Information Fusion Algorithm of D-S Evidential Reasoning and Cross-Layer for Multi-Target Recognition

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Abstract
To make full use of detection information, and improve the accuracy of multiple targets recognition in tracking system, solve the problem of target recognition in complex environment of multiple sensors correlation detection, this paper puts forward an information fusion algorithm between data correlation and D-S evidential reasoning, analyses the error of single sensor for tracking recognition and multiple sensors for fusion recognition, Besides, from the actual output of the sensor, the experiment and analysis of information fusion recognition was given. The results of experiment and simulation show that the information fusion algorithm combined between data correlation and D-S evidential reasoning has higher reliability and recognition ability than the traditional evidential reasoning method, the results verify the correctness and effectiveness of information fusion algorithm.
Key words: INFORMATION FUSION; D-S EVIDENTIAL REASONING; DATA CORRELATION; CROSS-LAYER

1. Introduction

In target tracking system, the tracking and positioning missions of system often are completed by the combination of multiple sensors [1].For tracking system composed of multiple sensors, the output information from sensors has the characteristics of diversity and complexity. Therefore, it is necessary to research fusion identification method for tracking system composed of multiple sensors. 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 [2-3].

In many data fusion methods, evidential reasoning is suitable for the fusion without prior information[4-6]. The advantages of uncertainty representation, measurement and combination have been appreciated extensively. The traditional evidential reasoning method just merges the basic probability assignment function according to D-S evidential reasoning method on the foundation of basic probability assignment function, which does not consider the information correlation characteristics between multiple sensors [7].However, in many practical applications, the information between various sensors has some correlative characteristic. In the presence of strong complex environment interference, the data correlation for target identification contribution is often greater than the output of single sensor itself.

Yet, this part of information is not reflected in the traditional evidential reasoning, which does not make full use of multi-source correlative information.

Therefore, in some occasions, it is need to construct a combinational data fusion method between data association and D-S evidential reasoning, to enhance the system capability of resisting interference and improve the ability of target recognition. According to the output information from multiple sensors, this paper researches information fusion algorithm for tracking target by using Unscented Kalman Filter.

2. Information fusion construction for multi-targets in tracking system

In tracking system, the combinational unit from multiple sensors can be used for tracking path, suppose b_1, b_2, b_3, $\cdots$, b_n are Belief Functions of n sensors unit from same recognition framework Ψ, m_1, m_2, m_3, $\cdots$, m_n are respectively the corresponding basic reliability allocation, $m(A)$ is value of basic reliability allocation on A. If $b_1 \oplus \wedge \oplus b_n$ exist and the value of basic reliability allocation ism, then, $\forall A \subset \Psi, A \neq \Phi$, the formula is as follows:

$$m(A) = \left| \sum_{\substack{A_1,\wedge,A_n \subset \Psi \\ A_1|\wedge|A_n \neq A}} m_1(A_1) \wedge m_n(A_n) \right|^{-1} \sum_{\substack{A_1,\wedge,A_n \subset \Psi \\ A_1|\wedge|A_n \neq A}} m_1(A_1) \wedge m_n(A_n) \quad (1)$$

$m(A)$ is an overall basic reliability combined by the propositionof the n sensors. As shown in Figure 1, $m_1(A_h)$, $m_2(A_h)$, $m_3(A_h)$, $\cdots$, $m_n(A_h)$,($h = 1,2,\cdots,n$) are basic reliability allocation of n sensors for A_h, $m_n(A_h)$ is updated basic reliability allocationobtained from combination of n propositions by Dempster. Using these indexes of credibility and plausibility degree of n propositionsto judge if these propositions are tenable [8-9], and the decision result of n sensors is obtained, the decision result is used to judge whether the tracking signal reallycomes from target information[10].

