ISSN 2616-5775 Vol. 6, Issue 1: 104-109, DOI: 10.25236/AJCIS.2023.060115

Research on conical UAV formation position adjustment based on CTLS algorithm and pigeon flock behavior mechanism

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Abstract: *UAVs should be kept as silent as possible during field operations and missions for concealment and to prevent electrostatic interference. In this paper, with rigorous mathematical argumentative thinking, the CTLS algorithm is referenced and optimized to give a solution model for the multi-error passive pure orientation cooperative position adjustment problem, and the results are reviewed in terms of polar coordinate groups. The self-adjustment problem of conical swarm is solved and the method is shown to be applicable to attitude correction of any ordered swarm where translation invariance of subsystems exists. The convergence results of the algorithm are reviewed in terms of polar coordinate groups and line graphs of iterative data, and the results are found to be good.*

Keywords: *Pure azimuthal passive localization; Pigeon flock behavior mechanism; CTLS algorithm*

1. Introduction

With the development of UAV technology, UAVs have become an increasing security threat in the air, and traditional equipment technology is difficult to implement accurate and effective handling of them, and they are prone to accidents caused by inaccurate positioning [1]. Considering that the traditional active radar and other hardware devices are not suitable for the complex electromagnetic environment in cities, and that the scattering cross-sectional area of ordinary UAV radar is small and difficult to capture, as well as the cost, passive positioning technology has become the first choice for UAV positioning [2]. At the same time, passive positioning has the advantages of large coverage, low cost and good concealment, which can help UAVs avoid external interference during formation flight, maintain electromagnetic silence as much as possible, and emit less electromagnetic signals to the outside. In this paper, we have conducted an in-depth study on pure azimuth passive positioning in formation flight based on UAV attempts [3].

UAVs should be as silent as possible during field operations and missions for concealment and to prevent electrostatic interference. In this paper, address the problem of self-adjustment of conical swarms and demonstrate that the method is applicable to attitude correction of any ordered swarm in the presence of translational invariance of subsystems. Using the pigeon flock behavior mechanism and the CTLS algorithm, the problem is transformed into a multiple multiple error cooperative correction problem for the subsystem. The convergence results of the algorithm are finally reviewed in terms of polar coordinate clusters and iterative data fold plots, and the results are found to be good.

2. Assumptions and notations

2.1 Assumptions[4]

Use the following assumptions.

1) Assume that the UAVs in the formation are always flying at the same altitude.

2) Assume that the relative position of each UAV in the formation to the rest of the UAVs remains constant in the no-operation state.

3) Assume that all UAVs in the formation can adjust their positions normally and autonomously without malfunction.

ISSN 2616-5775 Vol. 6, Issue 1: 104-109, DOI: 10.25236/AJCIS.2023.060115

4) Assume that the deviation of UAV positions in the formation is small enough compared to the standard spacing.

5) Assume that the signals received by the UAVs are only from the other UAVs in the formation, without considering the interference from external sources.

2.2 Notations

The primary notations used in this paper are listed as Table 1.

Table 1: Notations

Symbols	Description
α_1, α_2	Observation angle of the UAV to be positioned
$\theta_0, \theta_1, \theta_j$	Signal source as abstract observation station observation angle
R	Characteristic linearity of the subsystem
d	Distance from the UAV to the origin
$\Delta\alpha$	Difference of observation angle
r_{nml}	Standard deviation from the standard position
$J(\alpha_1)$	Function to calculate the number of the UAV to be located
$K(\Delta\alpha)$	Function to calculate the number of the unknown signal source
r, φ	Coordinates of the total polar coordinate system
ρ, θ	Coordinates of the group of polar coordinate systems
σ	Standard deviation of the distribution of the error in the deviation of the UAV from the standard position

3 Model construction and solving

3.1 Defect Analysis

Considering the following problems of localization at large scale range[5].

1) Poor positioning accuracy, which can easily lead to loss of connection. Since UAVs receive interference from many other factors in their natural state, the resulting radio wave communication is not ideal.

2) High signal strength, weak concealment and strong interference. It is easy to produce uncontrollable electromagnetic interference, which leads to the malfunction of some UAVs.

Therefore, it is possible to imitate the hierarchy in the pigeon flock and grade the UAV flock in a certain way, thus narrowing the adjustment range and improving the adjustment accuracy while solving the above-mentioned errors. After the problem is solved, it can be found that the model based on this can be extended to any ordered UAV flock with translation invariance.

