Uncertain Internet Public Opinion Emergency Decision System Based on Case Reasoning and Grey Relational Analysis

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Abstract: To facilitate uncertain internet opinion emergency decision involved with multiple fuzzy index values, we design a new prewarning decision system mechanism for uncertain internet opinion emergency based on case reasoning and grey relational analysis. Through the invented software in recent patents in data mining areas we first collect the internet opinion and detect the emergency data. Then by calculating the comprehensive grey relational coefficient between the unknown internet opinion emergency and each source emergency case, we can easily retrieve the optimal historical case for current emergency problem. And the related emergency managers may adopt or modify the corresponding warning decision solution of the most matched source case to make urgent decision for the new occurred internet public opinion emergency with uncertain indexes and incomplete weight information.

Keywords: Case reasoning, distance measure, grey relational coefficient, warning decision system.

1. INTRODUCTION

Internet public opinion emergency is a kind of the unconventional emergency induced by internet opinions. And internet public opinion emergency often involve a large number of uncertain risk factors. Moreover, when some internet opinion emergency happens, the emergency management departments hardly collect the complete emergency index value, instead they easily obtain the incomplete or uncertain index value of internet sentiment emergency which are usually represented by interval value, fuzzy value and vague value. Notably, it is a very important goal to forecast warning degree and make decision-making for uncertain internet opinion emergency in the government crisis management field. The early warning methods and emergency decision models have been studied by many researchers. For example, Zeng [1] proposed fuzzy hierarch analysis to determine the importance of early warning index and then proposed some related warning decision mechanism for internet opinion emergency. Lin [2] investigated internet opinion emergency warning decision system model based on fuzzy reasoning rule. Li [3] also presented grey warning method for internet opinion emergency. Some intelligent systems for internet public opinion emergency warning decision have been introduced in [4, 5]. However, the above-mentioned emergency warning decision models are not very convenient to evaluate the risk alarm degree and make decision for uncertain internet public opinion emergency.

Recently, Huang [6] developed case-based reasoning method to study the enterprise crisis and early warning system. Patent US7813944 [7] provides a scoring system to distinguish opinion characteristics and predict emergency. Patent US7945515 [8] invents a system for identification of emergency point of compromise. Zhong [9] proposed the case representation and reasoning method in emergency management decision system. Zhang [10] presented an emergency decision system based on case reasoning. However, most of existing emergency warning decision systems use the nearest neighbor algorithm based on similarity to retrieve the optimal warning decision case. They can not efficiently measure the similarity between uncertain internet opinion emergency cases with multiple fuzzy warning decision indexes.

With the increasing complexity of internet opinion emergency system and lack of the precise knowledge, the related emergency decision-maker usually provide his/her preference over emergency index with fuzzy linguistic assessment values, so in this paper we try to introduce a new internet opinion emergency warning decision system based on case reasoning and gray relational [11] retrieval algorithm. In this uncertain internet opinion emergency warning decision system, we aim to develop an improved grey relational analysis and case reasoning method for dealing with uncertain internet opinion emergency warning decision-making with fuzzy index value and incomplete weight information. By applying the grey relational analysis in internet opinion emergency case reasoning, we employ the comprehensive grey relational degree to calculate the matching degree between the current unknown internet opinion emergency and the stored source cases, and especially consider the different importance of warning decision index in the process of internet opinion emergency case reasoning. This system can exclude the influence of inferior index on warning decision. By the designed internet opinion emergency system we can easily obtain the proper warning degree and the corresponding scheme for the current internet opinion emergency problem.

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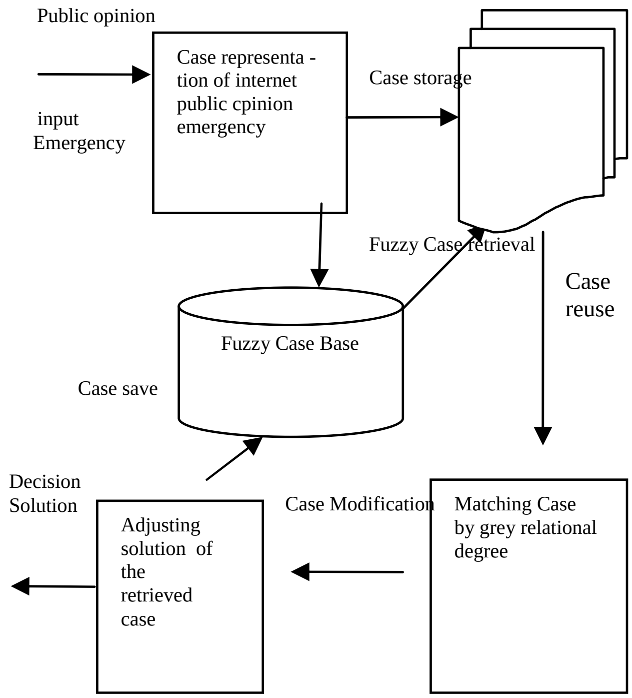

Fig. (1). Internet public opinion emergency warning decision system process.

