32nd URSI GASS, Montreal, 19-26 August 2017

Multi-Feature Fusion for Target Recognition based on Improved D-S Evidence Iterative Discount Method

Caiyun Wang *, Shuxia Wu, and Zhiyong He
University of Aeronautics & Astronautics, Nanjing, Jiangsu, China, 210016

Abstract

A new multi-feature fusion method is proposed for the radar target recognition based on D-S evidence iterative discount method. Firstly, the discount factor is defined based on the multi-feature confusion matrix and basic probability assignment (BPA) function. Then, when the conflict is high, the evidence is discounted using the discount factor, and basic probability assignment function, discount factor and conflict coefficient are updated; repeat the above discounts procedure and stop the evidence source correction when the evidence conflict coefficient is less than the threshold. Finally, fusion recognition is achieved by using the revised evidence. Compared with the other fusion recognition algorithm, the simulation results show that this proposed algorithm performs better.

1. Introduction

In radar target recognition system, the single feature is very difficult to comprehensive and accurate description of target information. Multiple feature fusion recognition technology has been widely concerned. Due to the influence of factors such as environment, the multiple features fusion recognition system has uncertainty. D-S evidence theory is a kind of effective uncertainty reasoning method based on recognition framework [1], which has been widely used in target recognition.

In 1967, Dempster [2] first put forward the means of set-valued mappings to calculate the upper and lower bounds of the probability. In 1976, Shafer [3] use the reliability function to further interpretation upper and lower probability, which has been generalized and developed into a kind of evidence reasoning method, namely "the mathematical theory of evidence". However, in the practical application, D-S evidence theory evidence fusion result maybe conflicts with convention. In order to solve this problem, researchers have been worked on two kinds of improved methods: the first one is Correction of combination rules, which aims to solve the problem of conflict redistribution, as in [4-5]; while the second one is the modification of evidence source, which means the evidence source is not suitable for fusion system that caused the conflict, as in [6-7].

In this paper, we study the correction of evidence source. Several different improved methods have been put forward, which inhibited the evidence conflict the influence of the fusion result. But their common point is for the correction of evidence source conduct only one time, therefore, this algorithm does not ensure that the revised evidence source has not high conflict. So this paper proposes a fusion recognition method based on improved D-S evidence iteration discount method. The basic idea is based on discounts correction methods, which revises the evidence source for iteration until evidence conflict less than the given threshold.

This paper is organized as follows: Section 2 describes multiple feature fusion based on D-S evidence theory. Section 3 introduces a new D-S evidence iteration discount method and the application of this method in radar target recognition. The simulation results are presented in Section 4. Finally, concluding remarks are given in Section 5.

2. Multiple feature fusion based on D-S evidence theory

The method of multiple feature fusion based on evidence has three key problems: the determination of BPA function; evidence synthesis formula of structure and selection of decision rules. Here is a brief introduction to the three key problems.

2.1 The determination of BPA function

Hypothesis the i^{th} feature of the testing samples is x and feature template library of the training sample set is x_T. The biggest correlation coefficient of the i^{th} feature is r_i. And its corresponding BPA function can be expressed as:

$$\begin{cases} r_i = \max \dfrac{\langle \boldsymbol{x}, \boldsymbol{x}_T \rangle}{\|\boldsymbol{x}\|_2 \cdot \|\boldsymbol{x}_T\|_2} \\ m_i = \dfrac{r_i}{\sum_{i=1}^{N} r_i} \end{cases} \quad (1).$$

2.2 The combination rule of D-S evidence

In typical evidence theory, Θ denotes the complete recognition framework, assuming that the recognition framework contains N incompatible elements, and then the identification frame can be expressed as: $\Theta=\{A_1,A_2,\cdots,A_N\}$.

