Study on multiple maneuvering targets tracking based on JPDA algorithm

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Abstract: A tracking algorithm for multiple-maneuvering targets based on joint probabilistic data association(JPDA) is proposed to improve the accuracy for tracking algorithm of traditional multiple maneuvering targets. The interconnection probability of the two targets is calculated, the weighted value is processed and the target tracks are obtained. The simulation results show that JPDA algorithm achieves higher tracking accuracy and provides a basis for more targets tracking.

Key words: path tracking; joint probabilistic data association (JPDA); internet probability; tracking accuracy

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0 Introduction

Multi-target tracking has been is a new technology in recent years. It involves many subjects such as random statistics, mathematical optimization, image processing, pattern recognition, artificial intelligence, automatic control, and so on[1]. Multi-target association and tracking maintenance are the core parts of tracking[2], and the data association is the most important aspect of multi-object tracking technology, which is the important means to ensure stability of the sensor tracking[3]. Domestic and foreign scholars have done a series of research on the data association technology. Mainstream data association algorithms include the nearest neighbor (NN) algorithm, probability data association(PDA) algorithm, multi-hypothesis(MH) algorithm interacting multiple model probability data association (IMMPDA), joint probabilistic data association (JPDA), etc[4-6]. For high signal-to-noise ratio and lower clutter density, the nearest neighbor algorithm tracks the target quickly. When the clutter density is larger, it is prone to association errors and needs to add a lot of restrictions. In high clutter environment, PDA algorithm has good single-target tracking performance, but the algorithm needs to calculate all measured probabilities of tracking door, which is difficult to meet real-time requirements. Multi-hypothesis algorithm has good tracking effect, but it depends on the prior knowledge of target and clutter too much. Interactive multi-model probability data association algorithm is applicable to single-target tracking in dense clutter enviroment, but the algorithm calculation amount is large, and system model selection also has an impact on target tracking accuracy. The JPDA algorithm effectively tracks the dense clutter wave in multi-target environment, which is a good algorithm for single-sensor multi-target tracking. The algorithm is proposed based on PDA algorithm, and it is particularly applicable in dense clutter wave environment[7]. Therefore, the JPDA algorithm has eminent advantages in computation quantity and tracking precision, and simultaneously it is the key data association technology.

This paper uses JPDA algorithm to carry out data association of the two targets of a sensor. Firstly, the probability of two interconnected goals is calculated. And then the weights for processing are done.

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Finally, the target tracking is accomplished. The simulation results show that the JPDA algorithm has the advantage of precise tracking.

1 JPDA algorithm

The JPDA algorithm is a good method for data interconnection of the target in the clutter environment[7]. It uses the point trace of current scan cycle falling within the track threshold to calculate the associated probabilities between the trace point and the corresponding trajectory, and then the associated probability is used to weigh the current trace points for track correction. The weight is the probability of the target. The actual calculation is to identify all possible combinations of plot track collection, by finding probability of the plot track association collection to get the right value.

1.1 Confirmation matrix

When echo falls into different target correlation gate overlap region, it should be comprehensively considered various measurement target sources. In order to express the complex relationship of echoes and the target tracking gate, the concept of confirmation matrix is introduced. Confirmation matrix is defined as

$$\boldsymbol{\Omega} = [w_{jt}] = \left.\overbrace{\begin{bmatrix} w_{10} & \cdots & w_{1T} \\ \vdots & \cdots & \vdots \\ w_{m_k 0} & \cdots & w_{m_k T} \end{bmatrix}}^{t}\right\} j. \quad (1)$$

In the formula, w_{jt} is a binary variable, $w_{jt}=1$ indicates that the measurement j is in the confirmation of the target t, while $w_{jt}=0$ represents that the amount of j is not left within the target t; $t=0$ means no target, and the corresponding column elements of matrix $\boldsymbol{\Omega}$ are all 1, which is because each measurement can be due to clutter or false alarm.