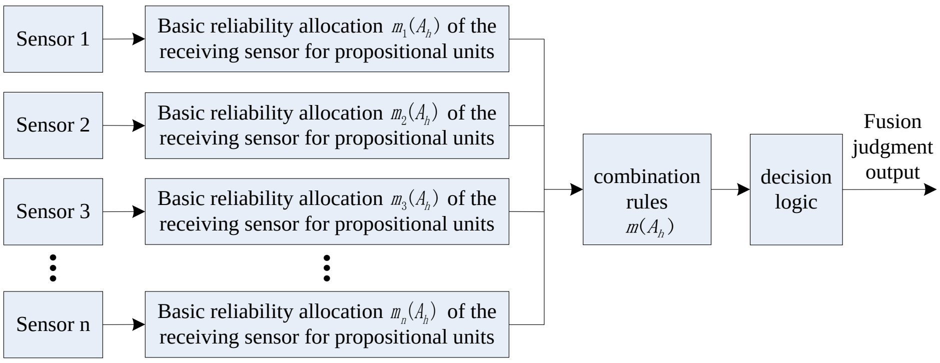


Figure 1. The construction principle of tracking target information fusion

3. Analysis of information fusion method based on data association and D-S evidential reasoning

3.1 D-S evidential reasoning method

Evidence theoryalso isknown as the Dewpster/Shafer evidential reasoning method (D-S evidential reasoning method), which is a kind of imprecise reasoning theory proposed by Dewpster and Shafer in the 1970's[11-12]. D-S evidential reasoning method is the further development of probability theory. It extends the concept of probability theory. The event of probability theory is extended to proposition and a set of event is extended to a set of proposition. The concept of basic probability allocation, belief function and likelihood function are proposed on basis of previous extension[13]. Thecorresponding relation between set and proposition is established which can transform the uncertainty problem ofproposition into the uncertainty problem of set.

Assuming V is a hypotheticset and all elements in the set are mutual independent and complete. Ψ denotes all subsets of the set Z and Ψ is also known as the recognition framework.If the setV has n hypothesis, then Ψ has 2^n subsets, and Φ is the empty set. The emergence of evidence can support some subsets in a certain extent[14].Therefore, for each of the evidence, there is a basic probability assignment function P. P is a mapping from Ψ to $[0,1]$, and the P also satisfy two condition: $P(\Phi) = 0$, $\sum_{A \subseteq \Psi} P(A) = 1$ Where $P(A)$

indicate the basic probability number of A, $0 \le P(A) \le 1$.

$P(A)$ is the basic probability number only provided to A, which reflects the confidence of A, but it is not the total confidence of A. In order to obtain the total confidence of A, it must add the basic probability numbers of all subsets B and B are all subsets of A.Using the confidence function (CF) expressed:

$$CF(B) = \sum_{B \subseteq A} P(B), A \subseteq \Psi \quad (2)$$

The likelihood function （SR） is defined as follows:

$$SR(A) = 1 - CF(\overline{A}) = \sum_{A \cap B \neq \Phi} P(B), A \subseteq \Psi \quad (3)$$

$CF(\overline{A})$ is support for the $\overline{A}$, the value of the likelihood function is used to express implicity degree for A, namely, the value of trust estimation of *A*. [CF(A), SR(A)] is called the confidence interval of *A*.

In the obtainedevidence about the proposition *A*, a part of evidencesupports proposition *A*, which is called supporting evidence; another part of evidence opposes proposition *A*, which is calledrejecting evidence. Furthermore, there is another kind of evidence which is neither obvious support nor obvious opposition to *A*. The concept of the 3 types evidence and the uncertainty measure is shown as Figure 2, and the total length value of the interval is 1.

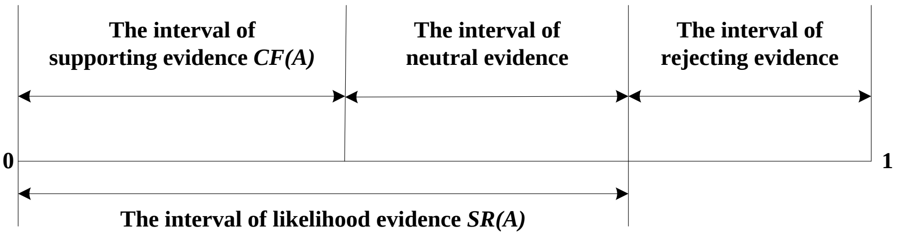


Figure 2.the uncertainty measure of the three types evidence

In practical problems, this situation usually appearedthat multiple evidences support a hypothesis or support the opposite of that hypothesis. At this time, we need to calculate the value of CF and P under the combination of evidences, and its structural rules are as follows:

$$P(A) = P_1(A) \oplus P_2(A) = \sum_{X \cap Y = A} \frac{P_1(X) \times P_2(Y)}{H} \quad (4)$$

$$H = 1 - \sum_{X \cap Y = \Phi} P_1(X) \times P_2(Y) = \sum_{X \cap Y \neq \Phi} P_1(X) \times P_2(Y) \quad (5)$$

3.2 Recognition information fusion algorithm on target of Cross-Layer

Assuming the measurement equation of a sensor S_i is:

$$O_i = f[I_i(a), K_i] + \sum N + \sum N_{in} \quad (6)$$

In(6), the sensor output is $O \in R^L$, the target signal input is $I_i \in R^L$, the internal parameters variable of sensors are $K_i \in R^n$, N is the environmental noise,Nin is internal noise.

