

Radar Target Tracking Algorithm Based on Alpha-Beta Filtering

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Abstract. Coastal radar tracking refers to the process of processing measured values from a target, maintaining the current state of the target, and associating them with the current and subsequent states of the target and performing smooth updating. With quick development of coastal and port vessel surveillance, a big amount of target's tracking needs a high efficient tracking algorithm. For this purpose, combining radar tracking with Alpha-Beta filtering, an improved radar target tracking algorithm is proposed in this paper. And some simulation tracking results are given to make a comparison of Kalman filter and Alpha-Beta filter algorithm. The results show that the proposed algorithm is superior to the above algorithms, which can effectively improve the tracking accuracy, obtain more accurate tracking information of the radar target, and lead to a widely application value in Vessel Traffic Service system.

Key words: Target tracking, Alpha-Beta filtering algorithm, Smooth and update.

INTRODUCTION

Vessel Traffic Services is a multi-technology integration and integration of modern radar technology, communication technology, computer network technology, and information processing technology. It is a water traffic management electronic information application system whose main function is to provide information services, navigation aids, tracking services and traffic organization services to ships in the waters, as well as assist with joint services and emergency services. The tracking service is one of the most important functions in the VTS system. Through the target tracking, accurate estimation of the target state is achieved, so that much subsequent information processing is performed. If the tracking effect is not good, it may bring about many problems, such as the wrong estimation of target threats, mistakes in commanding decisions, and so on.

Therefore, many scholars at home and abroad are committed to finding ways to obtain better tracking results. These methods must first determine the tracking business logic and then use different smoothing filtering methods. Commonly used tracking filter methods include: Kalman filter and Alpha-Beta filter, Kalman filter and many improved algorithms based on Kalman filter, which can produce good tracking for maneuvering targets, but the disadvantage of such algorithms is that the amount of computation is large and it is difficult to apply real-time processing when applied to multi-target tracking. Alpha-Beta filter, which is commonly used in engineering, is simple in calculation, but it is not ideal for tracking the maneuvering target and cannot fully exert the effects that the computing power of today's microprocessors should have. In order to solve these problems, based on grasping the essence of Alpha-Beta filter and using the gate of target prediction, this paper proposes a maneuvering target tracking algorithm that fully utilizes the computing power of today's microprocessors and has better tracking effect.

ALPHA-BETA FILTERING ALGORITHM

Alpha-Beta filtering algorithm is a simple, easy-to-implement, constant-gain filtering method. This method has been widely used in the design of tracking filters for various systems. The biggest advantage is that the calculation is small and easy to understand. It is a simplified scheme of Kalman tracking filter.

The basic idea of the Alpha-Beta filtering algorithm is: when tracking the target, there will be a target position prediction value and a target position measurement value in the concept of the target position; in the concept of the target velocity, there will be a target velocity at the previous time. and assume that the target is sailing at a constant speed. Both concepts have smooth filtered values for the target, namely the position smoothing filter value and the speed smoothing filter value. The smoothing filter value is neither a predicted value nor a measured value but is derived from these two values. The coefficients required for the operation are α and β . The smoothing filter value is the value used for updating the information in the target tracking process and is called a true value.

The main work of the Alpha-Beta filter consists of the following equations:

The gain is: $K(k+1) = [\alpha, \beta/T]$;

State further prediction equation: $\hat{X}(k+1|k) = F(k)\hat{X}(k|k)$;

The innovation is: $V(k+1) = Z(k+1) - H(k+1)\hat{X}(k+1|k)$;

State update equation: $\hat{X}(k+1|k+1) = \hat{X}(k+1|k) + K(k+1)V(k+1)$.

Wherein, the gain of α value controls the weight of the position filter value biased position prediction value. According to the state update equation, the larger the α value, the more the position filter value deviates from the position prediction value, and conversely, the position filter value is closer to the position prediction value. The β/T value controls the weight of the velocity filter value at the moment when the velocity filter value is upward, and according to the state update equation, the larger the β/T , the faster the velocity filter value deviates from the velocity value at the previous moment; otherwise, the closer the velocity filter value approaches. The speed of the moment. From the above equations, it can be seen that the determination of the gain value will largely affect the filtering results, thus affecting the accuracy of the target tracking. The innovation is essentially the difference between measured and predicted values. Its size may reflect two situations. The first case may reflect the fact that the true value deviates from the real track due to the influence of Gaussian white noise. The other case may reflect the mobility of the target.

