Solution to Evidence Conflict in Target Recognition

Yanjun Fu[1], Kaifeng Sun[2]
[1]School of Intelligence Science and Information Engineering,
Xi'an Peihua University, Xi'an, China
[2]Xi'an Precision Machinery Institute, Xi'an, China
3098391682@qq.com, 178215278@qq.com

Keywords: Multi-source information fusion; Dempster's rule; Evidence credibility

Abstract. To solve the problem of evidence conflict when using D-S theory in multi-source information fusion, This paper in-depth analyzed the principle of Dempster's rule and discussed its limitations and amendatory measures, Based on this, aiming at the air target recognition, a general method was proposed in this paper to deal with conflict problem by introducing evidence reliability judgment and absorption-fusion treatment.

1 Introduction

Multi-source information fusion is widely used in target recognition, integrated navigation and other fields. It refers to the coordinated use of multiple sensors by integrating the local incomplete observation information from similar or heterogeneous sensors to form a consistent description of object or environment, eliminating possible redundancy and contradiction between multi-sensor information. Information fusion can be carried out at three levels, including pixel level, feature level and decision level. Evidence reasoning is able to integrate multi-sensor information into basic probability distribution function (often named as mass function) without prior information [1], and it is the most suitable method of uncertain reasoning for air target recognition in military field. Dempster's combination rule is successful when the evidences being combined are of high confidence with low conflict. When the evidences being combined are of low confidence with high conflict, Dempster's combination rule often comes up with a n uncommon result. For this reason, many scholars have studied the problem of evidence conflict and put forward some improvement measures. On the basis of previous research, this paper proposed a decision level fusion scheme based on evidence reliability and absorption-fusion method for multi-sensor target recognition.

2 Discussion and Analysis of Dempster's Rule

2.1 Dampster's Rule

Dempster's combining rule reflects the joint effect of evidence, and the evidence here refers to the measurement of certain propositions in a variety of ways, such as expert experience, sensor information, and so on. The fusion formula are as formula (1) .

Let θ be the universe: the set representing all possible states of a system under consideration. The power set is the set of all subsets of θ, including the empty set. The non-zero mass (focal elements) are marked as $A_1, A_2, \cdots, A_k$ and $B_1, B_2, \cdots, B_k$ .under the condition of $\sum_{A_i \cap B_j = A} m_1(A_i) \cdot m_2(B_j) < 1$, then, for all non-empty sets, the function $m: 2^{\theta} \to [0,1]$ will satisfy the conditions: $m(\phi) = 0$ including the following terms:

$$m(A) = \frac{1}{1-K} \sum_{A_i \cap B_j = A} m_1(A_i) \cdot m_2(B_j) < 1 \tag{1}$$

Where $K = \sum_{A_i \cap B_j = A} m_1(A_i) \cdot m_2(B_j)$ (2)

From formula (1), we can see that m(A) denotes the proportion of all relevant and available evidence that supports the claim that the actual state belongs to A but to no particular subset of A.

Let n be the number of sources of evidence, and the average support of all the evidence for propositional A is defined as:

$$q = \frac{1}{n}\sum_{i=1}^{n} m_1(A_i) \tag{3}$$

2.2 Analysis of Dampster's rule

Frame of discernment defined by DST consists of a number of mutually exclusive and exhaustive focal elements, and the combining rule is concluded under the hypothesis that each focal element is independent and fully reliable.

In the Dempster's rule, if A is empty set (marked as ϕ) , there is $m(A) = m(\phi) = 0$, that is to say the combing rule forms a new brief structure based on the information without any contradiction by abandoning independent focal element's each conflict under the closed universe, and allocates the "conflict of evidence" to the various focal elements of the combined result in a certain proportion to achieve the normalization of BBA function. From the formula (2), we can see that the contradiction factor (marked as K) reflecting the conflict degree will increase with the increase of the number of evidence. Therefore, the combining rule is more suitable for dealing with occasions with high belief and low conflict and with limited number of evidence. When the conflict between evidence is relatively small, the belief of the evidence will concentrated in the proposition with small uncertainty, which will result in a reasonable result. On the other hand, there will be a variety of irrational phenomena.