3.2 Flock level setting

The perpendicular line from a certain corner along the cone array at that corner is specified as the potential field line, along which the potential energy decreases, and the higher the potential energy the higher the UAV is assigned a higher rank. The head pigeon is selected with the second head pigeon on its side as the standard to determine the standard geometric framework of the entire UAV cone array, i.e., a standard coordinate exists for each point. The purpose is to perform a step-by-step multi-error cooperative correction according to the rank of the UAV swarm. It can be shown that if FY11 is the head pigeon and FY12 is the secondary head pigeon, the potential field lines and equipotential lines are shown in Figure 1.

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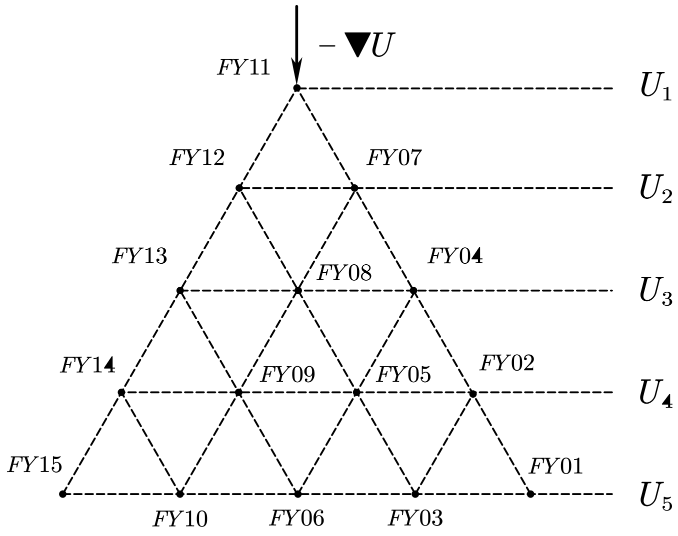

Figure 1: Artificial potential field diagram

Among them are $U_1 > U_2 > U_3 > U_4 > U_5$.

3.3 Problem Transformation

Depending on the setting of the flock rank, you can adjust the rank in order from highest to lowest, as shown in Figure 2.

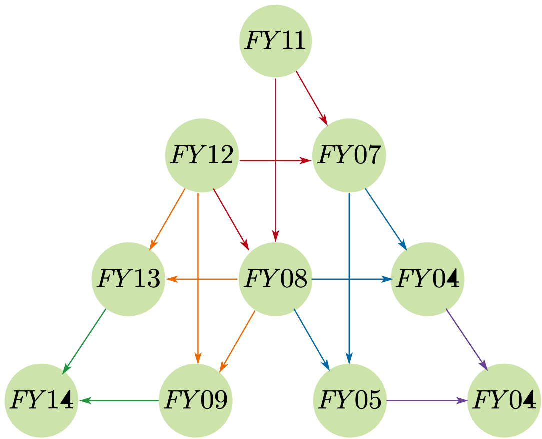

Figure 2: Conical formation flock level diagram

Then the problem can be reduced to an adjustment problem in the standard geometric subsystem, where there are two standard points that establish the coordinate system in the manner shown in Figure 3.

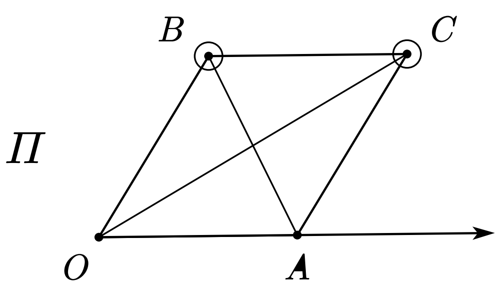

Figure 3: Subsystems Schematic

Then the point B,C is considered to be a real coordinate where a random error exists, and the problem becomes one of how to perform a multi-error cooperative correction of the subsystem Π so that it can be

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adjusted iteratively by the CTLS algorithm.

3.4 Model Testing

Adding errors to the coordinates of B and C respectively, the polar angle error $\Delta\varphi_B, \Delta\varphi_C$ and the radius error $\Delta r_B, \Delta r_C$ due to the two obey normal distribution

$$\begin{gathered} \Delta\varphi_B \sim N\left(0, \frac{\sigma}{d_B}\right), \quad \Delta r_B \sim N(0, \sigma) \\ \Delta\varphi_C \sim N\left(0, \frac{\sigma}{d_C}\right), \quad \Delta r_C \sim N(0, \sigma) \end{gathered} \tag{1}$$

Then, we simulate the distribution of the drone swarm in the subsystem corresponding to points B, C under natural conditions, and simulate the polar coordinates of points B,C according to this

$$\begin{gathered} \varphi_B = \varphi_{B0} + \Delta\varphi_B \\ \varphi_C = \varphi_{C0} + \Delta\varphi_C \\ r_B = r_{B0} + \Delta r_B \\ r_C = r_{C0} + \Delta r_C \end{gathered} \tag{2}$$

The standard deviation of the error distribution function for any of the UAVs is determined in the same way as in the second question , and thus the errors $\Delta\varphi_B, \Delta\varphi_C$ and $\Delta r_B, \Delta r_C$ are determined and combined to obtain the true value of the simulation.

