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Signal-receiving UAV Positioning Model Based on Geometric Analysis

Yinfeng Li, Qisen Wang, Yongcheng Gu, Xintong Zhou, Chenming Song

School of Shandong University of Science and Technology, China

ABSTRACT

A drone is an aerial vehicle without a pilot or controller that is remotely controlled using aerodynamics to fulfil a designated task under certain circumstances. With the encouragement and support of national policies, the development of China's UAV industry has a good prospect. In real life, location information is the key information for UAVs to accurately complete operations and realise mission requirements, and the importance of its accurate positioning is self-evident. For the UAV localisation model, the bias-free localisation model is established first, and then the localisation model in the case of bias is solved on this basis. When there is a deviation in the received signal UAV, the UAV may be located outside the circle, on the circle, and inside the circle. Specifically divided into four scenarios, see Figure 1-4. (Analysed: outside the circle: $\theta_1' < \theta_1$; inside the circle: $\theta_1' > \theta_1$; circle on the left: $\theta_2 > \theta_2'$, right: $\theta_2 < \theta_2'$; no deviation: $\theta_1' = \theta_1$, $\theta_2' < \theta_2$). When the position of the passive receiving signal UAV does not exist deviation, according to the position relationship obtained four cases, respectively, the establishment of the quadrilateral, the use of sinusoidal theorem to obtain the receiving signal UAV positioning model, the same can be obtained under the existence of deviation, the specific positioning model of the receiving signal UAV.

KEYWORDS

Sine-cosine theorem; System of linear equations; Passive localisation; Conical queue

1. BACKGROUND TO THE ISSUE

UAV is a powerful weapon for air defence reconnaissance and early warning in China, often used for military strategic reconnaissance, civil geographic investigation, etc. It is also an important guarantee force for national airspace security, and it plays an irreplaceable role in modern warfare. And in the traditional active radar is not suitable for working in the city and other places with complex electromagnetic environment, and because of the high cost, low efficiency and other reasons under the environment. Passive positioning technology becomes the key technology to solve the current situation of UAV [1].

External radio signals can be transmitted to the passive positioning device, and passive positioning device does not actively emit electromagnetic waves to the outside, so that the principle of positioning and tracking of the measured target, and passive positioning at the same time with a wide range of radiation, small consumption expenses and other advantages. It is an excellent choice for both military and civil use.

2. TEXT

2.1. Modelling and solving

2.1.1. UAV Positioning Model Establishment and Solution

(1) Receiving signal drones with deviations

When there is a deviation of the UAV receiving the signal, the deviation condition is mainly classified into three types: in-circle, out-of-circle, and on-circle.

Let $FY0H$, $FY0I$, $FY0J$ be the UAVs transmitting signals and $FY0K$ be the UAV receiving signals. Let the position points of these four drones be H , I , J , K . The angles formed between the four drones θ_1 , θ_2 , θ_3 are shown in the figure, $\angle = HKI\ \theta_1$, $\angle = IKJ\ \theta_2$, $\angle = HKJ\ \theta_3$.

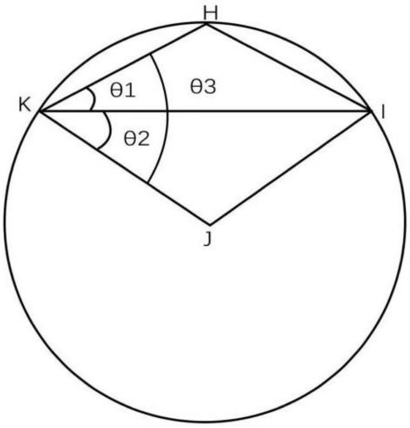

Figure 1. Relationship between the four UAVs

1) When the UAV receiving the signal has an offset and is outside the circle:

