

# An Improved Nearest Neighbor Data Association Method for Underwater Multi-Target Tracking

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**Abstract --** Nearest Neighbor (NN) data association method is the most popular and widely used algorithm for target tracking in the presence of clutter, due to its acceptable performance and low computational complexity. Despite of the good performance of this algorithm in single target tracking and even Multi-Target Tracking (MTT) with non-crossing paths scenarios, its performance degrades significantly in the cases of MTT with crossing paths. A new version of this algorithm, Inertial NN (INN) is proposed in this paper. INN uses inertial property of the target motion to make a better estimation of the observation in each time interval. The results of applying the new algorithm to practical STT and MTT with non-crossing paths and also simulated MTT with crossing paths scenarios show a significant improvement in the performance and robustness in different situations with a slight increase in the complexity. Because of the considerable improvements of INN, it is strongly suggested to be used instead of its former version in both single and multi target tracking with crossing or non-crossing paths. Although the dependence of INN to the inertial property of the target motion made it suitable for underwater target tracking, it is also applicable for other scenarios such as radar, speech processing, and etc.

## I. INTRODUCTION

Tracking of the objects using distributed multiple sensors is an important feature which is widely used in various application areas such as autonomous robotics, radar, sonar, and wireless communications. Tracking can be employed about various parameters of the objects such as: motion status, velocity, acceleration, frequency and etc. Based on the type of the achievable information about the objects, some of these parameters can be tracked.

In this paper, passive multi-target Bearing-Only-Tracking (BOT) in the underwater scenarios is considered. In such scenarios, sonar works only based on the impinging noise from the targets around it. Because of the significant non-ideality of the underwater environments and high ambient noise level, the impinging noise from the targets receive in several paths with significantly low SNR [1]. Therefore, tracking in such scenarios is more critical than the others. Clearly, using a single array and passive tracking yields only the bearing of the target.

However, the receiving signal by the array is processed by the Direction Of Arrival (DOA) estimator [2-4] block to prepare necessary data for tracking. Because of the multipath effect and high noise level in the underwater environments, the DOA estimator makes several rough estimates for each target. Since most of tracking methods need a unique observation to estimate the features of interest of the target, data association is necessary for separating the entries and extracting a unique observation from them.

Therefore, data association is a very important process should be done before tracking.

Data association is used to recognize and remove false alarms, and extracting the observations corresponds to each target. Finally, the tracking algorithm uses final observations to make better continuous estimates of the angular paths of the targets. In the other word, BOT is used to make a better and more accurate vision of the angular motion of the targets based on the observations produced by data association methods.

Target tracking is a main function of each sonar surveillance system. All tracking methods use the input observations from the target state to filter false alarms and estimate a better view of the target feature of interest. In the ideal case, the observations are the combination of the actual value of the target state the measurement noise. But in practice, even in the case of single target tracking, because of the multipath effect, clutters and other non-ideal effects of the underwater environment, there are usually several false alarms beside the actual observations. It is clear that these observations can't yield proper tracking results. Data association (DA) methods can be used to separate the corresponding observation to each target [5].

On the other hand, in the case of multi target tracking the need of DA methods are too necessary. In such scenarios, it is necessary to extract different target's observations. However, this extraction is done by gating algorithms, but usually data association and gating process are done together. In this paper the process of extracting different target observations, removing false alarms, and at last achieving a final observation from ones corresponded to each target is called data association. Because of the significant non-ideal underwater environment, imperfect operation of the data association methods causes significant degradation even in the case of using powerful tracking algorithms.

There are several data association method [6-8], each of which has special structure, performance, complexity and robustness. Nearest Neighbor method [6] is one of the most popular of them. In this paper, a new version of this method is established based on the inertial property of the underwater targets.

This paper is organized as follows. At first the Nearest Neighbor method is introduced in section II. After that, the new method is depicted in section III. Simulation results are yielded in section IV to evaluate the performance improvement of the new method and finally, conclusion remarks are given in section V.