Suppose that the frame of the recognition has M independent evidence. $m_j(A_i)$ $(j=1,2,\cdots,M)$ denotes the basic probability distribution function of j^{th} evidence correspond to the element A_i $(i=1,2,\cdots,N)$. A denote the new evidence of different characteristics after fusion. $m(A)$ denotes the new evidence of BPA function after fusion. The rules of the D-S combination can be expressed as:

$$\begin{cases} m(A)=\dfrac{1}{1-k}\displaystyle\sum_{A_1\cap A_2\cap\cdots\cap A_N=A}\prod_{j=1}^{M}m_j(A_i), \forall A\subseteq\Theta \\ m(\varnothing)=0 \end{cases} \quad (2).$$

where k is conflict coefficient, and it can be defined as the following form: $k=\displaystyle\sum_{A_1\cap A_2\cap\cdots\cap A_N=\Phi}\prod_{j=1}^{M}m_j(A_i)$

2.3 D-S evidence decision criterion

This paper chooses the method based on maximum confidence rules to achieve fusion. Suppose the sample is x, and its BPA function value $m_i(A)$ corresponding to different class samples are calculated separately. The rule can be denoted as:

$$j=\arg\max_i(\mathrm{m}_i(A)) \quad (3).$$

3. An improved D-S evidence iteration discount method and its application

3.1 D-S evidence discount method

Discount method is an effective solution to high conflict problem, and its core of the thought can be expressed as: the original evidence source due to the influence of interference has not conflict, which make the verdict has certain uncertainty. Therefore we construct the discount factor before evidence synthesis structure and use the discount factor achieve correction of the original evidence. Shafer [3] put forward a general method to discount the BPA; its rules are as follows:

$$m^*(A)=\begin{cases}\alpha\cdot m(A), A\neq\Theta \\ \alpha\cdot m(\Theta)+1-\alpha, A=\Theta\end{cases} \quad (4).$$

where $m(A)$ is the initial evidence source, $m^*(A)$ is new evidence after discount processing, α is the discount factor, which reflects the reliability of evidence $m(A)$.

In (4), the discount factor is the point of the discount method. Reference [5] focused on different discount factor defined algorithms. They obtained the category of the target according to the sensor evidence for decision. So it is closely related to the reliability of the evidence. However, reference [6] uses the training sample to build confusion matrix, and combine with the BPA function to construct Pignistic probability vector to determine the discount factor. Thus it can reduce dependence on the reliability of the evidence. This paper selects the discount factor definition method, propose a new method. The specific form is as follows:

$$\begin{cases}\boldsymbol{P}=\boldsymbol{P}\boldsymbol{C}_t \\ \alpha=\dfrac{\langle \boldsymbol{BetP}\ ,\boldsymbol{P}\rangle}{\|\boldsymbol{BetP}\ \|\cdot\|\boldsymbol{P}\|}\end{cases} \quad (5).$$

where $\boldsymbol{P}$ is prior probability vector for all kinds of target, Ct is confusion matrix of the training sample, $\boldsymbol{C}_t(i,j)$ is the probability for i^{th} type of samples is classifier to the j^{th} type. ***BetP*** is probability for current evidence after Pignistic conversion.

3.2 Iterative discount method

To some extent, the evidence discount method can alleviate the impact of the high conflict evidence to the fusion result. As is shown in (4) and (5), the discount methods have only once discount. But in practical application, the evidence after once discount processing may be highly conflict evidence, therefore this paper proposes a fusion recognition method based on D-S evidence iterative discount method. The key of this method is to use the iterative method to modify the source of evidence, until the conflict of the evidence less than the given threshold.

In order to ensure that there is not high conflict in the revised evidence, this paper adopts the way of iterative discount for the determination of the discount factor. General discount algorithm as shown in (5), the paper improved for the following form:

$$\begin{cases}\boldsymbol{P}=\boldsymbol{P}\boldsymbol{C}_t \\ \alpha_i^c=\dfrac{\langle \boldsymbol{BetP}^c,\boldsymbol{P}\rangle}{\|\boldsymbol{BetP}^c\|\cdot\|\boldsymbol{P}\|}\end{cases} \quad (6).$$