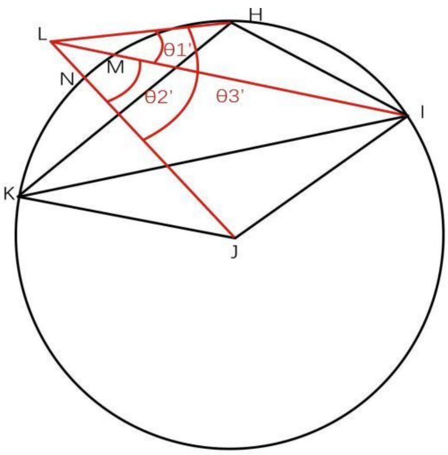

Figure 2. The drone is offset and outside the circle

$\angle = HLI\ \theta_1^{'}$, $= \angle\ ILJ\ \theta_2^{'}$, $\angle = HLJ\ \theta_3^{'}$, so that IL , JL intersect the circumference at M , N . Connect HM and IN respectively. According to the arc length correspondence, then $\angle = HKI\ HNI$. In Δ HMI and $\Delta\ HLI$, since $\angle\ HLI\ <\ \angle\ HMI$, then it can be concluded that $\angle\ HLI\ <\ \angle\ HKI$. That is: $\theta_1^{'} < \theta_1$.

It is concluded that $\theta_1^{'} < \theta_1$ holds when the drone lies outside the circle.

2) When the UAV receiving the signal has an offset and is inside the circle:

Similarly, $\theta_1^{'} > \theta_1$ holds.

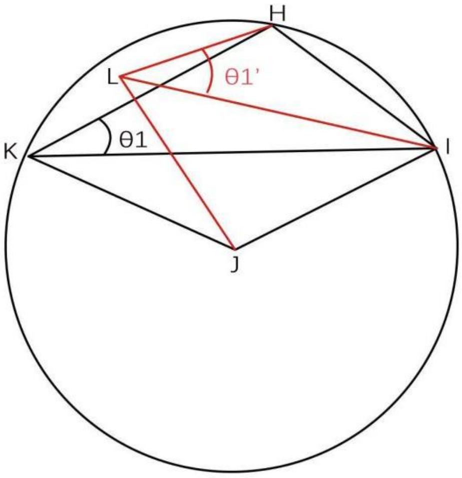

Figure 3. The drone is offset and inside the circle

3) When there is an offset of the UAV receiving the signal, on a circle, it is divided into the following two cases:

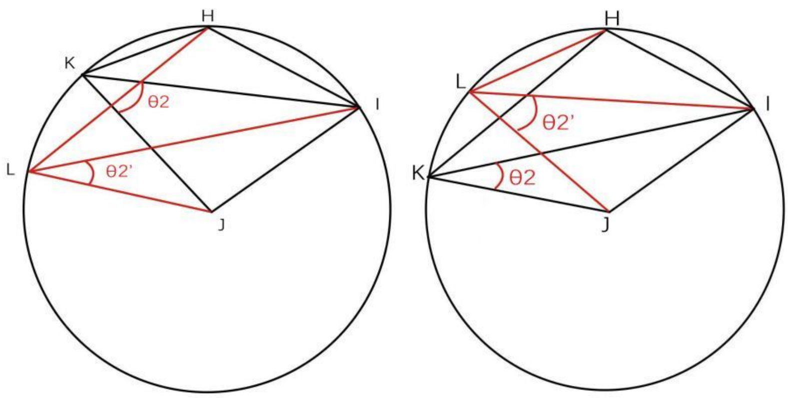

Figure 4. Two cases where the UAV is offset and on a circle

Case I Case II

a. The first case, when the offset position is to the left on the circle:

According to the arc length for, $\angle HKI = \angle = AEB\,\theta_1$. $\triangle LJI$ and $\triangle KJI$ are both isosceles triangles.

and $\angle KJI < \angle LJI$, then $\angle IKJ > \angle ILJ$.

It can be obtained that $\theta_2 > \theta_2^{'}$ when the drone's shift position is to the left on the circle.

b. The second case, when the offset position is to the right on the circle:

Similarly, $\angle IKJ < \angle ILJ$.

It can be obtained that $\theta_2 < \theta_2^{'}$ when the drone's shift position is to the right on the circle.

In this case, the solution method for the case of receiving signal UAVs with bias is the same as the solution method for the case of no bias.

