

Precision Analysis and Simulation of Locating the Single Source Based on Double-UAVs

Qiuju Zhang, Shaorong Xie, Jun Luo

School of Mechatronics Engineering and Automation
Shanghai University
Shanghai, China
children913@126.com, srxie@shu.edu.cn,
luojun@shu.edu.cn

Yan Peng, Zhouhao Ye

School of Mechatronics Engineering and Automation
Shanghai University
Shanghai, China
pengyan@shu.edu.cn, yezhouhao@gmail.com

Abstract—The passive direction finding cross localization has got great achievement and has been widely used in military and civilian fields. Currently, the researches on passive localization have focused on AOA, TDOA and FDOA. In our system, the passive direction finding cross localization is more effective and useful. We use two UAVs to locate a single source. We apply the geometric method to analysis positioning accuracy. In order to study the performance of a passive direction finding cross localization, MATLAB is used to simulate the result. Finally, the simulation results and performance analysis provide operational technical principle for such a system.

Keywords- the passive direction finding cross localization, precision analysis, geometric method, positioning fuzzy area

I. INTRODUCTION

Unmanned Aerial Vehicles can be applied to quickly locate ground targets without human beings in hazardous areas. It can autonomously control itself and reduce casualties. It is flexible and good for hiding. What's more, it could reduce the cost of search and locate.

To position the source, there are various techniques for calculating the direction of arrival, such as angle of arrival (AOA), time difference of arrival (TDOA), frequency difference of arrival (FDOA) or other similar associated techniques [1, 2].

Angle of arrival (AOA) measurement is a method for determining the direction of propagation of a radio-frequency wave incident on an antenna array. XIU Jianjuan, HE You is major in AOA and their study is the earliest and most authoritative in our country.

Using the time difference of arrival (TDOA) measurements is especially suited to the geolocation of high-bandwidth emitters, e.g. radars [3].

Frequency difference of arrival (FDOA), also frequently called differential doppler (DD), is a technique analogous to TDOA for estimating the location of a radio emitter based on observations from other points [4, 5].

However, in this system, AOA will be better. There are two reasons, one is simple system and the other is easy to obtain measurement data.

II. POSITIONING PRINCIPLE OF THE PASSIVE DIRECTION FINDING CROSS LOCALIZATION

A. The coordinate values of the source

Finding crossing localization is the most classic of a positioning. It uses a high-precision direction finding equipment, with two or more of the observation platform at the same time, to locate the target. Then according to the data of the measured radiation source and observation station, draw the location of the target in the map with geometry method. Use trigonometric formulas to determine the actual coordinates of the target radiation source [6]. The system presented in this paper is shown in Fig. 1.

Two direction finding equipments on UAVs are basically the same. The baseline length between two UAVs is related with positioning accuracy. Two UAVs first measure the direction of the target, and then cross-positioning.

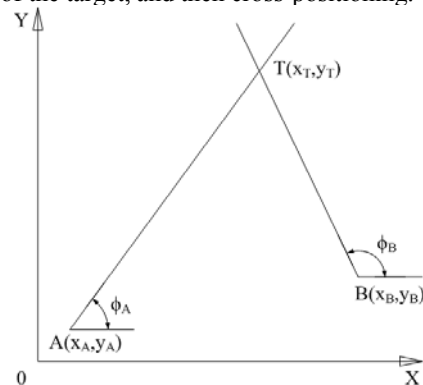


Figure 1. Schematic diagram of double UAVs locating the target

In this system, point A (x_A, y_A) and B (x_B, y_B) are the coordinate values of two UAVs, point T (x_T, y_T) is the coordinate values of the target. The geographic coordinates of this two UAVs are given by the on-board navigation system GPS positioning [7, 8]. At the same time, airborne direction finding equipment and measuring sensors measure directions and show dimension value ϕ_A and ϕ_B . Eq. (1) gives the expression of this problem:

$$\begin{cases} \tan \phi_A = \frac{y_T - y_A}{x_T - x_A} \\ \tan \phi_B = \frac{y_T - y_B}{x_T - x_B} \end{cases} \quad (1)$$

Then, we get $T(x_T, y_T)$ which show as follow:

$$\begin{cases} x_T = \frac{x_A \tan \phi_A - x_B \tan \phi_B - y_A + y_B}{\tan \phi_A - \tan \phi_B} \\ y_T = \frac{(x_A - x_B) \tan \phi_A \tan \phi_B - y_A \tan \phi_B + y_B \tan \phi_A}{\tan \phi_A - \tan \phi_B} \end{cases} \quad (2)$$

So the coordinate values of the target is T

$$\begin{cases} x_T = \frac{x_A \tan \phi_A - x_B \tan \phi_B - y_A + y_B}{\tan \phi_A - \tan \phi_B} \\ y_T = \frac{(x_A - x_B) \tan \phi_A \tan \phi_B - y_A \tan \phi_B + y_B \tan \phi_A}{\tan \phi_A - \tan \phi_B} \end{cases}.$$

B. The distance between the UAVs and target

By the above calculation, we get the coordinate values of two UAVs and the target. So it's easy to obtain the distance between the UAVs and target. The distance of A and B is known. We need to calculate the distance of A and T, called R_{AT} , and the distance of B and T, called R_{BT} .