Assuming $(\sum N' + \sum N'_{in})$ is the specific noise data of upper platform detective.Then,

$$O'_i = O_i - (\sum N' + \sum N'_{in}) = f[I_i(a), K_i] + \sum N + \sum N_{in} - (\sum N' + \sum N'_{in})$$
$$= f[I_i(a), K_i] + \sum N' + \sum N'_{in} \quad (7)$$

In (7), O_i is the sensor output after removing noise used by cross-layer information. $\sum N' + \sum N'_{in}$ is the sensor noise after removing noise used by cross-layer information[15].

Assumingthe SNR of original sensor S_i is ℓ, and the probability of detection is g, when $\sum N' + \sum N'_{in}$ is subtracted from the O_i, the SNR of S_i is ℓ'.

$$\ell' = \frac{\sum N + \sum N_{in}}{\sum N + \sum N_{in} - (\sum N' + \sum N'_{in})} \ell = \frac{\sum N + \sum N_{in}}{\sum N' + \sum N'_{in}} \ell \quad (8)$$

In practical applications, the target detection probability of sensor largely depends on the SNR, so the correction detection probability of sensor S_i is g'.

$$g' = \kappa \frac{\sum N + \sum N_{in}}{\sum N' + \sum N'_{in}} g \quad (9)$$

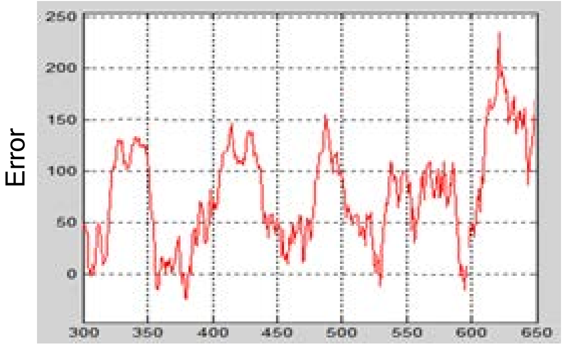
κ is correction factor, When the detection probability of each sensor in accordance with the original wireless sensor network is amended, the information of multiple sources sensors can be used by combination rules of D-S evidential reasoning in formula (4) to obtain the final tracing result.

4. Simulation calculation and experiment

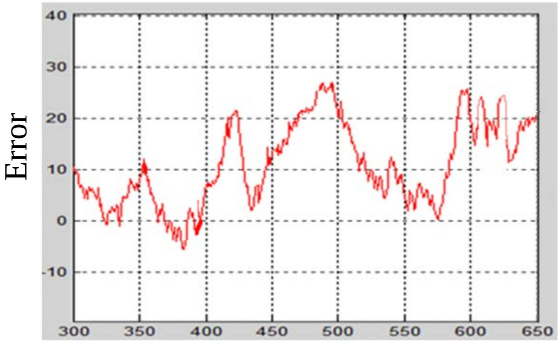
4.1Trajectory information for tracking target of sensor

In order to evaluate the effect of the fusion algorithm in tracking measurement technology, this paper uses the MATLAB simulation software to simulate the experiment, using Monte Carlo method to experiment, and the result is averagevalue of many timesexperiments, thenumber of times on experiments general is 50.

Firstly, the simulation system is initialized, the simulation time is set to TF[0,650s], the initial value of standard system is the st (0) and the initial value of measurement condition is s (0). Under these conditions, the generator for producing trajectory is created. In order to reflect theauthenticity of simulation system, considering the actual trajectory of the system should have a certain random and maneuvering. The actual motion trajectory is selected within the 200s. Then, Using Calman filter to respectivelysimulate the single sensor data and multiple sensors data, and the tracking pathsfrom signal sensor and multiple sensors are simultaneouslyshowed. Simulation results are as follows in Figure 3.



(a) The error of single sensor



(b) The error of multiple sensor

Figure 3. The error comparison of single sensor and multiple sensors

Figure 3 shows the error of system for tracking target in [300s, 650s]. Figure 3 (a) is the test data for a single sensor. From Figure 3 (a), it can be seen that the part in sharp increasearea should be the time of target maneuver, and the error on 320s and 635s, the value of error reached and exceeded 200.Figure 3 (b) is test data of multiple sensors. In Figure 3 (b), the value of measurement error in 450s and 500s are the largest in neighboring areas, but the values never exceeded 28.Contrastingthe Figure 3 (a) and (b), when the system uses a single sensor to measure, the value of error can reach 200; and when the system uses multiple sensors to measure, the value of error is in the vicinity of 25. It can be seen that the data fusion of multiple sensors can effectively reduce the error on maneuver time, which can achieve the purpose of rapid convergence and make the tracking system more stable.