Advantages of Alpha-Beta filtering algorithm: 1) Due to the formula is simplified under the Kalman filter algorithm, its computational complexity is small; 2) The algorithm assumes that there is no acceleration in the target model, so the target observation equation and measurement equation are simple, and small storage space.

Limitations of Alpha-Beta filtering algorithm: 1) It is assumed that the target is moving at a constant speed and the target observation noise and clutter have a greater impact on the tracking quality and stability; 2) Due to the change of the attenuation coefficient, it often leads to the orbit around the right and left disturbances of the target real-life course are approaching, the convergence is slow, and the track is not smooth; 3) If the acceleration of the target varies greatly in one scan, the valuation deviation of the target location and speed is large, and the system must immediately take corrective action, otherwise the target may be lost.

IMPROVED ALPHA-BETA FILTERING ALGORITHM

Division of Sectors

First, the target scanned by the radar is named plot, and then the radar scanning plane is divided into n sectors. The target scanned during radar scanning will fall within a certain sector. These n sectors are called targets sector, which is plot sector. Similarly, a half of the area of a target sector and a half area of the previous sector form an equal number of new sectors, called track sectors. During radar scanning, all targets are scanned in the plot sector and all tracks are scanned in the track sector. The track will capture the target within its own gate to complete tracking and information updates. The purpose of dividing the sector in this way is to accurately track while reducing unnecessary calculations.

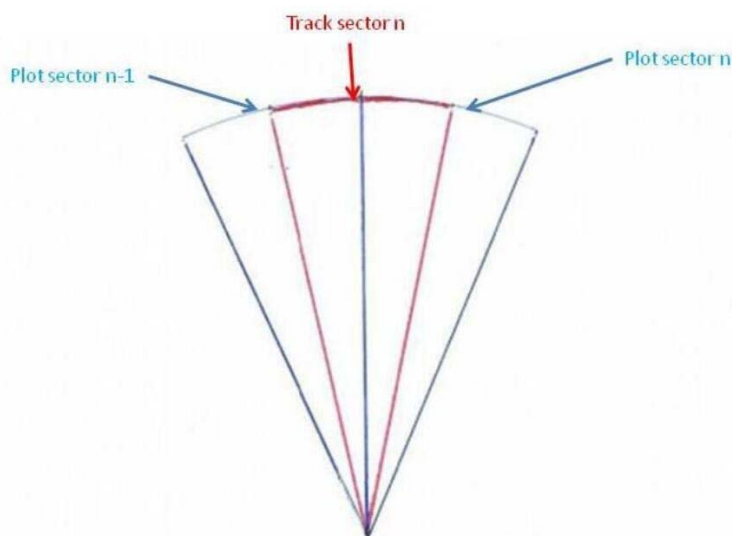


FIG. 1. Division of sectors

As shown in FIG. 1, the track sector n is composed of a half area of the plot sector n and a half area of the plot sector $n-1$. When the track in the track sector needs to be associated with the target, only two adjacent plot fans are needed. The search can be done in the zones, that is plot sector n and plot sector $n-1$, because the probability of the track exiting these two sectors is almost negligible, which greatly reduces unnecessary searches and calculations.

Gate Calculation

The track gate is used to capture new targets around the location of their own prediction points, and to complete target track tracking and information update in case of successfully associating new targets and not successfully associating new targets. If the association is successful, the calculation of the next smoothing filter value is performed. If the correlation is not successful, the prediction point information is used to analog extrapolation. The tracking stability of the track determines the size of the track gate.