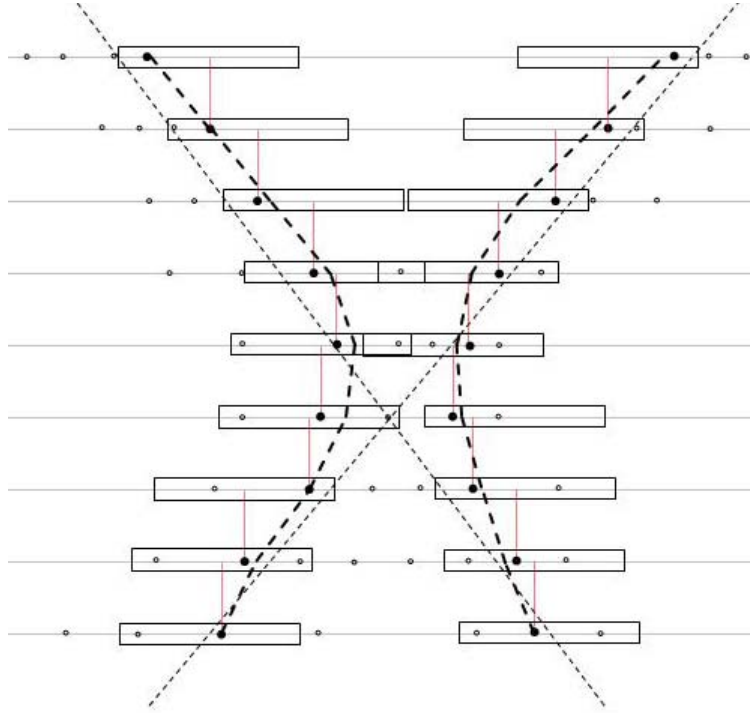


Fig.1. Operation of the NN method; the real angular paths of the targets and tracking result are shown as dotted straight crossing lines and bold dashed lines, respectively, gating intervals are shown by rectangles finally observations are shown as bold points.

## II. NEAREST NEIGHBOR DATA ASSOCIATION METHOD

NN algorithm is one of the most popular data association algorithms because of its performance and simplicity. In [6] there is an extend investigation about this algorithm. It is applicable for data association in different applications such as image processing, sonar, wireless communications and radar. But in this paper the application of this algorithm in the underwater passive scenarios is considered.

As seen in fig. 1, during DOA estimation several angles are corresponded to each target in each time interval. Data association is used to prepare a unique observation for tracking of each target angular paths. In this regards, following steps should be done:

- Step 1.** consider all entries as the new targets.
- Step 2.** find the corresponded entries to each target by considering gating intervals around the past position of each target (the entries inside the gating intervals are related to the corresponded targets).
- Step 3.** choose the nearest entry of each interval as the corresponding final observation of each target.
- Step 4.** run the tracking algorithm to estimate the paths based on their past position and the corresponded observations to each target.
- Step 5.** all paths which are smaller than a predetermined length should be removed.
- Step 6.** go to step 2.

However this algorithm can properly determine the false alarms and remove them in single target tracking, in case of multi target tracking is not very good. More significant

degradations occur in MTT with crossing paths scenarios. Fig. 1 shows a sample situation in which NN algorithm can not find proper observations in the crossing angle. In this figure, the results of DOA estimation for two distinct targets moving during two crossing paths are shown. As seen in this figure, following the above steps can not yield proper results for tracking. This is the major drawback of the NN algorithm which limits its applications significantly.

## III. INERTIAL NN METHOD

Generally, achieving more information about the receiving signal and the tracking environment, can severely improve the tracking performance. In order to mitigate the drawback of the NN method about the MMT with crossing paths, a new method is motivated based on some information about the underwater target motion. It is based on the natural inertial property of these targets. Based on this property, it is possible to assume the target motion as a markove chain random variable. In the other word, the target motion in each moment depend on the past motion status.

In this method, regarded to the past motion status of the target, the position of the target is calculated by assuming the same motion status as the past. This is a coarse approximation of the target position. By putting the gating interval around the new positions, the inertial NN (INN) method can properly extract the crossing path targets even with the same energy, velocity and acceleration. The order of the markove chain model, which shows amount of target position dependency to the past motion condition, depends on the type and especially maneuvering velocity of the vessel.

