A New Safety Evaluation Model of Coal Mine Roof based on Multi-sensor Fusion in case of Information Confliction

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***Abstract*—Factors that affect the safety of coal mine roof is a multi-faceted, information fusion technology can take full advantage of multi-source information complementary and comprehensive, and improving information quality and credibility of coal mine roof safety. In analyzing the current monitoring means, a coal mine roof safety evaluation model is presented based on Dempster-Shafer evidence fusion theory , After normalizing the various sensor data, the model can acquire the basic probability assignment of the system judging the security situation of the roof, and then using the Dempster-Shafe synthesis rule to synthesize the multi-evidence, and acquiring the whole judgment of the security situation of the roof; as to the problem of the failure of Dempster evidence synthesis rule under the high conflict, establish similarity matrix through the evidence distance, determine the weight coefficient of the evidence, and use the Dempster rule to combine after the pretreatment of the evidence. Through the simulation and compared with other improved methods, the model is proved to decrease the influences that the conflict makes to the combination result, and at the same time improve the convergence rate of evidence combination and reduce the risk of decision-making under the high conflict evidence.**

***Index Terms*— roof safety evaluation model, high conflict evidence, D-S evidence theory, multi-sensor data fusion.**

I. INTRODUCTION

In recent years the major safe accidents frequently occurred during coal mining has aroused the Party Central Committee and State Council to pay high attention, and has aroused the society's extensive concern. In all kinds of mining accidents, the coal mine roof accidents is still top. In analyzing the causes of the accident, the major reason is that in the coal mine production process, there is a lack of effective monitoring means and information processing technology, the usual roof safety monitoring mainly contains:mechanized support pressure monitoring,the coal mine roof abscission layer displacement monitoring, electromagnetic radiation monitoring, micro seismic monitoring and so on, but these means reflect conditions of roof safety from different aspects, and with many uncertain factors, thus unable to comprehensively evaluate the conditions of the roof safety, and now the monitoring data has large discreteness, the data processing mean is relatively backward, the feedback time to direct production lags behind, also not near the alarm or warning before the accident happen. According to these problems that exist in the monitoring means of coal mine roof, promoting model for safety evaluation of coal mine roof based on information fusion, has great significance for the prevention of coal mine roof accidents.

Information fusion technology is an automated comprehensive information processing technology developed in recent years, through the information from different sensors be processed in order to improve the quality of information and improve the accuracy of the information. The data fusion can be divided into the raw data level, feature level and target level according to different levels of data abstraction. There are many ways for data fusion, such as Kalman filtering, clustering analysis, expert systems approach, geostatistics and multivariate statistical methods, Bayes statistics, D-S evidence theory, artificial neural networks, data mining, rough set theory and so on [1-6]. In this the method of D-S evidence theory application is relatively common, it is a promotion of classical probability theory, uses the credibility function and the likelihood in interpretation of multi-valued mapping, constructs uncertainty reasoning model framework. This paper will use the D-S evidence theory fusing factor information which is optimized for the effect of the coal mine roof safety, thus carry out roof stability evaluation.

II. D-S EVIDENCE THEORY FUSION PRINCIPLE

D-S evidence theory is proposed by Dempster[1] in 1967,and developed by *mathematical method of the evidence* published by Shafer[2] in 1976.D-S theory is

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used when multi-sensor data fuse, and get information by the sensors, thus generates a measure of certain propositions, and forms the evidence of the theory, the use of these evidences constructing the corresponding basic probability assignment function, and giving a credibility for all propositions.

A. Credibility function and the likelihood function.

Suppose there is a decision problem, the set of all the possible result of this problem that can recognize is X: $X=\{x_1, x2,\ldots,x_n\}$, name X as frame of discernment, that can be formed by some elements which are exclusive and can be exhaustively cited. The power set 2^x of X forms a proposition set, for any proposition A in problem domain, always there is $A \in 2^x$, if the measurement function m: $2^x \to [0,l]$ content:

$$\begin{cases} m(\Phi)=0 \\ \sum_{A\subset X} m(A)=1 \end{cases} \tag{1}$$

In this, Φ is null, so name m as the basic credibility assignment of the frame of discernment of X, $\forall A \in X$,name $m(A)$ as basic credibility of A, also name $m(A)$ as basic probability assignment. If $A \subseteq X$, and $m(A)>0$, then name A as focus element.

