The Identification of Human Unsafe Acts in Maritime Accidents with Grey Relational Analysis

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ABSTRACT

It is well known that human errors is involved in most of maritime accidents. For the purpose of reducing the influence of human elements on maritime activities, it is necessary to identify the human unsafe acts in those activities.

The commonly used methods in identification of human unsafe acts are maritime accident statistics or case analysis. With the statistics data, people could roughly identify what kinds of unsafe acts or human errors have played active role in the accident, however, they often neglected some active unsafe acts while overestimated some mini-unsafe acts because of the inherent shortcoming of the methods. There should be some more accurate approaches for human error identification in maritime accidents.

In this paper, the application of technique called grey relational analysis (GRA) into the identification of human unsafe acts is presented. GRA is used to examine the extent of connections between two digits by applying the methodology of departing and scattering measurement to actual distance measurement. Based on the statistics data of maritime accidents occurred in Chinese waters in last 10years, the relationship between the happening times of maritime accidents and that of unsafe acts are established with GRA.

In accordance with the value of grey relational grade, the identified main human unsafe acts involved in maritime accidents are ranked in following orders: improper lookout, improper use of radar and equivalent equipment, error of judgment, act not in time, improper communication, improper shiphandling, use of unsafe speed, violating the rule and ignorance of good seamanship. The result shows that GRA is an effective and practical technique in improving the accuracy of human unsafe acts identification.

Key words: grey relational analysis (GRA), identification, human errors, unsafe acts, and maritime accidents.

1 Introduction

The primary work to be done in ship collision avoidance is to identify the unsafe acts or human errors involved in collision accidents. Researchers have already recommended some approaches for identifying the human errors in accidents (Williams, 1994). It is also a good and easy way to identify the human errors through statistics based on the accident investigation reports (ATSB, 1996). However, the results got through those methods are usually qualitative and of primary. There are some inherent deficiencies with those approaches. Firstly, it is difficult to reveal the varying tend of relationship between the accidents and human errors involved in them with the time. For example, if a certain kind of human errors is the main cause of most of accidents occurred in a certain year while in other years this kind of human errors has been overcome and is not the main cause of the accidents occurred in some other years, it can still be recognized as the main cause of accidents with statistics method. Secondly, the method of statistics analysis needs a great mount of sampling data, but the maritime accidents that could be investigated and reported in detail is only of a small portion of all maritime accidents. Hence, it seems to run risk to collect the statistical data mining from the accident investigation report directly and take that as the results of human errors identified.

The methodology of grey relational analysis can deal with the problems mentioned above (Deng, 2002). It is a method to analyze the relational grade for discrete sequences. The method quantifies all influences of various factors and their relation, which is called the whitening of factor relation. This is unlike the traditional statistics analysis handling the relation between variables. The grey relational analysis requires less data and can analyze many factors that can overcome the disadvantages of statistics method. Because of these advantages, the method is applicable in the present issue (Wu, 2001).

2 The method of grey relational analysis

The key of grey relational analysis is the calculation of the grey relational grade. The process of the calculation and analysis are presented as the following (Hu & He 2000):

2.1 The establishment of analyzing series

Based on the topic discussed, it is need to make definite a dependent variable factor and several independent variable factors. Let the data of dependent variable consist a referenced series of X0′ and each dependent variables’ data consist comparative series Xi′ (i＝1，2，3，…，n), referenced series and n comparative series form a matrix as following:

$$(X_0', X_1', \cdots, X_n') = \begin{bmatrix} x_0'(1) & x_1'(1) & \Lambda & x_n'(1) \\ x_0'(2) & x_1'(2) & \Lambda & x_n'(2) \\ \mathrm{M} & \mathrm{M} & \mathrm{M} & \mathrm{M} \\ x_0'(N) & x_1'(N) & \Lambda & x_n'(N) \end{bmatrix}_{N\times(n+1)} \quad (1)$$

Where,

$$X_i' = (x_i'(1), x_i'(2), \Lambda, x_i'(N))^T, i = 0,1,2,\Lambda, n$$

N is the length of variable series.

