

The Dynamic Programming TBD Algorithm Based On Morphological Characteristic

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Abstract. Based on the fact that target emerged by ground clutter or noise problem usually results in a low SNR or SCR and degrade the detecting ability, a dynamic programming algorithm and track before detect (TBD) algorithm is proposed to detecting the weak target. By analysis the target moving modal, the algorithm revised the target transporting state consulting on the target Morphological characteristic. The simulation and experiment result have approved that the proposed method have high detecting ability on weak target detecting from radar echo.

Introduction

Track before detect(TBD) technology as a under low SNR signal detection and tracking technology, more and more applied to the radar “low, slow, small” target’s detection. TBD methods including the recursive method based on particle filter [1,2] and energy accumulation method based on dynamic programming [3, 4], accumulation of uniform motion in a straight line track based on Hough transform method [5]. Particle filter algorithm is a kind of approximate recursive Bayesian filtering algorithm, the need to clear beforehand prior probability distribution (likelihood function), noise distribution, state equation and observation equation, the recursive method large amount of calculation, but also bad for project implementation; Hough transform algorithm through some form of projection transformation or logic operations, linear mapping to the parameter space, through energy accumulation in parameter space, in the strong noise and shift between the target frames is larger, or when the target movement model is not in conformity with the uniform motion in a straight line, energy accumulation performance degradation is serious. The ideas of dynamic programming algorithm is weak target trajectory search problem is converted to the optimal tracking problem, easily realized in engineering, it through designing a kind of objective function, joint processing frame of observation data, the target of energy along the track is to accumulate all possible, find a makes the optimal state of the objective function sequence as the target track is estimated. But when the target movement speed is unknown, target amplitude fluctuation, calculates the parameters of the state transition area in range to relax, the dynamic programming algorithm of computation increases rapidly, and may at some stage pseudo trajectory of target function is better than the real trajectories of the objective function, which will make the state of target track is wrong choice.

Aiming at this problem, this paper presents a dynamic programming TBD algorithm based on morphological characteristics of weak target detection.

Radar target model

Radars usually work in noise and clutter environment, noise can be seen as a Gaussian process, but the noise distribution type is not in conformity with the theoretical possibility of any kind of distribution, and distribution parameters such as mean and variance is unknown. Radar to detect the target structure is complex, it is difficult to accurately obtain the probability distribution of all kinds of target RCS and related functions, usually with a close and a reasonable model to estimate target fluctuations affect the performance of detection. Commonly used ups and downs model is Swerling model I or Swerling model II, target echo amplitude probability density obey Rayleigh distribution:

$$f(a) = \frac{a}{\sigma_a^2} \exp\left(-\frac{a^2}{2\sigma_a^2}\right), a \geq 0 \quad (1)$$

Swerling III or Swerling IV, target echo amplitude probability density a obedience to a superior and Rayleigh distribution:

$$f(a) = \frac{9a^3}{2\sigma_a^4} \exp\left(-\frac{3a^2}{2\sigma_a^2}\right), a \geq 0 \quad (2)$$

The first I and II class model are used by a large number of RCS approximation is equal to that of scatter III, IV class model is suitable for the goal is to have a larger RCS of scatter and many small scatter, or a strong scatter has little change in the direction. Different point of view, although for radar target's radar cross section area is different, the target echo pulse amplitude has ups and downs, but after a period of observation samples statistics processing, the shape of the target and clutter characteristics can be the analysis judgment, according to an optimal criterion to distinguish between them.

The extraction methods of morphological characteristics

For general feature extraction method for wave form, to extract the video echo data has is to be able to describe the characteristics of data, the basic trend accurately describe the structure of the extract, meet the target and clutter classification task. According to the features of radar original video to the two-dimensional distance azimuth data capture, divided into several units, each unit of the structure is not only to reflect the overall trends and to echo data, but also reflects the surrounding local trends and directions. Each unit of the video data is divided into N consecutive intervals, the intersection of these sub interval is empty, and sets the overall sequence of a cell. Judgment unit sequence and the known characteristics of the echo of shape similarity, wave amplitude, location span all are elements of a similar measure form, through the block of wave amplitude division order by location to the appropriate section of the slope difference weighted, similarity measurement method based on morphological characteristics.

To compare the unit sequence and sequence of known characteristics, and its morphological characteristics are represented as:

$$R = \{(k_1, A_1), (k_2, A_2), \dots, (k_n, A_n)\} \quad (3)$$

$$R' = \{(k'_1, A'_1), (k'_2, A'_2), \dots, (k'_n, A'_n)\} \quad (4)$$

Here A_i is to contrast unit sequence w amplitude value of the first i curve, A'_i for the amplitude value of paragraph i of known characteristics sequence w^i curve, compare the unit for similarity measure expressions.

$$D_w(R, R') = \frac{1}{n} \sum_{i=1}^n W_i, i = 1, 2, \dots, n \quad (5)$$

Here W_i is the volatility of the weights for the i segment, $W_i = \frac{(D_i - D_{min}) \times \lambda}{D_{max} - D_{min}} + (1 - \lambda)$, $\lambda \in [0.6 - 0.9]$, fluctuation value $D_i = \max(|A_{i-1} - A'_{i-1}|, |A_i - A'_i|)$, $i = 1, 2, \dots, n$.