In the D-S evidence theory, the description of event A use the interval $[Bel(A),Pl(A)]$, name it as confidence interval, the function between $Bel(A)$ and $Pl(A)$ is defined as:

$$\begin{cases} \mathrm{Bel}(A)=\sum_{A\subset X} m(B) \\ \mathrm{Pl}(\mathrm{A})=\sum_{A\cap B\not\subset X} m(B) \end{cases} \tag{2}$$

So name $Bel(A)$ as credibility function, $Pl(A)$ as the likelihood function, Bel and Pl are maximum probability and minimum probability that Dempster has said, the confidence interval $[Bel(A),Pl(A)]$ is the variation range of the proposition of the event A.

In the D-S evidence theory, the use of confidence interval for the description of events is $[Bel(A),Pl(A)]$, name this as confidence interval, in this, $Bel(A)$ shows the support level about the proposition "A is true" , $Pl(A)$ shows the level that can't deny the proposition "A is true", $Pl(A)- Bel(A)$ shows the unknown level about the event A.

B. Synthesis rule.

Dempster synthesis rule is used to merge evidences and update the credibility function. For the two credibility functions Bel_1, $Bel2$ under the same frame of discernment, if m_1, $m2$ are the corresponding basic credibility assignment, thus the orthogonal sum of the two credibility functions is: $A=A_i\cap B_i$, its total probability is:

$$\mathrm{Bel}(A)=\sum_{A_i \cap B_j=\Phi} m_1(A_i)m_2(B_j)<1 \tag{3}$$

If $A_i\cap B_i=\Phi$,but $\sum_{A_i\cap B_j=\Phi} m_1(A_i)m_2(B_j)>0$,for the total probability is 1,so we must delete $Ai\cap Bi=\Phi$ partly, and reallocate the probability, and by taking advantage of normalization factor the formula (3) can be rewritten as:

$$m(C)=\begin{cases} 0, A=\Phi \\ \dfrac{\sum_{A_i\cap B_j=C} m_1(A_i)m_2(B_j)}{1-\sum_{A_i\cap B_j=\Phi} m_1(A_i)m_2(B_j)}, A\neq\Phi \end{cases} \tag{4}$$

Among this, $\left[1-\sum_{A_i\cap B_j=\Phi} m_1(A_i)m_2(B_j)\right]^{-1}$ is the normalize factor. If make

$$K=\sum_{A_i\cap B_j=\Phi} m_1(A_i)m_2(B_j)$$

then the formula (4) can be rewritten as:

$$m(C)=\begin{cases} 0, A=\Phi \\ \dfrac{1}{1-K}\sum_{A_i\cap B_j=C} m_1(A_i)m_2(B_j), A\neq\Phi \end{cases} \tag{5}$$

For many credibility functions, their synthesis rule is as follows: suppose $Bel_1,Bel_2,\ldots,Beln$ are the credibility functions that base on frame of discernment of X, and $m_1,m_2,\ldots,m_n$ are the corresponding basic probability assignment, if $Bel_1,Bel_2,\ldots,Beln$ exist and the basic probability assignment is m, thus $\forall Z \in X$ ($Z\neq X$). The synthesis formula of the n evidence sources is defined as:

$$m(Z)=\frac{1}{1-K}\sum_{A_i\cap B_j\cap C_k\cap\ldots=Z} m_1(A_\mathrm{i})m_2(B_\mathrm{j})m_3(C_\mathrm{k})\ldots \tag{6}$$

Among this:

$$K=\sum_{A_i\cap B_j\cap C_k\cap\ldots=\Phi} m_1(A_i)m_2(B_j)m_3(C_k)\ldots \tag{7}$$

C. Synthesis rule paradox and its solution.

Form the evidence synthesis rule in section 1.2, when the conflict factor K is equal to 1, this means that the evidence completely conflicts, then it can't synthesize; When K is less than 1, this means that although it has conflict, it has consistency, so it can synthesize; when K is close to 1, it can fuse the evidence according to synthesis rule, but because the conflict factor is close to 1, the synthesis results often bring paradox.

