

Bearings only passive location of UAV in formation flight based on computer simulation

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Abstract: Azimuth-only target location and tracking based on image vision is a passive target location method, which has become a research hotspot of target tracking at present. Aiming at the problem of bearings only passive location of UAV, this paper establishes a geometric location model of UAV bearings, and finally realizes bearings only passive location of UAV. This paper first analyzes the data and establishes a data flow chart. By defining the position of the UAV, the positioning model of the UAV with a passive receiving signal is established. GeoGebra is used to visualize the data. This paper can determine that there are five positioning models of UAV position deviation, namely, inside and outside the circumference, left and right of the circumference, without deviation. Then, by adjusting the position of the received signal source UAV, this paper constructs a visual mathematical model by classification, discussion, arrangement, and combination, and determines that two more UAVs are needed to achieve effective positioning of the UAV. At last, GeoGebra is used to make assumptions about the position adjustment of the UAV, and Matlab is used to simulate it to obtain an ideal state model.

1. Introduction

Azimuth-only target location and tracking based on image vision is a passive target location method [1]. It can achieve target location and track only by passively receiving the target's azimuth angle information without radiating outward energy. It has the characteristics of good concealment, strong anti-interference ability, and high reliability [2]. Therefore, it has become a research hotspot of current target tracking. The current bearings only passive location of UAV is based on this background for bearing tracking [3].

Each UAV in the formation has a fixed number, and its relative position with other UAVs in the formation remains unchanged. The direction information received by the UAV receiving the signal is certain. In order to maintain formation and avoid external interference, the UAV cluster is proposed to adopt bearings only passive positioning to adjust the position of the UAV [4]. That is, a few UAVs in the formation transmit signals, and the rest receive signals passively to adjust the position of UAVs. Therefore, this paper establishes a mathematical model to solve the positioning problem of UAVs [5].

2. Model establishment and solution

By analyzing the problem, this paper determines that the UAV is at the same level. At this time, it only needs to study the same dimension space to achieve positioning. As shown in Figure 1, first establish a data flow chart and discuss the positioning of the UAV that deviates from the position step by step [6].

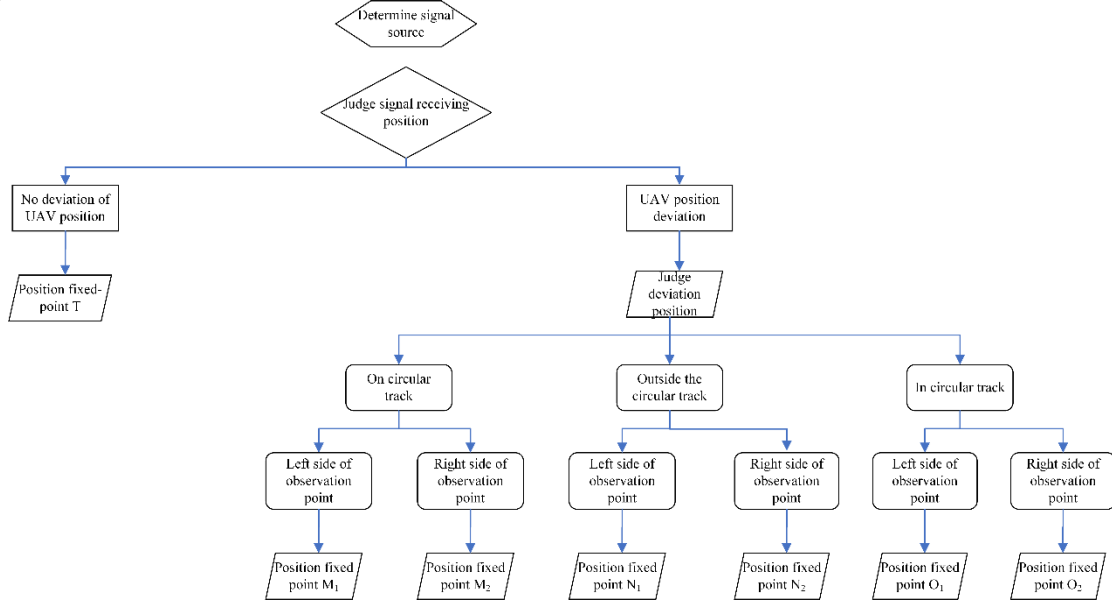


Figure 1: Flow Diagram

As far as the problem is concerned, there are 10 UAVs in the UAV formation, 9 UAVs are evenly distributed on the circumference, and the other UAV is located at the center of the circle. The UAV formation always maintains the same height, which means that 10 UAVs are in the same plane. Two UAVs transmitting the signal source are located on the circumference, one is located at the center of the circle, and there is no position deviation. The position of the UAV receiving the signal source is slightly deviation.

