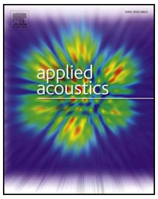
Applied Acoustics 131 (2018) 203–209

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust



Research on integrated navigation algorithm based on ranging information of single beacon

Yunfeng Han, Chunhao Shi, Dajun Sun*, Jucheng Zhang

College of Underwater Acoustic Engineering, Harbin Engineering University, Harbin 150001, China
Acoustic Science and Technology Laboratory, Harbin Engineering University, Harbin 150001, China

ARTICLE INFO

Keywords:
Single beacon ranging
Indirect adjustment
LBL positioning system
AUV

ABSTRACT

The conventional long baseline (LBL) positioning system based on beacon ranging has a high positioning accuracy, but it need at least three acoustic beacons, when positioning the autonomous underwater vehicles (AUVs). The LBL positioning system has a high deployment and recovery cost. It also has the problem that LBL positioning model does not take AUVs motion into consideration, so the signal to transmit and receive at different locations. To solve this problem, this paper constructs a model based on indirect adjustment. The model uses single beacon distance information, velocity information of target motion as the observations. The simulation analysis and test results show that model can solve signal to transmit and receive at different locations, and it can improve the positioning accuracy effectively. When dynamic positioning, it doesn't have missed detection problem of LBL positioning system. When static positioning, it is stable and error fluctuation is small. The tracking trajectory is smooth and continuous, and the computational complexity is equivalent to the conventional LBL. It has good engineering application value.

1. Introduction

The development and utilization of marine resources protection has the tendency from shallow water to deep water. Relying on manpower is not enough to complete underwater tasks. AUV as a representative of the autonomous underwater vehicle has become an important tool for underwater operation. The Accurate navigation and positioning is an important guarantee for the AUVs to successfully complete the task and return safely [14,1,3,11,10,5,6]. The conventional LBL positioning system has high positioning accuracy, but it needs at least three acoustic beacons. The deployment of the acoustic beacons and the calibration of the acoustic beacon array require a lot of time and money; LBL positioning system equipment is expensive, after the completion of the task, the seabed acoustic beacon recovery is also a big problem [7,13]. Therefore, in the context of long-term, large-scale positioning requirements, the positioning technology based on single beacon ranging is a new research direction of underwater acoustic positioning technology. It is a combination of conventional underwater acoustic positioning systems combination and simplification. Simplification is because it only needs to deploy one acoustic beacon,and it can improve the convenience and operational efficiency; the combination is because it combines the acoustic ranging positioning device with the vehicle motion sensor [12,15].

Yunfeng Han proposed an optimization method using LBL positioning system to track underwater target. The target position is determined by combining the distance measurement error and the beacon calibration error together. Although the test results show that the positioning accuracy is improved in deep sea, but there are shortcomings of high computational complexity, and in the shallow water test the positioning accuracy just improved little because of high precision calibration [21]. Zhao Li proposed a motion compensation algorithm for acoustic time-dependent correction and transponder coordinate inversion. The positioning accuracy of the LBL is improved by compensating the motion of the target. But the simulation results show that the algorithm is suitable for the system with at least timing accuracy [8,9]. Because the conventional single beacon ranging, using the direct reduced order algorithm is not suitable for the straight trajectory, so Jun Cao proposed the algorithm of linearized iterative method, and introduce the concept of virtual long baseline array. The simulation results show that the beacon calibration error brings the position error to each virtual beacon, the virtual beacon error is equal to the calibration error. There is a problem that the position error of the virtual beacon increases gradually due to initial beacon error [2]. In [4,17,16], a cooperative synchronous acoustic beacon instead of transponder is used to directly measure the one-way delay between the transceiver and the acoustic beacon, but there are clock skew and battery life problem in

---

* Corresponding author at: College of Underwater Acoustic Engineering, Harbin Engineering University, Harbin 150001, China.
E-mail addresses: hanyunfeng@hrbeu.edu.cn (Y. Han), shichunhao@hrbeu.edu.cn (C. Shi), sundajun@hrbeu.edu.cn (D. Sun), Zhangjucheng2006@126.com (J. Zhang).

https://doi.org/10.1016/j.apacoust.2017.10.029
Received 7 August 2017; Accepted 30 October 2017
0003-682X/ © 2017 Elsevier Ltd. All rights reserved.

long term deep-sea operation.

