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The Target Tracking Algorithm Based on Environment Technology

Yang Shen

Shanghai University of Medicine & Health Sciences, 279 ZhouZhu Road, Shanghai, China

Abstract

In the complex environment, such as strong clutter and dense target, the target track instability, the algorithm based on environment technology is proposed. The environmental information of the target is obtained by means of point density statistics and ship collision avoidance model. In the different circumstances, plot feature is used to improve the stability of target tracking. Verified by actual environment, it shows that the target tracking algorithm based on environment can improve the target-tracking performance of VTS system in complex environment.

Keywords: environment, plot feature, VTS system, tracking algorithm

Corresponding Author:
Yang Shen
sheny@sumhs.edu.cn

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1. Introduction

The navigation radar in the Vessel Traffic Services (VTS) is a fixed deployment, providing target tracks such as sea vessels or buoys for users to use [1]. In complex sea conditions, such as target encounter or cross dense in the clutter area, the denseness of points and the decrease in the credibility of the track quality will increase the difficulty of the target data association, resulting in a decrease in the quality of the target track. Therefore, data association technology in complex environments has always been a difficult and key technology for tracking targets on the sea surface. Since the development of data correlation algorithm, there have been many algorithms, such as the Nearest Neighbor Probability Data Association(NNPDA) [2], Multiple Hypothetical Tracking (MHT) [3] and so on. Through actual measurement, NNPDA is only suitable for target tracking in weak clutter environment. MHT proposed by Reid uses the posterior probability of the hypothetical path branch to solve the ambiguity of the target data association in dense area or clutter area, it is an optimal algorithm to solve multi-objective data association accuracy in complex environments [4, 5]. However, the number of hypothetical track branches generated by the MHT algorithm is exponentially increasing in relation to the false alarm rate, the number of targets and the number of scanning cycles processed, the amount of calculation and storage of the algorithm is very large and must be applied to the sea in real time, so there is still a certain degree of difficulty in radar target tracking. In summary, these two data association algorithms have certain limitations. This paper constructs a tracking algorithm based on environmental perception, according to the relation between the degree of density and the relative motion of the target, the environment information of the target is adaptive, and different data correlation algorithms are used for different environments. In the clutter environment, the characteristics of the target point trace and clutter point trace are used to correlate the data. In the target concentration area, the judgment of the trace source of the target correlation point is added to avoid the correlation to the anomaly spot trace. Based on the data of VTS system, the target tracking algorithm based on environment technology is verified to improve the tracking performance of the target.

2. Target Tracking Algorithm Based on Environmental Perception

In 2006, Haykin S of Canada introduced the concept of cognitive radar for the first time. The cognitive radar acquires environmental information through continuous interaction with the environment, combines prior knowledge and reasoning, continuously adjusts the parameters of the receiver and the transmitter, and adaptively detects the target [6]. Learn from this idea, in the process of target tracking, environmental factors can also be used to design the target tracking algorithm. Taking the VTS system as an example, the identification method and corresponding target tracking algorithm for constructing clutter zone and dense environment are emphasized.

2.1. Data association algorithm in clutter environment

Sea clutter generally refers to the backscattered echoes of sea surface under radar illumination, its probability distribution is obviously deviated from the Gaussian distribution, and it is non-Gaussian [7]. In some areas, radar can detect a large number of residual points of sea clutter, resulting in more false alarms, which increases the difficulty of target tracking [8]. It can be used to describe the attribute characteristics of different regions of radar by observing the degree of trace density, the spot density area belongs to the clutter zone, and the spot sparse region belongs to the non-clutter zone. The radar detection distance is set to be N kilometers and the azimuth is M

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degrees. The area ($N \times M$) is divided into several grid units by a certain distance and azimuth, and each trace can be mapped to different grid units, trace grid unit shown in Figure 1. Updates the number of traces that fall within the grid cell during each radar scan cycle, meanwhile, accumulate the sum of the number of historical points in the grid cell. After several scanning cycles of radar, the properties of corresponding regions are judged according to the point count and trace distribution characteristics in adjacent grid cells. If the point count and trace distribution characteristics of a grid cell meet the following conditions:

1. The value of the grid unit point trace is greater than the threshold value.
2. The number of trace counts in adjacent network units is greater than the preset threshold.

