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Review Article

INVESTIGATION OF DATA PROCESSING FOR PASSIVE ACOUSTIC AND ELECTROMAGNETIC UNDERWATER LOCALIZATION AND CLASSIFICATION

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ABSTRACT

In our earlier work, data fusion with specific application to underwater tracking environment is explored. The target can be tracked using array bearings while it is moving with constant velocity and maneuvering occasionally. In this paper, it is shown that if data fusion is carried out using the bearing measurements available from towed array along with hull mounted array's bearings, then tracking of a continuously moving target can be carried out easily. This algorithm is independent of ownship maneuver for the observability of the process. Song and Speyer's and Galkowski and Islam's modified gain algorithms are utilized with some modifications for estimation. Monte Carlo simulation is performed and results are shown for various typical geometries.

Keywords: Sonar, Estimation, Ownship, Torpedo, Hull mounted array, Towed array, Data fusion.

INTRODUCTION

The towed array's (TA's) and HA's LOS angle measurements are gone onto a PC and the fusion process is completed. For numerical calculation, HA's position is taken as starting point of the direction framework as appeared in the Fig. 1. The TA and HA are thought to be least 500 m separated. The estimations from both sonars are viewed as together in estimation framework. MGBEKF is used with a few changes for estimation of target movement parameters. It is observed that this process could track the target not only at constant velocity but also in pursuit motion.

The aim of the paper is to show that a continuously moving target can be tracked by fusing measurements from two sources of target bearing information. Key is that the algorithm is independent of ownship maneuver for the observability of this process. As such, it is advancement from the previous methods that require ownship maneuver [1-10]. For this purpose, a torpedo is assumed to be the target. In general, only one homing torpedo will be fired against a ship. Hence, data association is not dealt in this paper.

Let (R_{x1}, R_{y1}) and (R_{x2}, R_{y2}) be the x and y components of the target range with respect to HA and TA, respectively. The ownship is moving at an angle of "OCR" with respect to the Y-axis.

IMPLEMENTATION AND SIMULATION

Using MGBEKF, tracking of a target when it is moving with constant velocity and maneuvering occasionally is discussed and the results are shown in the paper [10-15]. Here, simulation results are shown for tracking of a torpedo when it is moving with constant velocity and pursuit motion. For the purpose of simulation, a scenario is considered and the results are shown in the Figs. 2-4. The raw bearing measurements are corrupted with Gaussian noise of the order of 0.5°.

$$X(0|0) = 1110\ 10\ 5000 * \text{Sin Bham}(1) 5000 * \text{Cos Bham}(1)] \quad (1)$$

It is assumed that the initial estimate, X (0|0), is uniformly distributed.

Then, the element of initial covariance matrix is a diagonal matrix and can be written as:

$$P(0/0)=\text{Diag}\left[\frac{4*\dot{x}^2(0/0)}{12} \quad \frac{4*\dot{y}^2(0/0)}{12} \quad \frac{4*r_x^2(0/0)}{12} \quad \frac{4*r_y^2(0/0)}{12}\right] \quad (2)$$

Initially, ownship is at constant velocity. Once it starts getting bearing measurements at 18^{th} sample (by this time ownship confirms that the threat is a torpedo), it carries out a maneuver in a course in such a way that it can go out of the scene quickly. As torpedo has speed advantage, the torpedo chases the ownship. The separation between HA and TA, that is, L is known (say 500 m).

It is assumed that torpedo homing range is 2 km. When the range between torpedo and ownship reduces to <2 km, torpedo homes onto ownship and chases the ownship in pursuit motion. It is assumed that when the range between torpedo and ownship reduces to <1 km, ownship deploys decoy and maneuvers in course (say at a rate of 3°/second). Then, the torpedo homes onto decoy and finds out that it is chasing a decoy. It is assumed that whenever it loses the contact of the target, it makes a circular search (as a lost contact search). After identifying it as a decoy, the torpedo does a circular search and homes onto ownship. The torpedo turning rate is assumed to be 8°/second. When the range reduces to around 500 m, it is not possible for sonar to do autotracking, and hence, at this point, estimation of target motion parameters is stopped. The convergence of the estimated solution is said to be obtained when the errors in predicted range, course, and speed are within 15% of the actual range, 4°, and 5 knots, respectively.

