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Research on D-S Evidence Reasoning Improved Algorithm based on Data Association

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Abstract

In order to make full use of detection information, improve the anti-interference ability of the system, solve the problem of target recognition in complex environment of multi-sensor correlation detection, this paper puts forward a information fusion method between data association and D-S evidential reasoning. It discussed the condition and the method of data association, on the basis of related information extraction, the assignment probability of multi-source sensors was revised, it also established the D-S evidential reasoning algorithm for target recognition based on data association.Through the establishment of model simulation, proved that the information fusion method between data association and D-S evidential reasoning evidence reasoning has higher reliability and recognition ability than the traditional evidential reasoning method, the results verify the correctness and effectiveness of this method.

Keywords: *information fusion, data association, D-S evidence reasoning method, target recognition*

1. Introduction

Information fusion is also known as data fusion, it refers to the use of computer technology for the information processing process, which according to the time sequence to analysis and synthesize the observation information obtained under certain rules in order to complete the task of decision-making and estimation [1-2]. The single point information about the object and the environment obtained by a plurality of sensors will get more complete and reliable output through the comprehensive and analysis of appropriate fusion algorithm. Therefore, the core problem of multi-sensor detection system is information fusion. The commonly used algorithm for multi-sensor data fusion are weighted average method, Kalman filtering method, neural network, evidence reasoning, fuzzy logic theory and so on.

For multi-sensor system, the information has the characteristics of diversity and complexity. Fusion of multi-sensor target recognition is attempting to fuse the information that is imprecise and incomplete about the target attribute of each sensor, producing more accurate and complete attribute estimation and judgment than the single sensor. In many data fusion method, evidential reasoning is suitable for the fusion without prior information [2-6]. The advantage of uncertainty representation, measurement and combination has been drawn wide attention. The traditional evidence reasoning method is just merge the basic probability assignment function according to D-S evidence reasoning method on the foundation of basic probability assignment function, which dose not consider the information correlation characteristics between multiple sensors [5]. However, in many practical applications, there is some correlative information between various sensors, in the presence of strong complex environment interference, the incidence relation of target identification contribution is often greater than the output of single sensor itself .Yet, this part of information is not reflected in the traditional evidence reasoning, which does not make full use of multi-source information. Therefore, in some occasions, it is need to construct a D-S evidence reasoning method based on data association, to enhance the system capability of multi-source information processing and improve the ability of target recognition.

Data associated with the D - S evidence reasoning information fusion methods mainly studies three aspects. First is the condition of information associated with D - S evidence reasoning "; Second is the method of correlation information acquisition; Third is the method

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that how correlation information and D-S evidence reasoning combined. In the application background of target recognition, this paper studied the three aspects above.

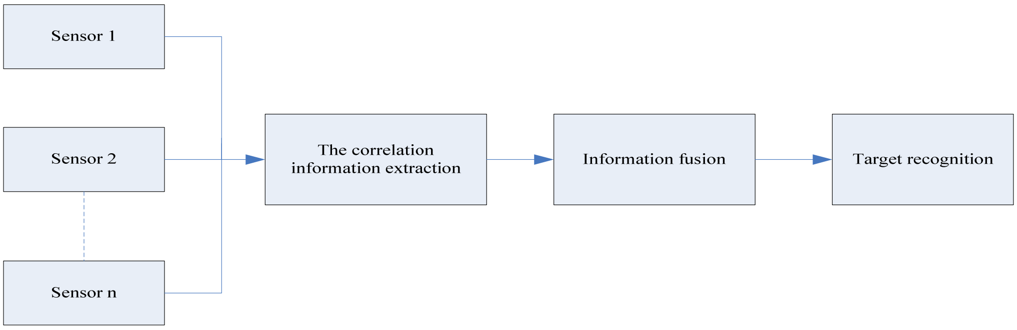

Figure 1. Information Fusion based on Data Association

2. Analysis of Information Fusion Method between Data Association and D-S Evidence Reasoning

2.1. D-S evidence reasoning method

Let Z be a set of assumptions, in this collection, assuming all elements are mutually independent and complete. The set of all subsets of Z sign as Ω, Ω is also known as the frame of discernment. If the Z has n hypothesis, then Ω has 2^n subsets, where Φ is the empty set. The emergence of an evidence can support some subsets in a certain extent .Therefore, for each of the evidence, there is a basic probability assignment function W. W is a mapping from Ω to $[0,1]$, also satisfy: $W(\Phi)=0$; $\sum_{A\subseteq\Omega} W(A)=1$ Where $W(A)$ indicate the basic probability number of A, $0\le W(A)\le 1$ [6].