TBD detection algorithm has the characteristics of dynamic planning

TBD dynamic programming algorithm based on shape feature contains all the paths of target may experience points for processing almost no information loss, after several scans or frames accumulation, the objective function of the hypothesis path accumulation value of the threshold, the objective function is the estimate of target similarity and amplitude cumulative value, has been estimated in the target trajectory, also announced the test results and the target trajectory.

Assume that the state of the scan target in the first k times is $x(k) = [x_k, y_k, \dot{x}_k, \dot{y}_k]^T$, x_k and y_k represents the target coordinates, \dot{x}_k and \dot{y}_k represents the corresponding speed. The motion of the target state equation:

$$x(k+1) = f(x(k), v(k)) \quad (6)$$

Here, f represents a state transition function, the $v(k)$ represents process noise.

Target tracking is defined from the first frame to the k frame, a series of target state is $X_k = \{x(1), x(2), \dots, x(K)\}$. Assuming that after the k times scanning, goal in the (I, j) unit ($I = 1, 2, \dots, M; j = 1, 2, \dots, N$), the measured value is:

$$Z_{ij}(k) = \begin{cases} w_{ij}(k), & \text{objective} \\ B(k) + n_{ij}(k) & \text{no objective} \end{cases}, \quad (7)$$

$$B(k) = A(k) \times \omega + D_w(k) \times (1 - \omega), \omega \in [0, 1] \quad (8)$$

Here, $B(k)$ represents the target range and shape similarity in fitting valuations, ω for the degree of confidence, usually value 0.6, $A(k)$ represents the target range, $D_w(k)$ represents the target and the known characteristic sequence similarity. $w_{ij}(k)$ said measurement noise, $w_{ij}(k) \sim N(0, \sigma_n^2)$, $n_{ij}(k)$ is a random variable, it is generally believed $n_{ij}(k) \sim N(0, \sigma_n^2)$. k measurement radar data representation for $z(k) = \{z_{ij}(k) | I = 1, 2, \dots, M; J = 1, 2, \dots, N\}$, dynamic programming to solve the problem is: hope to be able to according to all the measurement data from the initial frame to the k frame $z(1), (2), \dots, z(k)$, and to determine the most likely is a real target track is \hat{X}_i, \hat{X}_i is:

$$\{\hat{X}_k\} = \{X_k : \sum_{k=1}^k z_{ij}(k) > V_T\} \quad (9)$$

Here V_T is the first k frame data space threshold [6].

Said the size of the region state transition as in q , $q \in \{1, 9, 25, \dots\}$, in the $z_k = [x_k, y_k, \dot{x}_k, \dot{y}_k]$ state of the k frame to $k+1$ frame the $z_{k+1} = [x_{k+1}, y_{k+1}, \dot{x}_{k+1}, \dot{y}_{k+1}]$ state has q states, namely q areas, the area size is associated with radar system and its signal processing method. Possible status of z_{k+1} .

$$z_{k+1} \in [x_k + \dot{x}_k + \delta_{vx}, y_k + \dot{y}_k + \delta_{vy}, \dot{x}_k + \delta_{vx}, \dot{y}_k + \delta_{vy}] \quad (10)$$

Here $\delta_{vx}, \delta_{vy} \in \{\dots, -2, -1, 0, 1, 2, \dots\}$, is constant of state transition transformation respectively.

Target in each stage of the morphological characteristics as the likelihood function, constructed as the objective function with target range and measure the merits of the implementation process; Due to the test with target morphological characteristics, its performance is affected by target amplitude fluctuation is not big, the size of it is associated with the spatial distribution of noise and target, and do not have direct connection with the amplitude of the target, so it can be under very low SNR detection [7-8].

The experimental simulation

Experiment simulation has two targets for uniform linear motion, a radar antenna 10 sec/roll, so the interval of data accumulation process two frames for 10 seconds. Target motion duration of 200 seconds, the simulation target amplitude fluctuation as Swerling type I, additive zero mean Gaussian distribution, calculated SNR changes in the process of target motion. The initial state and the movement parameters of the target as shown in table 1.

Table 1 The simulation of target motion parameters

	The duration of time	Movement way	The initial position (km)		The initial velocity (m/s)	
			X axis	Y axis	X axis	Y axis
Object 1	0-200s	Uniform motion in a straight line	300	0	-400	0
Object 2	0-200s	Uniform motion in a straight line	300	60	-300	-300

State transition region unit number is 6×6 , namely the biggest motion between the adjacent two frames the distance of 2 km (corresponding to the rate of 500 m/s).

