

# Target Characteristic Fusion Recognition Based on D-S Evidence Theory

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**Abstract**—D-S evidence theory is an important target fusion recognition in the characteristic fusion level. With a strong theoretical basis, this method can deal with not only the uncertainty caused by random but also the ambiguity caused by uncertainty. In this article, after the RCS (radar cross section) and the target polarization (polarization scattering matrix) of the three of heavy-duty truck, light truck and car are extracted, the characteristic vector of the targets can be obtained by using gray relevance method, fuzzy mathematics method and template matching method. By applying of Matlab sampling data, the RCS and target polarization time series of the heavy-duty truck, light truck and car were drawn. And, by using the simulation of the data, the different methods of target recognitions are analyzed.

**Keywords**—Evidence theory; Radar cross section; Polarization scattering matrix

## I. Introduction

D-S evidence theory is an important target fusion identification in the characteristic fusion level. With a strong theoretical basis, this method can deal with not only the uncertainty caused by random but also the ambiguity caused by uncertainty. By using this theory, the density of the priori probability and conditional probability are not the necessity. Depending on the accumulation of the proof, default set can be reduced gradually, unknown can be separate from uncertain. This method has a strong superior in the target characteristic fusion recognition. It can increase the target recognition frequency remarkably.

## II. Summarize of the D-S evidence theory

Suppose  $U$  represents a set we study that all the  $x$  values, and all the elements in  $U$  are incompatible, then  $U$  is a recognition framework of  $X$ . Suppose  $A$  represents a recognition framework, then, when function  $m:2^U \rightarrow [0,1]$  ( $2^U$  is all the subset of  $U$ ) get the following requirement:

$$m(\emptyset) = 0, \sum_{A \subset U} m(A) = 1 \quad (1)$$

We name  $m(A)$  main probability evaluation of subset  $A$ . Shafer explained that function of main probability evaluation is a subjective express of the proof, that is the accurate trust to subset  $A$ , expressing the direct support to subset  $A$ .

We name  $BEL(A)$  is a trust function for accurate trust to subset  $A$  about  $U$

$$BEL(A) = \sum_{B \subset A} m(B) \quad (\forall A \subset U) \quad (2)$$

The trust function and main probability evaluation function is the only thing. The trust function can be read the support from proof to subset  $A$ . Or, to put it another way, under one proof, decision – maker has the reason to trust the subset  $A$  by using trust function.

The procedure to recognize the target by using the proof theory is a procedure to get the target character by using the main probability evaluation function. Then, it is a key to get the main probability evaluation using the proof theory to recognize the target.

Suppose recognition framework  $= \{\text{target 1, target 2} \dots \text{target } N\} = \{O_1, O_2, \dots, O_N\}$ , that means the kind number of the known target in the character bank is  $N$ , Suppose  $M$  is the number of the target echo that radar can prob.

## III. Base on the model

### A Target main probability evaluation based on gray relevance (Method 1)

Gray relevance is an uncertain relevance. Gray relevance analysis can measure the approximate level among the factors on the basis of similarity and dissimilarity of the develop pose of the data columns. As relevance analysis is a analysis according to the tendency of the development, it doesn't have the high requirement to the sample size. The typical distribution is not the necessary when we do the analysis. And commonly, the outcome of the analysis is coincidence to the qualitative analysis. So, we can apply the gray relevance analysis to do a synthesis to the data.

Suppose there are  $T$  characteristic vectors of reference model in the given character bank. It is expressed like this:

$$X_{is} = \{X_{is}(k) | i = 1, \dots, M; s = 1, \dots, T; k = 1, \dots, P\} \quad (3)$$

Among the above,  $i$  is the type of the echo data,  $s$  is the number of the reference model,  $k$  is the characteristic vector of the number  $k$ . And we also suppose the characteristic vectors of the targets that unrecognized is  $X_{i0}=\{X_{i0}(k)|i=1,\dots,M; k=1,\dots,P\}$ .