2. UNCERTAIN CASE REASONING MECHANISM FOR INTERNET PUBLIC OPINION EMERGENCY

Case-based reasoning (CBR) is an important analogue reasoning methodology in recent artificial intelligence field. It has been successfully applied to many real-life decision problems like medical diagnosis, fault diagnosis, enterprise finance forecasting [6], risk management and emergency warning decision [9, 10]. The case-based reasoning mechanism coincides with people's thinking habits and cognitive process. So, the CBR method is also suitable for early warning and urgent decision of uncertain internet opinion emergency. The core part of the warning decision support system is the design of case retrieval algorithm. Therefore, in this paper we design an effective warning decision system for uncertain internet opinion emergency based on grey relational retrieval method. First, we need to collect the related internet public opinion characteristics and emergency index data by using some software systems invented in Patents US8001597 [12], US7,953,695 [13], US7,895,139 [14], and US7,672,865 [15].

Through this prewarning decision system, we can retrieve the most matched source case of the current internet opinion emergency problem by searching all the historical emergencies in system case database. Then by modifying the matched source case, we get the optimal solution of current emergency problem and further update the new internet opinion case for storage backup. The entire case reasoning-based internet opinion emergency warning decision system structure is shown as in Fig. (**1**). It includes the procedure of case retrieval, case reuse, case modification and case study. In the above emergency warning decision system process, we try to use case-based reasoning technique and grey relational analysis method to deal with uncertain internet public sentiment emergency warning decision problem with hybrid indexes. Generally, internet opinion emergency warning decision comprises the following three main steps:

Step 1. First, we can use multivariable statistical analysis method to determine the key warning decision indexes [16] and their weights, then properly represent the internet opinion emergencies as formalized case. Finally, we need to store the formalized internet opinion emergency cases as source cases in the warning decision system database and formalize current internet opinion emergency input.

Step 2. According to the above extracted important early warning decision indexes, we employ grey relational retrieval algorithm to compute the comprehensive grey relational degree between current internet opinion emergency and each source case, and retrieve the most similar historical emergency case to direct the current internet public opinion emergency warning decision.

Step 3. Due to the uncertain decision system environment, it is so difficult to retrieve the completely matched emergency source case for current unknown emergency. Therefore, we need to establish the related case study mechanism for internet public opinion emergency case modification and update. By adjusting the corresponding solution of the matched source case, we can obtain the optimal warning decision solution for the current internet opinion emergency.

From the above process of internet public opinion emergency system case reasoning one can also see that most important step of all is to choose the effective case retrieval approach, which directly affects the timely internet opinion emergency warning decision. In traditional case-based reasoning system, researchers mainly utilized k-NN retrieval algorithm and induction index or knowledge index algorithm. Although k-NN algorithm is very simply and usefully in case reasoning, it only adapts to evaluate the similarity between emergency cases with crisp warning decision indexes, but hardly compute matching degree between uncertain emergency cases. However, the grey relational analysis method has been successfully applied in small size sample reasoning and fuzzy multi-attribute decision, and can forecast the divergence between the current case and historical case.

3. INTERNET PUBLIC OPINION EMERGENCY CASE RETRIEVAL BASED ON GREY RELATIONAL COEFFICIENT

Grey relational analysis [17] is an important theory method in uncertain grey system. In the developing of system, grey relational coefficient not only effectively compare the divergence between the current problem and old problem, but also measure the correlation coefficient between system cases and find the most matching cases of internet opinion emergency. If the grey relational degree between two cases is greater, then the trend of these two cases is more coincidence. So, the grey relational coefficient can reflect similarity between emergency cases with uncertain warning decision indexes.

In traditional case retrieval process, most researches use distance measures to calculate the similarity between internet opinion emergency indexes. However, the similarity based on these distances can reflect the position relation between two case data, but not reflect the emergency trend change. Thus, the traditional K-NN retrieval algorithm depending on similarity derived from these distances is not rational in uncertain emergency case reasoning system. So, in what follows we will use grey relation degree to replace traditional similarity measure to provide new case retrieval algorithm for internet opinion emergency warning decision system.

3.1. Determine Weight of Each Warning Decision Index of Internet Public Opinion Emergency

In the uncertain internet opinion emergency prewarning decision system based on case reasoning, the emergency knowledge and related expertise are usually represented by case structure. The characteristics of emergency case correspond to warning decision indexes.

