DOI:10.18686/ahe.v7i25.10174

Design and Application of a Model for Passive Positioning and Maintaining Formation Based on Unmanned Aerial Vehicles

Yulin Guo, Youmo Fei, Xu Wang, Mingtong Xue, Jinyang Zhang
City College of Dalian University of Technology Dalian, Liaoning 116000

Abstract: As an effective method for adjusting the position of unmanned aerial vehicles, bearings-only passive positioning can achieve the goal of maintaining formation formation very covertly due to its passive positioning. This article establishes a mathematical model between the transmitting signal and the passive receiving signal of the drone, and uses exhaustive method, genetic algorithm, and prediction model to measure the lateral direction angle to predict the position of the drone. This study can achieve effective localization, increase the accuracy and stability of localization results.
Keywords: Passive localization; Exhaustive method; genetic algorithm; GDOP mathematical measurement; Formation formation

With the rapid development of science and technology, people's living standards continue to improve, drones are also widely used in traffic control, emergency rescue, overall photography, anti-terrorism patrol and other industries. In recent years, security accidents brought by drones have also occurred frequently. To solve these problems, the UAV must be effectively and accurately positioned.

1. Overview of passive location based on UAV

The maturity of passive positioning is high and the cost is moderate. It not only has good passive positioning concealment, but also can locate the location of the drone operator. Therefore, the passive positioning method has many advantages to locate the UAV. Therefore, when the UAV cluster is flying in formation, in order to avoid external interference, electromagnetic silence will be maintained as far as possible, and electromagnetic wave signals will be emitted less, and orientation-only passive positioning method will be chosen to adjust the position of the UAV. To position the drone. Each drone in the formation has a fixed number, and the relative position relationship with other drones in the formation remains unchanged. The direction information received by the UAV receiving the signal is agreed to be the Angle between the UAV and any two UAVs transmitting the signal (as shown in Figure 1).

2. Uav passive positioning maintains formation model hypothesis

2.1 Algorithm implementation

The UAV flies at the same height based on its own perceived altitude information. Then the UAV that sends signals and the UAV that receives signals are located on the same plane. With the UAV (FY00) as the center of the circle, the Angle between the UAV that receives signals and the other two UAVs that transmit signals is analyzed. Since the UAVs transmitting signals are unbiased and their numbers are known, assume that the two UAVs transmitting signals are F and G in Figure (1), and K is the UAVs receiving signals with unbiased positions. Measure $\angle FKL$ and $\angle GKL$ as reference angles, and then measure the Angle between the remaining UAVs receiving signals with slightly biased positions and the UAVs transmitting signals. Such as $\angle FML$ and $\angle GML$, use the exhaustive method to compare these two included angles with the reference Angle, the smaller the difference, the more accurate the positioning. Therefore, using directional Angle measurement, error calculation, UAV flight height and distance between UAVs as constraint conditions, the objective function with minimum error is calculated. The parametric solution is obtained by using least square method.

Three UAVs can carry out effective positioning. In order to improve the positioning accuracy, it is necessary to optimize the position of the UAVs that transmit signals. In this regard, optimization strategies need to be established to achieve accurate and effective positioning. The location includes the distribution mode of the UAV receiving the signal and the distance between the UAV receiving the signal. In the moving state, the dynamic configuration between multiple drones and the target, that is, the real-time distance between each drone and the target, as well as the real-time Angle between any two drones and the target, directly affects the passive positioning accuracy and stable tracking effect of multi-aircraft coordination.

2.2 The establishment of algorithm model is based on heredity

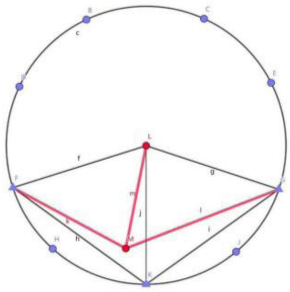

Figure (1) Schematic diagram of the position relationship between the transmitting signal and the receiving signal UAV

2.3 Model practice process and result analysis

In order to improve the accuracy, we usually use the geometric accuracy factor GDOP as an indicator to measure the positioning error. GDOP can describe the positioning error distribution at different locations more intuitively. The smaller the value of GDOP, the higher the positioning accuracy of the positioning system. In this case, the distribution mode of the three UAVs can be changed, and the distribution mode of the UAVs with the highest accuracy can be obtained by simulation. Then, the distance of the UAVs receiving signals can be changed, and the spacing with the highest accuracy can be obtained by simulation respectively.

Simulation 1: The effect of the distribution mode of the UAV receiving the signal on the positioning accuracy.

Simulation conditions: three UAVs receiving signals are set as A_1、A_2 and A_3, and the value of $\angle A_2A_1A_3$ composed of the three is β, the distance between A1A2 and A1A3 is 60m, the delay measurement error is 5ns, and the position error of the UAVs receiving signals is 0.05m.

The simulation results show that:

The larger the GDOP, the smaller the GDOP, but when the β exceeds 60°, the uniform detection in all directions cannot be achieved, so the distribution mode of β=60° into a triangle should be selected for effective positioning.

Simulation 2: The influence of distance between receiving signal drones on positioning accuracy.

Simulation conditions: Three UAVs A_1、A_2 and A_3 receiving signals are set to be distributed in β=60° triangle, the delay measurement error is still 5ns, and the position error of the UAVs receiving signals is 0.05m.