1.2 Interconnection matrix

For a given multi-target tracking problem, once giving the confirmation matrix that reflects an effective echo with the target or clutter interconnected situation, the confirmation matrix can be split to obtain interconnected matrixces of all interconnected events. The process must be based on two assumptions: ① it does not consider the indistinguishability of detection; ② for a given target, up to a measurement for its source.

1.3 Calculation of interconnection probability

The purpose of JPDA is to calculate probability of each measurement and its possible interconnection of various source targets. When the echo falls into different target correlation gate overlap regions, it must be comprehensive consideration of various measurement target sources. Setting $\theta_{jt}(k)$ indicates that measuration j originates from target $t(0\leqslant t\leqslant T)$, and $\theta_{j0}(k)$ represents that measuration j originates from the noise wave or virtual police. The definition of conditional probability in the target probability data association filter is

$$\beta_{ji}(k) = \Pr\{\theta_{ji}(k) \mid Z^k\},$$
$$j = 0,1,\cdots,m,\ t = 0,1,\cdots,T. \quad (2)$$

The formula represents the interconnected probability that the measurement j and the target T, and

$$\sum_{j=0}^{m_k} \beta_{ji}(k) = 1. \quad (3)$$

The state of the target t is estimated at the moment k as

$$\hat{X}^t(k \mid k) = E[x^t(k) \mid Z^k] =$$
$$\sum_{j=0}^{m_k} [X^t(k) \mid \theta_{ji}(k),]\Pr\{\theta_{ji}(k) \mid Z^k\} =$$
$$\sum_{j=0}^{m_k} |_{ji}(k)\hat{x}_j^t(k \mid k), \quad (4)$$

where $\hat{X}_j^t(k|k)=E[X^t(k)|\theta_{ji}(k),Z^k]$ indicates that state estimation of target t is obtained by Kalman filtering of the measurement j at the time k. And $\hat{X}_0^t(k|k)$ represents that there is no measurement that originated from a target at the moment k, then needs to be replaced with the predicted value $\hat{X}^t(k|k-1)$.

The interconnected probability of the measurement i and the target can be obtained by

$$\beta_{ji}(k) = \Pr\{\theta_{jt}(k) \mid Z^k\} =$$
$$\Pr\{\bigcup_{i=1}^{n_k} \theta_{jt}^i(k) \mid Z^k\} =$$

$$\sum_{i=1}^{n_k} \hat{w}_{jt}^i[\theta_i(k)]\Pr\{\theta_i(k) \mid Z^k\}, \tag{5}$$

where β_{it} is the event that j is derived from target t in a joint event of i; θ_i is the joint event i; and k is the number of combined events. And

$$\hat{w}_{jt}^i(\theta_i(k)) = \begin{cases} 1, & \text{if } \theta_{jt}^i(k) \subset \theta_i(k), \\ 0, & \text{others.} \end{cases} \tag{6}$$

The formula indicates in the joint event i that whether measurement j comes from target. When the target is t, $j=1$; otherwise $j=0$.

The joint event i is defined as

$$\theta_i(k) = \bigcap_{j=1}^{m_k} \theta_{jt}^i(k). \tag{7}$$

It represents the possibility of matching m_k measurements and different targets. The corresponding interconnection matrix is defined as

$$\hat{\boldsymbol{\Omega}}(\theta_i(k)) = [\hat{w}_{jt}^i(\theta_i(k))] = \begin{bmatrix} \hat{w}_{10}^i & \cdots & \hat{w}_{1T}^i \\ \vdots & \cdots & \vdots \\ \hat{w}_{m_k 0}^i & \cdots & \hat{w}_{m_k T}^i \end{bmatrix} t,$$

$$j = 1,2,\cdots,m_k;\ i = 1,2,\cdots,n_k;\ t = 0,1,\cdots,T. \tag{8}$$

According to the above two basic assumptions, it is easy to obtain that interconnection matrix meets

$$\sum_{t=0}^{T} \hat{w}_{jt}^i[\theta_i(k)] = 1,\ j = 1,2,\cdots,m_k,$$

$$\sum_{j=1}^{m_k} \hat{w}_{jt}^i[\theta_i(k)] \leqslant 1,\ t = 1,2,\cdots,T. \tag{9}$$

2 Simulation results

Due to the large amount of data collected, partial data of the sensor is attached to Table 1.