Aiming at the problems caused by the conventional LBL positioning system, this paper constructs an integrated navigation model based on indirect adjustment. The integrated navigation model uses single-beacon distance information and velocity information as the observations.While improving the convenience and efficiency at the same time, it provides stable, accurate real-time location. First introduce the LBL positioning system, and analyze its shortcomings. Aiming at the shortage of the system, an indirect adjustment method based on single beacon ranging is proposed, and the theoretical derivation and mathematical formula are given. The localization results of the model are simulated and verified. The feasibility of the method is proved by the experimental data, and the final positioning accuracy is given.

2. Basic principle and existing problems of LBL

When LBL positioning system is positioning AUVs, we usually install transceiver on the AUV. The acoustic beacon array is installed in the water. The distance between acoustic beacon and transceiver can get by sound propagation delay. And then use the distance information to solve the AUV position. Fig. 1 shows the basic principle of the LBL positioning system [19].

LBL positioning system has a variety of solution models, in which the spherical intersection model is most commonly used. The coordinates of the acoustic beacons in the water are (x_i,y_i,z_i), $i = 1,2,3,4$, the coordinates of the transceiver is (x,y,z) ,set underwater sound velocity as a constant value of c,sone way propagation time between acoustic beacon i and transceiver is t_i, if the factors such as the sound ray bending are not taken into account, the distance between the acoustic beacon$i$ and the transceiver can be given by $r_i = c\cdot t_i$, $i = 1,2,3,4$.

According to the geometric relationship between the acoustic beacon and the transceiver, the observation equations are listed:

$$\begin{cases}(x-x_1)^2+(y-y_1)^2+(z-z_1)^2=r_1^2\\(x-x_2)^2+(y-y_2)^2+(z-z_2)^2=r_2^2\\(x-x_3)^2+(y-y_3)^2+(z-z_3)^2=r_3^2\\(x-x_4)^2+(y-y_4)^2+(z-z_4)^2=r_4^2\end{cases} \tag{1}$$

If the target depth is known $z = h$, Eq. (1) can be simplified as Eq. (2).

$$\begin{bmatrix}(x_2-x_1) & (y_2-y_1)\\(x_3-x_2) & (y_3-y_2)\\(x_4-x_3) & (y_4-y_3)\\(x_1-x_4) & (y_1-y_4)\end{bmatrix}*\begin{bmatrix}x\\y\end{bmatrix}=\begin{bmatrix}({r_1}^2-r_2^2+d_2^2-d_1^2)/2-h(z_2-z_1)\\({r_2}^2-r_3^2+d_3^2-d_2^2)/2-h(z_3-z_2)\\({r_3}^2-r_4^2+d_4^2-d_3^2)/2-h(z_4-z_3)\\({r_4}^2-r_1^2+d_1^2-d_4^2)/2-h(z_1-z_4)\end{bmatrix} \tag{2}$$

where d_i is $d_i = \sqrt{x_i^2+y_i^2+z_i^2}$, $i = 1,2,3,4$. The Eq. (2) is written in matrix form $AX = B$ When the matrix AA^T is nonsingular, the least squares solution of the equation is obtained as follows:

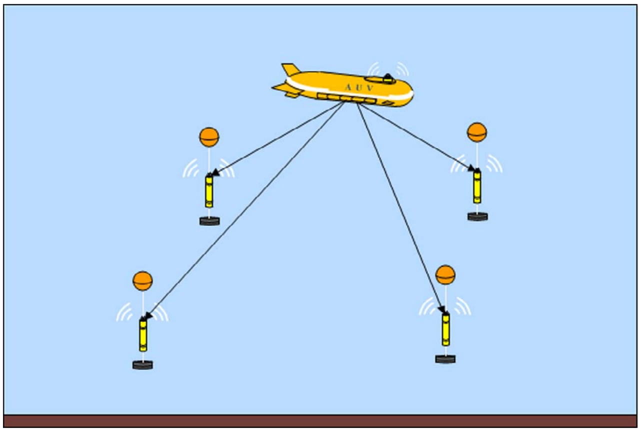


Fig. 1. An LBL system with four beacons.