(2) No deviation of receiving signal drones

For the case in which there is no bias, we have classified the positional situation of the transmitting UAVs on the circumference into four cases by analysing the positional relationship between the two transmitting UAVs located on the circumference except $FY00$: two transmitting UAVs separated by 0, 1, 2, and 3 passive signal-receiving UAVs, respectively.

We will use $FY01$ as a fixed location for the transmitting signal UAV, and the four scenarios will be unfolded by spacing a different number of receiving signal UAVs from $FY01$ in a clockwise direction.

Let the distance of the drone transmitting the signal from $FY00$ be R

1) Situation one:

The transmitting signal drone on the circumference is $FY01$, $FY02$

When the transmitting signal drones are $FY00$, $FY01$, $FY02$, let the size of $FY02-FY01-D1$ be x_1, the size of $FY00-FY01-D1$ be x_2, the size of $FY02-D1-FY01$ be α_1, the size of $FY00-D1-FY01$ be α_2, and the distance from $D1$ to $FY01$ be L_1.

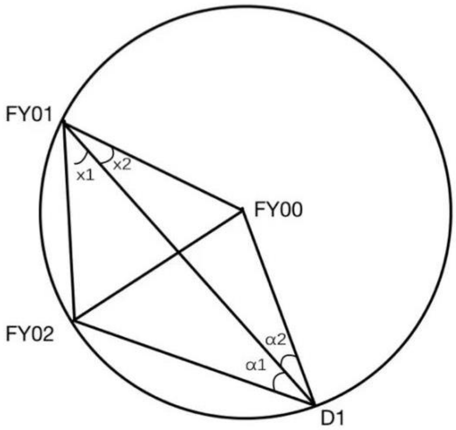

Figure 5. The first case where the UAV is not biased

According to the sine theorem:

$$\begin{cases} \dfrac{0.64R}{\sin\alpha_1}=\dfrac{L_1}{\sin(\pi-x_1-\alpha_1)} \\ \dfrac{R}{\sin\alpha_2}=\dfrac{L_1}{\sin(\pi-x_2-\alpha_2)} \\ \dfrac{0.64R}{\sin\alpha_1}\sin(x_1+\alpha_1)=\dfrac{R}{\sin\alpha_2}\sin(x_2+\alpha_2) \\ x_1+x_2=70^\circ \end{cases} \tag{1}$$

2) Situation two:

The transmitting signal drone on the circumference is $FY01$, $FY03$

When the transmitting signal drones are $FY00$, $FY01$, $FY03$, let the size of $FY03-FY01-D1$ be y_1, the size of $FY00-FY01-D1$ be y_2, the size of $FY03-D1-FY01$ be β_1, the size of $FY00-D1-FY01$ be β_2, and the distance from $D1$ to $FY01$ be L_2.

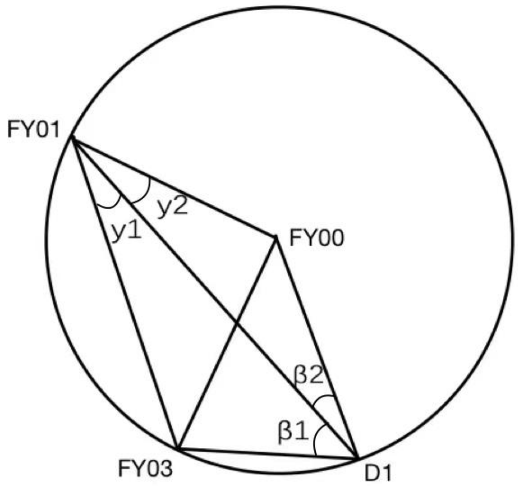

Figure 6. The second case where the UAV is not biased

According to the sine theorem:

$$\begin{cases} \dfrac{1.28\mathrm{R}}{\sin\beta_1} = \dfrac{L_2}{\sin(x - y_1 - \beta_1)} \\ \dfrac{1.28\mathrm{R}}{\sin\beta_2} = \dfrac{L_2}{\sin(x - y_2 - \beta_2)} \\ \dfrac{1.28\mathrm{R}}{\sin\beta_1}\sin(y_1 + \beta_1) = \dfrac{\mathrm{R}}{\sin\beta_2}\sin(y_2 + \beta_2) \\ y_1 + y_2 = 50^{\circ} \end{cases} \tag{2}$$

3) Situation three:

The transmitting signal drone on the circumference is $FY01$, $FY04$

When the transmitting signal drones are $FY00$, $FY01$, $FY04$, let the size of $FY04-FY00-D1$ be z_1, the size of $FY00-FY01-D1$ be z_2, the size of $FY04-D1-FY01$ be γ_1, the size of $FY00-D1-FY01$ be γ_2, and the distance from $D1$ to $FY01$ be L_3.

