A Multi-target Tracking Algorithm Based on Auxiliary Information

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***Abstract*—This article presents a study for reducing the complexity of data association in multi-target tracking by using the target location data and associated Doppler information measured by radar. A scenario of using characteristic parameters to modify the nearest neighbor algorithm is illustrated in the study of tracking algorithm, and the simulation results verified the applicability and effectiveness of this method for engineering application.**

Keywords- data Association, the nearest neighbor, Doppler frequency

I. INTRODUCTION

Data association has been the focus of multi-target tracking. The first step of data association is related with tracking gate, when the number of targets and effective echoes increase, establish an efficient and accurate tracking gate of data association can not only reduce the number of inter-related data and reduce the computational load, but also reduce the probability of error associated, thereby greatly improving the performance of data association algorithm. Typically, it uses radar measurements of position data to create a tracking gate. The drawback of this method for multi-target tracking is that it is prone to association errors when the distance of targets is close in space. In this paper, the tracking gate based on Doppler information is investigated to reduce the number of data associations, thereby achieving better performance, which is more suitable for engineering applications.

The nearest neighbor algorithm[1] is often used for target tracking in engineering practice since its simplicity and effectiveness. However, for multiple target tracking, especially when the target appears staggered, the usual nearest neighbor algorithm is prone to association errors, so for multi-target tracking, the joint probabilistic data association filter (JPDAF) is one of the most effective methods [2]. In literature [3], the data association algorithm based on speed-information- aided JPDA algorithm is discussed and certain results has been achieved, but since JPDA algorithm is comparatively complicated, especially when the target is large, the computation is too huge to apply in engineering. This article presents an algorithm suitable for engineering applications, i.e. using characteristic parameters of the targets to modify the nearest neighbor algorithm since the characteristics of different target parameters are different. The simulation results proved the effectiveness of this method.

II. TRACKING GATE BASED ON AUXILIARY DOPPLER INFORMATION

Data association is a core part of multi-target tracking, the process of which is to compare the candidate echo with the known target trajectory, and ultimately determine the correct observation and track matching. The first step of data association is using tracking gate to limit the interference, usually the tracking gate is the geometric area associated with the center of the forecast position. The commonly used tracking gates at present are: rectangular tracking gate, oval tracking gate and drop-shaped tracking gate [4], and oval tracking gate is used in this paper. As shown in Fig. 1, t is the target and j is the target echo. In the geodetic coordinate system (XOY coordinate system), when target 1 and target 2 are close to each other, the tracking gate will intersect and the echoes of the targets will be in the intersection, which significantly increase the complexity of matching echoes and the corresponding target, and is bound to increase the amount of calculation.

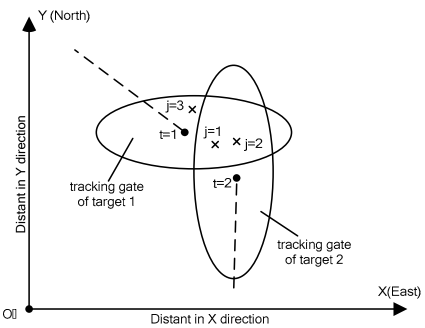

Figure 1. Schematic diagram of multi-target association in the geodetic coordinate system

The two-dimensional tracking gate in fig. 1 can be expressed as

$$\mathrm{K}_1 \cdot \| X_j - X_i^0 \| + \mathrm{K}_2 \cdot \| Y_j - Y_i^0 \| < \delta \qquad i=1,2...m; j=1,2...n \tag{1}$$

Where (Xj,Yj) is the coordinates of target measured by radar, (Xj0,Yj0) is the center coordinates of the tracking gate, K1、K2 are the corresponding coefficients related to the shape of the tracking gate, and δ is the threshold value of the tracking gate. Points less than the threshold value belong to the inside of the tracking gate; otherwise it is beyond the tracking gate.

The complexity of data association will increase when the locations of the targets are too close and the tracking gates overlap. So in this paper, the Cartesian coordinate system is converted to polar coordinates for Equation (1), and the relevant tracking gates based on Doppler information are adopted as shown in Equation (2):

$$\begin{cases} \mathrm{K}_1 \cdot \| S_j - S_i^0 \| < \delta_s^{'} \\ \mathrm{K}_2 \cdot \| \theta_j - \theta_i^0 \| < \delta_\theta^{'} \qquad i=1,2...m; j=1,2...n \\ \mathrm{K}_3 \cdot \| f_j - f_i^0 \| < \delta_f^{'} \end{cases} \tag{2}$$

Where Sj, θ j are the distance and azimuth measured by radar, fj is the Doppler frequency of j-th target, Si0, θ i0 are the distance and azimuth of the tracking gate center, fi0 is the corresponding Doppler frequency, K1, K2, K3 are the coefficients related to the shape of the tracking gate, and δ's, δ' θ , δ'f are the thresholds of the tracking gate. The plot-track correlation diagram is shown in Fig. 2, the target's position coordinates are so close that two-dimensional tracking gate is hard to distinguish between the locations of two radar plots. But when there is difference between the Doppler frequencies of two targets, it is very obvious that the two tracks of the tracking gate could be separated, thereby reducing the probability of association errors. The three-dimensional diagram of association between the radar plots and the center point of tracking gate is shown in Fig. 3.