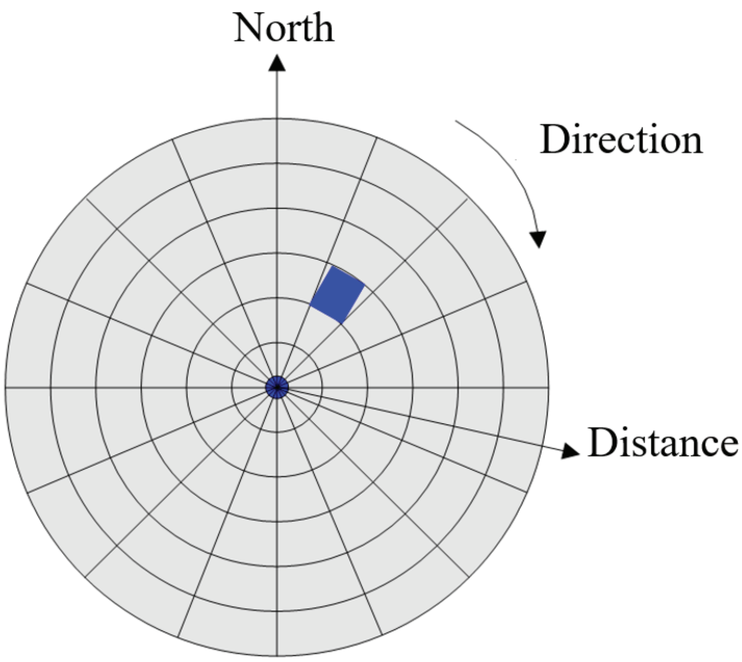


Figure 1: Dot trace grid unit diagram.

Then the grid is determined as a clutter area, otherwise it is a non-clutter area. For the target tracking in the clutter zone, we can consider using the point trace feature to assist the correlation. Although the characteristic information parameters of the target cannot be directly used for track update, it plays an important role in effectively distinguishing between targets and clutter [9-12]. Figure 2 shows a comparison of target and clutter signature parameters in clutter. The figure shows that the trace feature parameters can be classified into two distinct categories: clutter traces and target traces. The figure shows that the trace feature parameters can be classified into two obvious categories: clutter traces and target traces. The azimuth width and distance width of clutter traces are small and weak. The target track orientation width and distance width are large. Therefore, the point trace feature has a certain value for the target tracking in clutter area.

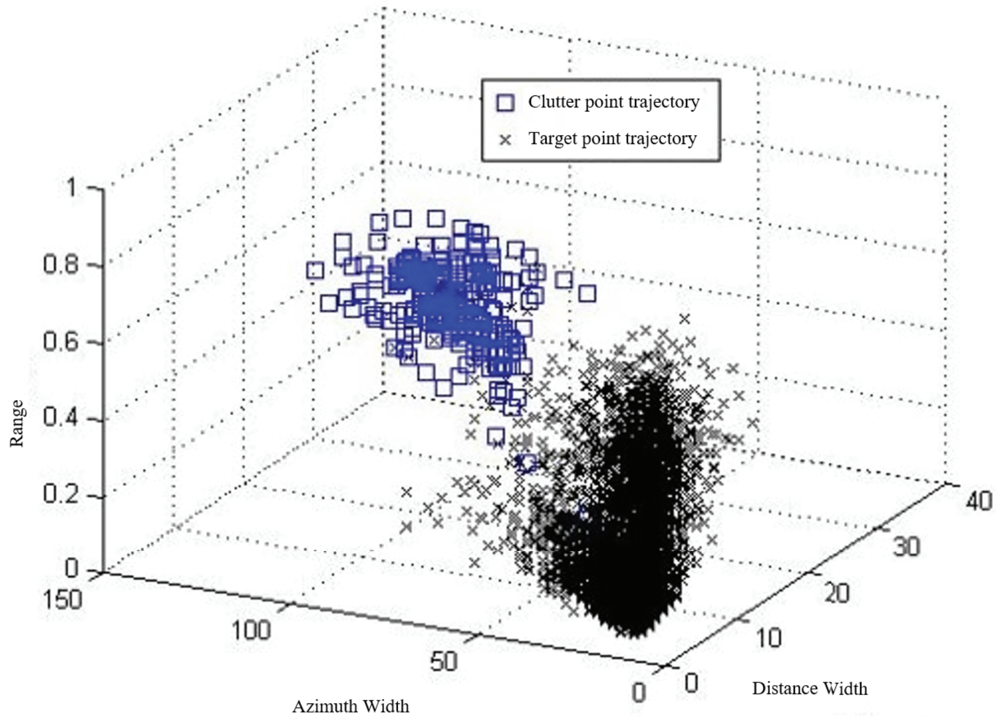


Figure 2: Distribution diagram of Clutter point trajectory and target point trajectory eigen value.

