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Review Article

INVESTIGATION OF TARGET MOTION PARAMETERS USING OPTIMAL RECURSIVE ESTIMATION TECHNIQUE FROM PASSIVE SONAR IN UNDERWATER NAVIGATION SYSTEMS

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ABSTRACT

In under water an observer pre-processes the noisy bearing measurements available from passive sonar and then the data are used by Kalman filter to find out target motion parameters. The pre-processing reduces the amplitude of the noise, replaces the missed bearings with estimated bearings, supplies the estimated bearings if the bearing measurement is not available or incorrect and finally it finds out mean and variance of the noisy data. The statistical characteristics of the data are used in Kalman filter which finds out the target motion parameters. Online estimation of bearing measurement is carried out using Pseudo-linear estimator. Finally, the whole algorithm is evaluated in Monte- Carlo simulation and the results for one typical scenario are presented.

Keywords: Estimation, Sonar, Kalman filter, Bearings, Passive, Pre-processing.

INTRODUCTION

In the sea environment, an onlooker screens uproarious sonar course from an emanating focus in inactive listening mode. An eyewitness procedures these estimations and discovers target movement parameters, namely, go, course, bearing, and speed of the objective. Nowadays, an advanced adaptation of Kalman sift is utilized to discover through the objective movement parameters. Kalman channel requires the factual qualities like mean and difference of the clamor in the bearing estimations [1-4]. This channel additionally accepts the clamor takes after Gaussian appropriation. When all is said in done, the bearing estimations in submerged are exceptionally ruined with clamor and Kalman channel fizzles with this commotion. Thus, pre-handling of the estimations is required to make the commotion Gaussian and to discover the mean and covariance of the uproarious estimations furthermore to lessen the adequacy of the clamor. The target-observer geometry is given in Fig. 1.

Added to the above, in submerged, in some cases, the auto-following of the objective fizzles and the latent sonar tracks the objective in manual mode, and subsequently, the estimations are not accessible persistently. It was likewise seen in submerged that the sonar estimation once in a while is spurious (the contrast between the present and past estimation being high) and the same is dealt with as invalid. Pre-handling of the measure evaluates the heading and replaces the terrible or missed course. This online pre-handling consistently screens the difference of the commotion in the estimations, and if any estimation is with more fluctuation than predefined, this procedure replaces the same with the assessed bearing, acquired by utilizing pseudo-linear estimator [3,4,2].

Segment 2 portrays the scientific displaying of the pre-preparing of information. The estimation of bearing utilizing Pseudo Linear estimator is depicted in area 3. Changed Gain Bearing Extended Kalman Filter is depicted in area 4. Reenactment and results are exhibited in area 5 finally the paper is finished up at segment 6.

PRE-PROCESSING OF THE MEASUREMENTS

In submerged, the commotion in the bearing estimations is high. The estimations accessible at consistently are found the middle value of more than 20 seconds so that the change of the commotion is lessened by an element of 20. The contribution to the Kalman channel is accessible at each 20th seconds, and the objective movement parameters are upgraded at 20 seconds interim. In submerged, the speed of the vehicle is very little thus overhauling of the arrangement by 20 seconds will not hamper the weapon control handle.

In the event that at least one estimation is not accessible amid 20 seconds interim, the normal will be done by no. of tests accessible. On the off chance that every one of the estimations is not accessible amid 20 seconds interim, then 20 seconds normal estimation is supplanted with a course estimation assessed by utilizing bearing rate, which is computed with the estimations accessible till then.

The mean or inclination in the estimations is thought to be zero. On the off chance that it is not zero, then the objective movement parameters contain predisposition. At the pre-preparing stage, there is no real way to discover mean of the clamor. In the event that inclination is available and is known by a few means, every one of the estimations is subtracted by this mean. The difference of the clamor is computed as takes after.