Table 1 Movement points of two targets

Distance(m)	Position(0)	Elevation(0)	Time(s)	Distance(m)	Position(0)	Elevation(0)	Time(s)
84 626.83	89.99	1.74	0.1	84 487.91	90.83	2.21	3.8
85 016.58	89.5	3.07	0.7	84 650.77	89.2	3.18	4.3
84 757.39	90.34	1.5	1.3	84 481.58	90.95	2.01	4.4
84 876.82	89.28	2.98	1.9	84 506.71	88.63	2.73	4.9
84 495.6	88.93	2.13	2.5	84 503.82	90.93	1.85	5.0
84 588.94	90.56	1.47	2.6	84 345.1	88.86	2.5	5.5
84 678.27	89.03	2.35	3.1	84 498.46	91.12	1.73	5.6
84 653.03	91.09	2.07	3.2	84 462.81	88.42	2.94	6.1
84 608.3	89.16	2.4	3.7	84 487.43	91.26	2.39	6.2

According to the flight envelope curves of two targets in a sensor, the interconnection probability of the two targets is calculated by Matlab, the weighted value is processed, and the target track is obtained. The results are shown in Fig. 1.

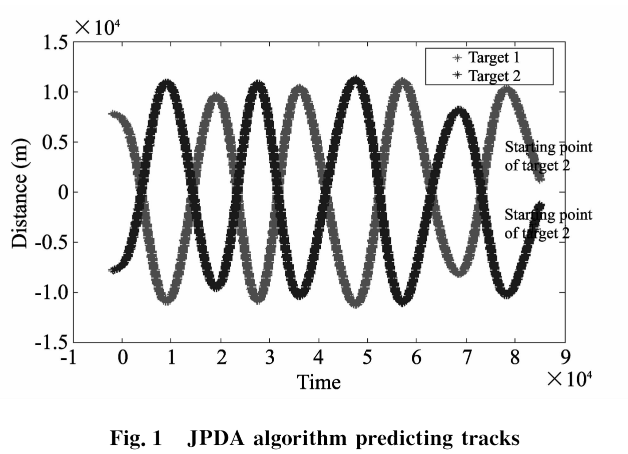

Fig. 1 JPDA algorithm predicting tracks

In Fig. 1, the two targets appear from the right side then, move spirally around the axis of symmetry, finally completely separate at the left end of the track.

In order to verify accuracy of the algorithm, the tracks of the target are moved relative to planes yoz and xoz, where xoy plane is made by using Matlab software. Target's the rectangular space coordinate of the target about sensor is shown in Fig. 2, where the origin position is the sensor location; A represents the target location; α is azimuth and θ is elevation.

The coordinates of the target can be written as

$$\begin{cases} x = L\text{os}\theta\sin\alpha, \\ y = L\cos\theta\cos\alpha, \\ z = L\sin\theta. \end{cases} \tag{10}$$

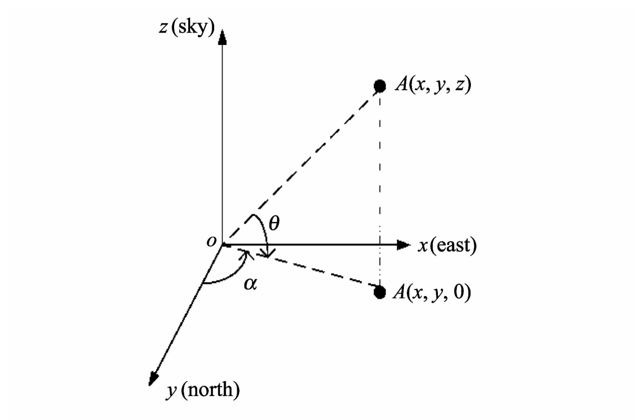

Fig. 2 Rectongular space coordinates of target relative to sensor

The trajectories of the target relative to the plane are shown in Figs. 3—5, respectively.