The angle between any two sides of the quadrilateral formed by the UAV is calculated by a system of equations, so that a certain number of signal UAVs can be used as observation stations, and after calculating the observation angle, the CTLS algorithm is used to adjust B,C to the standard position one by one.

In order to show the convergence of the algorithm, the concept of "polar coordinate group" is introduced. That is, for each UAV in the swarm, a polar coordinate system can be established with its standard position as the center of the circle, and the process of adjusting the UAV to the standard position one by one is the process of reaching the center of the circle through a certain path in its polar coordinate system.

A randomly selected set of results is transformed to the polar coordinate group, and the resulting approximation path is shown in Figure 4.

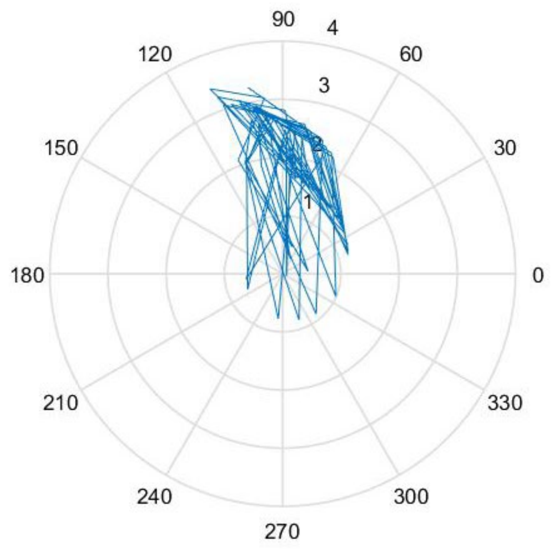

Figure 4: Schematic diagram of the convergence path of the group of polar coordinate systems

Four sets of errors are randomly selected, and each set of errors is solved only once for the subsystem.

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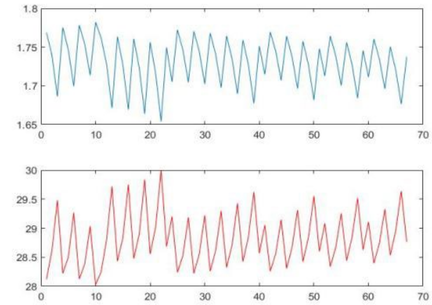
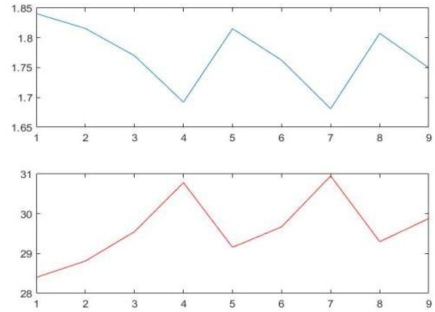
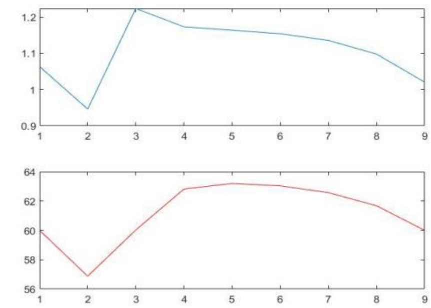
The results of the four iterations are shown in (a)(b)(c)(d) of Figure 5.



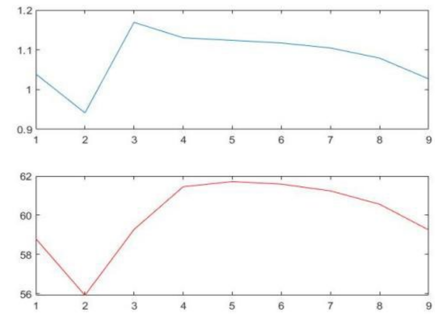
(a)



(b)



(c)



(d)

Figure 5: Schematic diagram of numerical fluctuations of four simulation iterations

4. Conclusion

In this paper, it solves the self-adjustment problem for conical swarms and demonstrate that the method is applicable to attitude correction of any ordered swarm in the presence of translational invariance of subsystems. The pigeon flock behavior mechanism and the CTLS algorithm are applied to transform the problem into a multiple multiple error cooperative correction problem for subsystems. The

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convergence results of the algorithm are finally reviewed in terms of polar coordinate swarms and iterative data fold plots, and the results are found to be good.

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