The formation of UAVs is circular during flight. The UAV FY00 at the center of the circle and two UAVs on the circumference (9 UAVs are evenly distributed on the circumference) send signals, and the other UAVs with position deviation receive signal sources. Because the signal source of UAV has certain certainty, it is necessary to determine the position of the UAV transmitting the signal first. At this time, any 2 of the 9 UAVs (numbered FY01~FY09) can be used as the launch source. Because there is a certain symmetry between UAVs on the circumference. We can find four cases [7].

At this time, the position of the UAV transmitting the signal source has been determined. The UAV receiving the signal source can be discussed according to the above four kinds of situations. First, select one of the situations to analyze the position of the UAV receiving the signal source [8].

We can assume that the UAV receiving the signal source has no position deviation and is always on the circumference. However, in the actual flight process, the UAV receiving the signal source has a certain position deviation. During the flight, the UAV receiving the signal source may not be in the circle D . The deviation position of the UAV receiving the signal source can be discussed as follows:

- 1) When the UAV receiving the signal is outside the circumference.

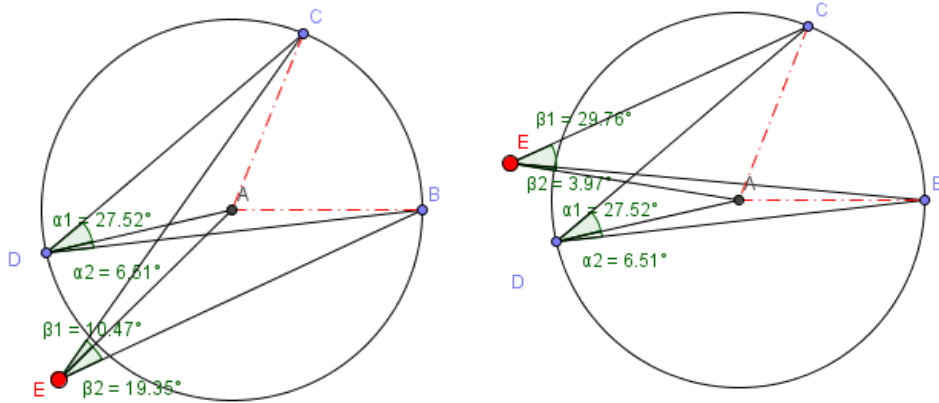


Figure 2: The receiving signal point is outside the circumference

As shown in Figure 2: ① $\angle CDA = \alpha_1$, $\angle ADB = \alpha_2$
 $\angle CEB = \beta_1$, $\angle AEB = \beta_2$

In $\triangle ACD$ and $\triangle ACE$, $\alpha_1 < \beta_1$, $\alpha_2 < \beta_2$

Namely: $\alpha_1 + \alpha_2 = \alpha > \beta = \beta_1 + \beta_2$

As shown in Figure 2: ② $\angle CDA = \alpha_1$, $\angle ADB = \alpha_2$
 $\angle CEB = \beta_1$, $\angle AEB = \beta_2$

In $\triangle ACD$ and $\triangle ACE$, $\alpha_1 < \beta_1$, $\alpha_2 < \beta_2$

Namely: $\alpha_1 + \alpha_2 = \alpha > \beta = \beta_1 + \beta_2$

2) When the UAV receiving the signal is on the circumference, the received signal UAV deviates to the left on the circumference, and the received signal UAV deviates to the right on the circumference.

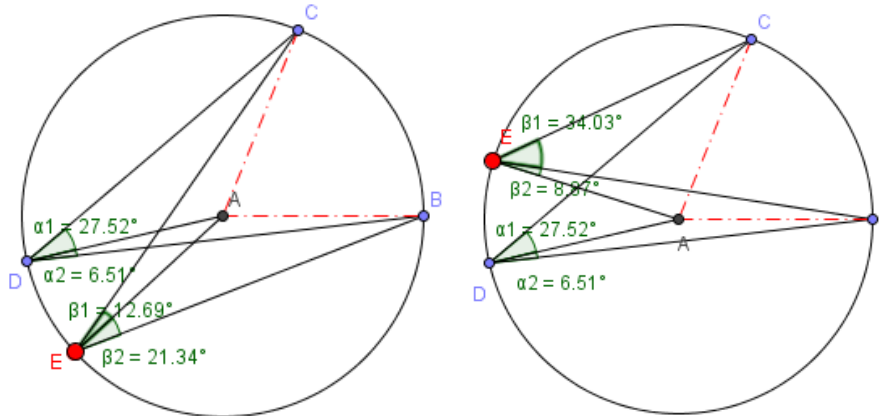


Figure 3: The received signal point is at the circumference

As shown in Figure 3: ① $\angle CDA = \alpha_1$, $\angle ADB = \alpha_2$
 $\angle CEB = \beta_1$, $\angle AEB = \beta_2$