where α_i^c is the discount factor of the c^{th} iteration and the i^{th} feature. $\boldsymbol{BetP}^{\boldsymbol{c}}$ is the probability for the c^{th} iteration revised evidence after Pignistic conversion. α_i^c and $\boldsymbol{BetP}^{\boldsymbol{c}}$ change according to the iterations of the algorithm. So evidence of iterative correction can be represented as:

$$m_i^c(A)=\begin{cases}\alpha_i^c\cdot m_i^{c-1}(A), A\neq\Theta \\ \alpha_i^c\cdot m_i^{c-1}(\Theta)+1-\alpha_i^c, A=\Theta\end{cases} \quad (7).$$

where $m_i^c(A)$ is the BPA function of the c^{th} iteration and the i^{th} feature corresponds to evidence A.

Thus, the method of iterative discount can ensure that the revised evidence does not conclude high conflict. The flow chart of the algorithm is shown in Figure. 1.

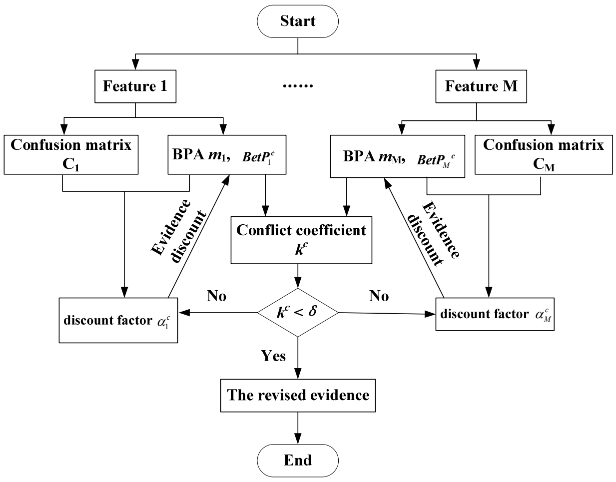

Figure 1. Flow chart of D-S evidence iterative discount theory

3.3 Target recognition based on improved D-S evidence iteration Discount method

Generally, high conflict has great influence in D-S evidence theory. In order to reduce the amount of calculation, this paper chooses the evidence which has high conflict to conduct iterative discount, and low conflict evidence directly for D-S evidence fusion. For a recognition system, suppose that the number of selected features is M and the number of target category is N. Set conflict coefficient threshold for the δ and the largest number of iterations for q. The steps of recognition algorithm are as follows:

1) Get confusion matrix C_t corresponding to t^{th} feature by N class target of training samples, and set the number of iterations c = 0;
2) calculate evidence conflict coefficient k, if $k<\delta$ or $c>q$, then go to step 5); otherwise, go to step 3);
3) c=c+1, calculate the BPA function of t^{th} feature and Pignistic probability vector BetPc; then calculate the discount factor α_t^c according to the (6) ;
4) According to (7) revised evidence, get the new BPA function and Pignistic probability vector, return to step 2);
5) Combination the revised evidence According to the (2);
6) Decision the class of the target according to the (3); end of the algorithm.

4. Simulation results

This paper uses the Ukraine software simulation of radar high resolution range profile (HRRP), whose carrier frequency is 10 GHz and bandwidth is 1.4 GHz. Five kinds of aircraft target are TU- 6, B-52, Mig-21, F-15, B-1b.The target data of azimuth range is 0~ 60º, azimuth accuracy is 0.1 º.

This paper chooses the following features to fusion: the radial length, point scattering amplitude, power spectrum and bispectrum. The BPA function respectively is m_1, m_2, m_3, m_4 . We use conflict coefficient threshold δ=0.6, when the conflict coefficient k <δ, it is the low conflict evidence, on the other hand, for high conflict evidence. At the same time set the largest iteration number is q=10.

4.1 Fusion recognition for low conflict evidence

The BPA of different feature is shown in Table 1. According to the (2), we can calculate that the conflict coefficient k is far less than the threshold value of δ. So there is no high conflict in this sample. We directly use the D-S evidence fusion algorithm for identification, which can save time and achieve good recognition effect. BPA values after fusion is shown in Table 2.