2.2. Dense target data association algorithm

In the VTS system, the target of radar detection often encounters intensive target movements such as encounters, overtaking or crossovers [13-14]. The change of tracking wave gate is analyzed from the physical angle. When there is a long distance between targets, there is no overlap phenomenon. When the target moves in a certain way for a certain period of time and encounters with other targets, the target wave gate overlaps, and there is ambiguity in the relation of trace track association. If the target motion state is not changed, the target is separated after several scanning cycles of radar, and the wave gate does not overlap. The minimum encounter time T_{cpa} of ship collision avoidance model is used to describe the movement situation of the target, thereby establishing the environmental information of the target. When T_{cpa} is less than a preset value, it is perceived that there is a scenario in which the target exists, and adaptive adjustment of data correlation algorithm. The minimum encounter time calculation model T_{cpa} is shown in Figure 3.

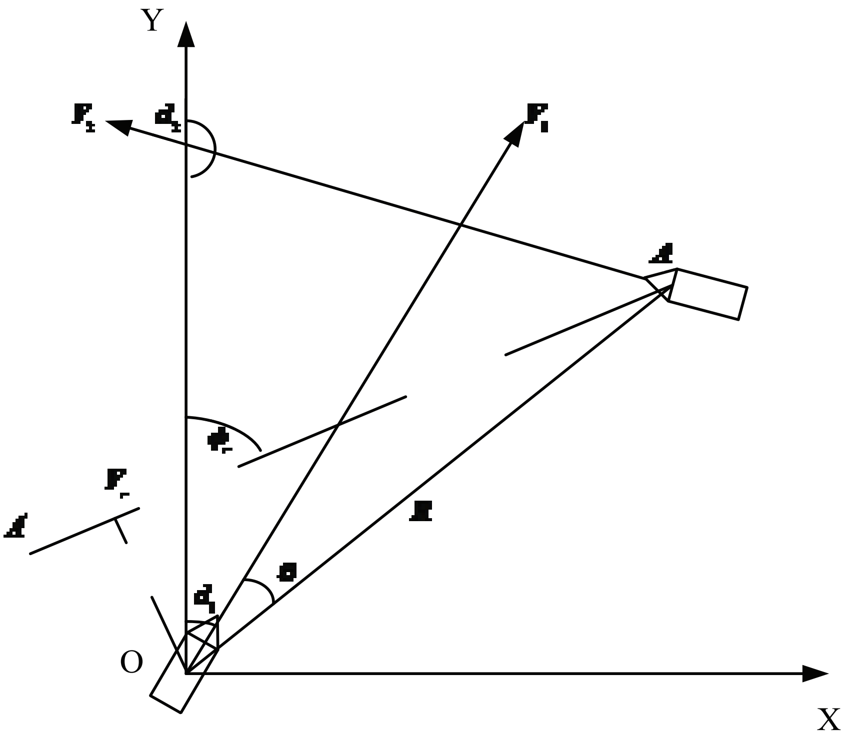


Figure 3: Ship collision avoidance model.

In the plane coordinate system *xoy*, the *y*-axis is the positive north direction. Let one ship be located at the origin *o* of the coordinates, with the heading d_1, and the speed v_1, another ship is heading d_2, speed v_2 uniform movement. At time t_1, the relative position of the two ships is point *A*, the relative distance is *R*, and the relative azimuth is θ. *AA* is the relative heading of the two targets with an angle of ϕ_r to the *y*-axis and the relative speed is v_r. ϕ_r and v_r can be derived from geometric relations.

$$v_r = \sqrt{v_2^2 + v_1^1 - 2v_2v_1\cos(d_1 - d_2)} \tag{1}$$

$$\phi_r = \text{arctan}\frac{v_2\cos d_2 v_1\cos d_1}{v_2\sin d_2 - v_1\sin d_1} \tag{2}$$