For example: Let A, B, and C be independent focal elements, and their basic probability assignment is respectively: $m_1(A) = 0.9, m_1(B) = 0.1;\quad m_2(B) = 0.1, m_2(C) = 0.9;$

According to Dampster's rule, the combining result will be : $m(B) = 0.1, m(A) = m(C) = 0.0$

We can see from the above example that: the new evidence which obtained from the fusion results of two evidences now fully supports B, while the two evidence are all very small support to the focal element B before fusion. While the BBA values of the other two focal elements A and C are now all changed to zeros, though evidence 1 highly supports A and evidence 2 highly supports C. This example shows the typical "one vote veto" phenomenon caused by Dampster's rule, which is obviously unreasonable. For this reason, many scholars have put forward improvement measures to this rule.

3 Solution to the Conflict of D-S evidence

At present, there are two main ideas for the analysis and improvement of this irrational phenomenon caused by fusion of conflicting evidence in the academic circle: one thought is that the irrational phenomenon is due to the incomplete frame of discernment, and the other thought is that the irrational phenomenon is due to the reliability of the evidence source or due to the Dempster's combination rule itself. The following are discussed separately.

3.1 Solution to the Conflict Based on Incomplete Frame of Discernment

Under D-S frame, the value of BBA is usually acquired by expert experience, statistical method or neural network method, and all of which are related to prior knowledge. While in some specific applications, for example, air military target recognition, because new products will appear as time goes by, due to the limitation of prior knowledge and cognitive ability, it is often impossible to accurately identify a closed discernment frame.

Aiming at how to combining evidence under incomplete discernment frame, Smets put forward a concept of "open world assumption" and his main viewpoint is to assign the belief of collision part caused by combing evidence to empty set, and not abandon focal element's each conflict as Dempster's rule does [2]. That is to say: $m(\phi) \geq 0$ according "open world assumption". Smets's idea equates evidence collision with incomplete frame of discernment, which is often not in accordance with the actual situation. Based on the analyze of "open world assumption", paper[3] put forward a

new point of view of ”open discernment frame”, which divides the incomplete discernment frame into the known part and the unknown part and clearly distinguishes between the two concepts of “incomplete discernment frame “ and “evidence collision”.

3.2 Solution to the Conflict Based on Complete Frame of Discernment

Because of the fact that it is often difficult to determine whether the discernment frame is complete in many practical problems, many researches mainly focus on finding solutions to evidence conflicts under the assumption of closed world.

1) Improvement Measures based on Modified Evidence Source

According to this method, Dempster’s combing rule is not wrong, and when the evidence is highly conflicted, we should first pre-treat the conflict evidence, and then use Dempster’s combining rule to fusion.

In the study of the preprocessing of conflict evidence, In the paper [4], the weighted average preprocessing of evidence is proposed to minimize the effect of unreliable data sources on the fusion results. Paper [5] proposed a new determine method for evidence weight based on the compatibility ratio and the evidence credibility ratio to deal with evidence collision. Paper [6] proposed to fusion multiple evidences in terms of Dempster’s combing rule after classification correction of the evidence collision which taking account of three parameters including the evidence distance parameter, the conflict parameter and the direction parameter. According to paper [7], the Q events with the highest evidence support will most likely be the events of recognition conclusion, and the abnormal evidence should be rejected before fusion. Paper [8] proposed a method combining the advantages of both modifying original evidence source and improving Dempster’s rule by introducing correlation degree.

2) Improvement Measures based on the Modified Dempster’s Combination Rule

This kind of method holds that the key to irrational phenomena lies in the improper handling of conflict by combination rules. The reason is that the combining rule completely lose the collision evidence by abandoning it.

From formula (1) and (2), it can be seen that, in order to maintain the normalization of the BBA, in the processing of the conflict factor (marked as K), the BBA of the common focus element of the two evidence be changed K times of the original, but the assignment of the conflict is not caused by all the focal elements, and such distribution will bring incompatibility. For such reason, many scholars have put forward some improvement measures on how to allocate the conflict aiming at Dempster’s rule. Yager[9] first proposed to assign all the conflicting evidence to the universe, and after that, Smets proposed to assign all the conflicting evidence to the empty set. Paper [10] proposed to allocate the collision evidence in terms of the evidence credibility and expressed an weighted form combing rule based on Yager’s method [9]. On the other hand, some scholars believed that the combination rule assigns the local conflict to the global unreasonable, and put forward the principle of local conflict being allocated in local. Paper [11] put forward the weighted allocation method and absorption method to deal with conflict evidence, and a combining rule for proportionally distributing conflicts is proposed in paper [12].