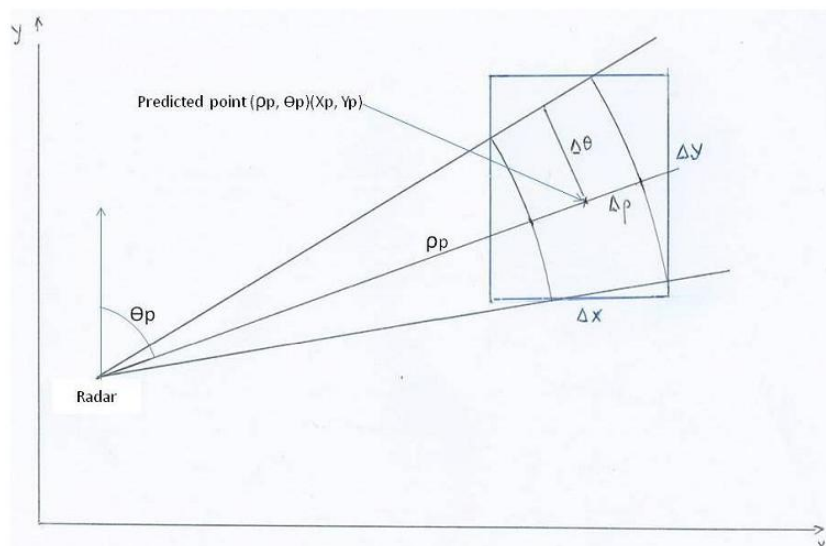


FIG. 2. Track gate

The shape of the gate

Sector structure

The size of the gate

The gate size is expressed in terms of polar coordinates, which is the length of the gate and the angle of the gate. Due to the shape of the gate is a sector structure, the size of the gate is specifically represented by four parameters: the maximum length of the gate, the minimum length of the gate, the maximum angle of the gate, and the minimum angle of the gate. Therefore, the length value referred to here is the difference between the maximum length of the gate and the minimum length, and the angle value is the difference between the maximum angle and the minimum angle of the gate.

The length of the gate: $(\sigma\rho * 2 + \text{the length of the plot}) * F_{Qp}$

The angle of the gate: $(\sigma\theta * 2 + \text{the angle of the plot}) * F_{Qp}$

Among them, the radar distance mean-square-error is denoted by $\sigma\rho$, the radar angle mean-square-error is denoted by $\sigma\theta$, and the track gate factor is denoted by F_{Qp} (a total of 30 constants, a maximum of 3, a minimum of approximately 0.3, gradient from large to small).

Based on the associated with successful and updated plot information of the latest track, increase the radar mean-square-errors in range and angle by two times. This increases the error tolerance rate for the radar error, and finally multiplies the gate factor to determine the gate size. The factor is related to the track prior to the track.

Track gate factor calculation

$$F_{Qp} = \sqrt{2 * (2 * N + 1) / (N * (N - 1))}$$

Where N is the quality factor of the track. The quality factor of the track represents the tracking situation of the track. The larger the value, the better the track tracking situation is. On the contrary, the tracking situation is worse. During each cycle of the radar scan, the track successfully associates with the radar target and the quality increases by 1. The larger the value of N, the smaller the gate factor value and the smaller the gate, which ensures the accuracy of follow-up tracking. If the radar target is not successfully linked within the scan cycle, the tracking fails, and the quality is subtracted from the larger one, resulting in an increase in the gate factor value, thereby quickly expanding the gate and increasing the probability of success in the next tracking.

Track Smoothing Filter

Radar scan surface sector division and track gate calculations are all prepared for track smoothing filtering. The track smoothing filter is also inseparably linked to the track quality factor N. In the improved Alpha-Beta filter algorithm, α and β also use the track quality factor.

$$\alpha = 2 * (2 * (N + 2) - 1) / ((N + 2) * (N + 2) + (N + 2))$$

$$\beta = 2 * (2 - \alpha) - 4 * \sqrt{1 - \alpha}$$

When the filtering starts (the track quality factor increases from 1), it can be seen from the formula of α and β that $\alpha \leq 0.8333333333333334$ and $\beta \leq 0.7003401714778814$. With the gradual increase of the track quality factor, α and β are getting smaller and smaller, gradually tending to 0.

The algorithm takes the ideal situation (tracking success) as an example. The coordinates (measured values) of the successfully associated plot positions are X_m , Y_m , and the predicted coordinates of the flight path (predicted values) are X_p , Y_p , and the smoothed filtering value is X_T , Y_T .