Data columns can be time series, index series and space series when we apply the method of gray relevance analysis. When the data can't be compared or operated, we can't get the initialization, minimum, maximum and average. So, we have to make the data have the comparability. This procedure is also has a non-dimensionalize role. The procedure is: add  $X_{i0}$  to  $X_{is}$ . The new  $X_{is}$  will be  $X_{is}=\{X_{is}(k)|i=1,\dots,M;s=1,\dots,T;k=1,\dots,P\}$ .

$$X_{is}(k) = \frac{X_{is}(k) - \min_s X_{is}(k)}{\max_s X_{is}(k) - \min_s X_{is}(k)} \quad k=1,2,\dots,P \quad s=0,1,2,\dots,T \quad (4)$$

The treated  $X_{i0}$  can be get from  $X_{is}$ .

The relevance coefficient of the treated  $X_{i0}$  and  $X_{is}$  is :

$$\xi_{is}(k) = \frac{\min_s \min_k |X_{i0}(k) - X_{is}(k)| + \rho \max_s \max_k |X_{i0}(k) - X_{is}(k)|}{|X_{i0}(k) - X_{is}(k)| + \rho \max_s \max_k |X_{i0}(k) - X_{is}(k)|} \quad (5)$$

Among above,  $\rho \in (0, +\infty)$  is the distinguish coefficient, the smaller the  $\rho$ , the bigger the capability of distinguish. Commonly, the value of  $\rho$  is in the interval  $[0,1]$ . More commonly,  $\rho = 0.5$ . When

$$\xi_{is} = \{\xi_{is}(k), k=1,2,\dots,P\} \quad (6)$$

The gray relevance is :

$$\gamma_{is} = \frac{1}{P} \sum_{k=1}^P \xi_{is}(k) \quad s=1,2,\dots,T \quad k=1,2,\dots,P \quad (7)$$

or

$$\gamma_{is} = \sum_{k=1}^P a_i(k) \xi_{is}(k) \quad a_{ik} \geq 0 \text{ and } \sum_{k=1}^P a_i(k) = 1 \quad k=1,2,\dots,P \quad (8)$$

From this we can see, gray relevance of the characteristic vectors in the un-surveyed target and characteristic bank can be turn into a series of numerical value by using (7) or (8). It can be normalized like this:

$$\gamma_{is} = \frac{\gamma_{is}}{\sum_{s=1}^T \gamma_{is}} \quad (s=1,2,\dots,T) \quad (9)$$

$\gamma_{is}$  is the relevance of the reference models in the

un-surveyed target and characteristic bank.

After the general gray relevance of the every typical target in the un-surveyed target and characteristic bank, it can be normalized like this:

$$m_i(O_j) = \frac{\gamma_i(O_j)}{\sum_{j=1}^N \gamma_i(O_j)} \quad (10)$$

Thus,  $m_i(O_j)$  is the main probability evaluation.

### B Improved method of the target main probability evaluation based on gray relevance (Method 2)

Condition of this method is the same as the method 1. Data  $X_{is}$  and data  $X_{i0}$  should be initiated to do the gray relevance analysis. If  $X_{is}(r)=X_{is}(r)-X_{is}(1)(r=2,3,\dots,P-1)$ ,  $X_{i0}(r)=X_{i0}(r)-X_{i0}(1)(r=2,3,\dots,P-1)$ , the relevance between  $X_{is}$  and  $X_{i0}$  is:

$$\gamma'_{is} = \frac{1 + |X_{is}| + |X_{i0}|}{1 + |X_{is}| + |X_{i0}| + |X_{is} - X_{i0}|} \quad s=1,\dots,T \quad (11)$$

Among above,

$$\begin{aligned} |X_{is}| &= \left| \sum_{r=2}^{P-1} X_{is}(r) + \frac{1}{2} X_{is}(P) \right| \\ |X_{i0}| &= \left| \sum_{r=2}^{P-1} X_{i0}(r) + \frac{1}{2} X_{i0}(P) \right| \\ |X_{is} - X_{i0}| &= \left| \sum_{r=2}^{P-1} (X_{is}(r) - X_{i0}(r)) + \frac{1}{2} (X_{is}(P) - X_{i0}(P)) \right| \end{aligned}$$

$\gamma'_{is}$  is the relevance of the reference models in the un-surveyed target and characteristic bank.

After the general gray relevance of the every typical target in the un-surveyed target and characteristic bank, it can be normalized like this:

$$m_i(O_j) = \frac{\gamma'_i(O_j)}{\sum_{j=1}^N \gamma'_i(O_j)} \quad (12)$$

Thus,  $m_i(O_j)$  is the main probability evaluation.

