PREDICTING THE ECONOMIC LOSS OF TYPHOON BY CASE BASE REASONING AND FUZZY THEORY

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Abstract:

This study presents the prediction of economic loss of typhoon by two methods, case base reasoning (CBR) and fuzzy theory (FT). The typhoon records in Taiwan before 2000 were used as the database for reference, and the records after the year 2000 were predicted using CBR and FT derived from the database. Three scenarios were calculated, the first is CBR with four parameters, maximum wind speed, minimum atmospheric pressure, maximum wind speed in typhoon center and lowest atmospheric pressure near typhoon center. The second scenario includes the four parameters with rainfall and calculated by CBR. The third scenario uses the fuzzy calculation with four parameters. The successful rate of prediction for the three methods was 12.5%, 37.5%, and 57%. The results reveal that the fuzzy calculation can significantly increase the prediction rate than the traditional CBR method.

Keywords:

Typhoon risk; Fuzzy theory; Case base reasoning

1. Introduction

Typhoon can be estimated from the previous data with different estimation methods. If we choose the most similar case in previous experience, then the economic loss can be estimated by the similar case. This is the basic concept of case base reasoning, CBR. The successful rate of prediction for this method depends on the previous data. If the data is enough, then the prediction results could be good, however, if the database can not provide enough case for reference, then the successful rate of prediction will not be good. [3] [5] [6]

Case Base Reasoning (CBR) is the process to solve new problems based on the solutions of similar past problems. Scientist fixes the prediction rule by recalling previous example that exhibited similar characteristics. So, the CBR process just resembles the elements of natural phenomenon, and treats then as a solution database to predict the appropriate results. [1] [2] [4] [7]

The process to conduct the CBR process should follow the following four-step procedure: (1) retrieve; (2) reuse ;(3) revise ;(4) retain.

Fuzzy theory is a new field of research constructed by the fuzzy logic, which is a form to deal with of uncertainty and ambiguous situation. Fuzzy set theory was proposed by Zadeh in 1965. Now it has been widely used in many field including science and technology. [8]

Fuzzy theory is useful in predicting the uncertainty of natural phenomenon. Since typhoon is not easy to describe, so the fuzzy theory can play an important role in describing this phenomenon. We also use the fuzzy to predict the economic loss of typhoon in this study.

2. Scenario I Experiment – CBR with four parameters

The data before 2000 were collected as the reference group, and after 2000 were used as the verification group. The selected case has an economic loss more than 5000000 NTD.

The similarity level was used to choose the reference case and use the results of the reference case to predict its results. The similarity index, η, was calculated by the following equation

$$\eta = P_{ref} / P_{true} \quad (1)$$

Where, P_{true} is the true value of economic loss, P_{ref} is the economic loss of the reference loss. The lower value means the similarity of the case is higher.

The original data of typhoon loss in Taiwan was shown in Table 1. In this table, α is the minimum speed (kt) near typhoon center when this typhoon is in its strongest condition. β is the minimum atmospheric pressure (hPa) near typhoon when typhoon is in its strongest condition. γ is the maximum wind speed(kt) near typhoon center when this typhoon is close to Taiwan within one latitude. δ is the minimum atmospheric pressure (hPa) near typhoon center when the center of this typhoon is close to Taiwan within one latitude.

Table 1. The original data of typhoon in Taiwan in two groups

year	*month*	*date*	*name*	*α*	*β*	*γ*	*δ*	*Total loss*
1986	8	21-25	WAYNE	100	940	100	940	12239280
1986	9	16-20	ABBY	95	945	90	950	7501473
1994	7	11	TIM	120	930	100	942	56853348
1996	7	8	HERB	140	910	110	935	37890050
1994	8	8	DOUG	130	910	100	942	8907992
1998	10	14-16	ZEB	155	880	90	950	8099891
2000	10	30-11.01	XANGSANE	90	950	70	970	5418116
2000	8	21-23	BILIS	140	900	115	925	7644368
2001	9	16-19	NARI	80	960	80	960	5691986
2001	7	29-31	TORAJI	75	962	70	968	14723151
2004	6	29-07.02	MINDULLE	90	942	60	975	6516458
2005	7	16-20	HAITANG	110	915	95	935	9831405
2008	9	9月17日	SINLAKU	100	930	90	940	5643770
2008	9	26-29	JANGMI	105	930	100	935	7547679

Table 2. Predicting of typhoon loss by CBR(%)