Variance of the noise in the measurement

The variance of the error in each bearing measurement is calculated as follows. Consider a simple linear regression model for the bearings given by $b = a_0 + a_1 t + \varepsilon$ where a_0 and a_1 are regression coefficients, ε is distributed with zero mean and unknown variance σ^2, t is time variable, and b is bearing. Here, a_0 represents the intercept on bearing axis and a_1, the bearing rate. Let there be n measurements in sample duration of 20 seconds. From simple regression analysis [1].

$$a_1 = \frac{\sum_{i=1}^{n}(b_i - \bar{b})(t_i - \bar{t})}{\sum_{i=1}^{n}(t_i - \bar{t})(t_i - \bar{t})} = \frac{\sum_{i=1}^{n}(dt_i \cdot db_i)}{\sum_{i=1}^{n}(dt_i \cdot dt_i)} \quad (1)$$

Where dt and db are the changes in time and bearings respectively between two successive measurements. $\bar{t}$ and $\bar{b}$ represent the average of time and bearings respectively in the 20 seconds time sample. The variance of the noise is given by

$$\sigma^2 = \frac{\sum(b_i - \bar{b})^2 + a_1^2 \sum\left[\frac{b_i - (t_i - \bar{t})}{a_1}\right] - 2a_1 \sum\left[(b_i - \bar{b})\,(t_i - \bar{t})\right]}{n} \quad (2)$$

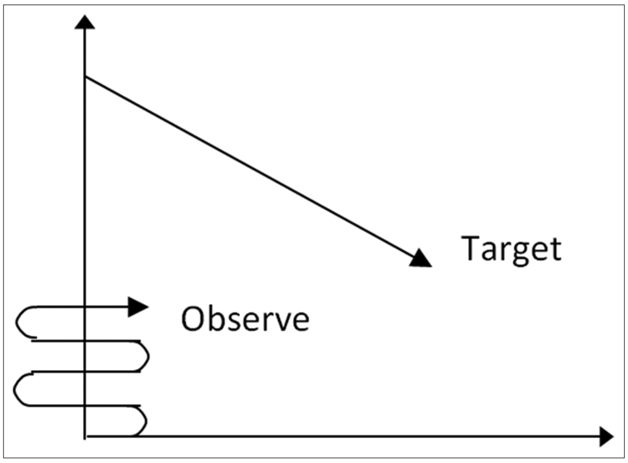

Fig. 1 Target motion analysis with single observation platform in S – maneuver

The measurement is bad or good, is determined by its variance of the noise. If the variance is high than the assumed one, then it is treated as bad or not available measurement.

ESTIMATION OF BEARING

In general, the state vector is with (target velocity components) and x (k) and y (k)(target position) components [5]. By rotating the coordinate system such that +y axis lies along the latest bearing entered, the state vector represents relative position and relative velocity at the time of the entry of the latest bearing. is [$\dot{B}(k)$ $\frac{\dot{R}(k)}{R(k)}$ Br(k) 1], where the first and second elements represent bearing rate and range rates respectively, and Br represents the estimated error of the given input bearing. R represents the relative range of the target with reference to the observer. Similar target state vector was utilized by Aidala and Hammel [3] in modified polar coordinate based Kalman filter. The estimated bearing at any time is given by the present bearing plus Br. If the bearing is missed at any time, then the present bearing is the previous bearing plus bearing rate multiplied by the time between the samples (assuming the measurements are available with fixed interval). For obtaining this required state vector, covariance matrix of Pseudo Linear Estimator is built up using Cartesian coordinate state vector and then converted to modified polar coordinate state vector in such a way that the +ve y-axis lies along the line of sight.

MODIFIED GAIN BEARING EXTENDED KALMAN FILTER (MGBEKF)

The alternative derivation of the modified gain function [4,2]of Song and Speyer's extended Kalman filter is slightly modified as follows. Let the target state vector be Xs (k) where

$$X_s(k)=[\dot{X}(k)\dot{y}(k)R_X(k)R_y(k)]^T \quad (3)$$

Where $\dot{x}(k)$ and $\dot{y}(k)$ are target velocity components and, $R_x(k)$ and $R_y(k)$ are range components, respectively.