According to the sine theorem and the picture showed follow, we can get the distance R_{AT} and R_{BT} .

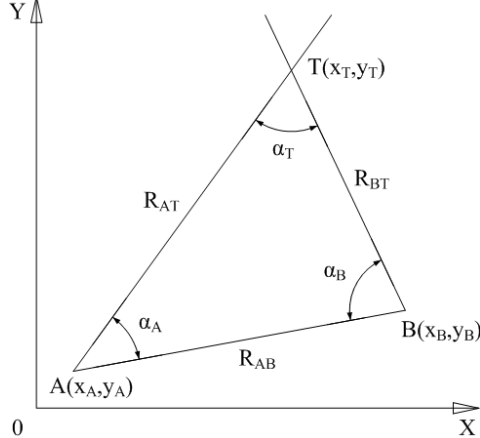


Figure 2. Schematic diagram of The distance between the UAVs and target

Knowing the value of the coordinates of three points, we can calculate the three side lengths of the triangle.

$$\begin{cases} R_{AB} = \sqrt{(x_A - x_B)^2 + (y_A - y_B)^2} \\ R_{AT} = \sqrt{(x_A - x_T)^2 + (y_A - y_T)^2} \\ R_{BT} = \sqrt{(x_B - x_T)^2 + (y_B - y_T)^2} \end{cases} \quad (3)$$

α_A is the degree between AT and AB, α_B is the degree between BT and AB, α_T is the degree between AT and BT.

$$\begin{cases} \alpha_A = \arccos\left(\frac{R_{AB}^2 + R_{AT}^2 - R_{BT}^2}{2R_{AB}R_{AT}}\right) \\ \alpha_B = \arccos\left(\frac{R_{AB}^2 + R_{BT}^2 - R_{AT}^2}{2R_{AB}R_{BT}}\right) \\ \alpha_T = \arccos\left(\frac{R_{AT}^2 + R_{BT}^2 - R_{AB}^2}{2R_{AT}R_{BT}}\right) \end{cases} \quad (4)$$

III. ERROR ANALYSIS

As showed in fig.3, direction finders have systematic errors. So the target will locate in an error region. This part we calculation error value. The area of quadrilateral ABCD is the value what we want.

$$\begin{aligned} S_{EFGH} &= S_{ABF} + S_{ABH} - S_{ABE} - S_{ABG} \\ &= \frac{1}{2}[(x_A - x_F)(y_B - y_F) - (x_B - x_F)(y_A - y_F)] \\ &\quad + \frac{1}{2}[(x_A - x_H)(y_B - y_H) - (x_B - x_H)(y_A - y_H)] \\ &\quad - \frac{1}{2}[(x_A - x_E)(y_B - y_E) - (x_B - x_E)(y_A - y_E)] \\ &\quad - \frac{1}{2}[(x_A - x_G)(y_B - y_G) - (x_B - x_G)(y_A - y_G)] \end{aligned} \quad (5)$$

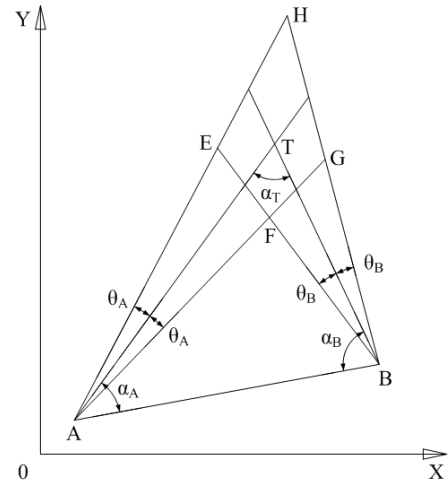


Figure 3. Error range

IV. MATLAB SIMULATION AND ANALYSIS

A. The simulation conditions

When the location of the target in the space changes, the target azimuth angle measured from the direction finders also changes. So the fuzzy area calculated is different too. In order to gain the distribution pattern of the fuzzy area, we

use MATLAB to simulate. We set target location on the plane as an independent variable parameter, fuzzy area as the dependent variable parameter. α_A ranges from 0 to 180 degree, α_B ranges from 0 to 180 degree, x_T ranges from -100 to 100 km, y_T ranges from 0 to 200 km, the coordinate values of the two UAVs is (-50km , 0km) and (50km , 0km).