The following given a simulation of paradox of synthesis rule. Suppose that the frame of discernment $X=\{A,B,C\}$, then there are two evidences as follows:

$$m_1(A)=0.99, m_1(B)=0.01, m_1(C)=0;$$
$$m_2(A)=0, m_2(B)=0.01, m_2(C)=0.99;$$

Synthesize the two evidences, firstly, calculate the conflict factor K , by the formula (5):

$$K=m_1(A)\times m_2(B)+m_1(A)\times m_2(C)+m_1(B)\times m_2(C)$$
$$=0.99\times0.01+0.99\times0.99+0.01\times0.99=0.9999$$

Because of K is close to 1, this means that the conflict is great,at this point if combining with D-S synthesis rule ,we can get the results as follows:

$$m(A)=0,m(B)=1,m(C)=0$$

As a result of the support that the two evidences make to B is only 0.01, while the support that the fusion result makes to B is up to 1, so when K is close to 1, the D-S synthesis rule contrary to common sense.

In D-S theory, the earliest evidence synthesis formula is Dempster formula, this formula particularly emphasize the coordination among many evidences, and abandon all the conflicting evidences. Therefore when use the Dempster formula to synthesize the high conflicting evidences, the results often contrary to common sense, consequently some researchers propose new revised formula, such as Yager synthesis formula[8] the improved formula proposed in references [9-16] and so on, the important difference among these formulas is the different treatments that make to the evidences' conflict.

In order to solve the problem of high evidence conflict, according to reference [8], Yager makes some improvements to Dempster formula, and proposes Yager formula:

$$\begin{aligned} &m(\Phi)=0 \\ &m(A)=\sum_{A_i\cap A_j\cap A_k\cap\cdots=A} m_1(A_i)m_2(A_j)m_3(A_k)\ldots, A\neq\Phi \\ &m(X)=\sum_{A_i\cap A_j\cap A_k\cap\cdots=A} m_1(A_i)m_2(A_j)m_3(A_k)\ldots+K \end{aligned} \tag{8}$$

Among this, K is similar to the definition in Dempster formula.

Yager uses computing synthesis method to synthesize the evidence that doesn't have conflict, and doesn't abandon all the conflicting evidences, but gives all the part of probability that support evidence conflict to unknown field. Although Yager formula can synthesize the high conflict evidence, because of it entirely negative conflicting evidence, thus when the source of evidence is more than 2, the synthesis result is unsatisfactory[12,15]. The methods of conflict solution that proposed in references [9-17], all considered the method of determining the weight coefficient of every evidence and the alternation of synthesis rule, but don't consider the cross-cutting and the extent of fusion, and the steps of information treatment are complicated.

Based on the analysis of the above synthesis formulas, the paper combines this paper's actual application environment and proposes a new synthesis formula, and determines the mutual support of evidence according to evidence distance. And it regards the eigenvector which the maximal Eigen value of module of the evidence support matrix corresponds to as weight vector of evidence, in this the critical evidence is the evidence which has the greatest weight coefficient, then gets the relative discount factors of every evidence, afterward discount the information of every evidence, at last uses D-S rule to fuse.

The reference [17] gives the definition of distance between the evidences of m_1, m_2 as follows:

$$\begin{aligned} &d(m_1,m_2)=\sqrt{\frac{1}{2}d\left(\vec{m_1}-\vec{m_2}\right)^T \underline{\underline{D}}\left(\vec{m_1}-\vec{m_2}\right)} \\ &D(A,B)=\frac{|A\cap B|}{|A\cup B|} \end{aligned} \tag{9}$$

In this, $\underline{\underline{D}}$ is a matrix of $2^N\times 2^N$, $A,B\in X$, X is the frame of discernment, N is the number of the basic assumption in X.

Suppose that there are n sensors information, so create n evidences $m_1,m_2,\ldots,m_n$, in the paper the steps of fusion algorithm are as follows:

(1) Determine the mutual support matrix according to evidence distance. Calculate the distance between the n evidences according to formula (9), and can determine the mutual support between two evidences according to evidence distance, denoted as:

$$Support(i,j)=1-d(i,j) \tag{10}$$

Get the n×n dimension mutual support matrix of evidence according to formula (10):

$$S=\begin{bmatrix} 1 & S_{(1,2)} & \cdots & S_{(1,n)} \\ S_{(2,1)} & 1 & \cdots & S_{(2,n)} \\ \vdots & \vdots & \vdots & \vdots \\ S_{(n,1)} & S_{(n,2)} & \cdots & 1 \end{bmatrix}$$

(2) Calculate the whole support λ_i that other evidences make to evidence m_i. According to the mutual support matrix S, calculate the whole support that other evidences make to evidence m_i. That is the weight coefficient of evidence m_i.

