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Research on Underwater Target PositioningTechniques Based on Unmanned Moblie Platform Cluster

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Abstract

As for the position calibration of underwater UAV mobile platform, the calibration model based on relative distance measurement and the calibration model based on relative distance and azimuth measurement are studied, and the observability of these two models is analyzed respectively; Aiming at the nonlinear problem of position calibration, the calibration algorithms based on extended Kalman filter (EKF) and unscented Kalman filter (UKF) are studied. The results show that the calibration model based on relative range and azimuth measurement has higher observability, and the performance of UKF algorithm is better than that of EKF algorithm.

Keywords

Unmanned mobile platform cluster; Underwater acoustical positioning; Position calibration; Outliers processin.

1. Introduction

The ocean is not only the traffic artery that bears more than 70% of the global trade volume, but also a huge treasure house containing rich resources such as natural gas, oil and minerals. With the continuous growth of the population on the earth, the land resources are decreasing due to over-exploitation, and the crisis of shortage of various resources has begun to appear all over the world. People began to look to the blue sea, hoping to develop all kinds of resources needed by human beings from this huge treasure house of resources [2] [3]. In addition, the ocean is called a blue land. With the continuous enhancement of China's national strength, China's investment in maritime military is also increasing. Various new ships and new equipment are constantly put into use, and maritime military security has become an important part of China's national defense [4].

2. Position Calibration Technology of Underwater UAV Moving Platform

The underwater target location studied in this paper is accomplished by an unmanned aerial vehicle (UAV) mobile platform cluster network composed of a surface USV and several underwater UUVs. In order to ensure that the positioning system can complete the task safely and efficiently, the position of unmanned platform must be calibrated first. The surface USV can update its position with high precision through Beidou system or GPS system. However, due to the rapid attenuation of electromagnetic waves in water, underwater UUV can not be calibrated by these radio positioning systems. In this chapter, the position calibration technology of underwater UAV mobile platform is studied. Its basic idea is to take USV with high positioning accuracy as the moving positioning reference point, and use the measurement information such as relative distance or relative azimuth to calibrate the position of UUV [55]. In this chapter, the calibration model based on relative distance measurement and the calibration model based on relative distance and azimuth measurement are studied, and the observability of these two models is analyzed. In order to solve the related nonlinear problems, the UUV position calibration algorithm based on extended Kalman filter and unscented Kalman filter is studied.

2.1. Position calibration model of underwater unmanned aerial vehicle moving platform

In this paper, dead reckoning is used as the basic motion model of UUV. Because the depth gauge can directly measure the depth information of UUV with high accuracy, the two-dimensional motion model of UUV can be written as

$$\begin{cases} x_{k+1} = x_k + V_k \cdot T \cdot \cos\varphi_k \\ y_{k+1} = y_k + V_k \cdot T \cdot \sin\varphi_k \\ \varphi_{k+1} = \varphi_k + \dot{\varphi}_k \cdot T \end{cases} \tag{2-1}$$

φ_k Where x and yk are the x-direction position coordinates, y-direction position coordinates and heading angle of UUV at k time,

$\mathbf{X}_k = [x_k \quad y_k \quad \varphi_k]^T$ $\dot{\varphi}_k$ The heading angle is defined as the included angle with the positive half axis of the x axis, and the counterclockwise direction is positive. At this time, the motion state of UUV is; Vk is the forward velocity and yaw rate of UUV, which can be measured by Doppler velocimeter and gyroscope, and the control input of the system is

$$\mathbf{u}_k = \begin{bmatrix} V_k \\ \dot{\varphi}_k \end{bmatrix} = \begin{bmatrix} V_{mk} - w_{Vk} \\ \dot{\varphi}_{mk} - w_{\dot{\varphi}k} \end{bmatrix}$$

(2-2)