B. The simulation results

We divide it into five kinds to simulation showed as followed:

- $\Delta\theta_1 = \Delta\theta_2 = \pi/60$;
- $\Delta\theta_1 = \Delta\theta_2 = \pi/72$;
- $\Delta\theta_1 = \Delta\theta_2 = \pi/90$;
- $\Delta\theta_1 = \Delta\theta_2 = \pi/120$;
- $\Delta\theta_1 = \Delta\theta_2 = \pi/180$;

Fuzzy area under different circumstances change with the contour of the target orientation showed in figure 4 to figure 8 as below. In the figure, the horizontal coordinates represent the orientation (unit: km), and vertical values represent fuzzy area (unit: km^2).

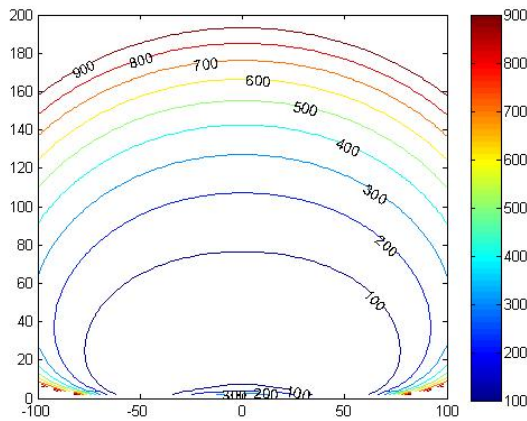


Figure 4. The fuzzy-area distribution($\Delta\theta_1 = \Delta\theta_2 = \pi/60$)

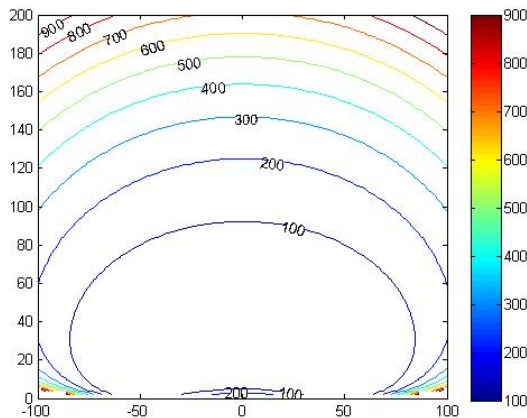


Figure 5. The fuzzy-area distribution($\Delta\theta_1 = \Delta\theta_2 = \pi/72$)

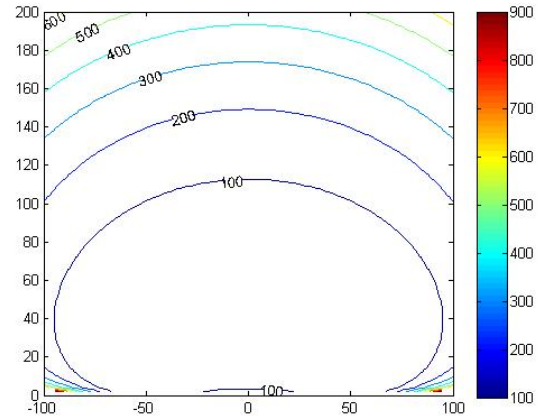


Figure 6. The fuzzy-area distribution($\Delta\theta_1 = \Delta\theta_2 = \pi/90$)

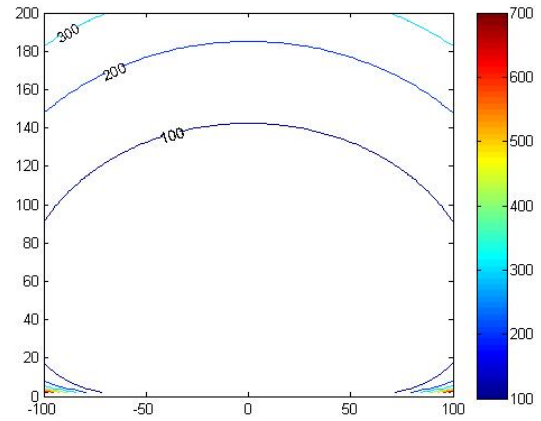


Figure 7. The fuzzy-area distribution($\Delta\theta_1 = \Delta\theta_2 = \pi/120$)