2.2 Non-dimension of variables series

In general, the primary variable series have different dimensions. For the purpose of analysis accuracy and avoidance of discrimination of variables at smaller value scale, it is necessary to have all variables be nondimension and standardized. The commonly used nondimension method is to have the values of variables averaged, which could be done with equation (2):

$$x_i(k) = \frac{x_i'(k)}{\frac{1}{N}\sum_{k=1}^{N} x_i'(k)} \quad (2)$$

The dimensionless variables series form a matrix as following:

$$(X_0, X_1, \Lambda, X_n) = \begin{bmatrix} x_0(1) & x_1(1) & \Lambda & x_n(1) \\ x_0(2) & x_1(2) & \Lambda & x_n(2) \\ M & M & & M \\ x_0(N) & x_1(N) & \Lambda & x_n(N) \end{bmatrix}_{N\times(n+1)} \tag{3}$$

2.3 The difference series, maximum difference and minimum difference

After the calculation of the absolute value of difference of referenced series and comparative series, the following matrix of absolute value of difference may get:

$$\begin{bmatrix} \Delta_{01}(1) & \Delta_{02}(1) & \Lambda & \Delta_{0n}(1) \\ \Delta_{01}(2) & \Delta_{02}(2) & \Lambda & \Delta_{0n}(2) \\ M & M & & M \\ \Delta_{01}(N) & \Delta_{02}(N) & \Lambda & \Delta_{0n}(N) \end{bmatrix} \tag{4}$$

Where,

$$\Delta_{0i}(k) = |x_0(k) - x_i(k)| \tag{5}$$

i=1,2, n; k=1,2...N

The maximum and minimum values in difference matrix will be the maximum difference value and minimum difference value, which may be expressed as following:

$$\max_{\substack{1\le i\le n\\1\le k\le N}}\{\Delta_{0i}(k)\} \overset{\Delta}{=} \Delta(\max) \tag{6}$$

$$\min_{\substack{1\le i\le n\\1\le k\le N}}\{\Delta_{0i}(k)\} \overset{\Delta}{=} \Delta(\min) \tag{7}$$

2.4 Grey relational coefficients

Translating the data of absolute value matrix with the equation (8)

$$\xi_{0i}(k) = \frac{\Delta(\min) + \rho\Delta(\max)}{\Delta_{0i}(k) + \rho\Delta(\max)} \tag{8}$$

A matrix of grey relational coefficients may get:

$$\begin{bmatrix} \xi_{01}(1) & \xi_{02}(1) & \Lambda & \xi_{0n}(1) \\ \xi_{01}(2) & \xi_{02}(2) & \Lambda & \xi_{0n}(2) \\ M & M & & M \\ \xi_{01}(N) & \xi_{02}(N) & \Lambda & \xi_{0n}(N) \end{bmatrix}_{N\times n} \tag{9}$$

where, ρ is called differentiating coefficient, whose value is taking from the area of (0,1),in general between 0.1-0.5,depending on the actual situation. The smaller the value of ρ, the greater the difference between the relational coefficients. Grey relational coefficients $\xi_{0i}(k)$ are usually small positive values smaller than 1, the smaller the $\Delta_{0i}(k)$, the greater the $\xi_{0i}(k)$.It indicates the relational grade of comparative series Xi of number i with the referenced series X0 in period k.

2.5 The grey relational grade

After obtaining the grey relational coefficient, its average may be taken as the grey relational grade:

$$r_{0i} = \frac{1}{N}\sum_{k=1}^{N}\xi_{0i}(k) \qquad (10)$$

2.6 Ranking the grey relational grade

Ranking the grey relational grades of each comparative series with referenced series, the order will tell something about the relational grade: the more consistent the referenced series with the comparative series, the higher the grey relational coefficient.

3 The calculation of relational grade between human errors and collision accidents

The data in table 1 are mining from 100 pieces of ship collision accident investigating reports. Except the numbers of collision accident occurred each year (indeed, the data here is the number of reports selected), the data of 12 unsafe acts roughly identified by statistics method have also been given in the table.