In Figs. 2-4, torpedo path simulated (tpd path sim), ownship (ownship), and torpedo path predicted (tpd path pred) are shown. The position of the torpedo and ownship at various sample times are shown with TPD *** and OS *** (*** are sample times), respectively. The position deployment of the decoy and the torpedo position at the time of deployment of decoy are also shown. The ownship checks if the target is a torpedo (checking time is approximately 18 seconds) and if target is a torpedo ownship tries to escape from the torpedo attack by doing evasive maneuver. The ownship evasive course is based on the HA bearing.

If HA's absolute value of relative bearing is <60°, then

Ownship evasive course = measured bearing + sign of torpedo side × 20

If HA's absolute value of relative bearing is >60°, then

Ownship evasive course = measured bearing + 180 + sign of torpedo side × 20. The sign of torpedo is positive if the torpedo is on starboard

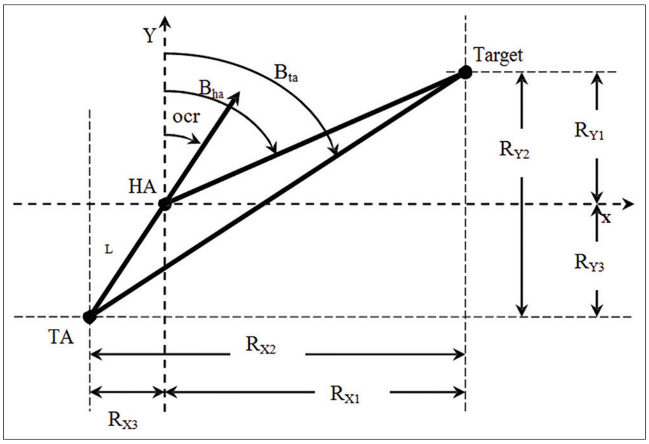

Fig. 1: Target and observer encounter

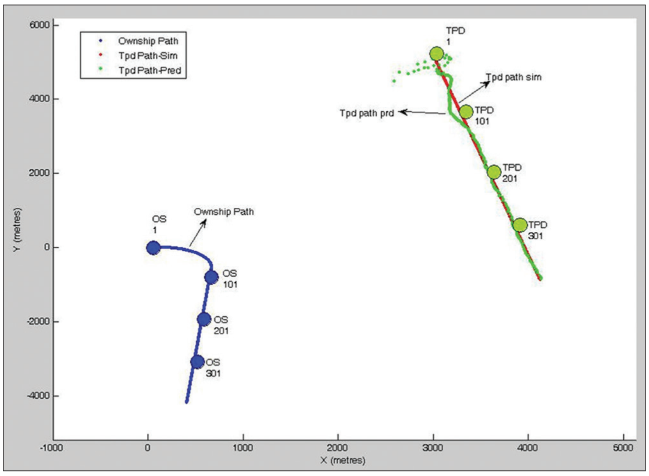

Fig. 3: Torpedo trajectory in Scenario 2

side and negative if it is on port side. In simulation, it is assumed that when the range is <1000 mts, decoy is dropped and then ownship carries out an evasive maneuver. The results of the Scenarios 1-3 are shown in Figs. 2-4, respectively.

Analysis of Scenario 1

It is assumed that torpedo is fired onto ownship in intercept mode (Fig. 2). Almost from the beginning of the torpedo run, the torpedo is tracked while it is at constant velocity, pursuit motion, and circular search. The torpedo has come closer to the ship twice and at these two times, decoy is dropped. The torpedo circled around the decoys. The errors in estimated torpedo motion parameters are well within the specified limits.