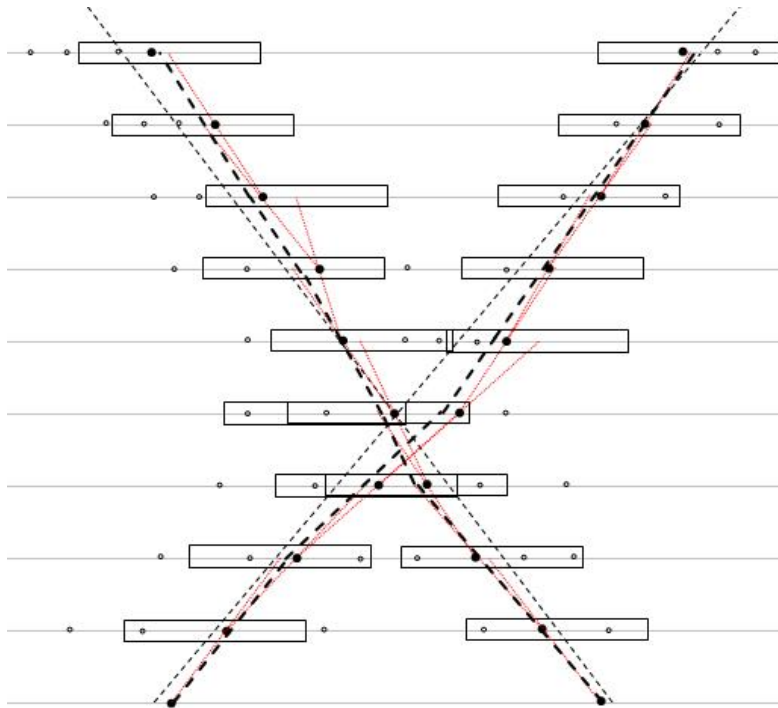


Fig. 2. Operation of the INN method; the real angular paths of the targets and tracking result are shown as dotted straight crossing lines and bold dashed lines, respectively, gaiting intervals are shown by rectangles finally observations are shown as bold points.

#### IV. SIMULATION RESULTS

A performance comparison of the NN and INN methods are given in Fig. 3 and table 1. During these simulations, a uniform linear hydrophone array with 40 elements is used. Besides, in order to preparing necessary data for tracking, beamforming based DOA estimation is used. During the tracking process both NN and INN methods are implemented and finally a second order Kalman filter is used to track angles of the targets.

Parts (a) and (b) of the Fig. 1 represent the effect of using NN and INN methods respectively for data association. Kalman filter [5] is used to track the output of these two DA methods. Although the inputs of these two methods are the same, it can be seen that INN can separate each target's observations properly but its former version, NN, can't. Whereas they are samples of the behavior of NN and INN methods, in order to achieve more reliable results, it should be repeated adequately. This test is repeated for 1000 times for random crossing paths. Simulation results of this comparison are tabulated in table 1. As seen in this table, the improvement of the tracking performance is considerable.

TABLE I  
COMPARISON OF THE NN AND INN METHOD

	Tracking Properly	Failure
NN	61%	39%
INN	88%	12%

The significant improvement of the data association performance in INN method is at the expense of a slight complexity increase to calculate the estimation of the target. Correspond to Fig.1, the operation of the tracking based on

INN is illustrated in Fig. 2. The operation of this method around the intersection point is worth noting.

In the INN data association method, it is necessary to set the inertial factor manually to operate properly. Of course, this algorithm can even work with non-optimum values of this factor but with degradation in its performance.

#### V. CONCLUSIONS

Because of the natural inertial characteristic of the motion of underwater vessels, it is possible to use the past motion status to make a coarse approximation of the target position. It improves the tracking performance by making better observations. The most important advantages of the new algorithm is its ability to correctly detect target's path in the intersected points and also, its ability to follow paths of the targets with higher maneuvering speed.

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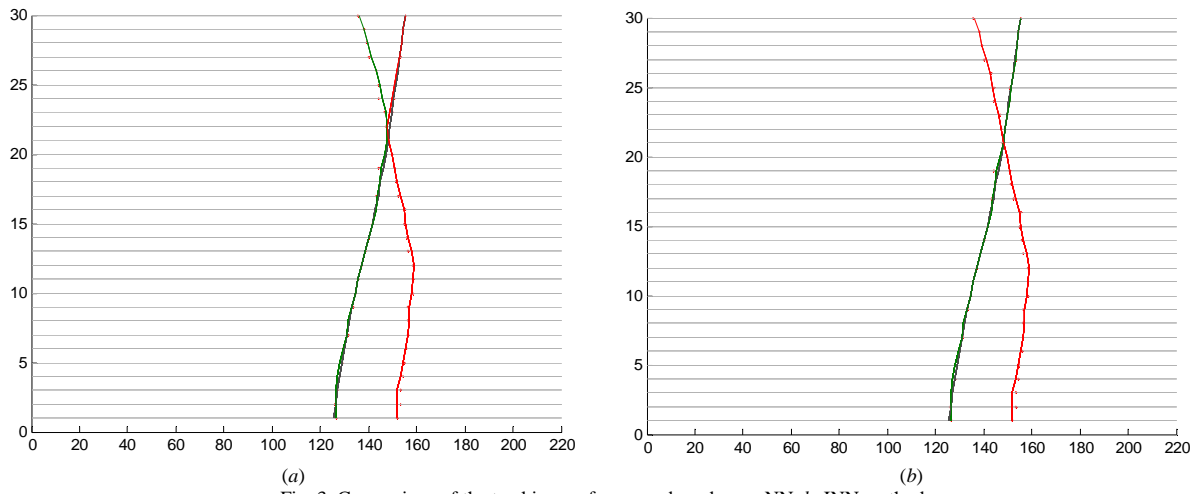


Fig. 3. Comparison of the tracking performance based on *a.* NN, *b.* INN method

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