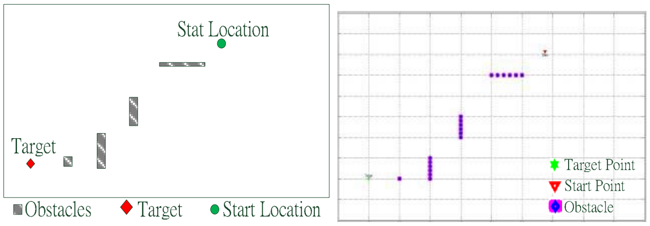


Fig. 1. Flow chart of the proposed RLPS method.

A. Map model generation

The first step in the RLPS method is to create an area that objects can move. Since most UAVs are flying at constant height, the space is set in a fixed height horizontal plane and the plane is assumed as a blank space. The obstacles in the space must be marked first so that the UAVs can avoid to collide it. If the obstacle is a large object such as building, it is assumed that buildings is a continuous obstacle. The generated map model is shown in Fig. 2.



(a) (b)

Fig. 2. Map model generation: (a) Real area floorplan (b) Map model.

B. Ramp generation with highland

The fixed height horizontal plane is turn into a 3D ramp map with obstacles highland by the following equations.

$$h_{\text{ramp}}(X,Y)=\sqrt{(X_{target}-X)^2+(Y_{target}-Y)^2} \qquad (1)$$

$$h_{obstacle}(X,Y)=\begin{cases}\text{k}, & \text{with obstacle}\\ 0, & \text{without obstacle}\end{cases} \qquad \text{k} \in \text{R} \qquad (2)$$

It is noted that h_{ramp} represents the height of any point in

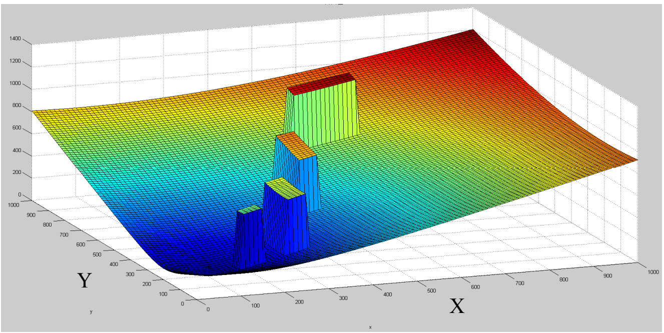


Fig. 3. The complete 3D ramp map.

the map and $h_{obstacle}$ represents the height of obstacles. X_{target} is the x coordinate of the target and Y_{target} is the y coordinate of the target. The function of complete 3D ramp map can be obtained by adding (1) and (2).

$$\mathrm{h}(\mathrm{X},\mathrm{Y}) = h_{\mathrm{ramp}}(\mathrm{X},\mathrm{Y}) + h_{obstacle}(\mathrm{X},\mathrm{Y}) \tag{3}$$

From the above explanations, the completed 3D ramp map is created as shown in Fig. 3.

C. Route planning

With the generated map model, it is assumed that the target is lowest point. The route planning is begin from the starting point and search the adjacent point with lower height that previous point each iteration. Since the obstacle is higher than other points, it will not be chosen during the route planning. Finally, the UAVs will automatically reach the lowest point and target is found.

III. IMPLEMENTATION

A. Input the map information

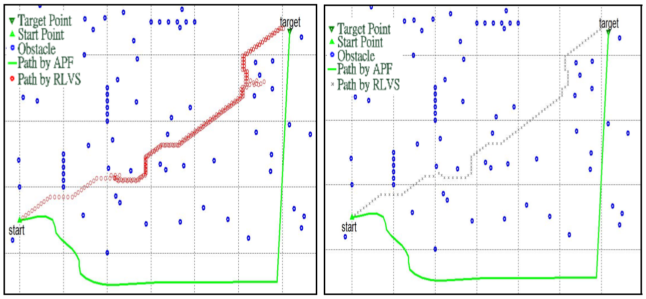
It is assumed that the map is a two-dimensional matrix. To create the map information, the coordinates of the starting and ending points are input to the model. The coordinates of the obstacles are input to the model as well.

B. Ramp and obstacle generation

According to (1), a fixed height horizontal flying space is created and a ramp function h1(X,Y) is generated. To avoid collide the obstacles, we extend the scope of the obstacle to three points. Thus, the size of obstacle is changed from 1 × 1 to 7 × 7. This can prevent the object too close to the obstacles. The coordinate of obstacle highland is h2(X,Y). If the obstacle exist, the coordinate will be a height. Otherwise, it will be zero.

C. Route planning and optimization

By import a route model, it will search for its own center around the eight-point position and find the lowest point. The route planning is begin from the starting point and search the adjacent point with lower height than previous point each iteration. Finally, the object will automatically reach the lowest point and target is found. However, if the moving direction is perpendicular to the obstacles, the UAVs will stuck. In this case, the proposed method cannot find a lower point than the previous one.



(a) (b)

Fig. 4. The route generated by using RLPS and APF method: (a) First planning (b) Third planning.

To solve this problem, we apply an autonomous move mechanism. When routing stocked, it will increase the height of previous point and move to another direction automatically. This can prevent the UAVs re-enter the trap area. By using this mechanism, if the whole route planed again, it can avoid UAVs enter this area. Therefore, this method can reduce the search iterations and find the optimal path.

Fig.4 shows the route generated by using RLPS and artificial potential field (APF) method [2] with the same step length. From the results, both method can find the path between staring point and target. However, APF method generated a longer path than that of the RLPS method. APF method must consider the repulsion caused by the surrounding obstacles during planning. However, RLPS method only need to analyze the surroundings lowest point on the ramp. Hence, RLPS can find the shorter path compared with APF method.

IV. CONCLUSION

In this paper, a novel ramp lowest point search (RLPS) method is proposed to find the route from any point in the space to the target. The proposed method generated the map model by adding the height of any points and obstacles in the space. With this map model, the proposed method search the adjacent point with lower height that previous point each iteration. Hence, it will automatically reach the lowest point and target is found. Moreover, an autonomous move mechanism is applied to prevent the UAVs re-enter the trap area. In practical, the proposed can be applied on optimal route planning of the UAVs.

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