Table 1 The statistics of human errors in ship collision

Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Number of collisions	6	6	8	11	8	10	17	18	12	4
Improper look out	5	5	8	9	7	10	16	14	10	2
Improper use of radar	2	2	1	7	1	3	3	3	4	1
Failure in signals	3	2	3	2	3	5	7	5	3	1
Failure in fixing	1	3	3	3	1	0	0	0	1	0
Improper routing plan	1	1	0	0	2	2	2	3	3	1
Fault decision making	6	5	5	11	8	6	12	15	10	3
Violating the rule	6	1	4	6	5	6	8	8	7	1
No use of good seamanship	2	0	4	0	2	5	4	7	5	1
Failure in safe speed	4	3	2	1	2	7	11	11	4	2
Late action	3	1	3	6	1	2	7	8	8	2
Improper communication	6	5	4	7	5	6	2	5	6	1
Improper ship handling	2	4	5	8	6	6	11	12	9	3

source: CMSA, MAIB, TSB, ATSB, USCG, NTSB, TAIC, SHK: the published maritime accident reports in the period of 1993 to 2003

As mentioned in section 1, the series for analysis should be determined first of all. Let the numbers of maritime accident occurred each year to be the dependent variable, the data as shown in the first line of table 1 will form the referenced series X_0' . Let each unsafe acts(human errors)to be independent variables, the data in rest lines of table 1 will form the comparative series Xi' (i=1, 2, 3, ..., n),where n is the number of kinds of unsafe acts. In this study, n will be 12. There are n+1 series all together, forming the follow matrix for analyzing:

$$(X_0', X_1', \cdots, X_n') = \begin{bmatrix} x_0'(1) & x_1'(1) & \Lambda & x_n'(1) \\ x_0'(2) & x_1'(2) & \Lambda & x_n'(2) \\ M & M & M & M \\ x_0'(N) & x_1'(N) & \Lambda & x_n'(N) \end{bmatrix}_{N\times(n+1)} \qquad (11)$$

Where,

$$X_i' = (x_i'(1), x_i'(2), \Lambda , x_i'(N))^T, i = 0,1,2,\Lambda ,12$$

N is the length of variable series that will be 10 here.

Step 2 is to make the series in table 1 nondimension for the purpose of analysis. With equation (2), the average of each series may be calculated as: 1.0, 8.6, 2.7, 3.4, 1.2, 1.5, 8.1, 5.2, 3.0, 4.7, 4.1, 4.7, and 7.0. Dividing each series in table 1 with corresponding value of average, averaged series may get, as shown in table 2.

Table 2 Dimensionless data of human errors involved in collisions

Year t	$X_0(t)$	$X_1(t)$	$X_2(t)$	$X_3(t)$	$X_4(t)$	$X_5(t)$	$X_6(t)$	$X_7(t)$	$X_8(t)$	$X_9(t)$	$X_{10}(t)$	$X_{11}(t)$	$X_{12}(t)$
1993	0. 6	0. 58	0. 74	0. 88	0. 83	0. 67	0. 74	1. 15	0. 67	0. 85	0. 73	1. 28	0. 86
1994	0. 6	0. 58	0. 74	0. 59	2. 5	0. 67	0. 62	1. 19	0	0. 64	0. 24	1. 06	0. 57
1995	0. 8	0. 93	0. 37	0. 88	2. 5	0	0. 62	0. 77	1. 33	0. 43	0. 73	0. 85	0. 71
1996	1. 1	1. 05	2. 59	0. 59	2. 5	0	1. 36	1. 15	0	0. 21	1. 46	1. 49	1. 14
1997	0. 8	0. 81	0. 37	0. 88	0. 83	1. 33	0. 99	0. 96	0. 67	0. 43	0. 24	1. 06	0. 86
1998	1.0	1.16	1.11	1.47	0	1.33	0.74	1.15	1.67	1.49	0.49	1.28	0.86
1999	1.7	1.86	1.11	2.06	0	1.33	1.48	1.54	1.33	2.34	1.71	0.43	1.57
2000	1.8	1.63	1.11	1.47	0	2	1.85	1.54	2.33	2.34	1.95	1.06	1.71
2001	1.2	1.16	1.48	0.88	0.83	2	1.23	1.35	1.67	0.85	1.95	1.28	1.29
2002	0.4	0.23	0.37	0.29	0	0.67	0.37	0.19	0.33	0.43	0.49	0.21	0.43

Step 3 is to calculate the difference series, maximum difference and minimum difference. The calculated results with equation (4) and (5) are given in table 3.