Suppose $X = \{x_1, x_2, \cdots, x_m\}$ is the set of all m relatively matching internet opinion emergency cases by using SQL sentence indexed by n significant warning decision indexes $\{c_1, c_2, \cdots, c_n\}$. Then the set of all the uncertain internet opinion emergency cases can be formalized by the following decision matrix.

$$X = \begin{bmatrix} f_1(1) & f_1(2) & f_1(3) & \cdots & f_1(n) \\ f_2(1) & f_2(2) & f_2(3) & \cdots & f_2(n) \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ f_m(1) & x_m(2) & f_m(3) & \cdots & f_m(n) \end{bmatrix},$$

where, $f_i(j)$ denote the value of internet opinion emergency x_i with respect to the j th warning decision index c_j, for $1 \le j \le n$, $1 \le i \le m$.

As is well known, the weight of emergency characteristic index plays an important role in internet opinion emergency system reasoning and warning decision. And the weight of each index reflects the different importance in the process of case matching and emergency warning decision evaluation. Thus, in this paper we will take the following two methods to obtain the comprehensive weight of each warning decision index of internet public opinion emergency.

(1) First, by the related knowledge experience and expertise of internet opinion emergency, the emergency managers can compare any pair of warning decision indexes and assign the fuzzy preference degree over index pair to get fuzzy preference relation matrix $R = (r_{ij})_{n\times n}$, where r_{ij} denotes the fuzzy preference degree of index c_i over index c_j. Then employing fuzzy AHP [18] we can get the first type of weight vector of all the emergency warning decision indexes as

$$W^{(1)} = (w_1^{(1)}, w_2^{(1)}, \cdots, w_n^{(1)}),$$

where, $w_j^{(1)}$ is the weight of the jth warning decision index obtained by fuzzy AHP method.

(2) Second, according to the contribution rate of each index to the warning decision system result or from the discrimination ability between two emergency cases regarding this index, we can compute the second type of weight vector of warning decision indexes.

$$W^{(2)} = (w_1^{(2)}, w_2^{(2)}, \cdots, w_n^{(2)}),$$

where, for any $1 \le j \le n$,

$$w_j^{(2)} = \sum_{i=1}^{m}\sum_{k=i+1}^{m} d(f_{ij}, f_{kj})^2 \Big/ \sum_{j=1}^{n} \Big[\sum_{i=1}^{m}\sum_{k=i+1}^{m} d(f_{ij}, f_{kj})^2\Big], \quad (1)$$

$d(f_{ij}, f_{kj})$ is the distance between the j th index value of historical emergency cases x_i and x_k.

Hence, we can combine the above two kinds of weight information to obtain the comprehensive weight vector of all the internet opinion emergency indexes.

$$W = (w_1, w_2, \cdots, w_n);$$

where, $w_j = w_j^{(1)} w_j^{(2)} \Big/ \sum_{j=1}^{n} w_j^{(1)} w_j^{(2)}$, $1 \le j \le n$ (2)

Obviously, the comprehensive weight is more rational than each kind of weight above.

3.2. Grey Relational Analysis for Uncertain Internet Public Opinion Emergency Warning Decision System

In the case-based reasoning process of internet opinion emergency system, each internet opinion emergency is formalized as case structure. The emergency criteria correspond to the warning decision indexes of internet public opinion emergency.

Suppose there are finite m historical source emergency cases in the designed internet opinion emergency warning decision system. And each emergency is determined by n early warning indexes, which can also be expressed by $x_i = (x_i(1), x_i(2), \cdots, x_i(n))$ $(1 \le i \le m)$ with n hybrid characteristic indexes in the internet opinion emergency warning decision system base. And we assume the new occurred internet opinion emergency is also described as $x_* = (x_*(1), x_*(2), \cdots, x_*(n))$, where $x_*(j)$ is the j th warning decision index value of internet opinion emergency. Retrieving the most matching source case is analogue to find the closest point near to the current emergency characteristic vector. Thus, we will adopt the grey relational theory to calculate the closeness of current internet opinion emergency with all the source cases in internet opinion emergency system.

First, we can compute the local grey relational degree of j th index between the unknown internet sentiment emergency x_* and the i th source case $x_i (1 \le i \le m)$ below.

$$\rho_{*i}(j) = G(x_*(j), x_i(j)),\ 1 \le j \le n,$$

$$= \frac{\min\limits_{1\le j\le n} d(x_*(j), x_i(j)) + \xi \max\limits_{1\le j\le n} d(x_*(j), x_i(j))}{d(x_*(j), x_i(j)) + \xi \max\limits_{1\le j\le n} d(x_*(j), x_i(j))} \quad (3)$$

where, $d(x_*(j), x_i(j))$ denotes the distance between current internet opinion emergency x_* and source case x_i with respect to jth characteristic warning decision index c_j; $\xi \in [0,1]$ is a given discriminate coefficient, in this paper we can take ξ =0.5 for convenience. Obviously, we can see that $0 \le \rho_{*i}(j) \le 1$.

