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Analysis and Research of multi-UAV autonomous formation based on azimuth adjustment model

Mingming Zhai[1], Siyu Chen[2], Jungang Fan[1], Mingrui Hu[2], Ruijing Zhao[2]

[1]School of Computer, Baoji University of Arts and Sciences, Baoji, 721016, China
[2]School of Mathematics and Information Science, Baoji University of Arts and Sciences, Baoji, 721016, China

Abstract: *The slight deviation of some plane positions of the Unmanned Aerial Vehicle (UAV) cluster in the formation flight is caused by force majeure factors. To maintain the UAV formation, the silent mode is defined, that is, the UAV thin line flight. The circular formation model and the UAV bearing adjustment model of the conical cluster UAV positioning are established. The UAV position can be adjusted, and the UAV formation can be adjusted into a circular formation and a conical formation.*

Keywords: *Triangulation; Cyclic characteristics; Formation control; Azimuth signal; Adjustment model optimization*

1. Introduction

With the continuous development of science and technology, unmanned aerial vehicles (UAVs) are developing rapidly. In real life, unmanned aerial vehicles (UAVs) are often used for formation flying. In order to make multiple UAVs fly at the same time and maintain a certain formation, we need to accurately locate and correct the yaw of each UAVs. Now, without using the outward radiation energy of UAVs, the position of UAVs during flight is changed simply by using the direction information of the desired target combined with the joint positioning of multiple UAVs, and the output of the direction information of several UAVs is used, so that the remaining UAVs in the formation can obtain and change the position[1-3]. Before flight, each UAV is independent and has a unique number in the system. When we fly fixed, the position information of each UAV remains relatively unchanged[4-5].

At present, the common UAV formation mainly includes circular UAV formation, as shown in Figure 1, and conical UAV formation, as shown in Figure 2. In this paper, the azimuth-only passive positioning method is adopted for two different formations, and the circular formation and conical UAV positioning model and UAV orientation adjustment model are established. The UAV formation of two formations is formed, which provides a certain basis for the formation of UAV formation.

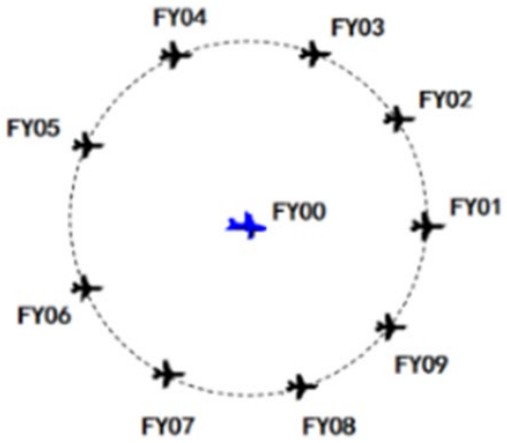

Figure 1: Schematic diagram of circular UAV formation

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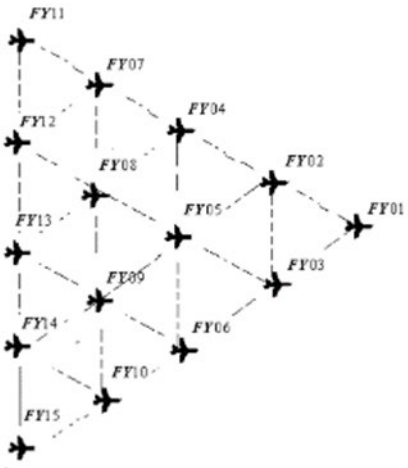

Figure 2: Schematic diagram of conical UAV formation

2. Establishment of circular UAV formation model

According to the initial position data of the UAV, it can be found that there are four circles on which all the 9 points are distributed, with the radius of 98m, 100m, 105m and 112m respectively. Since the positions of all UAVs are slightly different, it is assumed that the Angle deviation is ignored and the 9 UAVs are only adjusted to be on the same circle through signal transmission. In order to keep electromagnetic silence as much as possible, make the UAV emit less electromagnetic signals outward and move at a minimum distance, it is most appropriate to choose a circle with a radius of 105m evenly distributed through data comparison.

At this time, the distance of other points moving toward this circle is approximately 7m, which reduces the movement range of the UAV as much as possible. In order to make measurement more convenient, the circumference of the uav numbered 4, 7 is determined with the radius of 105m and point O as the center of the circle.