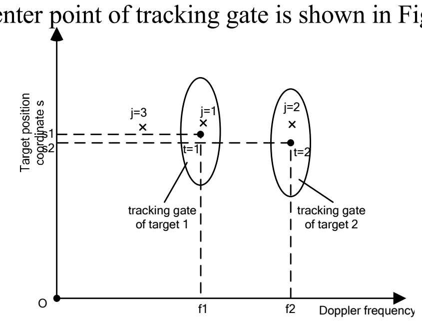

Figure 2. Schematic diagram of multi-target association in the location-frequency coordinate system

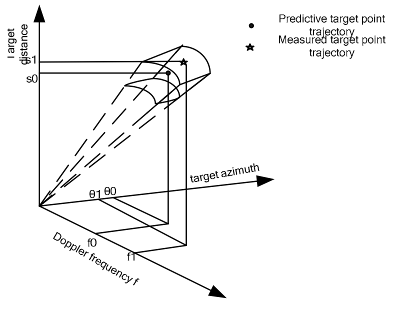

Figure 3. Schematic diagram of the three-dimensional association of target plot feature information.

III. NEAREST NEIGHBOR ALGORITHM BASED ON TARGET FEATURE

In the sea, the background environment is relatively simple, so the nearest neighbor algorithm is still the most commonly used target-tracking algorithm for sea search radars. According to the literature [5], the working principle of the nearest neighbor algorithm is: first, set tracking gate and the screen the echoes by the tracking gate (the relevant wave gate) for the candidate echoes to limit the number of targets in the relevant identification. The tracking gate is a subspace of the tracking space, and its center is located in the forecast position of the tracked targets. If there is only one echo falling into the tracking gate, then the measured value is directly used for track update; if there are more than one echo falling into the track gate, then take the candidate echo with the smallest statistical distance as the target echo. Typically, the statistical distance is calculated according to the target location information, as shown

$$d^2 = \begin{bmatrix} (S-\hat{S}) & (\theta-\hat{\theta}) \end{bmatrix} \begin{bmatrix} (S-\hat{S}) \\ (\theta-\hat{\theta}) \end{bmatrix} \tag{3}$$

Where S is the distance measurement of the target, $\hat{S}$ is the forecast value of the target distance, θ is the angle measurement of the target, $\hat{\theta}$ is the forecast value of the target angle, and take the echo measurement with the least d2 to be the updated value. When tracking a single target in the sea, this method is very simple and effective, thereby applicable for engineering, but when there are multi-ship targets on the sea, especially for targets with close location information, the phenomenon of track correlation error occurs. In this paper, information features of the target are added in the statistical distance, so that for two or more targets with close location information, the probability of error tracking can be reduced by the target. The modified statistical distance formula is shown below. Define

$$\vec{a}(i) = (S(i), \theta(i), f(i), M(i)) \tag{4}$$

$$\vec{b}(i) = (\hat{S}(i+1 \mid i), \hat{\theta}(i+1 \mid i), f(i), M(i)) \tag{5}$$

$$\vec{\mathrm{K}} = (\mathrm{K}_1, \mathrm{K}_2, \mathrm{K}_3, \mathrm{K}_4) \tag{6}$$

$$d'^2 = \| (\vec{\mathrm{K}} \cdot \vec{a}(i)) - (\vec{\mathrm{K}} \cdot \vec{b}(i\text{-}1)) \| \tag{7}$$

Where S(i) is the distance measurement of the target in i-th moment, $\hat{S}(i+1 \mid i)$ is the forecast value of the target distance in (i+1)-th moment, $\theta(i)$ is the angle measurement of the target in i-th moment, $\hat{\theta}(i+1 \mid i)$ is the forecast value of the target angle in (i+1)-th moment, f(i) is Doppler frequency value of the target in i-th moment, M(i) is the characteristic parameters of the target echo, $\vec{\mathrm{K}}$ is the weighting coefficient for each variable, and take the modified echo measurement with the least d'^2 to be the updated value of the track.

After the modification of the nearest neighbor algorithm, when the target's spatial position and Doppler frequency are relatively close, the targets of the same type can still be associated by the characteristic parameters, thereby greatly reducing the occurrence of association errors due to target intersect.

IV. EXAMPLES AND SIMULATION RESULTS

(1) Simulation and verification of multi-target tracking correlation

To verify the feasibility of this method, the simulation of a track intersect scenario: Cross-navigation target group. The specific simulation scenario is as follows: there are six targets of different speeds and navigation directions, in which track number from 1 to 3 are targets of parallel navigation with speed of 7m/s and spacing of 200m, and track number 4 to 6 are targets of cross-navigation in small angles with speed of -6m/s,-10m/s and 13m/s respectively, moreover, tracks 4 and 5 has a cross-track angle of 3 degrees, while track 5 and 6 has a cross-track angle of 1 degree, as shown in Fig. 4.