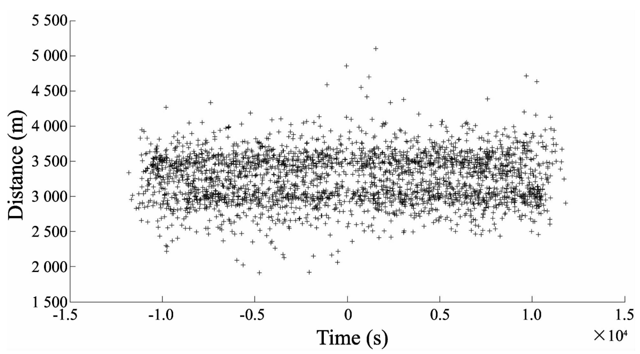

Fig. 3 Mmoving trajectory of target relative to plane *yoz*

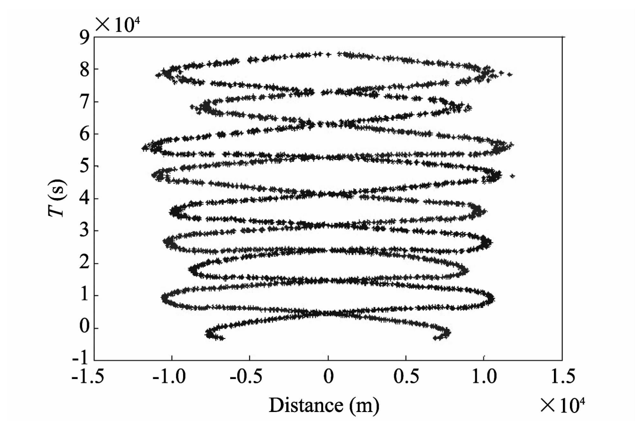

Fig. 4 Moving trajectory of target relative to plane *yox*

As can be seen from Fig. 3, the trajectories of the two targets are approximate ellipse. In Fig. 4, two gargets in the opposite directions, and the trajectory-ies move almost spirally. In Fig. 5, targets move along the negative direction axis of x, the trajectories are within the range of 2 000—4 000. The two tracks overlap first, then they separate gradually as time changes. Finally, they completely separate, form two independent movements, which are symmetrical about plane $z=3\ 246$.

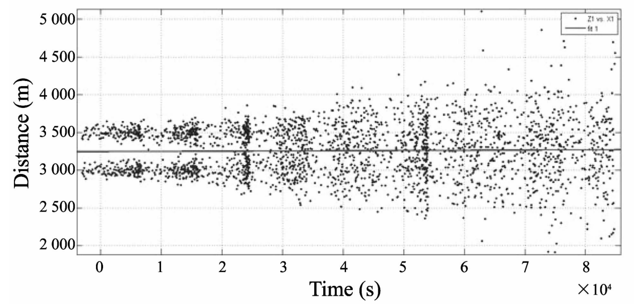

Fig. 5 Moving trajectory of target relative to plane *xoz*

In summary, the targets make the spiral motion along the negative direction axis of x. Around the axis of symmetry. The results are consistent with the trajectory predicted by JPDA algorithm therefore the accuracy of the proposed algorithm is verified.

3 Conclusion

This algorithm paper proposes a tracking algorithm based on JPDA aiming at the problem of inaccurate measurement of the traditional tracking algorithm for maneuvering target. The simulation results show that the proposed algorithm has higher accuracy. It can also be applied to two-target tracking and has broad application prospect.

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基于JPDA算法的多机动目标航迹跟踪研究

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摘　要： 针对传统多机动目标航迹跟踪算法精度不高的问题，提出基于JPDA的多机动目标航迹跟踪算法。首先计算两目标的互联概率，然后对加权值进行处理，最后得到目标航迹，并对航迹进行仿真。结果表明，本文所提出的算法具有较高的跟踪精度，可为多目标航迹跟踪实现提供了参考。

关键词： 航迹跟踪；联合概率数据关联；互联概率；跟踪精度

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