$W(A)$ is the basic probability number only provided to A, reflects the confidence of A, but it is not A's total confidence. In order to obtain the total confidence of A, it must add all subsets B of A's basic probability numbers, using the confidence function (Bel) expressed:

$$Bel(B)=\sum_{B\subseteq A} W(B), A\subseteq\Omega, \quad (1)$$

The definition of the likelihood function Pl as follows:

$$Pl(A)=1-Bel(\overline{A})=\sum_{A\cap B\neq\Phi} W(B), A\subseteq\Omega \quad (2)$$

$Bel(\overline{A})$ is support for the $\overline{A}$, so the value of the likelihood function is expressed no doubt degree of A, namely, the estimation of A trust value. $[Bel(A), Pl(A)]$ is called the confidence interval of A.

In practical problems, it often appears a situation that there are several evidences to support a hypothesis or its negation. At this moment, it needs to calculate the value of W and the Bel under the combined evidence, the structural rules are as follows:

$$\begin{cases} W(\Phi)=0 \\ W(A)=W_1(A)\oplus W_2(A)=\sum_{X\cap Y=A}\dfrac{W_1(X)\times W_2(Y)}{K}, A\neq\Phi \end{cases} \quad (3)$$

Here,

$$K = 1 - \sum_{X \cap Y = \Phi} W_1(X) \times W_2(Y)$$

2.2. Analysis on Data Association Method

D-S evidence reasoning method is based on the detection of independent sensors. In many practical applications, although the probability assignment function of each sensor is independent, and they may detect the target at the same time, but their information related to a certain. This information is not reflected in the traditional evidence reasoning, which does not make full use of multi-source information. The establishment of data association method between the sensors will make full use of the related information, in order to improve the system's target recognition probability [7-12].

The physical or logical system design makes the output of multi-source sensors exist a certain relationship, which is mainly manifested in the time domain specific synchronous or asynchronous logic,may also display to spatial data particular relevance or waveform space data, especially in the detection system of multi-source heterogeneous sensors, the characteristics of the same target association is determined by the physical properties of the heterogeneous sensor. This relationship can be obtained through theoretical derivation, but also through the pre-simulation or test. There are many related factors in the correlation of multi-source sensors' output, some factors appear to support the target recognition, but others are opposite. How to select the correlation factor is a key problem to be solved in engineering practice [8-9]. The output of multi-source sensors mainly includes image, waveform, data and other information, which exist many correlation factors in it. According to the design of actual detection system, the selection of related factors must be the most beneficial to the determination of the target, and can eliminate all kinds of interference furthest. Effect of multi-sensor association analysis is a complex problem, which needs to analyze the specific problems in practice.

In practical application, for each sensor and the associated sensor can select a specific relational variable value as a quantitative index of the information association, the index can be calculated also can be obtained through practical test [10-16]. A selection principle of the index is when the associated variable reaches to the value, the target identification probability is not less than the single sensor's decision probability. Through the ratio of calculation of the practical associated variables value and the specific associated variables value to ascertain that the contribution of target determination about the correlation information, the ratio is called correlation [11-12]. By calculating the degree of correlation, to revise the target recognition assignment probability of the sensor and to reflect the related information of the sensor identification appears to support or refute.

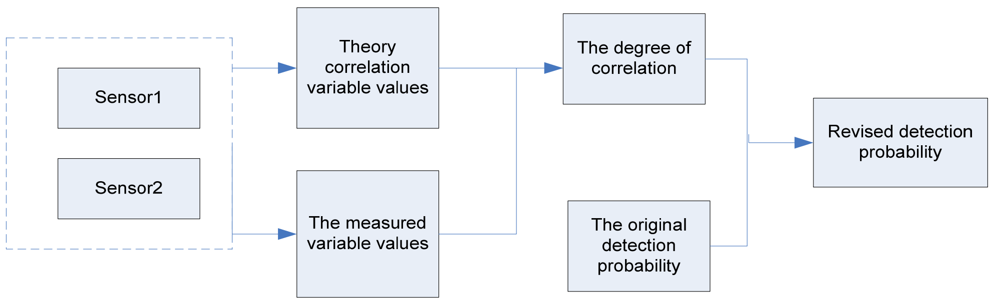

Figure 2. The Correction Method of Target Recognition Probability

Set a detection system Z with P sensors, the detection probability assignment of each sensor to target is W_i. The sensor P_i and $q(q \le p-1)$ sensors associated. So, when every association evidence appears, will give support to the sensor P_i of target detection probability assignment. Let the ratio of correlation information of real measured relevance and the setting relevance to be K_i, at the same time ,setting the impact factor of related information to be λ_i. According to the relevant information, it can give out the revision value of W_i.

