Obstacle Avoidance Algorithm for UAVs in Unknown Environment based on Distributional Perception and Decision Making *

Zhuofan Xu, Ruixuan Wei, Qirui Zhang, Kai Zhou, and Renke He

***Abstract*—Guaranteeing the flight with safety and efficiency for UAVs in unknown environment is one of the most important problems for researchers. In this paper, a novel obstacle avoidance algorithm for UAVs in unknown environment based on distributional perception and decision making is proposed, where the obstacle avoidance problem is divided into two parts: distributional decision making and global decision making. The global optimal obstacle avoidance path is get with mission completed safely at last. The simulation shows the algorithm proposed is capable of solving the obstacle avoidance problem for UAVs in the unknown environment and is valuable to improve the perception and decision making ability of UAVs.**

***Keywords*—UAV; Obstacle avoidance; Distributional perception and decision making**

I. Introduction

Nowadays, with the development of technology and the opening of low-altitude airspace, the application of UAVs (Unmanned Aerial Vehicles) has become more and more popular. For example, the investigation, surveillance and attack in military use, the aerial photograph, reconnaissance and plant protection in civilian use, the wide open sky will be more and more crowded. As a result, how to guarantee the safety of UAVs has been the target of more and more research institution and colleges around the world[1-4].

Obstacle avoidance ability is the insurance to complete the mission for UAVs and there are three popular obstacle avoidance algorithms: path planning algorithm, artificial potential field algorithm and geometrical algorithm[5-8]. The main idea of path planning algorithm is to convert the obstacle avoidance problem to path planning problem. In [9], the rapid spanning tree protocol algorithm is applied in this problem and effective path is created due to the spur track of the tree. In [10], multi UAVs cooperative path planning method is proposed to solve the cooperative method in the avoidance problem. The artificial potential field algorithm [11-13] convert the UAV and the target to positive and negative electric charge. The distance keeping of UAVs and the path planning is through the repulsion force and gravitation force of electric charges. Geometrical algorithm avoids the obstacle through analyzing the Geometrical relationship between UAVs and obstacles. [14] validates the validity of changing yaw angle to avoid obstacle based on the best geometrical way.

During the missions of a UAV, it is required to plan the path according to the apriori information of the mission area and then fly along the path[15-16]. However, this method is not suitable when the information of the mission area is not clear[17-18]. Therefore, this paper propose an obstacle avoidance algorithm based on distributional perception and decision making from the cognizance perspective of humans, where the UAV avoid the obstacles through the information get from the sensors in real time and record the information. After the UAV arrived the destination, it will plan the path again base on all the information get from the memory vault to provide an optimal path.

II. Framework

A. Mission Area

In the process of cruising of a UAV, it is often required to fly in a fixed height with a constant velocity. Therefore, the mission area is simplified to a planar area and the obstacles is simplified to several circles in the mission area, where the coordinate of the circle represents the location of the obstacles and the radius represents the range of the obstacles, as shown in Fig.1.

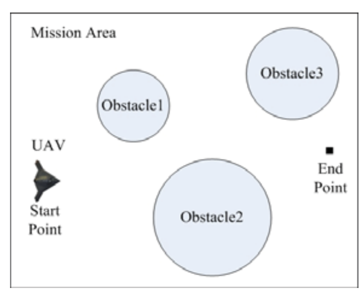

Figure 1. Mission Area

In the mission area, the space around a UAV is divided to three layers, as shown in Fig.2. Out of the range of the sensor of the UAV is the priori knowledge layer. In this layer, the UAV can not obtain information of the environment through its own sensor but to rely on the information recorded in the memorizer or through the communication link. Within the priori knowledge layer is the sensor layer. In this layer, the information is get through the sensors of the UAV, including laser radar, ultrasonic transducer, binocular vision and so on.

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Within the sensor layer is the avoidance layer. In this layer, the UAV will avoid the obstacles with the obstacle avoidance strategy.

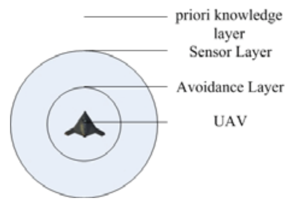

Figure 2. UAV Obstacle Avoidance Model

B. *Framework of UAV Obstacle Avoidance*

In the process of obstacle avoidance, the UAV recognize the information of the obstacles through the sensors, including the orientation, the distance and the size of the obstacle, and then the threat level is calculated to pass to the distributional decision making module. In the distributional decision making module, the obstacle space around the UAV is recognized by the distributional perception and decision making module and an avoidance path is given in the sensor layer. With the movement of the UAV, there will be more obstacles included in the sensor layer, the obstacle avoidance path will be updated in real time and the information of the obstacle and the path will be recorded in the memory vault. After the UAV have arrived at the destination, all the obstacle information of whole mission area in the memory vault will be taken out to replan the path for the UAV in order to provide a better path when it return the base.