In $\triangle ACD$ and $\triangle ACE$, $\alpha_1 < \beta_1$, $\alpha_2 < \beta_2$

Namely: $\alpha_1 + \alpha_2 = \alpha = \beta = \beta_1 + \beta_2$, $\alpha_1 < \beta_1$, $\alpha_2 < \beta_2$

As shown in Figure 3: ② $\angle CDA = \alpha_1$, $\angle ADB = \alpha_2$
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Namely, $\alpha_1 + \alpha_2 = \alpha = \beta = \beta_1 + \beta_2$, $\alpha_1 < \beta_1$, $\alpha_2 < \beta_2$.

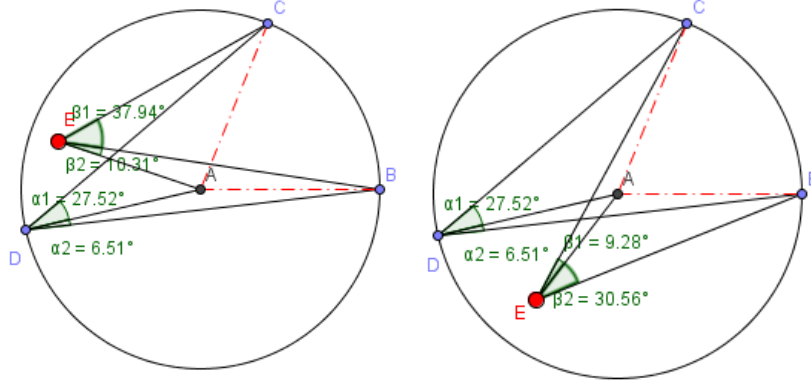


Figure 4: The received signal point is in the circle

3) The UAV receiving the signal is within the circle.

As shown in Figure 4: ① $\angle CDA = \alpha_1$, $\angle ADB = \alpha_2$

$$\angle CEB = \beta_1, \angle AEB = \beta_2$$

In $\triangle ACD$ and $\triangle ACE$, $\alpha_1 < \beta_1, \alpha_2 < \beta_2$

Namely: $\alpha_1 + \alpha_2 = \alpha < \beta = \beta_1 + \beta_2$

As shown in Figure 4: ② $\angle CDA = \alpha_1$, $\angle ADB = \alpha_2$

$$\angle CEB = \beta_1, \angle AEB = \beta_2$$

When $\triangle ACD$ and $\triangle ACE$, $\alpha_1 > \beta_1, \alpha_2 < \beta_2$

Namely: $\alpha_1 + \alpha_2 = \alpha < \beta = \beta_1 + \beta_2$

To sum up, the positioning model of three UAVs that transmit signals and receive signal sources is shown in Table 1:

Table 1: UAV Positioning Analysis Results

UAV position deviation scenario	Judgment basis	Positioning position of UAV
Outside the circle	$\alpha > \beta$	UAV is located outside the circumference
Inside the circle	$\alpha < \beta$	UAV is located outside the circumference
No deviation	$\alpha = \beta$, $\alpha_1 = \beta_1$, $\alpha_2 = \beta_2$	UAV is located at the circumference
Circle up to left	$\alpha_1 < \beta_1$, $\alpha = \beta$	The UAV is located at the circumference and deviates to the left
Circle up to right	$\alpha_1 > \beta_1$, $\alpha = \beta$	The UAV is located at the circumference and deviates from the right side

Based on the research, at this time, it is determined that the UAV transmitting the signal is numbered *FY00* and *FY01* (no position deviation), and the position of the UAV receiving the signal source has deviation [9]. In addition, the UAV can accept the signals transmitted by several UAVs in the formation. Now it is judged that in addition to *FY00* and *FY01*, several UAVs in formation need to transmit signals to achieve effective positioning of UAVs (there is a certain angle between the UAV receiving the signal source and the UAV transmitting the signal to achieve effective positioning of UAVs).