4.2 Experiment and analysis of data fusion recognition

In order to examine the effect of information fusion between theD-S evidential reasoning method anddata association for multiple targets in tracing system, using three targets of tracing system carried on the experiment for data fusion and recognition.Assuming the target recognition framework is $\Psi=\{T_1,T_2,T_3\}$,and T_1,T_2,T_3 are three targets. The system uses three kinds of sensors. The basic probability assignment of a sampling period is shown as table 1. Ψ represents the basic probability assignment of uncertainty proposition.

Table 1. Basic probability assignment of three kinds of sensors

recognized target	T_1	T_2	T_3	Ψ
s_1	0.22	0.24	0.25	0.28
s_2	0.25	0.32	0.15	0.35
s_3	0.21	0.15	0.25	0.33

Without the data association, the results of combined evidence obtained only by the D-S evidential reasoning method are showed in table 2. It can be seen that, the recognition probability of result for combined evidence has a certain degree improvement by using the D-S evidential reasoning method.

Table2. Basic probability assignment for 3 kinds of combined evidence without considering the correlation information

recognized target	T_1	T_2	T_3	Ψ
S_{123}	0.32	0.30	0.24	0.16

Assuming the two groups of sensors have pairwise correlation, the correlation obtained by the analysis of actual acquisition signal is shown as follows.

Table3. Correlation distribution between evidence of sensor

Correlation	T_1	T_2	T_3
Ks_1s_2	0.79	0.63	0.51
Ks_1s_3	0.62	0.51	0.37
Ks_2s_1	0.51	0.42	0.59
Ks_2s_3	0.79	0.69	0.60
Ks_3s_1	0.67	0.53	0.71
Ks_3s_2	0.58	0.66	0.40

The probability assignment of each sensoramended by calculation on correlation is shown in table 4. It can be seen that the detection probability of each sensor is improved to some extent after the introduction of correlation information.

Table4. Probability assignment of each sensor amended by the calculation on correlation

recognized target	T_1	T_2	T_3	Ψ
s_1'	0.362	0.301	0.241	0.099
s_2'	0.260	0.298	0.181	0.271
s_3'	0.324	0.199	0.257	0.262

When the probability assignment is amendedby the calculation on correlation, then adding the D-S evidential reasoning to the probability assignment, the combined evidence can be obtained in table 5.

Table5. Basic probability assignment combined between amended value and the D-S evidential reasoning

recognized target	T_1	T_2	T_3	Ψ
s_{12}'	0.4004	0.3730	0.2248	0.0510
s_{123}'	0.4672	0.3427	0.2354	0.0231

Table6. Comparison between thecombined resultsof original D-S andthecombined results of introduction on correlative information

recognized target	T_1	T_2	T_3	Ψ
s_{123}	0.32	0.30	0.26	0.16
s_{123}'	0.4583	0.4024	0.2836	0.1729

By comparison of the two combined results, It can be seen that the latter has obvious higher identification probability and accuracy, at the same time, the uncertainty of system reduces obviously. It shows that the target recognition rate of tracking system can be greatly improved by using the reasonable data fusion method when the information of multi-source sensors is made full use.

5. Conclusions

Based on the recognition method of information fusion for multiple targetsin target tracking system, This paper researched combined information fusion between data correlation and D-

S evidential reasoning, and provided the detailed process of analysis and reasoning, and the error analysis of single sensor for tracking recognition and multiple sensorsfor fusion recognitionhas done combined the tracking target trajectory information of the output from sensor; Besides, from the actual output of the sensor, the experimentand analysis of information fusion recognition was given. From the comparison result, compared with the traditional D-S evidential reasoning method, when the cross-layer information is introduced by appropriate method, the accuracy of target recognition has been obviously improved in multiple sensors system and the uncertainty of system has been obviously reduced. The problem of anti-interference in specific environment can be solved via flexible application of cross-layer information fusion method. This paper proposed a new idea and an approximate method for engineering treatment about the information correlation of multiple platforms and cross-layer, to improve the accuracy of multiple targets recognitionin tracking system.

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