The coordinate of A point is,

$$x_A = R\sin(d_1 + \theta) \tag{3}$$

$$y_A = R\cos(d_1 + \theta) \tag{4}$$

After the *t* moment, the relative displacement of the two ships is calculated as follows,

$$\Delta x = x_{t0} + \int_0 (v_2 \sin d_2 - v_1 \sin d_1)dt \tag{5}$$

$$\Delta y = y_{t0} + \int_0 (v_2 \cos d_2 - v_1 \cos d_1)dt \tag{6}$$

Derive the relative distance and direction of the two ships from Δx and Δy,

$$R(t) = \sqrt{\Delta x^2 + \Delta y^2} \tag{7}$$

$$\theta(t) = \arctan\frac{\Delta x}{\Delta y} \tag{8}$$

Calculate T_{cpa} from equations (7) and (8),

$$T_{cpa} = R(t)|\cos(\phi_r - \theta(t))|/v_r \tag{9}$$

Target A's polar coordinate position is PA(18Km,187°), speed is 6m/s, heading is 330°, uniform linear motion. Target B's polar coordinate position is PB(17Km,189°), speed is 4m/s, heading is 190°, uniform linear motion. Target A and Target B will meet after several radar scan cycles, and the target motion status will not change during the encounter time. After several scanning cycles, the two target echoes are separated. The Tcpa parameter of target A is shown in Figure 4.

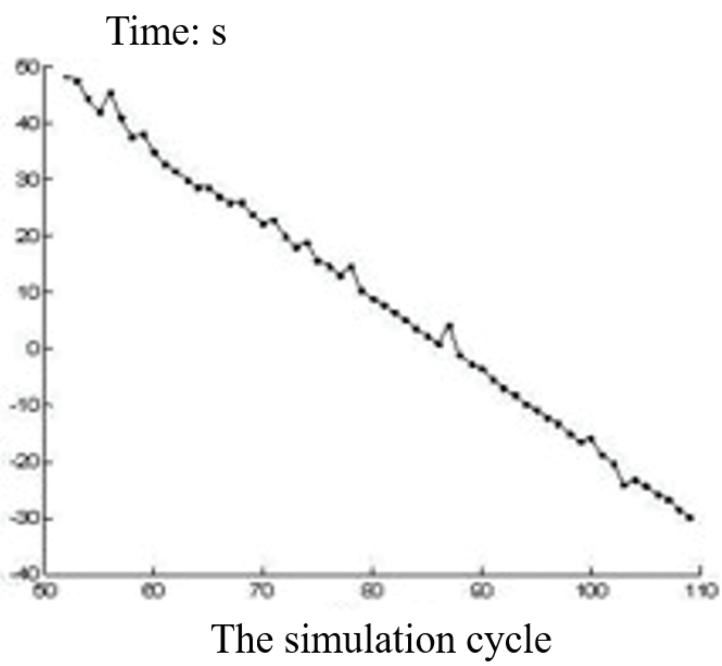


Figure 4: T_{cpa} diagram of *A* target.

In the initial stage of the two targets tracking, the targets are far apart and there is no overlapping of the wave gates, the target A's $t_c \geq 0$. After the two targets move towards each other for a number of scans, target *A* and target *B* will encounter each other gradually, resulting in a wave overlap. At this point, the t_c value of the target A gradually becomes smaller as the multi-target density meets. When $t_c < 0$, the multi-objective is transferred to the target separation situation and the absolute value of t_c of target *A* gradually increases with the degree of separation of the target. It can be obtained by combining the target movement scene and the corresponding change t_c value: The change of t_c value can reflect the degree of the target density. The smaller the absolute value of t_c, the denser the target is; On the contrary, the target is in a non-intensive situation. If a reasonable threshold τ is set, the multi-object separation-intensive encounter-separation process can be automatically identified.

In the course of the target meeting, the target wave gate overlaps and there may be n points in the wave door, $\{d1, d2, ..., dn\}$, $n \geq 1$. At this time, the adaptive data correlation strategy is adjusted, and the multi-feature of the target correlation point trace is used to identify and assist the correlation. Tracking source results are divided into: C_0indicates that the trace originates from the tracking target *s*, C_i indicate that the trace originates from other tracking targets $T_i (i = 1, 2, ..., N)$, C_{N+1} indicates that the traces originate from other factors, such as the trace or clutter after the target echo overlaps. The calculation process of the trace d_n from the target T_i is as follows:

In the first step, the mean value of the feature vector of the target *s* and target T_i history-related trace features is calculated, $\overline{\lambda} = [u_1, u_2, u_3]$,

$$u_p = \frac{\lambda_{p1} + \lambda_{p2} + \cdots + \lambda_{pt}}{n}, quad p = 1, 2, 3, \ t = 1, 2, \ldots, K \tag{10}$$

Where, K is the target history tracking period.