By increasing the number of UAVs on the circumference, we know that at least 3 UAVs can achieve effective positioning of UAVs. In the question, the position of the target UAV (that is, the UAV receiving the signal source) has a slight deviation, so the UAV participating in the positioning can be set as the target parameter Z , and now Z_{min} is required [10].

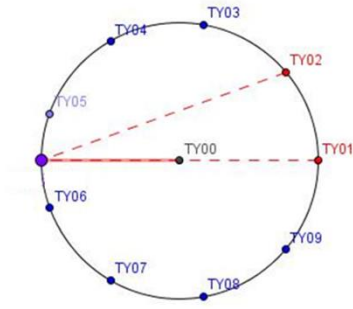


Figure 5: UAV invalid positioning

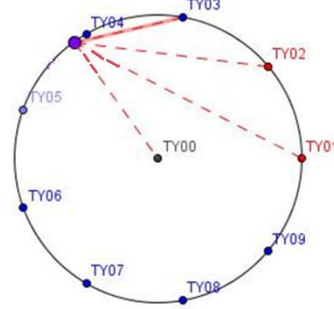


Figure 6: Effective Positioning of UAV

As shown in Figures 5 and 6, the UAVs that have been located at present include $FY00$ and $FY01$. Assuming that there are N UAVs (except the UAV that has been located at the determined position $FY01$) on the circumference, $N + 2$ UAVs will participate in the location.

$$Z_{\min} = N + 2 \quad \{2 < Z \leq 10, 2 \leq N \leq 8 (Z, N \in \mathbb{N}^+)\} \quad (1)$$

1) Assuming that there is no deviation in the positions of UAVs, they are all located on the circumference, and then they can be arranged and combined:

$$A_m^n = n(n-1) \cdots (n-m+1) = \frac{n!}{(n-m)!} \quad (2)$$

$$C_m^n = \frac{P_m^n}{P_m^m} = n(n-1) \cdots (n-m+1) / m! = n! / (n-m)! \quad (3)$$

$$A_m^n = C_m^n A_n^n \quad (4)$$

Since there are 8 UAVs on the circumference, first select any one of the 8 UAVs, namely:

$$m = 8, n = 1 \quad (5)$$

$$A_8^1 = C_8^1 A_1^1 = 8 \quad (6)$$

If the selected UAV position is in the same diameter as the UAVs numbered $FY00$ and $FY01$, effective positioning cannot be achieved.

When the number of UAVs selected on the circumference is 2, as shown in Figure 7, then:

$$A_8^2 = C_8^2 A_2^2 = 56 \quad (7)$$

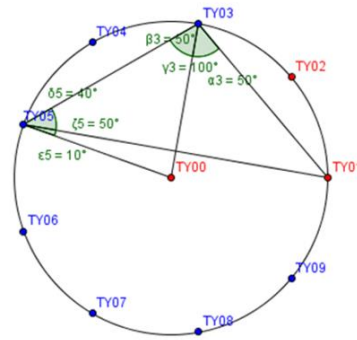


Figure 7: Select any 2 UAVs on the circumference

As shown in Figure 7, at this time, the UAV receiving the signal source has certain direction information, indicating that effective positioning of the UAV can be achieved. Then increase the

number of UAVs selected on the circumference by 3, 4... 8, and it is found that effective positioning of the UAV can be achieved. $N = 2$, $Z_{min} = N + 2 = 4$.

In case of deviation of UAV position, $N = 2$, $Z_{min} = N + 2 = 4$.

To sum up, the 4 UAVs can achieve effective positioning. Since the UAVs *FY00* and *FY01* transmit signals, it is necessary to have two UAVs to achieve effective positioning. That is to say, two UAVs need to send signals to achieve effective positioning of UAVs.

3. Model evaluation

3.1 Model advantages

- 1) It is very original, and most of the models in the article are self derived.
- 2) The calculation of the model adopts professional mathematical software with high reliability,
- 3) Use more image combination methods to improve the persuasiveness of the paper.
- 4) Data visualization makes it more convenient for observation and research.
- 5) The reliability is high, the research method adopted is highly portable, and the estimated value is within the allowable error range.
- 6) It is relatively comprehensive to simulate the data and establish the model.

3.2 Model Disadvantages

- 1) The constraints of the planning model are a little simple.
- 2) The model establishment is too idealistic and does not consider other external factors.
- 3) We only consider the position of the UAV that we can adjust within the circumference.

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