Table 3 Absolute difference values

年份 t	$\Delta_{01}(t)$	$\Delta_{02}(t)$	$\Delta_{03}(t)$	$\Delta_{04}(t)$	$\Delta_{05}(t)$	$\Delta_{06}(t)$	$\Delta_{07}(t)$	$\Delta_{08}(t)$	$\Delta_{09}(t)$	$\Delta_{010}(t)$	$\Delta_{011}(t)$	$\Delta_{012}(t)$
1993	0. 02	0. 14	0. 28	0. 23	0. 07	0. 14	0. 55	0. 07	0. 25	0. 13	0. 68	0. 26
1994	0. 02	0. 14	0. 01	1. 9	0. 07	0. 02	0. 59	0. 6	0. 04	0. 36	0. 46	0. 03
1995	0. 13	0. 43	0. 08	1. 7	0. 8	0. 18	0. 03	0. 53	0. 37	0. 07	0. 05	0. 09
1996	0. 05	1. 49	0. 51	1. 4	1. 1	0. 26	0. 05	1. 1	0. 89	0. 36	0. 39	0. 04
1997	0. 01	0. 43	0. 08	0. 03	0. 53	0. 19	0. 16	0. 13	0. 37	0. 56	0. 26	0. 06
1998	0. 16	0. 11	0. 47	1	0. 53	0. 26	0. 15	0. 67	0. 49	0. 51	0. 28	0. 14
1999	0. 16	0. 59	0. 36	1. 7	0. 37	0. 22	0. 16	0. 37	0. 64	0. 01	1. 27	0. 13
2000	0. 17	0. 69	0. 33	1. 8	0. 2	0. 05	0. 26	0. 53	0. 64	0. 15	0. 74	0. 09
2001	0. 04	0. 28	0. 32	0. 37	0. 8	0. 03	0. 15	0. 47	0. 35	0. 75	0. 08	0. 09
2002	0. 17	0. 03	0. 11	0. 4	0. 27	0. 03	0. 21	0. 07	0. 03	0. 09	0. 19	0. 03

Based on table 3 and equation (6) and (7), the maximum difference and minimum difference will be:

$$\Delta\ (\min) = 0.01,\quad \Delta\ (\max) = 1.9$$

Step 4 is to calculate the grey relational coefficients $\xi_{0i}(t)$.translating the data in table 3 with equation (8), the grey relational coefficients may get as show in table 4.attentions must be pay to the determination of the value of ρ, since it determine the significance of difference between relational coefficients. As $\Delta\ (\max) = 1.9$, which is a somewhat big value, 0.1, a smaller data is taken as the value for ρ. Thus the relational coefficients $\xi_{0i}(t)$ in table 4 may calculated by equation (12):

$$\xi_{0i}(t) = \frac{0.2}{\Delta_{0i}(t) + 0.19} \qquad (12)$$

Table 4 Grey relational coefficients

Yeart	$\xi_{01}(t)$	$\xi_{02}(t)$	$\xi_{03}(t)$	$\xi_{04}(t)$	$\xi_{05}(t)$	$\xi_{06}(t)$	$\xi_{07}(t)$	$\xi_{08}(t)$	$\xi_{09}(t)$	$\xi_{010}(t)$	$\xi_{011}(t)$	$\xi_{012}(t)$
1993	0.95	0.61	0.43	0.48	0.77	0.61	0.27	0.77	0.46	0.63	0.23	0.44
1994	0.95	0.61	1	0.1	0.77	0.95	0.26	0.25	0.87	0.36	0.31	0.91
1995	0.63	0.32	0.74	0.11	0.2	0.54	0.91	0.28	0.36	0.77	0.83	0.71
1996	0.83	0.12	0.29	0.13	0.16	0.44	0.83	0.16	0.19	0.36	0.35	0.87
1997	1	0.32	0.74	0.91	0.28	0.53	0.57	0.63	0.36	0.27	0.44	0.8
1998	0.57	0.67	0.30	0.17	0.28	0.44	0.59	0.23	0.29	0.29	0.43	0.61
1999	0.57	0.26	0.36	0.11	0.36	0.49	0.57	0.36	0.24	1	0.14	0.63
2000	0.56	0.23	0.39	0.1	0.51	0.83	0.44	0.28	0.24	0.59	0.22	0.71
2001	0.87	0.43	0.39	0.36	0.20	0.91	0.59	0.30	0.37	0.21	0.74	0.71
2002	0.56	0.91	0.67	0.34	0.44	0.91	0.5	0.77	0.91	0.71	0.53	0.91