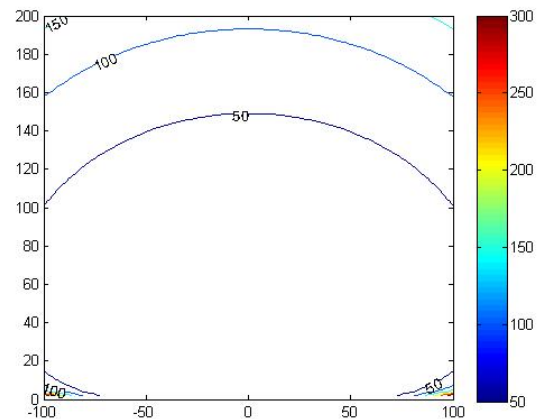


Figure 8. The fuzzy-area distribution($\Delta\theta_1 = \Delta\theta_2 = \pi/180$)

From the figure it can be concluded:

- The fuzzy-area is related with the systematic error of the direction finder. When the systematic error of the

direction finder increases, the fuzzy-area also increases. Between them is not linear change.

- The minimum fuzzy area appears in two direction-finding stations nearby.
- Fuzzy area is not normally distributed.

Through the observation of six charts, improving the accuracy of systematic error can reduce the error range of the whole system.

When $\Delta\theta_1 = \Delta\theta_2 = \pi/60$, the maximum the fuzzy-area distribution is 999.34 km^2 , the minimum is 2.19 km^2 .

When $\Delta\theta_1 = \Delta\theta_2 = \pi/72$, the maximum the fuzzy-area distribution is 996.53 km^2 , the minimum is 1.52 km^2 .

When $\Delta\theta_1 = \Delta\theta_2 = \pi/90$, the maximum the fuzzy-area distribution is 980.12 km^2 , the minimum is 0.97 km^2 .

When $\Delta\theta_1 = \Delta\theta_2 = \pi/120$, the maximum the fuzzy-area distribution is 388.19 km^2 , the minimum is 0.55 km^2 .

When $\Delta\theta_1 = \Delta\theta_2 = \pi/180$, the maximum the fuzzy-area distribution is 343.27 km^2 , the minimum is 0.24 km^2 .

V. CONCLUSION AND OUTLOOK

This paper presents a passive direction finding cross localization based on angle of arrival (AOA). On the basis of the analysis of the problem, the angle sensor measures the target's location. Then the system merges the data obtained by the two sensors. The experimental results confirmed that the presented method is valid and error is within the permissible range.

However, as a common problem of passive location, the systematic error of the sensor and random error of measuring is limited, so error range is valid or satisfactory, but not optimal.

Our future work includes: improving the sensor to reduce the systematic error; researching the better model of AOA based on the collected data; developing a comprehensive

measure control system to control the error range completely and autonomously, and so on.

ACKNOWLEDGMENT

The research is financially supported by the National Natural Science Foundation of China (No. 60975068), supported by "Chenguang" Project, which supported by Shanghai Municipal Education Commission (No.10CG43).

The author would like to thank Shanghai University for providing the infrastructure support for the UAVs flight experiments.

REFERENCES

- [1] Wang Xiaomo, ZHANG Guangyi. Radar and detection [M]. Beijing: National Defense Industry Press, 2008.
- [2] Liao Haijun. A new finding cross-location algorithm [J]. Electro-optic and Control, 2008,15 (9): 29-31.
- [3] F. Fletcher, B. Ristic, and D. Musicki, "TDOA measurements from two UAVs," in 10th International Conference on Information Fusion, Fusion 2007, Quebec, Canada, July 2007.
- [4] G. Yao, Z. Liu, and Y. Xu, "TDOA/FDOA joint estimation in a correlated noise environment," in IEEE Int. Symp. Microwave, Antenna, Propagation EMC Technol. Wireless Commun., Beijing, China, Aug. 2005.
- [5] K. C. Ho, X. Lu, and L. Kovavisaruch, "Source localization using TDOA and FDOA measurements in the presence of receiver location errors: Analysis and solution," IEEE Trans. Signal Process., vol. 55, no. 2, pp. 684-696, Feb. 2007.
- [6] XIU Jianjuan, HE You, Wang Hongguo. Pure orientation system positioning fuzzy area analysis [J]. Systems Engineering and Electronics, 2005,27 (8): 1391-1393.
- [7] XIU Jianjuan, HE You. Two-station passive location system in the multi-target tracking algorithm [J]. Journal of Electronics, 2002,30 (12): 63-66.
- [8] D. Musicki and R. Evans, "Measurement Gaussian sum mixture target tracking," in 9th International Conference on Information Fusion, Fusion 2006, Florence, Italy, July 2006.