4 An Improved Air Target Recognition Method Based on Evidence Reasoning

Due to the continuous emergence of new air targets in the air defense operations, in the discernment framework, in addition to various known models, such as bombers and fighters, the unknown type is introduced as the focal element of the discernment framework. Based on the analysis of the foregoing theory of evidence, a comprehensive target recognition scheme based on multi-source information fusion is presented in this paper. The flowchart is shown in Fig. 1.

Step1: Determine whether there existed an unknown new weapon;

In multi-sensor target recognition, the result of each sensor's judgement on the target category is evidence, which can be converted to the BBA for the target.

Given a threshold marked as T, if all the BPA values of all the known focal elements in the discernment frame are less than the threshold, then the recognition target is likely to be an unknown new weapon, and go to step 6.

Step2: Determine whether there is a conflict between the multi-sensor evidence;

The method of detection adopts the idea proposed in paper [7], and the steps are as follows:

- Calculate the average support of each sensor to the same focal element *A* based on the formula(3);
- Select a threshold marked as β, which meets the requirement of $\beta > 1$ (The selection of threshold is related to the accuracy of BPA function. The higher the data accuracy of BPA function, the more concentrated the focal element supporting the same event, the larger the threshold), then calculate the judgment threshold of normal evidence in terms of formula (4);

$$\gamma = \frac{\beta\text{-}1}{\beta} q(A) \tag{4}$$

- If there is $0 \le m_i(A) < \gamma$ then $m_i(A)$ is conflict evidence, and go to step 4 , otherwise, $m_i(A)$ is normal evidence, and go to step 3;

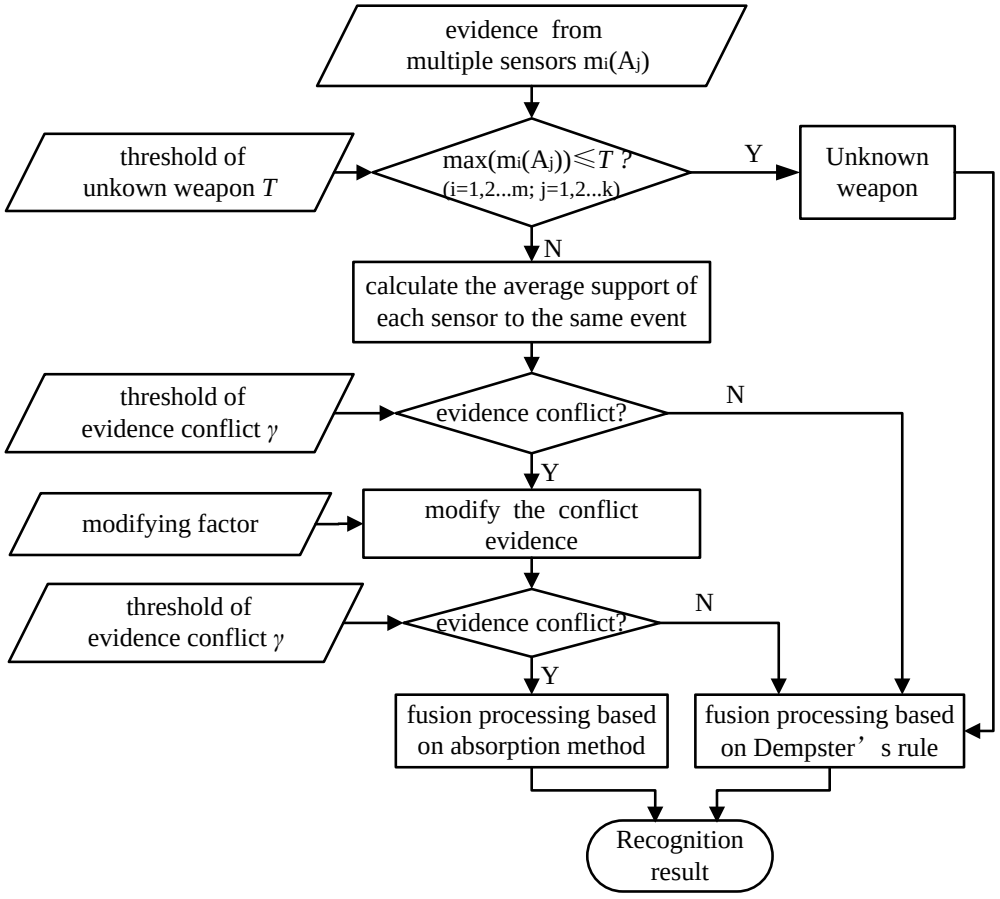

Figure 1. Flow chart of air target recognition

Step 3: Modify the conflict evidence in terms of the formula (5)-(6), then determine whether there still existed conflict between the modified evidence, if yes, then go to step 5, else, go to step 4;