The modified calculation method on W_i.

$$W_i^{'} = (1 + \sum_{i=1}^{p-1} \lambda_i K_i) W_i \quad , \tag{4}$$

When P_i does not correlate with another sensor, $K_i = 0$

$W_i^{'}$ is the revision value of W_i. Sensor modified detection probability assignment still meets the application conditions of D-S evidence reasoning method, can be synthesized by D-S evidence reasoning synthesis method.

3. Algorithm Design

Let Z be a set of assumptions, in this collection, hypotheses elements are mutually independent and complete.All the collection of subsets of Z be marked Ω. If Z has n hypothesis, then Ω has 2^n subsets.

Set Z has p supportive evidence, for each of the evidence, there is a basic probability assignment function W. W is a mapping from Ω to [0,1], also satisfied:

$$\begin{cases} W(\phi)=0 \\ \sum_{A\subseteq\Omega} W(A)=1, 0 \le W(A) \le 1 \end{cases} \tag{5}$$

Supposed, a detection system Z with P sensors, the detection probability assignment of each sensor to target is W_i. The sensor P_i and $q(q \le p-1)$ sensors associated. Let the ratio of correlation information of real measured relevance and the setting relevance to be K_i, at the same time ,setting the impact factor of related information to be λ_i. According to the relevant information, it can give out the revision value of W_i, the value is $W_i^{'}$.

Similarly, $W^{'}$ is also a mapping from Ω to [0,1], and satisfy the D-S evidence reasoning conditions, it can be calculated according to the type synthesis of evidence combination of $W^{'}(A)$.

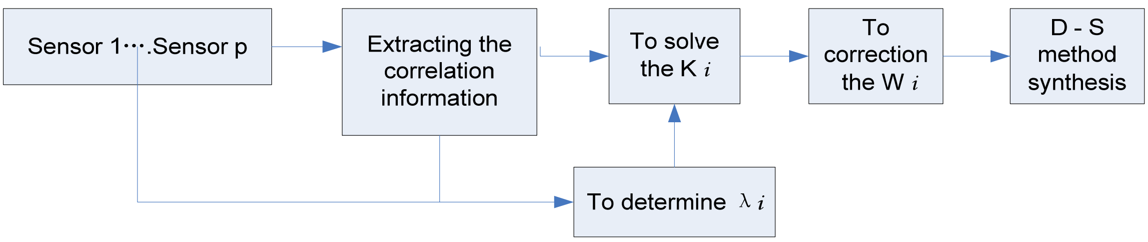

Figure 3. The Information Fusion Algorithm of Data Associated Combined with D-S Evidence Reasoning

4. Test Result and Analysis

In order to examine the fusion effect of the D-S evidence reasoning method based on data association in target recognition, it has carried on the experimental calculation and comparison.

Let the target recognition framework as $\{O_1, O_2, O_3\}$, O_1, O_2, O_3 are three targets. The system uses 3 kinds of sensors μ_1, μ_2, μ_3, the basic probability assignment of a sampling period corresponding as shown in the matrix D. D is expressed as follows.

$$D = \begin{bmatrix} 0.3 & 0.25 & 0.2 & 0.25 \\ 0.2 & 0.25 & 0.15 & 0.4 \\ 0.25 & 0.15 & 0.2 & 0.4 \end{bmatrix}$$

The rows of the matrix correspond to sensor μ_1, μ_2, μ_3, the columns correspond to O_1, O_2, O_3, Θ, each element of the matrix represent the corresponding target detection probability of the corresponding sensor, Θ indicate the basic probability assignment of uncertain proposition.

If we do not consider the correlation information between the sensors, according to D-S evidence reasoning synthesis method directly, the evidence results we can get is [0.36 0.28 0.22 0.14]. By comparing the synthetic result and the detection probability of single sensor, it can be seen that, the combination evidence results of the recognition probability obtained in accordance with the D-S evidence reasoning synthesis method was improved than the detection probability of single sensor to some extent.

In this paper, using the proposed algorithm of D-S evidence reasoning based on data association to do data fusion calculation.