$$\lambda_i=\sum_{j=1}^{n} S_{(i,j)} \tag{11}$$

(3) Calculate the relative discount factors of evidence m_i. Choose the evidence which has the greatest weight coefficient that is the evidence has the greatest credibility as the critical evidence, and its weight coefficient is:

$$\lambda_{max}=max(\lambda_1,\cdots,\lambda_i,\cdots,\lambda_n) \tag{12}$$

Next, get the relative weight vector of every evidence:

$$\lambda'=\frac{[\lambda_1,\cdots,\lambda_n]}{\lambda_{\max}} \tag{13}$$

Then get the relative discount factors of every evidence:

$$\xi_i=\frac{\lambda_i}{\lambda_{\max}} \tag{14}$$

(4)Amend the basic probability assignment of evidence according to the relative discount factors.

$$\begin{cases} m_i^*(A)=\xi_i m_i(A), A\subseteq X \\ m_i^*(X)=1-\xi_i+\xi_i m_i(X) \end{cases} \tag{15}$$

Here X is the frame of discernment.

(5)According to formula (15), give the amendatory *BPA* value $m_i^*(A)$ to Dempster synthesis rule, and calculate the fusion result.

Through the treatment of this algorithm, the fusion result of multi-sensors' information is determined by the sensor's information which has greater weights and higher credibility, however, those respective sensor's information which has high conflict and possibly caused by the noise jamming, because of its lower weight, its influences to fusion result decreased, and this is beneficial to quickly get the correct judgment and decision-making according to the fusion result.

III. THE EVALUATION MODEL OF ROOF SAFETY BASED ON DEMPSTER-SHAFER EVIDENCE THEORY

A. Factors affecting the roof safety & monitoring methods.

At present, many scholars and research institutions at home and abroad conduct the safety monitoring research of the roof from the roof pressure, the roof separation, advance support pressure, electromagnetic radiation, micro-seismic and so on[18,24], and launch a series of monitoring systems, because these systems research from different starting points, and all have their own distinct characteristics, but there are many deficiencies, thus if we can use the data provided by various systems to make information fusion, we can get the satisfactory monitoring effects of the roof. Currently the data got from real-time monitoring data and the main source of other information shown in Figure 1.

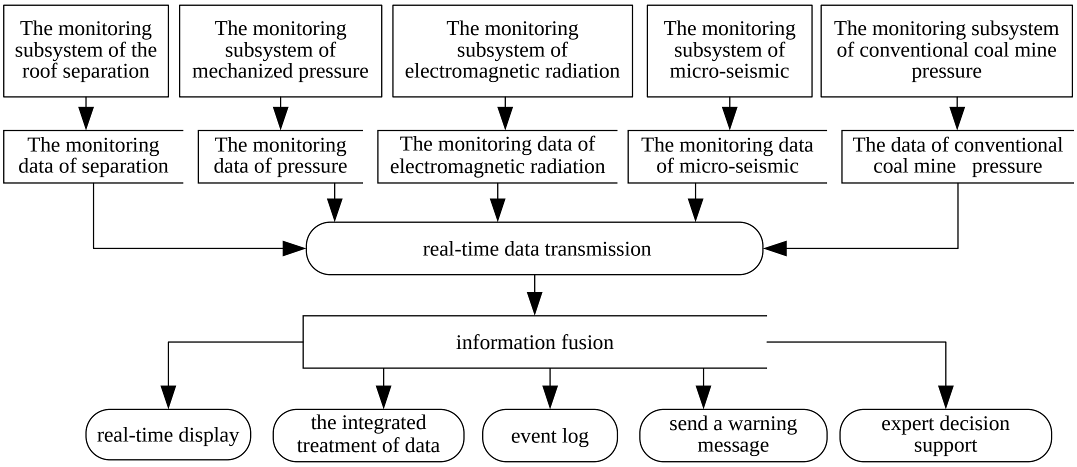

Fig.1 Monitoring data source of coal mine roof

B. The foundation of evaluation model.

The D-S evidence theory is used for multi-systems information fusion, its essence is under the same Frame of Discernment, using the Dempster synthesis rule, basic probability assignment of different evidence bodies are merged into one general probability assignment, and then it can be decided by decision rule.

According to psychological research, because of the limitations of people's recognition capability, the numbers of classification generally is better not more than 7,this paper according to the real production situation of coal mine, and define the state of roof safety as 5 dangerous classifications, expressed as: $S=\{S_1,S_2,S_3,S_4,S_5\}$, The meaning of each state in Table I.