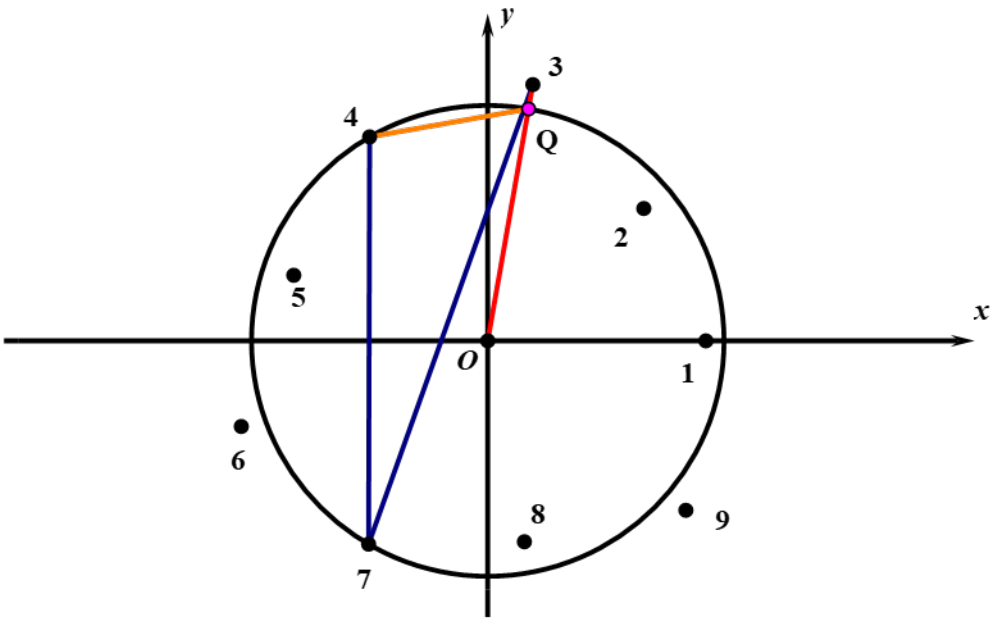

Figure 3: Deviation location diagram of UAV

As shown in Fig. 3, take UAV No. 3 as an example, connect the point located at No. 3 with the center of the circle O, and connect the line segment with circle O at point Q. At this time, the Angle remains unchanged, and the solution formula is as follows

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$$\alpha_0 = \arcsin\frac{\sqrt{2-2\cos(\theta_1-\theta_2)}}{2} \quad (1)$$

The adjustment direction of UAV No. 3 is its own polar diameter direction. When it receives the direction information of UAV No. 4 and 7, the Angle is equal to, it can be determined that UAV No. 3 is located on the circumference.

Repeat the above method to adjust the uavs numbered 1,2,5,6,8,9 to circle O.

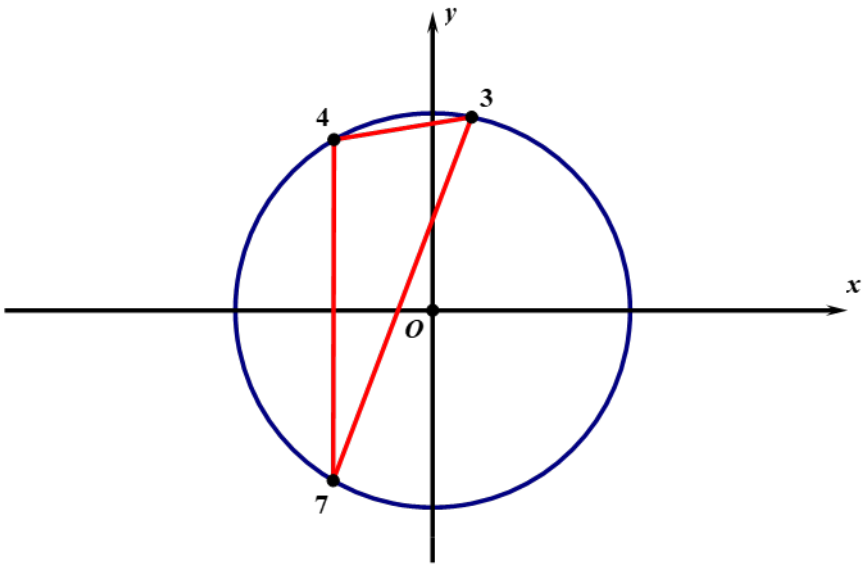

Figure 4: Schematic diagram after adjustment

After determining that the nine UAVs are in the same circle, we adjust the distribution of the nine aircraft evenly. According to the problem, the central Angle corresponding to the strings determined by the two UAVs should be equal to, that is, the circumference Angle is equal to, as shown in Fig. 4. The ideal position of UAVs 3 should be determined when it receives UAVs 4 and 7 and the direction information obtained from the transmitted signals is.

Similarly, adjust the rest of the aircraft so that the nine UAVs are evenly distributed on the same circle.

According to the uav bearing adjustment model is established, using MATLAB software to the writing of the relevant procedure, can be as shown in figure 5 left visual image, with the ideal formation, comparing the situation as shown in figure 5 the right image contrast found that calculate adjusted in the same formation and the ideal state.