The target state dynamic equation is given by

$$X_s(k+1) = \phi\, X_s(k)+ b(k+1)+\omega\Gamma(k) \quad (4)$$

Where ϕ and b are transient matrix and deterministic vector respectively.

The transient matrix is given by

$$\phi = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ t & 0 & 1 & 0 \\ 0 & t & 0 & 1 \end{bmatrix}$$

Where t is sample time

$$b(k+1)=\begin{bmatrix} 0 & 0 & -\{x_0(k+1)-x_0(k)\} & -\{y_0(k+1)\} \end{bmatrix}$$

$$\text{And } \Gamma=\begin{bmatrix} t & 0 \\ 0 & t \\ \frac{t^2}{2} & 0 \\ 0 & \frac{t^2}{2} \end{bmatrix}$$

Where x_o and y_o Are ownship position components. The plant noise, $\omega(k)$ is assumed to be zero mean white Gaussian. True North convention is followed for all angles to reduce mathematical complexity and for easy implementation. The bearing measurement, B_m is modeled as

$$B_m(k+1) = \tan^{-1}\left(\frac{R_x(k+1)}{R_y(k+1)}\right) + \varsigma(k) \quad (6)$$

Where $\varsigma(k)$ is error in the measurement, and this error is assumed to be zero mean Gaussian with variance σ^2. The measurement and plant noises are assumed to be uncorrelated to each other. Equation (4) is a nonlinear equation and is linearized by using the first term of the Taylor series for R_x and R_y. The measurement matrix is obtained as

$$H(k+1)=\begin{bmatrix} 0 & 0 & \hat{R}_y(k+1|k)/\hat{R}^2(k+1|k) & -\hat{R}_X(k+1|k)/\hat{R}^2(k+1|k) \end{bmatrix} \quad (7)$$

Since the true values are not known, the estimated values of R_x and R_y are used in the above equation. The covariance prediction is

$$P(k+1|k) = \phi(k+1|k)P(k|k)\phi^T(k+1|k)+\Gamma Q(k+1)\Gamma^T \quad (8)$$

Where Q is plant noise covariance matrix. The Kalman gain is

$$G(k+1) = P(k+1|k)\, H^T(k+1)[\sigma^2+H(k+1)\, P(k+1|k)\, H^T(k+1)]^{-1} \quad (9)$$

The state and its covariance corrections are given by

$$X(k+1|k+1) = X(k+1|k)+G(k+1)[B_m(k+1)-h(k+1, X(k+1|k))] \quad (10)$$

Where h(k+1, X(k+1|k) is the bearing using predicted estimate at time index k+1

$$P(k+1|k+1) = [I-G(k+1)\, g(B_m(k+1), X(k+1|k))]P(k+1|k)$$

$$[I-G(k+1)g(B_m(k+1), X(k+1|k)))]^T+\sigma^2 G(k+1)\, G^T(k+1) \quad (11)$$

Where g(.) is modified gain function as defined in [2]. The value of g is

$$g = \begin{bmatrix} 0\ 0\ \cos B_m/(\hat{R}_X \sin B_m + \hat{R}_y \cos B_m) \\ -\sin B_m/(\hat{R}_X \sin B_m + \hat{R}_y \cos B_m) \end{bmatrix} \quad (12)$$

Since the true bearing is not available in practice, it is replaced by the measured bearing to compute the function g (.).

SIMULATION AND RESULTS

For the implementation of the algorithm, the initial estimate of target state vector is chosen as follows. As only bearing measurements are available, it is not possible to guess the velocity components of the target. Hence, these components are each assumed as 10 m/seconds, which are close to the realistic speeds of the vehicles in underwater. The range of the day, say 15000 m, can be utilized in the calculation of initial position components of the target as follows

$$X(0|0)=\begin{bmatrix} 10 & 10 & 15000*\sin B_m & 15000*\cos B_m \end{bmatrix}^T \quad (13)$$