TABLE I. ROOF SAFETY STATUS TABLE

Rank	Meaning	Warning Signal
S_1	very dangerous	orange alert
S_2	dangerous	red alert
S_3	more dangerous	yellow alert
S_4	more safe	blue signal
S_5	safe	green signal

Suppose there are n kinds of sensors(source) to monitor the coal mine roof state, the evaluation of every sensor is denoted by m_i, $i=1\ldots n$, then the system's basic credibility can be allocated as:

$$m_1(A_1)=x_1,\ \ A_1=\{S_1\}$$
$$m_2(A_2)=x_2,\ \ A_2=\{S_2\}$$
$$\ldots$$
$$\sum_{i=1}^{n} m_i = 1$$

First, calculation conflicting values of each sensor according to formula (7) :

$$K=\sum_{A_1\cap A_2\ldots\cap A_n=\Phi} m_1(A_1)m_2(A_2)\ldots m_n(A_n)$$

Decide whether it can use the D-S evidence theory according to the value of K, when K=1 or close to 1, then think that $A_1,A_2,\ldots,A_n$ are contradictory, and can't combine the basic credibility assignment, but can combine after the treatment of high conflict evidence according to the method proposed in section II; if K!=1,then we can use formula (6) to determine one basic credibility assignment, also we can make them combine with each other according to formula (5). The data fusion and decision-making process shown in Figure 2.

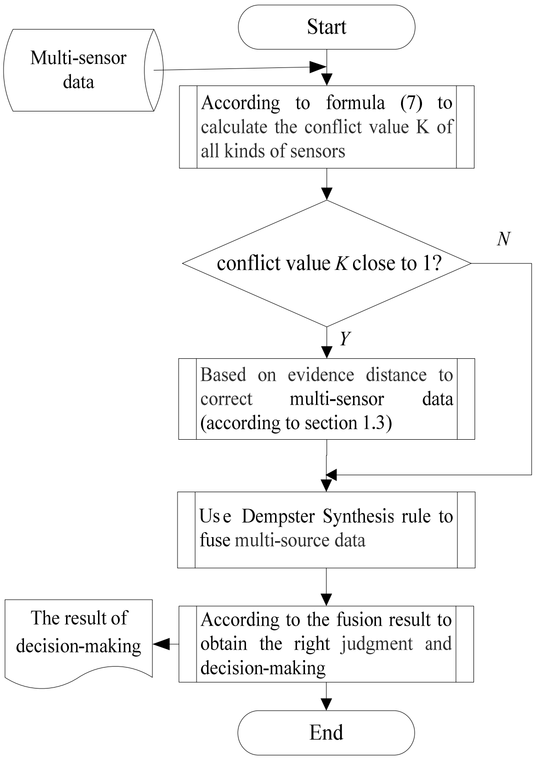

Fig.2 Data fusion and decision-making process

C.Security state decision-making rules.

After obtaining the basic credibility assignment for the use of Dempster synthesis rule, we must make decisions according to decision-making rule, while the decision-making rule must be ensured by the specific issues; currently mainly use the basic probability assignment method [19-23]. This paper based on the application area of the evaluation of roof safety, proposes the following decision-making rule of security state classification of the roof:

(1) The objective state of roof safety should have the greatest basic probability assignment;

(2) The basic probability assignment of the objective state must be greater than the uncertainty basic probability assignment.

(3) The margin between the basic probability assignment of the objective state and other type of basic probability assignment should be greater than or equal to the setting threshold 0.20;

(4) The uncertainty basic probability assignment of objective state should be less than the setting threshold 0.30.

IV SIMULATION ANALYSIS

A.Simulation 1.

Suppose that the system uses 3 types of sensor m_1—mechanized support pressure sensor,m_2—coal mine roof separation instrument,m_3—electromagnetic radiation instrument, the objective recognition framework is $S=\{S_1, S_2, S_3\}$, respectively show the three different states of the safety of coal mine roof, the basic probability assignment of each sensor corresponding in one sampling period showed in Table II, in this, S figures the basic probability assignment of uncertain proposition.

TABLE II. BASIC PROBABILITY ASSIGNMENT

State	S_1	S_2	S_3	S
$M_1(*)$	0.25	0.35	0.15	0.25
$M_2(*)$	0.2	0.4	0.3	0.1
$M_3(*)$	0.2	0.3	0.3	0.2

Through the evidence theory synthesis rule, the basic probability of sensors m_1 and m_2 fused $m_{1\times 2}$, and its combinations showed in Table III.