Position smoothing filter formula:

$$X_T = X_p + (X_m - X_p) * \alpha$$

$$Y_T = Y_p + (Y_m - Y_p) * \alpha$$

Speed smoothing filter formula:

$$V_{xT} = V_{xp} + (X_m - X_p) / P * \beta$$

$$V_{yT} = V_{yp} + (Y_m - Y_p) / P * \beta$$

Among them, V_{xT} , V_{yT} represent the smoothed filtered X-direction and Y-direction sub-speeds, V_{xp} , V_{yp} represent the track's current X-direction and Y-direction sub-speeds, and P represents the time of a radar scan cycle.

The α and β are calculated from the above α and β filter coefficient formulas according to the track quality factor, and then the position smoothing filter value and the speed smoothing filter value are calculated through the above smoothing filter formula.

SIMULATION RESULTS AND ANALYSIS

Using the improved algorithm to achieve the above radar target tracking and compare it with Kalman filter algorithm and Alpha-Beta filter algorithm. The experimental conditions are: Intel Dual-Core i7, CPU 2GHz, and 8G memory, the algorithm used Matlab R2016a prepared.

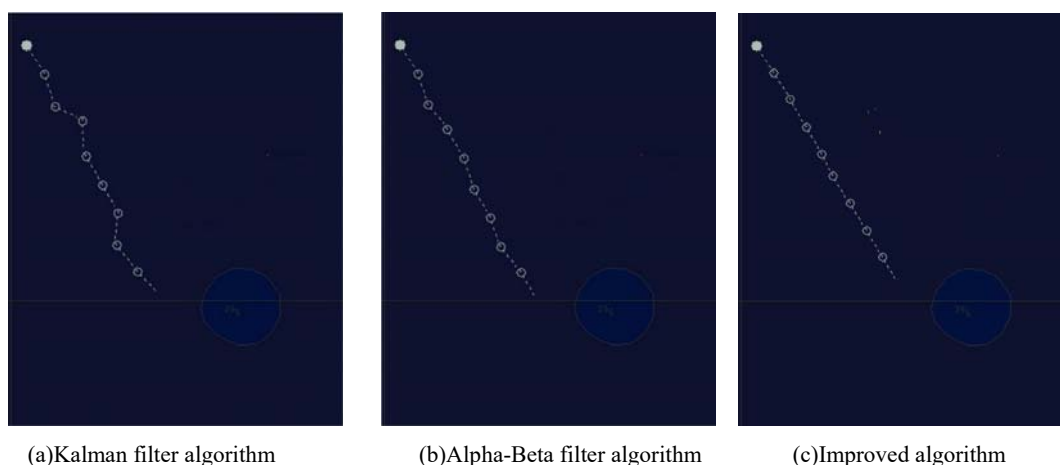


FIG. 3. The experimental results of each algorithm

We compare the tracking results of various algorithms applied to the radar target tracking system and subjectively analyze the tracking effects of various algorithms. Figure a, Figure b, Figure c is a track comparison chart formed by various smoothing filtering algorithms for tracking the target. From these comparisons, we can see that: Because of the complexity of the formula and the large amount of calculation, the track following the Kalman filter algorithm has a very obvious tracking error, and the target direction fluctuates greatly. The tracking error of the track following the Alpha-Beta filter algorithm is less than that of the Kalman filter algorithm. However, the track is still not smooth enough and the target is easily lost. The track following the algorithm in this paper reduces the tracking error in the Kalman filter algorithm and the Alpha-Beta filter algorithm to some extent. The track smoothing effect is good, and the overall effect is better than other tracking algorithms. The comparison results are shown in Table 1.

TABLE 1. Comparing the mean-squared-errors of three algorithms

	Kalman filter algorithm	Alpha-Beta filter algorithm	Improved algorithm
Angle	0.03	0.02	0.01
Range	11.25	10.36	9.88

CONCLUSION

This paper proposes an improved algorithm based on Alpha-Beta filtering algorithm. It fully considers the characteristics of radar target tracking, divides the radar scanning surface into multiple sectors, and constructs target sectors and track sectors respectively. To ensure the tracking success rate to minimize the computational complexity. The simulation results show that the algorithm significantly reduces the computational complexity, high speed of operation, better tracking effect, and improves the problem of target loss and tracking smooth during radar scanning

and tracking. It can meet the requirements of the Vessel Traffic Services system, applied to target tracking processing module of radar processing unit.

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