Table 2. The BPA of different feature in low conflicts

BPA	TU-16	B-52	Mig-21	F-15	B-1b
m_1	0.13	0.26	0.08	0.25	0.28
m_2	0.05	0.38	0.11	0.27	0.19
m_3	0.15	0.33	0.10	0.20	0.22
m_4	0.17	0.29	0.15	0.21	0.18

Table 2. The BPA of D-S evdience fusion

BPA	TU-16	B-52	Mig-21	F-15	B-1b
Fusion results	0.01	0.64	0.01	0.19	0.15

From Table 2, we can make the following statement: the test target is B-52. Therefore, when the conflict is small, the algorithm can be omitted discount iteration steps, thus reduce the recognition time. At the same time the degree of differentiation for each target become bigger, then improved the recognition rate.

4.2 Fusion recognition for high conflict evidence

Select the test sample which conflict larger (k>δ). The BPA of different feature is shown in Table 3. In order to compare the superiority of the algorithm in dealing with conflict evidence, the classic D-S evidence theory, Murphy, [6], [7] and the proposed algorithm are simulated respectively. Five kinds of D-S evidence theory fusion of BPA are presented in Table 4.

Table 3. The BPA of different feature in high conflicts

BPA	TU-16	B-52	Mig-21	F-15	B-1b
m_1	0.21	0	0.12	0.26	0.41
m_2	0.18	0.40	0.05	0.24	0.13
m_3	0.24	0.38	0.09	0.18	0.11
m_4	0.15	0.46	0.10	0.16	0.13

Table 4. Five kinds of D-S evidence theory fusion of BPA

BPA	TU-16	B-52	Mig-21	F-15	B-1b
Classic D-S	0.34	0	0.12	0.35	0.19
Murphy	0.08	0.59	0.27	0.03	0.03
[6]	0.03	0.88	0.00	0.05	0.04
[7]	0.04	0.84	0.01	0.07	0.04
Proposed method	0.00	0.98	0.00	0.01	0.01

We can see that the classical D-S algorithm appear error in dealing with high conflict evidence, the proposed algorithm for target B-52 has the maximum BPA value after fusion and the maximum degree of differentiation with other targets. So the proposed algorithm has an obvious advantage in dealing with high conflict.

4.3 The comparison of different recognition algorithm

Selection of 100 samples for each kind of target as the test sample, and compare single feature recognition and fusion recognition algorithm which proposed in this paper.

From Figure. 2, we can see that the average recognition rate of the proposed method is higher than the average recognition rate of the single identification. When the signal-to-noise ratio (SNR) is less than 5 dB, the fusion feature recognition rate is growing rapidly, the improvement effect of recognition is more outstanding, when SNR is higher than 20 dB, the fusion recognition rate is steady, and the recognition rate is more than 98%.

5. Conclusion

This paper proposes a fusion recognition method based on improved D-S evidence iteration discount method. The algorithm uses the confusion matrix and BPA function to determine the discount factor. For high conflict evidence , correction of BPA function by means of iterate discount processing, until the conflict is less than the given threshold or the number of iterations to achieve a given maximum number of iterations. The algorithm greatly reduced the effects of high conflict with the result of recognition in D-S evidence theory. Simulation results show that the proposed algorithm can effectively solve the fusion recognition problem with high conflict, and has high noise robustness.

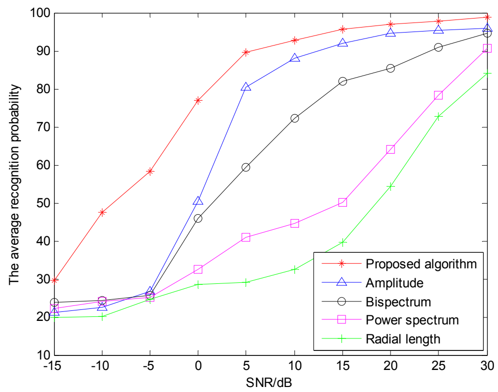

Figure 2. Recognition results with the fusion feature vs. single feature.

6. Acknowledgements

This work was supported by the National Natural Science Foundation of China (no. 61301211).

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