And the larger the value of $G(x_*(j), x_i(j))$, the more similarity between the current internet opinion emergency x_* and historical source case $x_i (1 \le i \le m)$ with respect to the warning decision index $c_j (1 \le j \le n)$.

Then we can construct the following grey relational coefficient matrix

$$\rho = (\rho_{*i}(j))_{m\times n} = \begin{bmatrix} \rho_{*1}(1) & \rho_{*1}(2)\cdots\cdots\rho_{*1}(n) \\ \rho_{*2}(1) & \rho_{*2}(2)\cdots\cdots\rho_{*2}(n) \\ \rho_{*3}(1) & \rho_{*3}(2)\cdots\cdots\rho_{*3}(n) \\ \cdots\cdots & \cdots\cdots\cdots\cdots \\ \rho_{*m}(1) & \rho_{*m}(2)\cdots\cdots\rho_{*m}(n) \end{bmatrix},$$

where, $\rho_{ij} = \rho_{*i}(j)$ denotes the grey relational degree between the current unknown internet opinion emergency x_* and i th source case x_i regarding j th decision index.

Thus, we can get the comprehensive grey relational coefficient between the current internet opinion emergency and each source case in the emergency system case base.

$$\rho_i = G(x_*, x_i)$$

$$= \sum_{j=1}^{n} w_j \rho_{*i}(j) = \sum_{j=1}^{n} w_j G(x_*(j), x_i(j)) \quad (4)$$

where, w_j is the weight of j th warning decision index obtained by formula (2). ρ_i can be regarded as the comprehensive grey relational coefficient between the current internet sentiment emergency x_* and historical source case x_i.

By using the grey relational coefficient ρ_i, we can get the corresponding similarity measure between emergency x_* and source case x_i. $\forall \alpha \ge 1$,

$$S_{*i} = S(x_*, x_i) = 1 - [\sum_{j=1}^{n} w_j (1 - \rho_{*i}(j))^{\alpha}]^{\frac{1}{\alpha}} \quad (5)$$

From formula (5), one can see that the greater ρ_i is, the more similarity between the current internet opinion emergency problem x_* and source case x_i.

Therefore, we can retrieve the desirable source case according to the comprehensive grey relational degree ρ_i between the current unknown emergency and each source case x_i $(1 \le i \le m)$ in this designed internet opinion emergency warning decision system.

If $\rho_s = \max\ \{\rho_i / 1 \le i \le m\}$, then the most matching case of unknown internet opinion emergency is source case x_s. That is to say, the historical source case x_s is most similar (close) to the current internet opinion emergency problem. Thus, we can use the corresponding warning decision solution of historical emergency case x_s to facilitate the warning decision of the unexpected internet opinion emergency.

Due to the uncertain internet opinion emergency warning decision system environment, it is hard to find some source case completely matching the unknown emergency. And any warning decision solution of the matching case can only partially satisfy the current internet opinion emergency. So, we still need to modify the solution of the retrieval case to suit the current emergency. In the following, we can employ the distance measure to modify case and correct the warning decision solution for current unknown internet opinion emergency.

4. CASE MODIFICATION FOR INTERNET PUBLIC OPINION EMERGENCY BASED ON DISTANCE

Suppose the designed case base of internet opinion emergency warning decision system comprises m historical source cases $\{x_1, x_2, \cdots, x_m\}$. We denote by the current unknown internet opinion emergency x_*. Assume the distance measure d between the j th warning decision index value of internet opinion emergencies x_* and x_i are given as follows.

(1) If the j th index values of internet opinion emergency are crisp data, then the distance between them can be evaluated by

$$d(x_{*j}, x_{ij}) = \left|x_{*j} - x_{ij}\right| / (\max{}_j - \min{}_j) \quad (6)$$

where, x_{*j}, x_{ij} denote the jth index value of internet opinion emergencies x_* and x_i, respectively; $\max_j$, $\min_j$ are the maximum and minimum value of j th emergency index.

(2) If the j th index value of internet opinion emergency x_* and x_i are interval values as $x_{*j} = [x_{*j1}, x_{*j2}]$ $x_{ij} = [x_{ij1}, x_{ij2}]$ then the distance [19] between them is evaluated by

$$d(x_{*j}, x_{ij}) = \frac{\max\{\left|x_{*j1} - x_{ij1}\right|, \left|x_{*j2} - x_{ij2}\right|\}}{\left|\max\{x_{*j2}, x_{ij2}\} - \min\{x_{*j1}, x_{ij1}\}\right|} \quad (7)$$

(3) If the j th index values of internet opinion emergency are vague (intuitionistic fuzzy) values [20, 21], $x_{*j} =< \mu_{x_{*j}}, \nu_{x_{*j}} >$ $x_{ij} =< \mu_{x_{ij}}, \nu_{x_{ij}} >$, then the distance between them is evaluated by

$$d(x_{*j}, x_{ij}) = \sqrt{[\left|\mu_{x_{*j}} - \mu_{x_{ij}}\right|^2 + \left|\nu_{x_{*j}} - \nu_{x_{ij}}\right|^2 + \left|\pi_{x_{*j}} - \pi_{x_{ij}}\right|^2]/2} \quad (8)$$