(a) based on amplitude value accumulation dynamic programming TBD detection target.

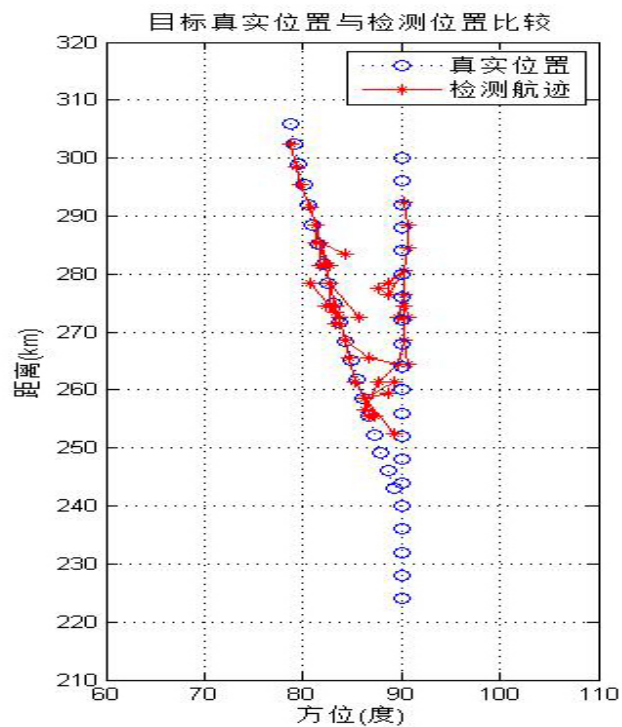


Figure 1 Based on the target range value accumulation dynamic programming TBD detection simulation

As shown in figure 1, energy accumulation, according to unit highest average 4 db SNR, detection probability is small, testing the required length more than about 10 frames, due to the target amount of ups and downs, there'll be more location, detection error phenomenon.

(b) Based on the morphological characteristics of the dynamic programming TBD detection target.

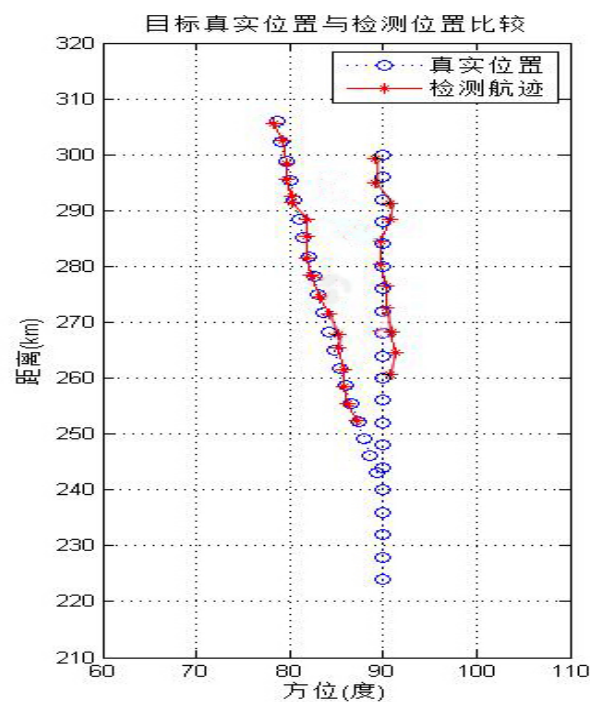
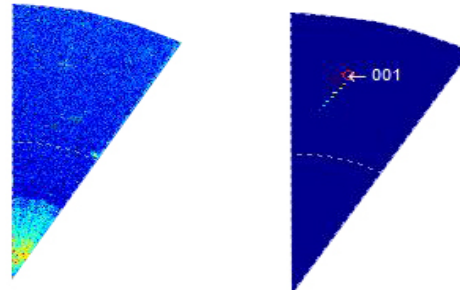


Figure 2 Dynamic programming TBD detection based on morphological characteristics simulation

As shown in figure 2, the average SNR is 4 db, testing the required length more than about 9 frames, due to increased the discriminate of target shape characteristic, the false track is greatly decreased.

- (c) Use real video, based on the morphological characteristics of the dynamic programming TBD detection target.



(1) Radar original video (2) After the TBD detection

Figure 3 Radar real video detection figure

Summary

When the target is completely submerged in the noise, can be more frame accumulation method, obtain certain SNR gain to detect the target, target amplitude fluctuation directly affects the possible state of the frame income target through analyzing the objective morphological characteristics, on the basis of dynamic programming TBD target detection, the similarity measure is proposed based on morphological characteristics, combining with the target range, form the objective function of the dynamic programming. Experiment proved that the method can reflect the target characteristics form dissimilarity degree, improve the weak target detection probability.

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