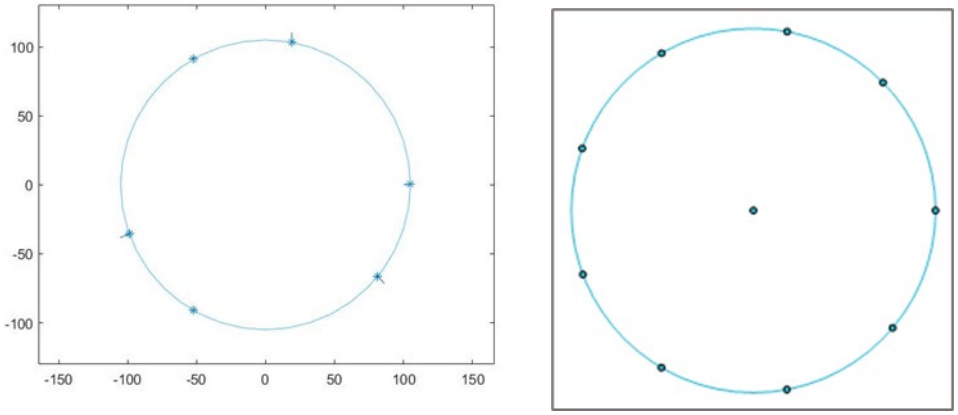

Figure 5: Image after program running (left) Idealized image (right)

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3. Establishment and solution of conical UAV formation model

When UAVs fly in a conical formation, the orientation information [4~5] of azimuth-only passive positioning above is used to adjust and optimize the formation (assuming that all the adjusted UAVs are on the same plane).

The biggest difficulty of this problem is that the initial position is unknown, and the position of each UAV cannot be measured directly through the direction information of bearing-only passive positioning. Therefore, it is necessary to calculate the position of the UAV by the distance and Angle between neighboring UAVs, and adjust the position of the UAV.

After setting the initial point for this problem, the requirements for setting the next point to be corrected are:

1) When adjusting the position of the UAV, the number of UAVs that need to transmit signals should be as small as possible;

2) The adjusted point can be as close as possible to the position of the UAV swarm when the conical formation is realized.

The termination condition is that all UAV positions have been adjusted.

Based on the above requirements, we can design the adjustment scheme of UAV position.

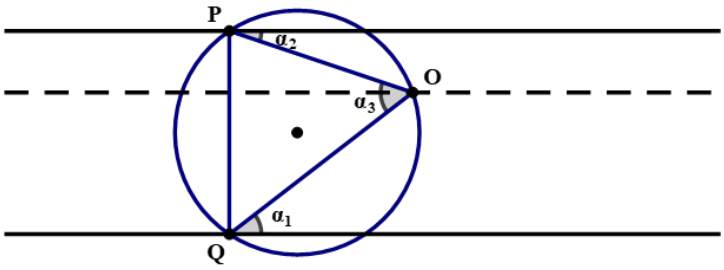

Figure 6: UAV O is located by UAV P and Q

As shown in Fig 6, it can be obtained from the principle of triangle and alternate interior angles: $\alpha_3 = \alpha_1 + \alpha_2$

if and only if $\alpha_1 = \alpha_2 = 30°$, $\triangle OPQ$ Is an equilateral triangle.

Our solution is to take the three adjacent points in the middle part and select the transmitting signal UAV as P, Q and O as the signal receiving points. If and only if the receiving Angle is $60°$, the conical formation is satisfied and the question is satisfied. According to the knowledge of circles and triangles, we can form $\triangle OPQ$ equilateral triangles.

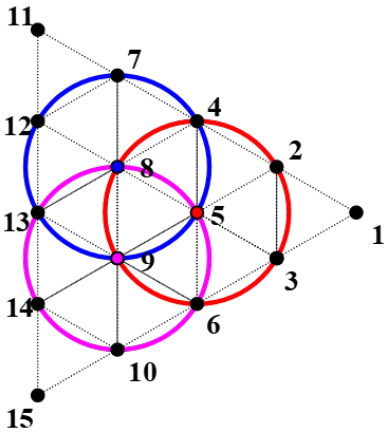

Figure 7: The circle formed by UAV 5, 8 and 9

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Based on the signals from five, eight, and nine UAVs that have already adjusted their positions, UAVs 13 can be adjusted to the correct position through the orientation information.

It can be obtained from 1 that equilateral triangle is formed at 5, 8 and 9 points. According to the conclusion obtained from question (3) of question 1, the adjustment scheme of UAV 4, 7 and 12 can be obtained in circle 8. By analogy, the adjustment schemes of 2, 3, 6, 10, 14 and 13 in circles 5 and 9 can be obtained. Finally, other UAVs in the conical formation except those in the three corners can be adjusted properly, and the spacing of two adjacent UAVs on the line can be equal (as shown in Figure 7).

Loop this three times to adjust the position of all remaining UAV.

Finally, the position of all UAVs in the conical formation can be adjusted well, and the spacing of two adjacent UAVs on the line can be equal.

4. Conclusion

In this paper, based on the definition of the silent state, that is, the UAV flies according to the originally designed route, the azimuth passive positioning method is adopted to establish the UAV positioning model of circular formation and conical formation and the UAV orientation adjustment model. The UAV position is adjusted, and the UAV formation can be adjusted into circular or conical formation.

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