(4) If the j th index values of internet opinion emergency are fuzzy number [22, 23] as

$x_{*j} = (x_{*j1}, x_{*j2}, x_{*j3}, x_{*j4})$, $x_{ij} = (x_{ij1}, x_{ij2}, x_{ij3}, x_{ij4})$

then the distance between them is computed by

$$d(x_{*j}, x_{ij})$$

$$= 1 - [1 - \frac{\sum_{k=1}^{4}\left|x_{*jk} - x_{ijk}\right|}{4} \times \frac{\min(p(x_{*j}), p(x_{ij}) + 1}{\max(p(x_{*j}), p(x_{ij}) + 1} \quad (9)$$

where,

$$p(x_{*j}) = \sqrt{(x_{*j1} - x_{*j2})^2 + 1} + \sqrt{(x_{*j3} - x_{*j4})^2 + 1}$$
$$+ (x_{*j3} - x_{*j2}) + (x_{*j4} - x_{*j1});$$

$$p(x_{ij}) = \sqrt{(x_{ij1} - x_{ij2})^2 + 1} + \sqrt{(x_{ij3} - x_{ij4})^2 + 1}$$
$$+ (x_{ij3} - x_{ij2}) + (x_{ij4} - x_{ij1});$$

represent the perimeters of fuzzy numbers x_{*j} and x_{ij}, respectively.

Notably, the weighted distance of current unknown internet opinion emergency x_* to the i th historical source case is defined as

$$d(x_*, x_i) = \sum_{j=1}^{n} w_j d(x_{*j}, x_{ij}) \quad (10)$$

From formula (10), we can see that the smaller the weighted distance $d(x_*, x_i)$ is, the nearer the source case x_i close to the unexpected internet opinion emergency x_*.

If there are many source cases x_i such that $d(x_*, x_i) \leq \delta$, where δ is the given referred distance threshold by the related emergency managers. Generally we take $\delta = 0.1$ for convenience, so we can use all the solution of the relatively matching source cases x_i to modify the warning decision solution of the most matching source case obtained by grey relational retrieval algorithm for the new occurred internet opinion emergency. This is the case modification mechanism by using the solutions of relatively similar source cases to adjust the solution of the most matching case for current internet opinion emergency.

5. APPLICATION EXAMPLE

Recently, grey relational analysis has been widely used in uncertain system control and decision and has drawn the attention of many researchers in order to perform multi-criteria decision making [19-21]. In this section, we shall give an application example to demonstrate the feasibility of the proposed comprehensive grey relational analysis method to the internet opinion emergency system retrieval process with multiple uncertain warning decision indexes.

Example 1. Suppose we now designed an early warning decision system based on case reasoning for dealing with uncertain internet opinion emergency. And assume the case base of this emergency warning decision system stored six historical internet opinion emergency cases. And by using fuzzy AHP, we extract the following nine important indexes {News report, Micro-blog, Transmitting number, public sentiment spread speed, Public opinion tendency, Economic Loss, Casualty, Traffic jam, Response speed} for internet opinion emergency warning decision. Moreover, each internet opinion emergence case is characterized and formalized by nine important warning decision index value as shown in Table **1**. Now if there is an unexpected internet opinion emergency occurring in some area, the warning decision index values of the new occurred emergency are also recorded in Table **1**, then we need to forecast the proper alarm degree of this new internet opinion emergency and retrieve the most matching historical case by this designed warning decision system to facilitate the urgent decision -making for the current unknown internet opinion emergency.

In the case base of warning decision system, we also evaluate the rang of news report number is [10, 5000]; the rang of micro-blog number is [100, 60000]; the rang of transimitting number is [50, 40000]; and all the uncertain linguistic values in the warning decision system correspond to the following fuzzy numbers [22, 23] as in Table **2**.

From the emergency case data in this warning decision system, we see that there are nine significant warning decision indexes, each internet opinion emergency case x_i can be expressed by a multi-dimensional characteristic vector

Table 1. Uncertain internet public opinion emergency warning decision system.