TABLE III. COMBINATIONS OF m_1,m_2

	$m_1(*)$				
$m_2(*)$		0.25	0.35	0.15	0.25
	0.2	0.05	0.07	0.03	0.05
	0.4	0.1	0.14	0.06	0.1
	0.3	0.075	0.105	0.045	0.075
	0.1	0.025	0.035	0.015	0.025

From Table 2, according to the calculation of formula (7),we can obtain the conflict factor of the evidence $m_1(*)$, $m_2(*)$ is:

$$K = 0.07+0.03+0.1+0.06+0.075+0.105=0.44$$

The basic probability assignment of the sensor m_1、m_2 that after fusing are:

$$m_{1\times 2}(S_1) = \frac{0.05+0.05+0.025}{1-K} \approx 0.223$$
$$m_{1\times 2}(S_2) = \frac{0.14+0.1+0.035}{1-K} \approx 0.491$$
$$m_{1\times 2}(S_3) = \frac{0.045+0.075+0.015}{1-K} \approx 0.241$$
$$m_{1\times 2}(S) = \frac{0.025}{1-K} \approx 0.045$$

Similarly, we can calculate the evidence conflict factor $K=0.4998$ of the sensors m_1、m_2 and m_3, the basic probability assignment after fusing showed in Table IV.

TABLE IV. RESULT OF DATA FUSION

	S_1	S_2	S_3	S
$m_{1\times 2}(*)$	0.223	0.491	0.241	0.045
$m_{1\times 2\times 3}(*)$	0.196	0.518	0.268	0.018

From Table II, although that the basic probability assignment of each sensor in the state of S_2 are to the maximum, but the basic probability assignment of the uncertainty proposition S is also great, so we can't clearly judge which state the object in from the single sensor, with the fusion of many evidences, with the integration of the uncertainty for the judgment of the state, and the basic probability assignment of state S_2 is also prominent.

With the results in Table IV, and according to the decision-making rule of security state in section 3.3 we can determine, that the state S_2 is the greatest credibility, and accord the threshold that set by the decision-making rule of security state, so the state S_2 satisfy the fusion rule, and the results of the roof security state identification is S_2, and this is in line with the result that the expert system determined.

B.Simulation 2.

The basic situation of the system is similar to simulation 1. The following is the situations in one sampling cycle acquire the basic probability assignment of evidence of all kinds of sensors:

TABLE V. BASIC PROBABILITY ASSIGNMENT

State	S_1	S_2	S_3
$m_1(*)$	0.5	0.2	0.3
$m_2(*)$	0	0.9	0.1
$m_3(*)$	0.6	0.1	0.3
$m_4(*)$	0.8	0.1	0.1

Calculate the evidence distance matrix according to the fusion algorithm steps in section II :

$$D=\begin{bmatrix} 0 & 0.7 & 0.1 & 0.3 \\ 0.7 & 0 & 0.8 & 0.8 \\ 0.1 & 0.8 & 0 & 0.2 \\ 0.3 & 0.8 & 0.2 & 0 \end{bmatrix}$$

From matrix D, the evidence $m_2(*)$ has great conflict to evidence $m_1(*),m_3(*),m_4(*)$, and the degree of conflict reaches 0.7,0.8,0.8; the degree of conflict among other evidences is lower, and are below 0.3. So in the process of evidence combination, the weight coefficient of evidence $m_2(*)$ is lower to other evidences, and the weight coefficient of other evidences is similar.

Then the evidence mutual support matrix of 4×4 dimensions is:

$$S=\begin{bmatrix} 1 & 0.3 & 0.9 & 0.7 \\ 0.3 & 1 & 0.2 & 0.2 \\ 0.9 & 0.2 & 1 & 0.8 \\ 0.7 & 0.2 & 0.8 & 1 \end{bmatrix}$$

According to formula (11), calculate the weight coefficient vector of every evidence $\lambda=\{2.9,1.7,2.9,2.7\}$; According to formula (12)、(13), calculate the relative weight vector of every evidence $\xi=\{1.000,0.5862,1.000,0.9310\}$, that the relative discount factor of every evidence . According to formula (15), after a discount treatment makes to the basic probability assignment of every evidence, combine the evidence in terms of Dempster synthesis rule, the result of combination shown in Table VI.