The simulation results show that:

Increasing the distance between the receiving UAVs can reduce the positioning error.

3. Optimization of genetic algorithm model

3.1 In addition to FY00 and FY01, at least one drone is required to transmit signals in order to achieve effective positioning of the drone. Moreover, the three UAVs are distributed in a positive triangle with a direction Angle of 60°, and the accuracy is highest when the receiving signal UAVs are farther away from the detectable range.

According to the formation requirements, one drone is located in the center of the circle, and the other nine drones are evenly distributed on the circle with a radius of 100 m. That is, a circle can be made with (0,0) as the center of the circle and 100 as the radius. Using the polar coordinate data of the initial position of the UAV given in Table 1, the position of the UAV in the circle can be determined. Based on the three points you can identify a concentric circle, find another circle. Based on the established measurement model, a simple positioning model is established, and then the optimization and the test of the results are carried out.

According to the initial position data of the UAV given in the table, the distance between the UAV 2, 5 and 8 is 98m from the center of the circle, and the "on a certain circle" in the question indicates that r does not necessarily =100. A concentric circle can be determined according to the three points, and a circle with (0,0) as the center and 98 as the radius can be determined. GeoGebra can make the figure (5).

Assuming that the drone transmitting the signal can also receive the signal, 2,5 transmit the signal to adjust the position of the drone. This problem takes drone No. 6 as an example, as shown in Figure (6), when the circular angles of the same arc are equal, that is, when α=β=59.88°, 2, 5, 6 and 8 are all in concentric circles. In this way, the pairwise adjustment locates all the remaining drones to a circle with drone 0 as the center and 98 as the radius, thus solving the problem that all drones are located on the same circle.

Also taking UAV 6 as an example, UAV 0,5 emits signals. When the Angle between UAV 5, UAV 0 and UAV 6 is γ=40°, as shown in Figure (7), the problem of equidistance on the circumference of the UAV can be solved. At this time, the position of UAV

6 is the real ideal position.

It can be seen from the question:

The polar coordinates of Drone 5 are (98,159.86 °).

Convert it to cartesian coordinates of (-92.01, 33.74)

Let A(-92.01, 33.74), radius =98, and B be drone 6 (not ideal)

γ is the Angle between UAV 5, UAV 0 and UAV 6, that is, the AB line is the opposite side of γ

$$\cos\gamma = \frac{a^2+b^2-c^2}{2ab}$$

From the law of cosine: $= \frac{r^2+r^2-AB^2}{2r*r}$

$$= \frac{98^2+98^2-AB^2}{2*98*98}$$

Let B(x,y), according to the distance between two points formula:

AB=d= $\sqrt{(x_1-x_2)^2+(y_1-y_2)^2} = \sqrt{(x+92.01)^2+(y-33.74)^2}$

AB can be found, and since there are nine drones on the circumference, gamma =40° is ideal

So when gamma →40 degrees, the optimal solution is reached

3.2 The above results are verified based on the prediction model

3.2.1 Uav groups can form formation based on the group behavior mechanism of geese, and can stabilize the formation and maintain the formation after changing the formation [3]. If the formation change is to be achieved in flight, it can be achieved by the direction Angle and distance of a certain UAV relative to a specific point.

Based on the establishment of the formation arrangement: Since three points determine a plane, this problem assumes that the three points are B, D and E, as shown in Figure (8), and then assumes that four UAVs B, D, E and I transmit signals.

3.2.2 Take any three UAVs that transmit signals to determine a plane, and any line in the plane is the line on the plane. Now connect two points of the two UAVs that transmit signals to determine a straight line, connect the remaining points with this line, measure and calculate whether the sine value of the Angle between the two lines is equal to 0, if the sine value is equal to 0, it means that the Angle between the line and the plane is 0. Otherwise, the drone is not located on the same plane. Therefore, in order for all drones to be located on a plane, it is necessary to ensure that the linear plane Angle formed by the connection of all drones and the plane is 0.

Secondly, it is necessary to ensure that ∠ABC=∠CDN=∠NEF=∠HDG=∠HIG=60°, because only when these angles meet this condition can we ensure that the general direction of all drones is the same.

In addition to the four UAVs that emit signals at known locations, the remaining UAVs are represented by points (x, y), using the distance between two points formula:

d= $\sqrt{(x_1-x_2)^2+(y_1-y_2)^2} = 50$

This ensures that the distance between two adjacent drones is 50m.

4. Peroration

The development of science and technology, as one of the key research directions in the era of technology, requires a higher degree of machine automation. Uav can replace manual, perform reconnaissance, surveillance, anti-submarine, meteorological observation and other tasks without causing personnel damage, so it has been widely used. In order to make up for the problems faced by multiple UAVs when performing tasks, the problem of passive positioning of UAVs has become the focus of improving the application efficiency of UAVs. In this design, geometric accuracy factor GDOP and GeoGebra are used to optimize the algorithm model and reduce the accuracy error. Finally, it is calculated by data test that γ=40° Angle is the most accurate and ideal position.

References:

[1] Yunlong Chen. Research and implementation of Passive time difference positioning Method for UAV [D]. Xidian University,2021.

[2] Hao ZHONG. Autonomous generation method of UAV passive location track based on graph neural network [J]. Value Engineering,2020,39(12).

About the author: Yulin Guo(2001-), male, Han nationality, born in Jinzhong, Shanxi Province, undergraduate, research direction is control science and engineering.