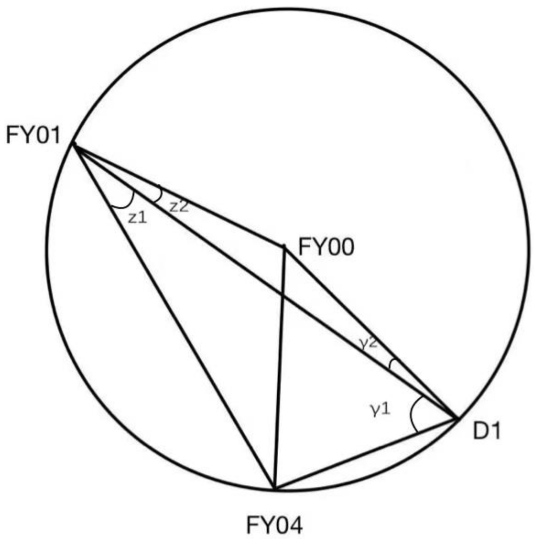

Figure 7. The third scenario in which the UAV is not biased

According to the sine theorem:

$$\begin{cases} \frac{1.74\mathrm{R}}{\sin\gamma_1} = \frac{\mathrm{L}_3}{\sin(\pi - z_1 - \gamma_1)} \\ \frac{\mathrm{R}}{\sin\gamma_2} = \frac{\mathrm{L}_3}{\sin(\pi - z_2 - \gamma_2)} \\ \frac{1.74\mathrm{R}}{\sin\gamma_1}\sin(z_1+\gamma_1) = \frac{\mathrm{R}}{\sin\gamma_2}\sin(z_2+\gamma_2) \\ z_1 + z_2 = 30^\circ \end{cases} \tag{3}$$

4) Case IV:

The transmitting signal drone on the circumference is $FY01$, $FY05$

When the transmitting signal drones are $FY00$, $FY01$, $FY05$, let the size of $FY00-D1-FY05$ be m_1, the size of $FY01-D1-FY00$ be m_2, the size of $FY00-D1-FY05$ be θ_1, the size of $FY05-FY01-D1$ be θ_2, and the distance from $D1$ to $FY00$ be L_4.

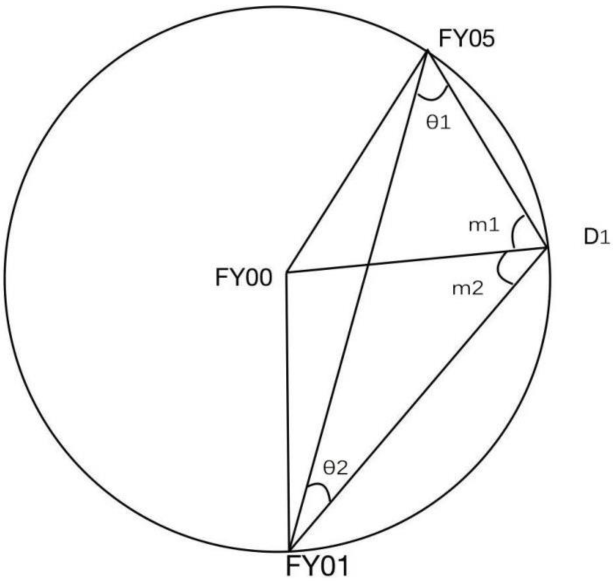

Figure 7. The fourth case where the UAV is not biased

According to the sine theorem:

$$\begin{cases} \frac{R}{\sin m_1} = \frac{L_4}{\sin(\theta_1 + 10^\circ)} \\ \frac{R}{\sin m_2} = \frac{L_4}{\sin(\theta_2 + 10^\circ)} \\ \frac{R}{\sin m_1}\sin(\theta_1+10^\circ) = \frac{R}{\sin m_2}\sin(\theta_2+10^\circ) \\ m_1 + m_2 = 100^\circ \end{cases} \tag{4}$$