The second step, assuming that the point d_n in the wave gate belongs to C_0 or C_i, $i=1,2,...,N$, calculate the eigenvectors mean value of the updated associated tracing points with target *s* and target T_i, $\overline{\lambda}' = [u'_1, u'_2, u'_3]$. The formula (11) is the objective decision function, which is used to measure the distance between the point d_n and the center eigenvector C_i.

$$J_i = \sum_{p=1}^{3} |u'_p - u_p|^2, \quad d_n \in C_i \tag{11}$$

The third step is to determine the principle of track distribution. Set a threshold ε, if $J_i \leq ε$, d_n belongs to C_0 or C_i, $i=1,2,...,N$. If $J_i > ε$, d_n does not belongs to C_0 or C_i, d_n belongs to C_{N+1}, that is, the trace originates from other factors. In special cases, if the trace d_n belongs to C_0 or C_i at the same time, the multi-trace and target track association matrix is constructed, and the point track and track interval are used as feature distances. Each target track is temporarily associated with the minimum trace of the feature distance and remove the duplicate trace. After the target point track association is completed, the target association point trace feature set is updated.

3. The Verification of Algorithm

Collecting radar measurement data from VTS system, we analyze target tracking performance based on environment-aware technology. Figure 5 shows the wave gate counts for the target in the separation-exposure-separation phase. In the 323th radar scan period, two spots appeared in s_A and s_B wave doors, and the correlation was ambiguous. Calculate the distance of d_n to C_i by Equation (11), the calculation results are shown in Table 1.

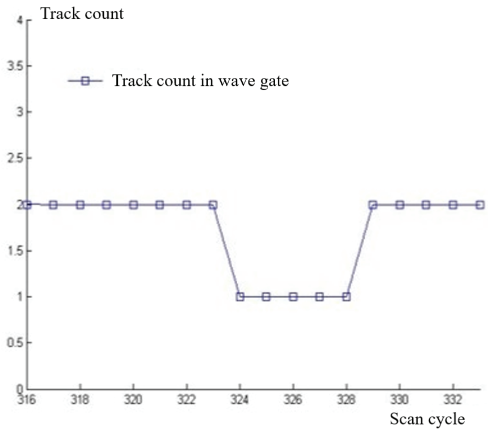
Table 1: Dot distribution calculation results.

Trace	Feature distance results belonging to target A	Feature distance results belonging to target B
1	16.038	7.500
2	22.449	1.090

According to the principle of similarity distribution of points associated with tracks, track 1 belongs to sA and track 2 belongs to sB. The admissible function curves for sA and sB in the 324th to 328th radar scan period is shown in Figure 6. It can be seen from the figure that there is an obvious step process for the value of the ruling function during the period of the target meeting and separation period. This shows that after the multi-target echo overlaps, there is indeed a significant change in the characteristics of the detection trace feature in the energy, contour and target history associated traces. Therefore, the trace does not belong to any target and should be attributed to the target echo overlap trace. It can be seen that environmental information plays a certain prior knowledge in the target tracking process.

4. Conclusion

In the VTS system, using clutter density statistics and ship collision avoidance models to construct the target's environmental information for clutter and target-intensive encounter scenarios. Different data association strategies are used for different environments. Verified by actual environment, it shows that the target tracking algorithm



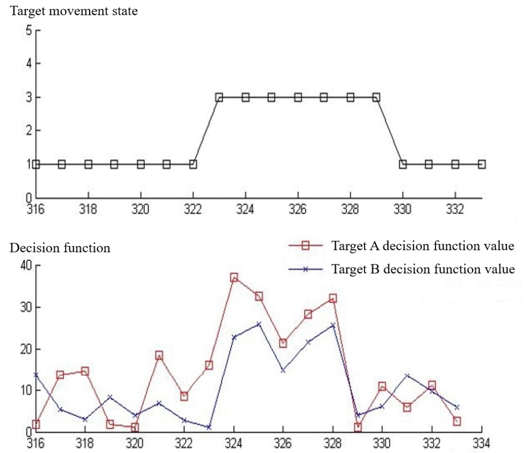


Figure 5: Dot count changes curve. Fig.6 Decision function curve.

based on environment can improve the target tracking performance of VTS system in complex environment.

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