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Data fusion of towed array and hull mounted array measurements for passive acoustic and electromagnetic underwater localisation and classification

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Abstract

Background/Objectives: In our earlier work, data fusion with specific application to underwater tracking environment was explored. The target can be tracked using array bearings, while it is moving with constant velocity and maneuvering occasionally.
Methods/Statistical analysis: In this paper, it is shown that if data fusion is carried out using the bearing measurements available from Towed Array (TA) along with hull mounted array's bearings, then tracking of a continuously moving target can be carried out easily.
Findings: This algorithm is independent of ownship maneuver for the observability of the process**.** Song and Speyer's modified gain algorithms are utilized with some modifications for estimation.
Application/Improvements: Monte Carlo simulation is performed and results are shown for various typical geometries which revealed that this algorithm is useful naval based applications.
Keywords: estimation, sonar, tracking, data fusion, Kalman filter, observability, maneuver

1. Introduction:

The TA's and HA's LOS angle measurements are gone on to 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 Figure 1. The TA and HA are thought to be least 500 meters separated. The estimations from both sonar's 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 [1-9].

Table 1. Scenarios

Item Description	Scenario1	Scenario 2	Scenario 3
Initial Range (mts)	5000	6000	6000
Initial Bearing (deg)	273	30	30
Torpedo Course (deg)	91	190	170
Torpedo Speed (Kts)	28	24	60
Ownship Course (deg)	90	200	90
Ownship Speed (Kts)	20	18	18

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. 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.

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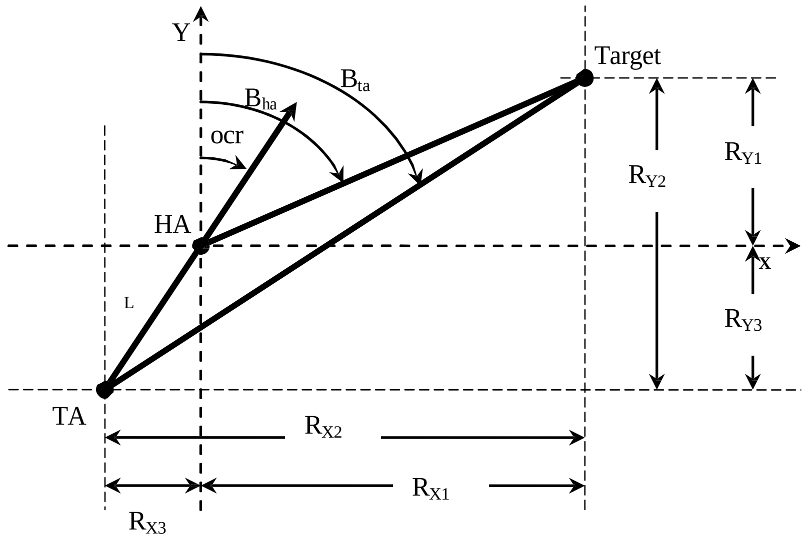
Figure 1. Target & Observer Encounter



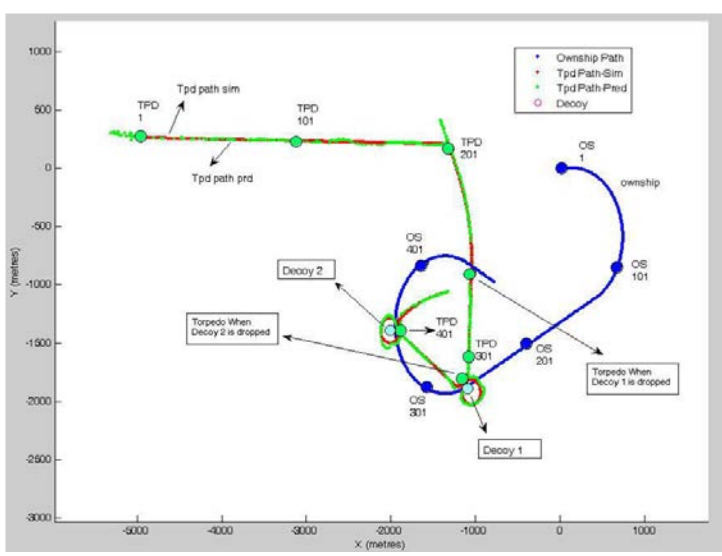
Let (R_{x1}, R_{y1}) & (R_{x2}, R_{y2}) be the x and y components of the target range w.r.to HA and TA respectively. The ownship is moving at an angle of „ocr‟ w.r.to the Y-axis.