Set up that the two groups of sensors μ_1, μ_2, μ_3 exist pairwise association, by the analysis of actual acquisition signal, the correlation obtained as follows.

Table 1. Correlation between a Sensor Evidence Distribution

Correlation	O_1	O_2	O_3
K_{12}	0.82	0.51	0.46
K_{13}	0.67	0.35	0.37
K_{21}	0.45	0.37	0.62
K_{23}	0.83	0.75	0.61
K_{31}	0.65	0.49	0.76
K_{32}	0.57	0.68	0.39

Selecting the impact factor $\lambda = 0.2$, according to the formula (3), fusing associated information, calculating the revised probability for each sensor assignment. Results are the E, expressed as follows.

$$E = \begin{bmatrix} 0.389 & 0.293 & 0.233 & 0.085 \\ 0.251 & 0.306 & 0.178 & 0.265 \\ 0.311 & 0.185 & 0.246 & 0.258 \end{bmatrix}$$

Compared D and E,we can see that, after introduced the correlation information, the detection probability of each sensors is improved than those before introducing, at the same time the uncertainty of the sensor decreases. This shows that, when introduced the relevant information, the system can analyze the target detection information of the multi-source sensor network from multiple perspectives, the target recognition ability is enhanced, such as FIgur 4.

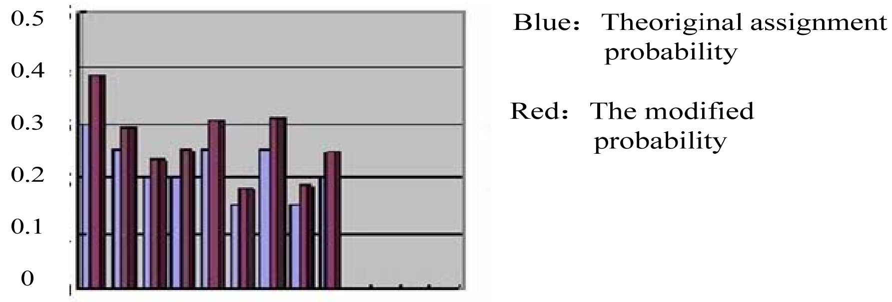

Figure 4. The Comparison between Original Assignment Probability and Association Revised Target Recognition Probability

The probability assignment after correction E , according to the D-S evidence reasoning synthesis method , the evidence results we can get [0.4553 0.3053 0.2214 0.0180]. E is expressed as fellows.

$$E = \begin{bmatrix} 0.389 & 0.293 & 0.233 & 0.085 \\ 0.251 & 0.306 & 0.178 & 0.265 \\ 0.311 & 0.185 & 0.246 & 0.258 \end{bmatrix}$$

Table 2. Comparison between the Original D-S Synthesis Results and the Correlative Introduced Information Results

Target identification	O_1	O_2	O_3	Θ
Without introducing Association	0.36	0.28	0.22	0.14
Introducing Association	0.4553	0.3053	0.2214	0.0180

The detection system of correlation introduced information detection probability of the target A increased from 0.36 to 0.4553, the detection probability of B increased from 0.28 to 0.3053, the detection probability of C increased from 0.22 to 0.2214. By comparing the synthesis results of the D-S evidence reasoning which not introduced relevance information: obviously, the synthesis result of the correlation introduced information of D-S evidence reasoning has higher recognition probability and accuracy. At the same time, the uncertainty of the system is reduced to 0.0180 from 0.14. It means that, making full use of various information of multi-source sensors, while maintaining the hardware of the original detection system unchanged, the data fusion method can greatly improve the detection performance of the system, such as Figure 5.

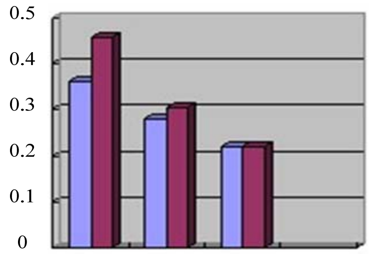

Figure 5. Comparison the Original D-S Synthesis and Correlative Introduced Information

5. Conclusion

As can be seen from the simulation result after introducing the correlation information, by revising the original probability assignment, the accuracy of D-S evidence reasoning method has been improved obviously. And the uncertainty of the system is greatly reduced. By flexibly using this method, it can also solve the anti-interference problem of particular environment targeted. This paper provides a approximate approach for engineering processing and a train of thought for correlating information between sensors which is a complex issue associated with designing the system structure in practice. How to effectively use multiple sensor information to detect system needs further research and exploration.

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