$$m_i(A_j) = m_i(A_j) + 1/l \tag{5}$$

$$m_i'(A_j) = m_i(A_j) \Big/ \sum_j m_i(A_j) \tag{6}$$

Where the value of l is related to the number of focal elements (marked as n), and often less than $\frac{1}{n}$.

Step 4: Fusion evidences from multiple sensors according formula (1)

Step 5: Fusion evidences from multiple sensors using the combing method expressed in paper [11] according formula (7)-(8).

$$m(A) = \sum_{B \cap C = A} m_1(B) \cdot m_2(C) + \Delta \tag{7}$$

$$\Delta = \sum_{A \cap X = \Phi} J_X() \cdot [m_1(A) \cdot m_2(X) + \cdot m_1(X) \cdot m_2(A)] \tag{8}$$

Where $J_X(\,)$ is the conflict allocation function, and its independent variable is the BBA related to the focal element, such as *A*, *X* and {*A*,*X*}, and satisfies:

$$\sum J_X(S) = 1, S \in \{A, X, \{A, X\}\} \tag{9}$$

It can be seen from formula (7)-(9) that local conflict being allocated in local.
Step 6: Gain the recognition result.

5 Conclusions

Aiming at the problem of the failure of Dempster's rule in multi-sensor target recognition case, this paper proposed a comprehensive solution by combining the modification of evidence with the modification of combining rule. The proposed method can get a reasonable recognition result even in the case of conflict of evidence.

Acknowledgment

This work was supported by Aeronautical Science Fund under Grant No.20141996018 and Special Scientific Research Program of the Shaanxi Provincial Education Department under Grant No.17JK1056.

References

[1] J. Hou, Z. Miao, Q. Pan. Target recognition a method of sequential images based on the weight-DSmT, Fire Control and Command Control, 2006, 31(7): 53-56.

[2] P. Smets. The combination of evidence in the transferable belief model. IEEE Trans. PAMI, 12(5):447-458.

[3] C. Zeng, B. J. Zhao, P. K. He. The combination of evidence in an incomplete frame of discernment, Journal of Electronics & Information Technology, 2005,27(7): 1043-1046.

[4] H. W. Guo, W. K. Shi, Y. Deng, Z. J. Chen. Evidence conflict and its 3D strategy: discard, discover and disassemble? Systems Engineering and Electronics, 2007, 36(1): 30-32.

[5] L. L. Li, D. J. Ma, C. S. Wang, X. H. Gu. New method for conflict evidence processing in D-S theory, Application Research of Computers, 2011,28(12):4528-4531.

[6] L. Wang, W. M. Lu, K. N. Teng, Y. C. Jin. Combination method of multi-evidence based on classification correction, Control and Decision, 2015,30(01):125-130.

[7] X. Guan. C. M. Sun, Y. He. A novel fusion method for conflicting evidences, Journal of University of Electronic Science and Technology of China, 2007, 36(1): 30-32.

[8] G. N. Yang, X. F. Feng. New conflict evidence fusion method in D-S evidence theory, Computer Applications and Software. 2014,31(02):82-85.

[9] R R. Yager. On the Dempster-shafer framework and new combination rules, Information Science, 1989, 41(2):93-137.

[10] Q. Sun, X. Q. Ye, W. K. Gu. A New Combination Rules of Evidence Theory, Acta Electronica Sinica, 2000(08):117-119.

[11] S. Y. Zhang, Q. Pan, H. C. Zhang. Conflict problem of Dempster-Shafer evidence theory, Acta Aeronautica Et Astronautica Sinica, 2001(04):369-372.

[12] Q. H. Xing, Y. J. Lei, F. X. Liu .One combination rule of evidence theory based on distributing conflict in proportion, Control and Decision, 2004(12):1387-1390.