It is assumed that the initial estimate, X(0|0) is uniformly distributed. Then the elements of initial covariance diagonal matrix can be written as

$$P_{00}(0|0) = \frac{4*\dot{x}^2(0|0)}{12}$$

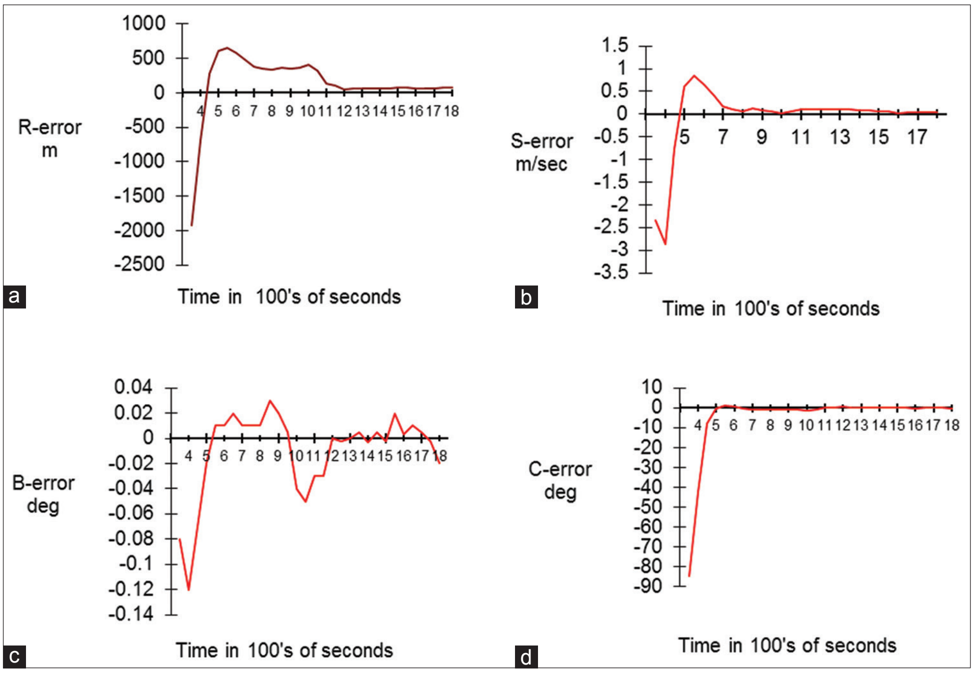

Fig. 2 (a) Error in range estimates, (b) error in speed estimate, (c) error in bearing estimate, (d) error in course estimate

$$P_{11}(0|0) = \frac{4*\dot{y}^2(0|0)}{12}$$

$$P_{22}(0|0) = \frac{4*R_x^{\ 2}(0|0)}{12}$$

$$P_{33}(0|0) = \frac{4*R_y^{\ 2}(0|0)}{12} \qquad (14)$$

Every one of the 1 second examples is adulterated by added substance zero mean Gaussian commotion with a r.m.s level of 0.5°. The eyewitness is thought to do "S" move (as appeared in the figure) on hold of sight at a consistent speed of 3 m/seconds at a turning rate of 1°/second. MGBEKF is actualized, and the outcomes are exhibited for a situation in which the objective is an underlying scope of 20000 m with the zero beginning bearing in respect to the spectator. The objective is thought to move at a speed of 10 m/seconds. With the end goal of the investigation, this situation at target course equivalent to 140° is appeared in Fig. 1. The recreation is done for a time of 30 minutes. The consequences of this situation after 100 Monte Carlo runs are appeared in Figure 2a-d. In these figures and the consequent figures, the blunders in the range, course, bearing and speed evaluations are signified by R-mistake, C-blunder, B-blunder, and S-mistake individually. From the outcomes, it was watched that the arrangement with required precision is gotten from 6th moment onward.

CONCLUSION

The authors have attempted to pre-process the passive sonar bearing measurements to reduce and find out the statistical characteristics of the noise in the measurements, etc., so that the data can be effectively used for tracking an underwater target by Kalman filter effectively. The simulation results confirm that the algorithm is suitable for underwater applications.

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