### C Target main probability evaluation based on fuzzy mathematics (Method 3)

Impacted on all kinds of environment factors, echo signal of radar is uncertain and un-integrity. So, survey vectors and characteristic vectors in the characteristic bank are all fuzzy. It is bad to the target recognition to apply the accurate method on the uncertain factors in the echo signal. We can turn these factors into fuzzy subsets or membership functions to express the uncertainty by applying the fuzzy mathematics method. The key technology to recognize the target by using the fuzzy mathematics is to determine the membership functions or

fuzzy subsets.

When the meanings of the characteristic parameters of the characteristic vector in the characteristic bank and un-surveyed targets are different, for example, the meanings of the 8 parameters of the un-surveyed targets and characteristic bank in the RCS echo data are different, the membership functions of the normal distribution is:

$$\mu_{is}(k) = \exp(-\tau_i(k)(\|X_{is}(k) - X_{i0}(k)\|/\sigma_i(k))^2) \quad (13)$$

When the meanings of the parameters in the characteristic bank is the same, the membership functions of the normal distribution is:

$$\mu_{is}(k) = \exp(-\tau_i(\|X_{is}(k) - X_{i0}(k)\|/\sigma_i)^2) \quad (14)$$

Among that,  $\|X_{is}(k) - X_{i0}(k)\|$  expresses the Euclidean distance from the un-surveyed target to the number  $s$  reference module in the characteristic bank.

$\tau_i(k)$  and  $\tau_i$  are all the adjustment ranges,  $\sigma_i(k)$  and  $\sigma_i$  are spreads. Adjustment range and spread can be got from the known target in the characteristic bank. In another words, adjustment range and spread can be fixed after the fix of the characteristic bank of the target.

#### D Target main probability evaluation based on template matching (Method 4)

Suppose there are  $T$  characteristic vectors of reference model in the given character bank. It is expressed like this:

$$X_{is} = \{X_{is}(k) | i = 1, \dots, M; s = 1, \dots, T; k = 1, \dots, P\}$$

Among the above,  $i$  is the type of the echo data,  $s$  is the number of the reference model,  $k$  is the characteristic vector of the number  $k$ . And we also suppose the characteristic vectors of the targets that unrecognized is  $X_{i0} = \{X_{i0}(k) | i = 1, \dots, M; k = 1, \dots, P\}$ .

Distance from  $X_{i0}$  to  $X_{is}$  is:

$$D_{is} = \|X_{is} - X_{i0}\| \quad s = 1, \dots, T$$

Matching degree from  $X_{i0}$  to  $X_{is}$  can be got by using two different methods:

(1) Method 1 to get the matching degree:

$$TP_{is} = \frac{1}{\sum_{s=1}^T \frac{1}{D_{is}}} \quad s = 1, \dots, T \quad (15)$$

(2) Method 2 to get the matching degree:

$$TP_{is} = 1 - \frac{D_{is}}{\sum_{s=1}^T D_{is}} \quad s = 1, \dots, T \quad (16)$$

After get the matching degree about the un-surveyed target and every reference module, we also have to get the general matching degree  $TP_i(O_j)$  about the un-surveyed target and

every target. We can use the method like gray relevance analysis. After the general gray relevance of the every typical target in the un-surveyed target and characteristic bank, it can be normalized like this:

$$m_i(O_j) = \frac{TP_i(O_j)}{\sum_{j=1}^N TP_i(O_j)} \quad (17)$$

Thus,  $m_i(O_j)$  is the main probability evaluation.

#### IV. Simulation experiment of the target recognition

To verify the effects of the method mentioned above in the recognition of the mobile target, using two characteristic vectors including the RCS (radar cross section) and the target polarization of the un-surveyed target which obtained by radar, applying gray relevance method, fuzzy mathematics method and template matching method, we get the main probability evaluation of the two characteristic vectors of the un-surveyed targets under the target recognition framework. At the first, the un-surveyed target set recognized by single characteristic method. Then, the single characteristic recognition frequency of the un-surveyed targets can be got.

##### A Target recognition based on gray relevance analysis method

RCS and polarization single characteristic can be recognized applying gray relevance method. Parameter values used in the gray relevance analysis method listed in Chart 3.