(1-1)

Index	Case x1	Case x2	Case x3
News report number	2123	2680	1196
Micro-blog number	87691	19903	157353
Transmitting number	19768	12961	5953
public sentiment spread speed	Very slow	Medium	Very quick
Public opinion tendency	<0.6,0.3>	<0.7,0.2>	<0.8,0.13>
Economic Loss	[10, 100]	[700, 1000]	[500, 700]
Casualty number	[2, 10]	[30, 80]	[50, 70]
Traffic jam	Slight	Severe	Very severe
Response speed	Medium	quick	Very quick

(1-2)

Index	Case x4	Case x5	Case x_*
News report number	480	555	1534
Micro-blog number	11247	8553	135678
Transmitting number	2752	4258	5012
public sentiment spread speed	Extremely quick	Slow	Quick
Public opinion tendency	<0.9,0.1>	<0.5,0.4>	<0.8,0.2>
Economic Loss	[200, 900]	[400□1000]	[600, 800]
Casualty number	[100,150]	[200, 300]	[40, 60]
Traffic jam	Extremely severe	Medium	Severe
Response speed	Slow	Extremely quick	quick

$(f_{i1}, f_{i2}, \cdots, f_{i9})$, f_{ij} denotes the value of j th index c_j of internet opinion emergency x_i, for $1 \le i \le 5$, $1 \le j \le 9$.

By using Table **2**, we can transfer all the uncertain fuzzy linguistic terms in the above early warning decision system to the corresponding Trapezoid fuzzy numbers.

Table 2. Uncertain Linguistic Terms and The Corresponding Fuzzy Numbers.

Uncertain Linguistic Term	Trapezoid Fuzzy Number
Extremely quick/Extremely high/ Extremely severe	(0.93,0.98,1.0,1.0)
Very quick /Very high / Very severe	(0.72,0.78,0.92,0.97)
Quick/ High/ Severe	(0.58,0.63,0.8,0.86)
Medium	(0.32, 0.41, 0.58, 0.65)
Slow / Low / Slight	(0.17,0.22,0.36,0.42)
Very Slow / Very Low / Very slight	(0.04,0.1,0.18,0.23)
Extremely slow / Extremely Low / Extremely slight	(0, 0, 0.02, 0.07)

Then, according to formulae (6)-(9) we first compute the following distance measures.

$d(f_{11}, f_{21}) = 0.1116$, $d(f_{11}, f_{31}) = 0.1858$, $d(f_{11}, f_{41}) = 0.3293$, $d(f_{11}, f_{51}) = 0.3142$

$d(f_{21}, f_{31}) = 0.2974$, $d(f_{21}, f_{41}) = 0.4409$, $d(f_{21}, f_{51}) = 0.4259$,

$d(f_{31}, f_{41}) = 0.1435$ $d(f_{31}, f_{51}) = 0.1285$ $d(f_{41}, f_{51}) = 0.015$

$d(f_{12}, f_{22}) = 0.3391$, $d(f_{12}, f_{32}) = 0.3485$, $d(f_{12}, f_{42}) = 0.3824$, $d(f_{12}, f_{52}) = 0.3959$,

$d(f_{22}, f_{32}) = 0.6876$, $d(f_{22}, f_{42}) = 0.0433$, $d(f_{22}, f_{52}) = 0.0568$,

$d(f_{32}, f_{42}) = 0.7309$ $d(f_{32}, f_{52}) = 0.7444$ $d(f_{42}, f_{52}) = 0.0135$

$d(f_{13}, f_{23}) = 0.0851$, $d(f_{13}, f_{33}) = 0.1728$, $d(f_{13}, f_{43}) = 0.2128$, $d(f_{13}, f_{53}) = 0.194$

$d(f_{23}, f_{33}) = 0.0877$, $d(f_{23}, f_{43}) = 0.1277$,
$d(f_{23}, f_{53}) = 0.1089$,

$d(f_{33}, f_{43}) = 0.04$ $d(f_{33}, f_{53}) = 0.0212$
$d(f_{43}, f_{53}) = 0.0188$

$d(f_{14}, f_{24}) = 0.3956$, $d(f_{14}, f_{34}) = 0.7203$,
$d(f_{14}, f_{44}) = 0.8489$, $d(f_{14}, f_{54}) = 0.1849$

$d(f_{24}, f_{34}) = 0.3783$, $d(f_{24}, f_{44}) = 0.5482$,
$d(f_{24}, f_{54}) = 0.2235$,

$d(f_{34}, f_{44}) = 0.2074$ $d(f_{34}, f_{54}) = 0.555$
$d(f_{44}, f_{54}) = 0.713$

$d(f_{15}, f_{25}) = 0.1$, $d(f_{15}, f_{35}) = 0.2$,

$d(f_{15}, f_{45}) = 0.2646$, $d(f_{15}, f_{55}) = 0.1$

$d(f_{25}, f_{35}) = 0.1$, $d(f_{25}, f_{45}) = 0.1732$, $d(f_{25}, f_{55}) = 0.2$,

$d(f_{35}, f_{45}) = 0.1$ $d(f_{35}, f_{55}) = 0.3$ $d(f_{45}, f_{55}) = 0.3606$

$d(f_{16}, f_{26}) = 0.9091$, $d(f_{16}, f_{36}) = 0.6061$,
$d(f_{16}, f_{46}) = 0.8081$, $d(f_{16}, f_{56}) = 0.9091$