TABLE VI.RESULT OF COMBINATION

Method	$m_{1\times2}(*)$	$m_{1\times2\times3}(*)$	$m_{1\times2\times3\times4}(*)$
Dempster [1]	$m(S_1)$=0 $m(S_2)$=0.8571 $m(S_3)$=0.142 $m(X)$=0	$m(S_1)$=0 $m(S_2)$=0.6667 $m(S_3)$=0.3333 $m(X)$=0	$m(S_1)$=0 $m(S_2)$=0.6667 $m(S_3)$=0.1429 $m(X)$=0
Yager[8]	$m(S_1)$=0 $m(S_2)$=0.18 $m(S_3)$=0.03 $m(X)$=0.89	$m(S_1)$=0 $m(S_2)$=0.018 $m(S_3)$=0.009 $m(X)$=0.973	$m(S_1)$=0 $m(S_2)$=0.0018 $m(S_3)$=0.0009 $m(X)$=0.9973
Murphy[9]	$m(S_1)$=0.1543 $m(S_2)$=0.7469 $m(S_3)$=0.0988 $m(X)$=0	$m(S_1)$=0.3912 $m(S_2)$=0.5079 $m(S_3)$=0.1008 $m(X)$=0	$m(S_1)$=0.7996 $m(S_2)$=0.1752 $m(S_3)$=0.0251 $m(X)$=0
Reference [11]	$m(S_1)$=0.1331 $m(S_2)$=0.4727 $m(S_3)$=0.1364 $m(X)$=0.2578	$m(S_1)$=0.2448 $m(S_2)$=0.2851 $m(S_3)$=0.1648 $m(X)$=0.3053	$m(S_1)$=0.3341 $m(S_2)$=0.2304 $m(S_3)$=0.1416 $m(X)$=0.2939
Reference [13]	$m(S_1)$=0.2024 $m(S_2)$=0.6851 $m(S_3)$=0.1125 $m(X)$=0	$m(S_1)$=0.4419 $m(S_2)$=0.3896 $m(S_3)$=0.1865 $m(X)$=0	$m(S_1)$=0.6324 $m(S_2)$=0.2427 $m(S_3)$=0.1249
Method in this paper	$m(S_1)$=0.3854 $m(S_2)$=0.3507 $m(S_3)$=0.2639 $m(X)$=0	$m(S_1)$=0.6692 $m(S_2)$=0.1016 $m(S_3)$=0.2292 $m(X)$=0	$m(S_1)$=0.9104 $m(S_2)$=0.0276 $m(S_3)$=0.0620 $m(X)$=0

From Table VI, Dempster rule can't provide effective treatment for conflicting evidence , if the support that one evidence provides for one proposition is 0, no matter how much support probability other evidence provides for the proposition, the combination result is 0, apparently this is unreasonable; Yager allocates all the part of probability which includes evidence conflict to X, the value of the unknown term $m(X)$ increases with the amount of evidence growing, thereby leading to increase of the uncertainty of combination result; the method of Murphy doesn't consider the relativity among evidences, and only has a simple average to evidence; The references [11] and [13] don't have enough precision of probability assignment, also has slow convergence, and only when the collected evidences amount to more than 4, then it can make correct decision-making. The proposition S_1 of the combination results in this paper has the greatest probability, and reaches 0.9104, also when collect three evidences, then it can get correct result.

V. CONCLUSIONS

(1) Because the assessment of the roof security state is a nonlinear system, the factors that affect the roof safety have multi-sources, when carrying out roof caving forecasts, only to make treatment or policy decisions independently for a specific kind of information, and this may affect the accuracy of the prediction results, so this

paper proposes the data fusion technology is used for multi-source monitoring data processing of the roof, can be effectively eliminate the uncertain factors of multi-source data information, thereby improve the accuracy of the roof safety assessment, also prove its rationality.

(2) The improved algorithm D-S proposed in this paper considers the weight of evidence in the process of combination, determines the mutual support among evidences based on evidence distance, and finally gets the weight coefficient of every evidence.

(3) The simulation demonstrates the algorithm in this paper can effectively deal with the evidence conflict, also can get correct results in the case of less evidence, and it reduces the risk of decision-making, and when evidences have conflict it improves the credibility of fusion results.

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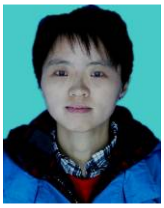

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