$\mathbf{W}_k = \left[w_{V_k} \quad w_{\dot{\varphi}_k} \right]^T$ $w_V \sim \left(0, \sigma_{V_k}^2\right)$, $w_{\dot{\varphi}} \sim \left(0, \sigma_{\dot{\varphi}_k}^2\right)$ Where, for measurement noise, it is usually assumed to be independent and uncorrelated zero-mean Gaussian white noise, which satisfies. Then the time-discrete motion equation of UUV can be abbreviated as

$$\mathbf{X}_{k+1} = f\left(\mathbf{X}_k, \mathbf{u}_k, \mathbf{W}_k\right) = \mathbf{X}_k + \Gamma\left(\mathbf{u}_k, \mathbf{W}_k\right) \tag{2-3}$$

$\Gamma\left(\mathbf{u}_k, \mathbf{W}_k\right)$ Where, it is a nonlinear term, and the global noise variance matrix satisfies

$$\mathbf{Q}_k = E\left\{\mathbf{W}_k \mathbf{W}_k^T\right\} = \begin{bmatrix} \sigma_{V_k}^2 & 0 \\ 0 & \sigma_{\dot{\varphi}_k}^2 \end{bmatrix} \tag{2-4}$$

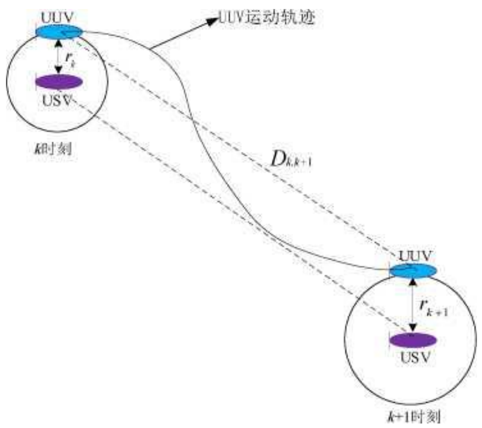

Figure 1 Schematic diagram of UUV position calibration based on relative distance measurement

Figure 1 shows a schematic diagram of UUV position calibration based on relative distance measurement, and its specific implementation steps are given below:

(1) Time synchronization between USV and UUV.

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(2) USV sends a beacon signal to UUV at time K according to a fixed period and broadcasts position information.

(3) At time k, the position coordinates of USV and UUV are.

After UUV receives the underwater acoustic signal from USV, the three-dimensional relative distance lk between UUV and USV is calculated by underwater acoustic ranging technology. As shown in Figure

2.2. Position calibration model based on relative distance and azimuth measurement

The relative azimuth angle 0 is defined as the positive angle between the connecting line between UUV and USV and the Y axis, and the clockwise rotation is positive and the counterclockwise rotation is negative. The UUV position calibration model based on relative distance and azimuth measurements is shown in Figure 2.

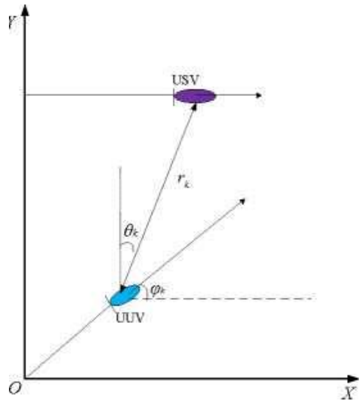

Figure 2 Schematic diagram of UUV position calibration based on relative distance and azimuth measurements

When UUV position calibration is performed based on relative distance and azimuth measurements at time K+1, the measurement information thereof include θ_{k+1} The distance rk+1 and relative azimuth between usv and uuv are measured by underwater acoustics, and the measured information is. Where Vk+1 is the measurement noise and its variance matrix is

$$\mathbf{R}_{k+1} = E\left\{\mathbf{V}_{k+1}\mathbf{V}_{k+1}^{T}\right\} = \begin{bmatrix} \sigma_{r_k}^2 & 0 \\ 0 & \sigma_{\theta_k}^2 \end{bmatrix} \quad (2\text{-}11)$$

Based on the above analysis, a nonlinear mathematical model of UUV node position calibration based on relative distance and azimuth measurements can be obtained by simultaneous models (2-1) .

3. Observability simulation

From the discussion, it can be seen that in the UUV position calibration method based on relative distance measurement, the observability of the system depends on the characteristics of the relative motion path between USV and UUV, while the calibration system based on relative distance and azimuth measurement is completely observable. This section mainly analyzes the influence of path observability on UUV position calibration accuracy under different measurement models by simulation.