Analysis of Scenario 2

The torpedo is at intercept course (or constant bearing) onto the ownship (Fig. 3). This scenario is chosen to highlight that ownship can carry out an evasive maneuver and can escape from torpedo attack.

At 18th second, the ownship has carried out an evasive maneuver as described earlier (The escape maneuver algorithm is same for all the scenarios). With this logic in this scenario, the distance between the torpedo and ownship is never less than homing range. Hence, ownship escapes to safe state and there is no need for dropping a decoy.

Analysis of Scenario 3

Here, the aim is to show that ownship maneuver is not required, when HA and TA bearings are used (Fig. 4). This is shown for the purpose of academic interest. In general, when torpedo is fired onto ownship,

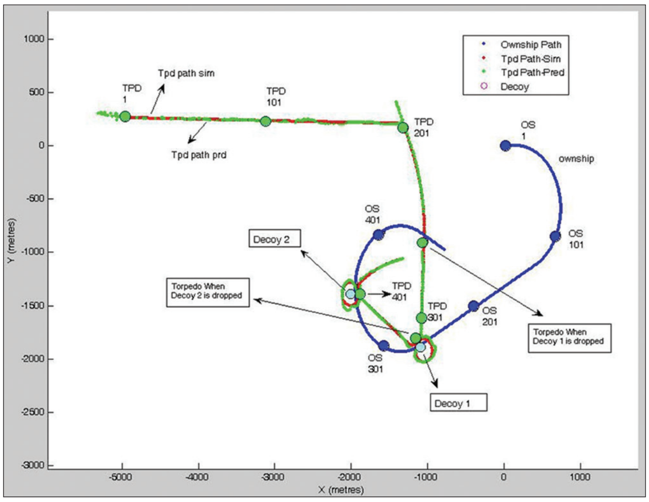

Fig. 2: Torpedo trajectory in Scenario 1

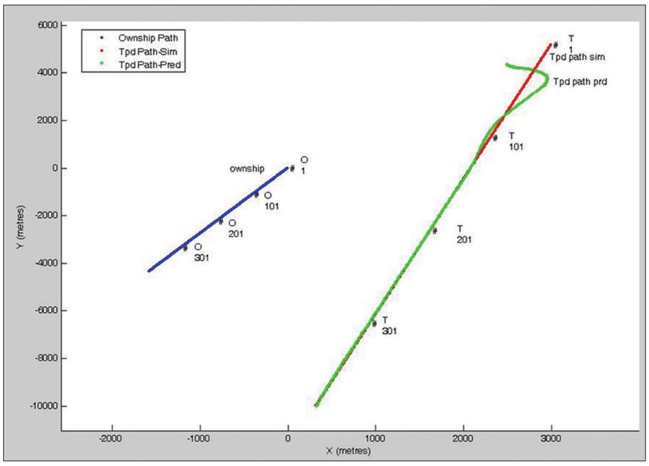

Fig. 4: Torpedo trajectory in Scenario 3

ownship definitely tries to make evasive maneuver and escape form the scene. In this scenario, the torpedo is not fired in intercept course onto the ownship. Even though ownship has not done evasive maneuver, the torpedo is tracked satisfactorily. The torpedo speed is taken as 60 knots (futuristic torpedo) and it is shown that this algorithm is useful to track even high speed torpedoes.

CONCLUSION

The algorithm is evaluated and the results in Monte Carlo simulation (with 50 runs) are shown for three scenarios. The case of ownship dropping number of decoys and torpedo making circular search is depicted in Scenario 1. In Scenario 2, it is shown that sometimes ownship can escape from the torpedo attack with a simple ownship maneuver. In Scenario 3, it is shown that ownship maneuver is not required for the observability of the process because bearings from two sensors are used. In all these scenarios, algorithm is able to track the torpedo. Hence, this algorithm can be recommended for torpedo tracking.

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