$d(f_{26}, f_{36}) = 0.303$, $d(f_{26}, f_{46}) = 0.5051$,
$d(f_{26}, f_{56}) = 0.303$,

$d(f_{36}, f_{46}) = 0.303$ $d(f_{36}, f_{56}) = 0.303$ $d(f_{46}, f_{56}) = 0.202$

$d(f_{17}, f_{27}) = 0.07$, $d(f_{17}, f_{37}) = 0.06$, $d(f_{17}, f_{47}) = 0.14$,
$d(f_{17}, f_{57}) = 0.29$

$d(f_{27}, f_{37}) = 0.02$, $d(f_{27}, f_{47}) = 0.07$, $d(f_{27}, f_{57}) = 0.22$,

$d(f_{37}, f_{47}) = 0.08$ $d(f_{37}, f_{57}) = 0.23$ $d(f_{47}, f_{57}) = 0.15$

$d(f_{18}, f_{28}) = 0.435$, $d(f_{18}, f_{38}) = 0.555$,
$d(f_{18}, f_{48}) = 0.713$, $d(f_{18}, f_{58}) = 0.2235$

$d(f_{28}, f_{38}) = 0.1451$, $d(f_{28}, f_{48}) = 0.3375$,
$d(f_{28}, f_{58}) = 0.2393$,

$d(f_{38}, f_{48}) = 0.2074$ $d(f_{38}, f_{58}) = 0.3783$
$d(f_{48}, f_{58}) = 0.5482$

$d(f_{19}, f_{29}) = 0.2393$, $d(f_{19}, f_{39}) = 0.3783$,
$d(f_{19}, f_{49}) = 0.2235$, $d(f_{19}, f_{59}) = 0.5482$

$d(f_{29}, f_{39}) = 0.1451$, $d(f_{29}, f_{49}) = 0.435$,
$d(f_{29}, f_{59}) = 0.3375$,

$d(f_{39}, f_{49}) = 0.555$ $d(f_{39}, f_{59}) = 0.2074$
$d(f_{49}, f_{59}) = 0.713$.

Using formula (1), for $1 \le j \le 9$,

$$w_j^{(2)} = \sum_{i=1}^{5} \sum_{k=i+1}^{5} d(f_{ij}, f_{kj})^2 / \sum_{j=1}^{9} [\sum_{i=1}^{5} \sum_{k=i+1}^{5} d(f_{ij}, f_{kj})^2],$$

we can get the second kind of weight vector of emergency warning decision indexes as

$$W^{(2)} = (w_1^{(2)}, w_2^{(2)}, \cdots, w_9^{(2)})$$

= (0.0835, 0.1306, 0.0626,0.1667,0.0663, 0.1798, 0.0464, 0.132, 0.132).

Given the fuzzy preference degree assessment from the related emergency experts and by employing fuzzy AHP method, we can easily get the first kind of weight vector of all the important warning decision indexes as below.

$$W^{(1)} = (w_1^{(1)}, w_2^{(1)}, \cdots, w_9^{(1)})$$

=(0.05,0.05,0.2,0.15,0.2,0.05,0.15,0.05,0.1)

Thus, according to formula (2),

$$w_j = w_j^{(1)} w_j^{(2)} / \sum_{j=1}^{9} w_j^{(1)} w_j^{(2)}, \ 1 \le j \le 9,$$

we can combine the above two kinds of weight information and get the comprehensive weight vector of emergency warning decision indexes below.

W= (0.0429, 0.0672, 0.1288, 0.2571, 0.1364, 0.0925, 0.0716, 0.0679, 0.1357).

Further, with distance measure formulae (6)-(9) we can also calculate the following distances between the current unknown internet opinion emergency and each source case regarding nine warning decision indexes.