3. TESTING OF THE MODEL

This model test is for the algorithm applied in the third sub-question of Problem 1, in order to show that the algorithm is not only applicable for getting the UAVs uniformly adjusted to the same circumference, but also for getting the UAVs uniformly adjusted to the same square, thus demonstrating the generalisability of the algorithm.

For example, in a square queue consisting of UAVs evenly spaced, there are two UAVs with some deviation from the target position, requiring an adjustment of the programme.

For the case where there is a deviation in the position of the UAV on the square, as shown in Figure:

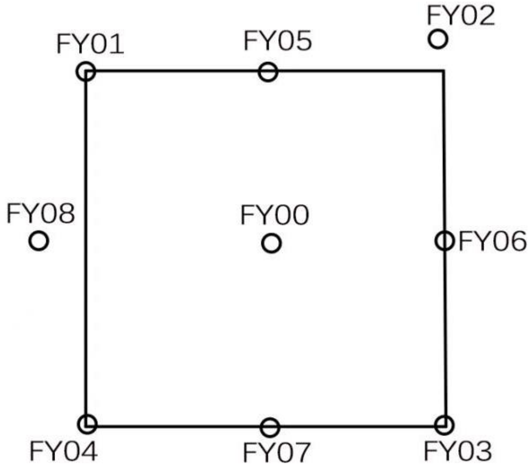

Figure 9. Initial position of the drone

Let's still transform the new scenario into one similar to the third sub-question of Problem 1, and use the drone offset around the circle to solve the drone offset around the square. We can use the centre of the square, FY00, as the centre of the circle and make the inner and outer circles of the square respectively:

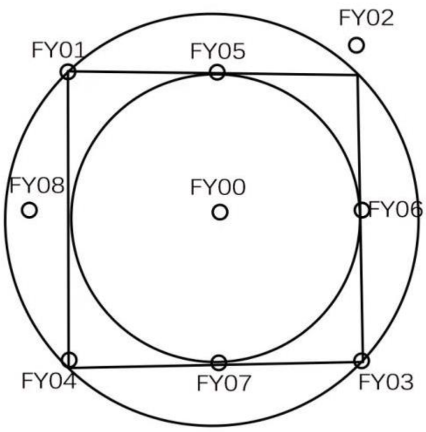

Figure 10. Circle tangent to a square, external circle

Drawing on the algorithm in the third sub-question of Problem 1, we can start by dividing the drones at different positions on the square into 2 categories: 1 drone that needs to be adjusted to the vertex of the square, and 1 drone that needs to be adjusted to the mid-point of the side of the square.

(1) For drones that need to be adjusted to the apex of the square:

We just need to follow the same algorithm on the circumference of the square's outer circle, adjusting the FY02 to the outer circle first, and then making it evenly distributed so that it lies just at the vertices of the square.

(2) For UAVs that need to be adjusted to the midpoint of a square side:

We just need to follow the same algorithm on the circumference of the square's inner tangent circle, adjusting FY08 to the inner tangent circle first, and then making it evenly distributed so that it lies just at the midpoint of the square's sides.

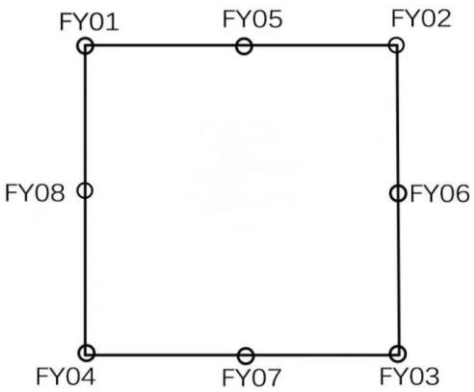

Figure 11. The effect after adjustment

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