α	*JANGMI*	*SINLAKU*	*HAITANG*	*MINDULLE*
ABBY	9.52	5	13.64	5.56
WAYNE	4.76	0	9.09	11.11
TIM	14.29	20	9.09	33.33
DOUG	23.81	30	18.18	44.44
HERB	33.33	40	27.27	55.56
ZEB	47.62	55	40.91	72.22
β	JANGMI	SINLAKU	HAITANG	MINDULLE
ABBY	1.61	1.61	3.28	0.32
WAYNE	1.08	1.08	2.73	0.21
TIM	0	0	1.64	1.27
DOUG	2.15	2.15	0.55	3.4
HERB	2.15	2.15	0.55	3.4
ZEB	5.38	5.38	3.83	6.58
γ	JANGMI	SINLAKU	HAITANG	MINDULLE
ABBY	10	0	5.26	50
WAYNE	0	11.11	5.26	66.67
TIM	0	11.11	5.26	66.67
DOUG	0	11.11	5.26	66.67
HERB	10	22.22	15.79	83.33
ZEB	10	0	5.26	50
δ	JANGMI	SINLAKU	HAITANG	MINDULLE
ABBY	1	1.06	1.6	2.56
WAYNE	0.53	0	0.53	3.59
TIM	0.75	0.21	0.75	3.38
DOUG	0.75	0.21	0.75	3.38
HERB	0	0.53	0	4.1
ZEB	1.6	1.06	1.6	2.56
Predicted case	WAYNE TIM	WAYNE	WAYNE TIM DOUG	ABBY
Reference case	ABBY	TIM	DOUG	TIM
Y/N	Fail	Fail	Success	Fail

Table 2. Predicting of typhoon loss by CBR(%)

α	TORAJI	NARI	BILIS	XANGSANE
ABBY	26.6	18.75	32.14	5.5
WAYNE	33.33	25	28.57	11.11
TIM	60	50	14. 29	33.33
DOUG	73.33	62.5	7.14	44.44
HERB	86.67	75	0	55.56
ZEB	106.67	93.75	10.71	72.22
β	TORAJI	NARI	BILIS	XANGSANE
ABBY	1.77	1.56	5	0.53
WAYNE	2.29	2.08	4.44	1.05
TIM	3.33	3.13	3.33	2.11
DOUG	5.41	5.21	1.11	4.21
HERB	5.41	5.21	1.11	4.21
ZEB	8.52	8.33	2.22	7.37
γ	TORAJI	NARI	BILIS	XANGSANE
ABBY	28.57	12.5	21.74	28.57
WAYNE	42.863	25	13.04	42.86
TIM	42.86	25	13.04	42.86
DOUG	42.86	25	13.04	42.86
HERB	57.14	37.5	4.35	57.14
ZEB	28.57	12.5	21.7	28.57
δ	TORAJI	NARI	BILIS	XANGSANE
ABBY	1.86	1.04	2.7	2
WAYNE	2.89	2.08	1.62	3.09
TIM	2.69	1.88	1.84	2.89
DOUG	2.69	1.88	1.84	2.89
HERB	3.41	2.6	1.08	3.61
ZEB	1.86	1.04	2.7	2.06
Predicted case	ABBY	ABBY	HERB	ABBY
Reference case	WAYNE	TIM	ABBY	TIM
Y/N	Fail	Fail	Fail	Fail

Table 3. the total evaluation coefficient of the typhoon after 2000

name	*κ*	*Module output code*
XANGSANE	2.265096	4
BILIS	2.190364	4
NARI	2	4
TORAJI	2.06523	3
MINDULLE	2.466154	*
HAITANG	2.136504	4
SINLAKU	2.100473	1
JANGMI	2.044652	3

Table 2 is the predicting results of typhoon by CBR. The typhoon records after 2000 were used to obtain the outcome as shown in table 3. The number to represent the typhoon is 1.TIM 2.ZEB 3. WAYNE, ABBY 4. HERB DOUG.

The successful rated of Scenario I, CBR with four parameters, is only 12.5%, as shown in table 2 and table

3.This means the prediction method still need to improve. Therefore we have to find other appropriate parameters to improve the prediction efficiency.

The possible reason for the high unsuccessful rate may be comes from the fact that the parameter is not enough to describe the whole phenomenon. Since typhoon brings a lot of rain, it may cause landslide and floods which are the main influence of economic loss, so we have to take into account the effect of rainfall amount. The results of prediction results with the four parameters with the new variable, rainfall, was presented in the next section.