$d(x_*(1), x_1(1))$ =0.118, $d(x_*(2), x_1(2))$ =0.2401,

$d(x_*(3), x_1(3))$ =0.1846, $d(x_*(4), x_1(4))$ =0.6019,

$d(x_*(5), x_1(5))$ =0.1732, $d(x_*(6), x_1(6))$ =0.7071,

$d(x_*(7), x_1(7))$ =0.05, $d(x_*(8), x_1(8))$ =0.435,

$d(x_*(9), x_1(9))$ =0,

$d(x_*(1), x_2(1))$ =0.2297, $d(x_*(2), x_2(2))$ =0.5792,

$d(x_*(3), x_2(3))$ =0.0994, $d(x_*(4), x_2(4))$ =0.2393,

$d(x_*(5), x_2(5))$ =0.1, $d(x_*(6), x_2(6))$ =0.202,

$d(x_*(7), x_2(7))$ =0.02,

$d(x_*(8), x_2(8))$ =0, $d(x_*(9), x_2(9))$ =0.2393,

$d(x_*(1), x_3(1))$ =0.0677, $d(x_*(2), x_3(2))$ =0.1084,

$d(x_*(3), x_3(3))$ =0.0118, $d(x_*(4), x_3(4))$ =0.1451,

$d(x_*(5), x_3(5))$ =0.1, $d(x_*(6), x_3(6))$ =0.101,

$d(x_*(7), x_3(7))$ =0.01,

$d(x_*(8), x_3(8))$ =0.1451, $d(x_*(9), x_3(9))$ =0.3783,

$d(x_*(1), x_4(1))$ =0.2112, $d(x_*(2), x_4(2))$ =0.6225,

$d(x_*(3), x_4(3))$ =0.0283, $d(x_*(4), x_4(4))$ =0.3375,

$d(x_*(5), x_4(5))$ =0.1, $d(x_*(6), x_4(6))$ =0.404,

$d(x_*(7), x_4(7))$ =0.09,

$d(x_*(8), x_4(8))$ =0.3375, $d(x_*(9), x_1(9))$ =0.207,

$d(x_*(1), x_5(1))$ =0.1962, $d(x_*(2), x_5(2))$ =0.6359,

$d(x_*(3), x_5(3))$ =0.0094, $d(x_*(4), x_5(4))$ =0.435,

$d(x_*(5), x_5(5))$ =0.2646, $d(x_*(6), x_5(6))$ =0.202,

$d(x_*(7), x_5(7))$ =0.24,

$d(x_*(8), x_5(8))$ =0.2393, $d(x_*(9), x_5(9))$ =0.5482.

From formula (3), we can calculate the local grey relational degree between current emergency x_* and source case x_i regarding each warning decision index $c_j, 1 \le i \le 5$, $1 \le j \le 9$,

$$\rho_{*i}(j) = G(x_*(j), x_i(j))$$

$$= \frac{\min_{1\le j\le 9} d(x_*(j), x_i(j)) + \xi \max_{1\le j\le 9} d(x_*(j), x_i(j))}{d(x_*(j), x_i(j)) + \xi \max_{1\le j\le 9} d(x_*(j), x_i(j))},$$

Then we can construct the following grey relational matrix

$$\rho = (\rho_{*i}(j))_{5\times 9} =$$

$$\begin{bmatrix} 0.7498 & 0.5956 & 0.657 & 0.37000 & 0.6712 & 0.3333 & 0.8761 & 0.44840 & 1.0000 \\ 0.5577 & 0.3333 & 0.7445 & 0.5476 & 0.7433 & 0.5891 & 0.9354 & 1.00000 & 0.5476 \\ 0.7754 & 0.6693 & 0.9910 & 0.5958 & 0.6887 & 0.6864 & 1.0000 & 0.59580 & 0.3510 \\ 0.6499 & 0.3636 & 1.0000 & 0.5234 & 0.8257 & 0.4747 & 0.8462 & 0.52340 & 0.6552 \\ 0.6429 & 0.3493 & 1.0000 & 0.4414 & 0.5686 & 0.6359 & 0.5933 & 0.59400 & 0.3843 \end{bmatrix}$$

According to formula (4),

$$\rho_i = \sum_{j=1}^{9} w_j \rho_{*i}(j) = \sum_{j=1}^{9} w_j G(x_*(j), x_i(j)),$$

we immediately obtain the comprehensive grey relational coefficient below.

ρ_1 = 0.6032; ρ_2 =0.6481; ρ_3 =0.6762;

ρ_4 =0.6573; ρ_5 =0.5647.

From the above grey relational coefficient result, one can see that $\rho_3 = \max_{1\le i\le 4} \rho_i$. So the historical internet opinion emergency case 3 has the greatest grey relational degree to the current unknown emergency problem, so this source case 3 is the nearest one to the current unexpected internet opinion emergency. That is to say, the historical emergency 3 is the most matching case in all the candidate emergencies stored in the designed internet opinion emergency system case base. The solution of source case x_3 is the optimal resolution of the new occurred emergency. Thus, emergency management decision-makers can adjust or modify the warning decision solution of historical internet sentiment emergency x_3 to facilitate the urgent decision for the current unknown internet opinion emergency. And according to the warning degree obtained by this warning decision system, the government department can take the corresponding emergency response and coordinate all kinds of emergency sources or facilities among different municipal zones to avoid or decrease the risk loss of the current unexpected internet opinion emergency.

6. CONCLUSION

The paper has designed a new warning decision system mechanism for uncertain internet public opinion emergency by using the fuzzy grey relational retrieval method and the invented software tools in some patents. It can improve the efficiency of emergency decision. Furthermore, we will try to develop a hybrid retrieval algorithm in the case reasoning process to enhance the flexibility and practicability of internet public opinion emergency risk forecasting system.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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