Chart 1 Illustration of the Parameter

parameter	value	content
$\rho$	0.5	distinguish parameter

Recognition frequencies got by different gray relevance method (method 1 and method 2) are listed in the chart 2. From the compare in the chart, we can draw the conclusion that the different recognition frequency can be get by applying the different method. But for the current data, method 1 is more better than method 2. Among that, data of the 20 RCS of the un-survey target including heavy-duty truck, light truck and car are generated by additional 70% random error.

Chart 2 recognition frequency of the single characteristic

survey target and characteristic	method 1	method 2
heavy-duty truck (RCS)	90%	90%
light truck (RCS)	100%	100%
care (RCS)	85%	80%
heavy-duty truck (polarization characteristic)	95%	80%
light truck (polarization characteristic)	100%	65%
care (polarization characteristic)	100%	80%

### B Target recognition based on fuzzy mathematics

RCS and polarization single characteristic can be recognized by applying fuzzy mathematics method. Parameter values used in the fuzzy mathematics method listed in Chart 5. RCS and spread  $\sigma(k)$  of the polarization characteristic are decided by characteristic bank. The value of the spread is fixed when the characteristic bank is determined. There are only 3 kinds of targets. To get the every spread  $\sigma(k)$ , the following method can be used:

$$\sigma^2(k) = \frac{[X_i(k) - c(k)]^2}{-\log 0.5}$$

Among that,  $c(k) = \frac{\sum_{i=1}^s X_i(k)}{2}$

Chart 3 Illustration of the Parameter

parameter	value	content
$\tau_{RCS}(k)$	0.1	RCS adjust degree, k is the number of the characteristic parameter
$\tau_j$	0.01	adjust degree of the polarization characteristic
R	(0.2,0.2,0.2,0.2,0.2)	RCS is the right parameter

The characteristic of the target RCS can be recognized by method 3(choosing membership functions of the normal distribution). The polarization characteristic can be recognized by method 3(choosing membership functions of the normal distribution).

Chart 4 recognition frequency of the single characteristic (method 3)

target and characteristic	70% inaccuracy	50% inaccuracy
heavy-duty truck (RCS)	90%	95%
light truck (RCS)	90%	95%
care (RCS)	80%	90%
heavy-duty truck (polarization characteristic)	90%	95%
light truck (polarization characteristic)	60%	85%
care (polarization characteristic)	80%	90%

### C Target recognition based on template matching

The RCS and polarization characteristic of the heavy-duty truck, light truck and care can be recognized by method 4. The parameters are listed in chart 1.

Chart 5 recognition frequency of the single characteristic (method 4)

target and characteristic	70% inaccuracy	50% inaccuracy
heavy-duty truck (RCS)	95%	95%
light truck (RCS)	100%	100%
care (RCS)	80%	85%
heavy-duty truck (polarization characteristic)	80%	90%
light truck (polarization characteristic)	70%	85%
care (polarization characteristic)	80%	90%

## V. Analysis of simulation result

(1) When the single characteristic is used to recognize the mobile targets in the artillery battlefield, it is very important to chose a proper method because it has a strong impact on the target recognition frequency. Recognition method should be determined according to the specific characteristic of the target.

(2) Mobile target can be recognized basing on gray relevance, fuzzy mathematics and template matching. Judging from the simulation result, the highest recognition frequency can be get by using the fuzzy mathematics method. Regarding to gray relevance method, a higher recognition frequency to the limited data can be got by using method 1 than using method 2.

Due to the multiformity and complexity of the recognition targets as well as the variability and uncertainty of the recognition environments, there isn't one universal method that can be used to recognize every typical of target and can be got a good recognition result. To increase the probability of the target recognition frequency, many methods are included in the article. When the specific target to be recognized, multiple methods should be tried to get a better result.

## References

- [1] Dang Hongshe, HAN Chongzhao. *Evidence of reasoning based on target identification method [J]*. Computer Engineering and Applications, 2003,12 (6):25-26
- [2] LIU Tongming, Xia Zuxun,Xiehongcheng. *Data fusion technology and its applications [M]*. Beijing: National Defence Industry Press, 1998
- [3] Jiang wanlu, Li Chongxiang, Liu Jigang. *Multi-sensor data fusion technology and prospects [J]*. Machine tools and hydraulic, 2003,8 (3):16-18
- [4] XU Congfu, Geng Weidong, Pan Yunhe. *Dempster-Shafer evidence theory and application of theoretical methods of synthesis [J]*. Pattern Recognition and Artificial Intelligence, 1999,12 (4):424-42.