2. 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 shown in Table 1 is considered and the results are shown in the Figure 2, 3 & 4.The raw bearing measurements are corrupted with Gaussian noise of the order of 0.5^0.

$$X(0|0) = [1\ 1\ 10\ \ 10\ \ 5000 * \sin B_{ham}(1)\ \ 5000 * \cos B_{ham}(1)]' \quad (1)$$

Figure 2. Torpedo Trajectory in Scenario 1



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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

$$P(0/0) = Diag\begin{bmatrix} \frac{4*\dot{x}^2(0/0)}{12} & \frac{4*\dot{y}^2(0/0)}{12} & \frac{4*r_x^{\,2}(0/0)}{12} & \frac{4*r_y^{\,2}(0/0)}{12} \end{bmatrix} \qquad (2)$$

Initially ownship is at constant velocity. Once it starts getting bearing measurements, at 18th sample (by this time ownship confirms that the threat is a torpedo), it carries out a maneuver in 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 meters).

It is assumed that torpedo homing range is 2 km. When the range between torpedo and own ship reduces to less than 2 km, torpedo homes on to ownship and chases the own ship in pursuit motion. It is assumed that when the range between torpedo and own ship reduces to less than 1 km, ownship deploys decoy and maneuvers in course (say at a rate of 3 deg/sec). Then the torpedo homes on to 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 on to ownship. The torpedo turning rate is assumed to be 8 degrees/second. When the range reduces to around 500 meters, it is not possible for sonar to do auto tracking 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 degrees and 5 knots respectively.

In Figure 2 to 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 less than 60 deg, then
Ownship evasive course = measured bearing + sign of torpedo side *20
If HA‟s absolute value of relative bearing is greater than 60 deg, then
Ownship evasive course = measured bearing + 180 + sign of torpedo side *20 The sign of torpedo is positive if the torpedo is on stbd side and negative if it is on port side. In simulation, it is assumed that when the range is less than 1000 mts, decoy is dropped and then ownship carries out an evasive maneuver. The results of the scenario1, 2 and 3 are shown in Figure 2, 3 and 4 respectively.

2.1 Analysis of scenario 1

It is assumed that torpedo is fired onto ownship in intercept mode (Figure 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.

2.2 Analysis of scenario 2

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

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Figure 3. Torpedo Trajectory in Scenario 2

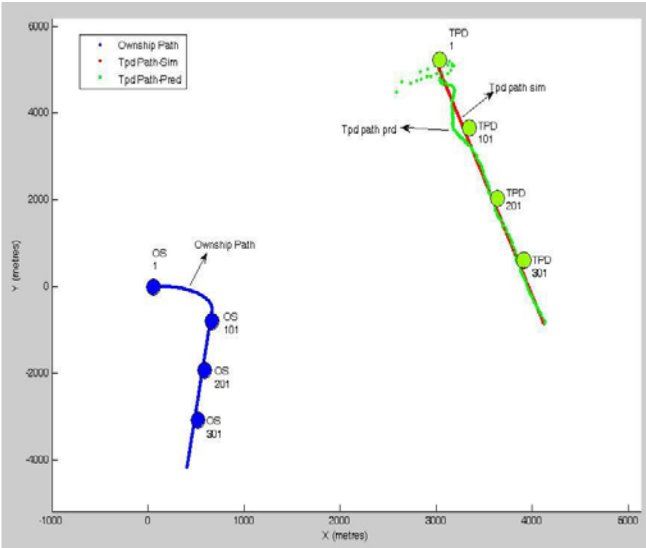
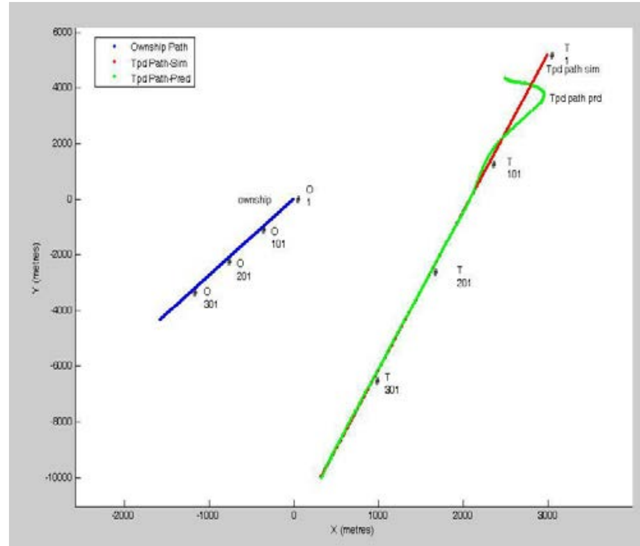


Figure 4. Torpedo Trajectory in Scenario 3



2.3 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 on to ownship, ownship definitely tries to make evasive maneuver and escape form the scene. In this scenario, the torpedo is not fired in intercept course on to 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.

3. 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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