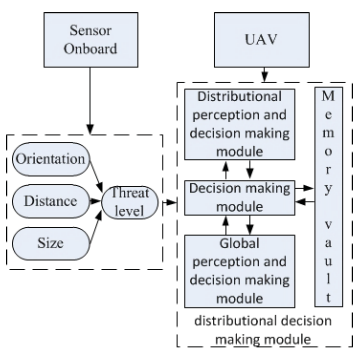

Figure 3. Framework of UAV obstacle avoidance

III. UAV DISTRIBUTIONAL PERCEPTION OBSTACLE AVOIDANCE ALGORITHM

A. *Principles of distributional perception and decision making*

If a man walks in an unknown environment, he will walk towards the direction of the destination and avoid all obstacles within his sight. After arrived at the destination, the man will always think the environment he just walked again. When he needs to go back, he will have a better way to choose. Likewise, if an UAV flies in the unknown environment, the thinking way of a man can be applied for the UAV.

Defining set $A_i = \{O_l, O_m, O_n \cdots\}$ $i, l, m, n \in N$, where O_m is the obstacle m . Defining state $K = 0, 1, 2, 3 \cdots$,the UAV is at the starting point when $K = 0$. During the flying of the UAV, if the obstacle information in the sensor layer has changed, namely $A_{i+1} \neq A_i$, then the obstacle information is recorded. If the newly appeared obstacle is in the way to the destination of the UAV, the path in the sensor layer will be replanned to generate the new obstacle avoidance path.

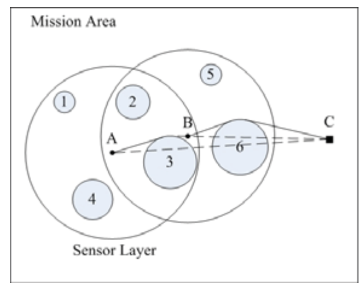

Figure 4. Distributional perception obstacle avoidance

In Fig.4, an UAV is flying towards the destination. When it is in the position A, there are four obstacles O_1, O_2, O_3, O_4 within the sensor layer, where only O_3 is on the way of the UAV. Therefore, the new obstacle avoidance path $\overset{\frown}{ABBC}$ is planned and the old one AC will be abandoned. When the UAV is in the position B, there are four obstacles O_2, O_3, O_5, O_6 in the sensor layer, where only O_6 is on the way of the UAV and O_1, O_2 are out of range. Therefore, the new obstacle avoidance path $\overset{\frown}{BC}$ is planned and the old one BC will be abandoned.

B. *Algorithm Flow*

The algorithm flow graph is shown in Figure 5, where the obstacle information including orientation, distance and the size is detected by the sensor onboard first. Then the obstacle avoidance path in the carried out and recorded in the memory vault. During the following flying, the UAV detect the environment constantly, if there are some changes in the obstacles, the path will be replanned and recorded. After arriving at the destination, the UAV replan the whole mission area through the information in the memory vault to get an optimal path.

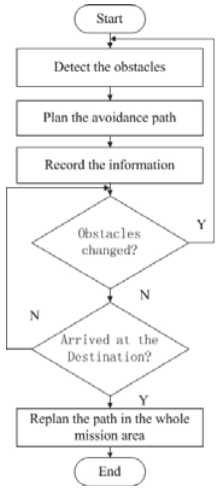

Figure 5. The basic flow of the algorithm

IV. Simulation and Analysis

Supposing the mission area is a planar area size of 100km×50km. Adding 11 circular obstacles in the mission area. The position and the size of the obstacles are random chosen, as shown in Fig.6, where " ◆ " represents the initial position of the UAV and " ■ " represents the destination. During the mission, the UAV keeps detecting the environment and generate the obstacle avoidance path constantly. After arriving at the destination, the optimal path is generated according to the memory vault, as shown in Fig.7.

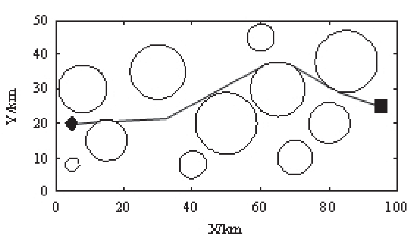

Figure 6. Path of distributional perception and decision making

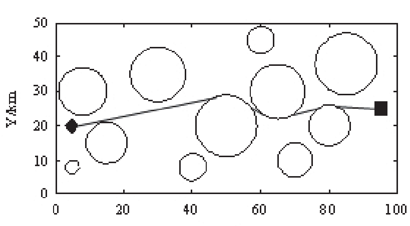

Figure 7. Path of global perception and decision making

Comparing the length of the path generated by distributional decision making and global decision making, as shown in Table I. It is obvious that the length of the path generated by distributional decision making is longer then that generated by global decision making. It is evidence that the UAV can not decide the optimal path only with part of the information of the mission area but to complete the mission safely. The simulation is just an example, if the distribution of obstacles is more complicated, the length of the path generated by distributional decision making will be much more longer than that generated by global decision making.

TABLE I. Compare in Length of the Path

Step	Length
Global	104.578 km
Distributional	88.395 km

V. Conclusion

In this paper, the decision making method for a human in an unknown environment is simulated in an UAV without priori information in the unknown mission area. The obstacle avoidance problem is divided to distributional decision making and global decision making, which will not only guarantee the safety of the UAV, but also get the optimal path in the mission area. However, there are still some questions to be solved, for example, the size and the kinematics of the UAV is to be considered, which will be discussed in the subsequent papers.

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