Experiment 1: USV and UUV do uniform linear motion with the same speed and parallel to each other

Simulation conditions: As shown in Fig3, both USV and UUV move in a straight line at a uniform speed, and the USV trajectory is parallel to the UUV trajectory. It is assumed that USV starting

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point coordinates are (0, 1000) (unit: m), UUV starting point coordinates are (0, 0) (unit: m), Simulation conditions:

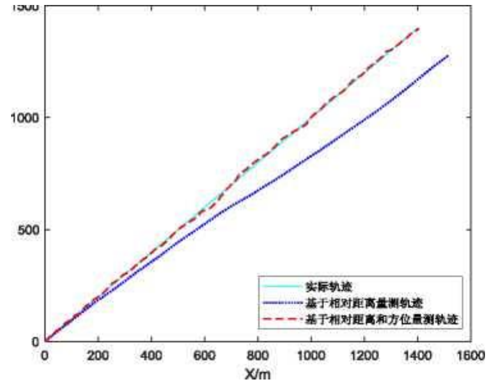

Figure 3 AV mobile platform cluster generally has more than two UUV platforms to be calibrated

4. TOA positioning performance analysis

Firstly, the AOA positioning model is directly used for positioning solution without square data processing, and the solution result is shown in Figure 5.21. Observing the results, we can see that there is obvious deviation between the target positioning trajectory and GPS trajectory. The reason for this situation should be the data mismatch between the data of each observation platform, so it is necessary to solve the spatio-temporal correlation of the square data. Figure 3 shows the positioning results of the spatio-temporal correlation solution of azimuth data, and Figure 3 shows the comparison of positioning errors before and after the spatio-temporal correlation of azimuth data.It can be seen that the target trajectory solved by the azimuth data spatio-temporal association algorithm is obviously more in line with the GPS trajectory. First of all, the traditional TDOA positioning model is directly used for positioning without processing the time delay data, and the results are shown in Figure 2. Observing the results, we can see that there is obvious deviation between the target positioning trajectory and GPS trajectory, which should be caused by the data mismatch and range ambiguity of each observation platform, so it is necessary to solve the time-space

5. Advantages of the article

The position calibration technology of underwater UAV moving platform is studied. This paper adopts the general idea of UUV position calibration based on USV high-precision position information and supplemented by relative distance or relative azimuth measurement information, The calibration model based on relative distance measurement and the calibration model based on relative distance and azimuth measurement are studied, and the observability analysis of these two models is carried out. The analysis results show that the calibration method based on relative distance and azimuth measurement has higher observability because of more measurement information; Aiming at the nonlinear problem of position calibration, the basic principles of EKF and UKF are studied and the corresponding calibration algorithm steps are designed. Simulation results show that the two algorithms can effectively realize UUV position calibration. Compared with EKF algorithm, UKF algorithm is simple in calculation, avoids the error caused by linearization of nonlinear model, and has higher calibration accuracy.The underwater target location technology of unmanned cluster is studied. Aiming at active working mode, based on the basic principle of traditional TOA positioning algorithm, the model mismatch problem is analyzed, and the TOA optimal positioning model is put forward and the model solving method is given. Simulation results show that this method can effectively solve the model mismatch problem and has higher positioning accuracy; In view of the passive working mode, AOA localization algorithm and TDOA localization algorithm are studied. Aiming at the problems of azimuth data mismatch, time delay data mismatch and range ambiguity in the algorithms, the spatio-temporal correlation localization algorithm of azimuth data and time delay data are studied, and the two algorithms are simulated and verified. The simulation results verify the effectiveness of the above algorithms.

6. Conclusion

In this paper, the research on underwater target location technology based on unmanned platform cluster is still in its infancy, and the existing work still has some shortcomings and needs to be improved:

(1) On the basis of observability analysis, the path planning method of UAV should be further studied, and the track should be set to improve the position calibration accuracy of UAV and the positioning accuracy of underwater targets.

(2) In the process of underwater target location in unmanned cluster, it is necessary to consider the problem of interference suppression of friendly platform echo information in active mode, and the problem of batch division and correlation of multi-target azimuth information in passive mode when using azimuth solution.

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