$$X = (A^TA)^{-1}A^TB \tag{3}$$

However AUV is usually in motion. We calculate the one-way acoustic travel time from AUV to the acoustic beacon by halving the observed two-way travel-time from AUV to the acoustic beacon and back. Because the number of valid beacons may be less than 3, there is a missing detection in practical application.

If the rate of missed detection is decreased, then the transceiver is required to have strong signal detection ability, and the response signal is required to have good time resolution and anti-noise ability. Therefore, when the LBL positioning system cant solve the position of the AUVs, the positioning efficiency will be reduced.

3. Indirect adjustment model based on single beacon distance measurement

3.1. Indirect adjustment

In solving a problem of adjustment, when the number of independent parameters chosen is equal to the necessary number of observations, each observation can be expressed as a function of the t parameters to form observational equations. This method of adjusting the function model is the indirect adjustment. Indirect adjustment of the function model is [18,20]:

$$\widehat{L} = B\widehat{X} + d \tag{4}$$

When using indirect adjustment to solve, take an approximation $\hat{x}$ of the parameter $\widehat{X}$ and the error equation is:

$$V = B\widehat{X}-l \tag{5}$$

where $l = L-(BX^0+d) = L-L^0$ the variance matrix of the observed vector L is:

$$D = \sigma_0^2Q = \sigma_0^2P^{-1} \tag{6}$$

where Q is the cofactor matrix of L, P is the weighted array of L, σ_0^2 is variance of unit weight The adjustment criteria is $V^TPV = min$. The indirect adjustment is to determine the error parameter $\hat{x}$ in the error equation under the least squares criterion.

3.2. Modeling and construction of model based on indirect adjustment

The observation information is the distance L between the point to be located and the beacon, the velocity in the X axis direction isV_x, the velocity in the Y axis direction is V_y,A is the initial position of the AUV, and B is the position of acoustic beacon, the coordinates of the D to be determined is $(\widehat{X}_D,\widehat{Y}_D)$.

The necessary observation is $t = 2$, let $\widehat{X}_D$ and $\widehat{Y}_D$ as the parameter. Their approximate values X_D^0,Y_D^0 can be solved as follows: $X_D^0 = X_A + V_xt,Y_D^0 = Y_A + V_yt$, so approximate calculation of approximate coordinates of undetermined D: $X_D^0 = X_D^0 + \hat{x}_D,Y_D^0 = Y_D^0 + \hat{y}_D$ (see Fig. 2).

The distance observation equation can be listed: $\widehat{L} = L + v_1 = \sqrt{(\widehat{X}_D-X_B)^2+(\widehat{Y}_D-Y_B)^2}$. The above equation is expanded by the Taylor formula:

$$\widehat{L} = L + v_1 = S_{BD}^0 + \frac{\Delta X_{DB}^0}{S_{DB}^0}\hat{x}_D + \frac{\Delta Y_{DB}^0}{S_{DB}^0}\hat{y}_D \tag{7}$$

where $S_{BD}^0 = \sqrt{(X_D^0-X_B)^2+(Y_D^0-Y_B)^2}$,$\Delta X_{DB}^0 = X_B^0-X_D^0$,$\Delta Y_{DB}^0 = Y_B^0-Y_D^0$. Let $l_1 = L-S_DB^0$, then the error equation can be listed:

$$v_1 = \frac{\Delta X_{DB}^0}{S_{DB}^0}\hat{x}_D + \frac{\Delta Y_{DB}^0}{S_{DB}^0}\hat{y}_D-l_1 \tag{8}$$

The velocity observation equation can be listed:

Download English Version:

https://daneshyari.com/en/article/7152398

Download Persian Version:

https://daneshyari.com/article/7152398

Daneshyari.com