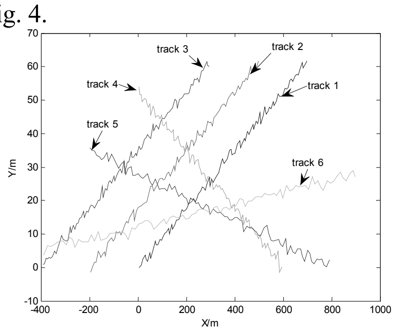

Figure 4. Schematic diagram of multi-target track cross

The multi-target tracking trajectory with correlation in two-dimensional geodetic coordinate is shown in Fig. 5. According to the algorithm illustrated in this paper, the simulation results based on three-dimensional Doppler correlation is shown in Fig. 6.It can be seen from Fig. 5 and Fig. 6 that when using two-dimensional correlation, track correlation errors occur, which can cause tracking errors, while the three-dimensional correlation based on this method made the correct association with the cross-track targets.

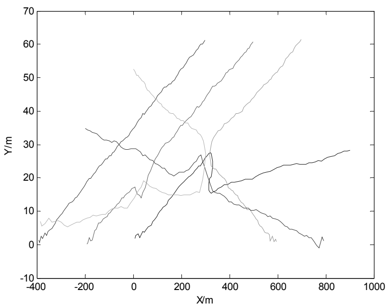

Figure 5. Schematic diagram of multi- target track based on two-dimensional correlation

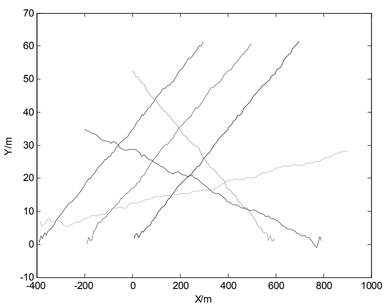

Figure 6. Schematic diagram of multi- target track based on three-dimensional correlation

(2) Measured data validation of multi-target track association

Extract a set of measured data of intersected targets, and apply traditional tracking algorithm for cross-track targets. As a result, association error occurred when track 1 and track 2 intersected, which is shown in Fig. 7. On the contrary, the use of modified target tracking algorithm made a correct association for track 1 and track 2, as shown in Fig. 8. In this simulation, when using the modified nearest neighbor algorithm, the target characteristic parameter M(i) is the number of pixels of the target echo. The so-called number of pixels is the share of the number of coordinates in the Doppler – distance coordinate system, which reflects certain characteristics of the target.

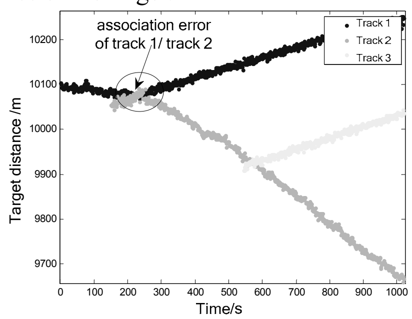

Figure 7. Schematic diagram of the track association of the unmodified nearest neighbor algorithm

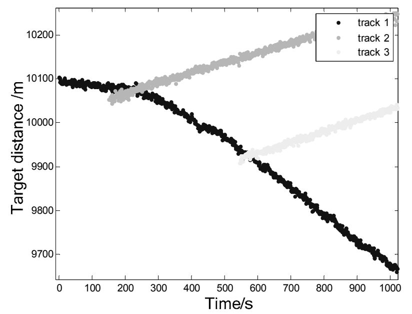

Figure 8. Schematic diagram of the track association of the modified nearest neighbor algorithm

V. SUMMARIES

It can be seen from the above analysis that the design of three-dimensional correlation is superior to the design of two-dimensional correlation, and the performance of three-dimensional correlation in multi-target tracking is remarkable. The most widely used tracking algorithm in engineering applications is still the nearest neighbor algorithm, but since it has the problem of association errors in multi-target tracking, a scenario is presented by using characteristic parameters to modify the algorithm. This method is easy to implement in engineering and the simulation results proved that the modified algorithm is more effective. Though the selection of target feature parameter has not been introduced in detail in this paper, it will be further improved in the future research.

REFERENCES

[1] X. R. Li, Y. Bar-Shalom. Tracking in clutter with nearest neighbor filters: Analysis and performance [J]. IEEE Transactions on Aerospace and Electronic Systems. 1996, 32(3): 995-1009.

[2] T. E. Fortmann, Y. Bar-Shalom and M. Scheffe. Sonar tracking of multiple targets using joint probabilistic data association[J]. IEEE Journal of Oceanic Engineering, 1983, 8(3):173~184.

[3] J. WANG. Research on data association with velocity-assisted information for radar targets[J]. Systems Engineering and Electronics. 2008.

[4] J. Zhang. Influence of Tracking Gate upon Multiple Target Tracking System[J]. Journal of East China University of Science and Technology(Natural Science Edition). 2006.

[5] Y. He. Radar Data Processing With Applications[M]. Bei Jing: Publishing House of Electronics Industry.2009.

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