Step 5 is to calculate the grey relational grade. Make use of equation (10), the relational grade of each unsafe acts to the number of maritime accidents may be calculated, such as:

$$r_{01} = \frac{1}{10}(0.95 + 0.95 + 0.63 + 0.83 + 1 + 0.57 + 0.57 + 0.56 + 0.87 + 0.56) = 0.749$$

Other unsafe acts' grey relational grade to the accidents may be calculated in the same way, as shown in table 5.

Table 5 the relational grade of unsafe acts to maritime accidents

r_{01}	r_{02}	r_{03}	r_{04}	r_{05}	r_{06}	r_{07}	r_{08}	r_{09}	r_{010}	r_{011}	r_{012}
0.749	0.448	0.531	0.281	0.397	0.665	0.553	0.403	0.429	0.519	0.422	0.73

For convenience of analysis, table 5 has been transferred into Fig.1.

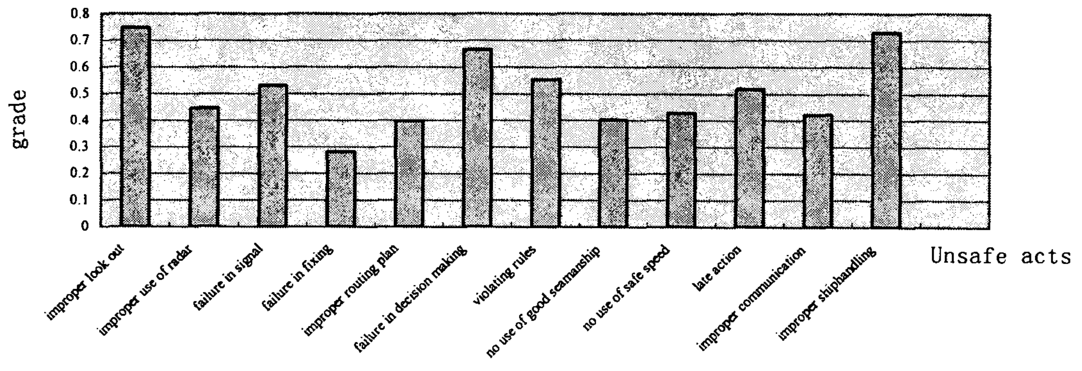

Fig. 1 Grey relational grade

4 The identified results of human errors in ship collisions

In accordance with table 5 and fig.1, it can be tell that which kinds of human errors (or unsafe acts) are major causes lead to ship collisions.

The unsafe acts whose the relational grade with collisions is greater than 0.7 are improper look out and improper shiphandling. The unsafe acts whose relational grade with collision is between 0.7-0.5 are failure in decision making, violating the regulations, failure in displaying signals, and delayed action in collision avoidance.

Failure in use of radar, failure in use safe speed, failure in communication and negligence in use of good seamanship are those unsafe acts that have relational grade with collisions in between 0.5-0.4.

Only the improper routing plan and failure in fixing are unsafe acts that have lower relational grade than 0.4 with collision accidents.

If the unsafe acts whose relational grade with collisions are neglected, than these unsafe acts as improper look out, improper shiphandling, failure in decision making, violating the regulations, failure in displaying signals, and delayed action in collision avoidance may be deemed as main cause lead to ship collisions.

5 Conclusion

The identification and management of human elements in maritime accidents is ad hoc in the research area of maritime safety. To cope with this developing tendency, the methods for identifying human errors in collision accidents are dealt with in this paper. It seems that the method of grey relational analysis is a practicable approach in identification of human errors in maritime accidents. There still more words to note here. Firstly, the method of grey relational analysis presented in this paper is established on the base of maritime accidents investigation report, so the accuracy of identification is affected by the reliability of investigation. Secondly, the identification of unsafe acts in only the first step in human element research, more important work is to identify the deeper causes lead to the unsafe acts. There is still great work need to be done in human element research work.

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