3. Scenario II Experiment– CBR with five parameters

In order to increase the successful rate or prediction, the rainfall was chosen to be the new parameter. The new similarity index is the total value of the five parameters, ζ, as shown in table 4. The successful rate after improvement with five parameters is 3/8=37.5%, as shown in table 5. Although the result is better than the previous one, it is still not good enough, so we use the fuzzy theory to predict the same case in the next section.

For example, the value of κ for typhoon Wayne is, κ = 100/100 +940 /940 = 2.

The fuzzy interval of total evaluation index, κ, was shown in table 6. From table 7 and 8, the module output code by fuzzy theory of typhoon Sangsane, Bilis, Nari is 4, which is the number of typhoon Herb, and Doug. However, the prediction results were Tim(1) and Abby(3). Therefore, the prediction results were not correct.

The total evaluation coefficient of typhoon Mindulle can not find a corresponding typhoon because there is no data in the interval [2.4~2.49], it was marked by a symbol,*.

Because there are two records in the interval of [2.0, 2.09] and [2.2, 2.29], therefore, the values were adjusted. For example, the new value of total economic loss and the upper and lowest level of economic loss. The successful rate of prediction is 4/7=-57%, as shown in table 9.

Table 4. Predicting the economic loss of typhoon with five parameters

year	*month*	*date*	*name*	*α*	*β*	*γ*	*δ*	*Total loss*	*ζ*
1986	8	21-25	WAYNE	100	940	100	940	12239280	2842.4
1986	9	16-20	ABBY	95	945	90	950	7501473	1906.7
1994	7	11	TIM	120	930	100	942	56853348	2379
1996	7	8	HERB	140	910	110	935	37890050	4082
1994	8	8	DOUG	130	910	100	942	8907992	3048
1998	10	14-16	ZEB	155	880	90	950	8099891	2996
2000	10	30-11.01	XANGSANE	90	950	70	970	5418116	3043
2000	8	21-23	BILIS	140	900	115	925	7644368	2377
2001	9	16-19	NARI	80	960	80	960	5691986	3356
2001	7	29-31	TORAJI	75	962	70	968	14723151	2833
2004	6	29-07.02	MINDULLE	90	942	60	975	6516458	3249
2005	7	16-20	HAITANG	110	915	95	935	9831405	3270.5
2008	9	8-21	SINLAKU	100	930	90	940	5643770	3517.7
2008	9	26-29	JANGMI	105	930	100	935	7547679	2882

Table 5. Similarity level for CBR with five parameters

	JANGMI	SINLAKU	HAITANG	MINDULLE
ABBY	0.86	17.37	11.12	10.54
WAYNE	1.37	19.2	13.09	12.51
TIM	17.45	32.37	27.26	26.78
DOUG	5.76	13.35	6.8	5.76
HERB	41.64	16.04	24.81	25.64
ZEB	3.96	14.83	8.39	7.79
Predicted case	ABBY	DOUG	DOUG	DOUG
Reference case	ABBY	TIM	DOUG	TIM
Y/N	Success	Fail	Success	Fail

Table 5. Similarity level for CBR with five parameters

	TORAJI	NARI	BILIS	XANGSANE
ABBY	2.6	13.39	22.28	4.48
WAYNE	0.33	15.3	19.58	6.59
TIM	16.03	29.11	0.08	21.82
DOUG	7.59	9.18	28.23	0.16
HERB	44.09	21.63	71.73	34.14
ZEB	5.75	10.73	26.04	1.54
Predicted case	WAYNE	DOUG	TIM	DOUG
Reference case	WAYNE	TIM	ABBY	TIM
Y/N	Success	Fail	Fail	Fail

Table 6(a). Summary statistics of typhoon before 2000

year	*month*	*date*	*name*	*α*	*β*	*γ*	*δ*
1986	8	21-25	WAYNE	100	940	100	940
1986	9	16-20	ABBY	95	945	90	950
1994	7	11	TIM	120	930	100	942
1996	7	8	HERB	140	910	110	935
1994	8	8	DOUG	130	910	100	942
1998	10	14-16	ZEB	155	880	90	950

Table 6(B). Summary statistics of typhoon before 2000

year	*T*	*LL*	*LU*	*κ*
1986	12239280	9791424	14687136	2
1986	7501473	6001178.4	9001767.6	2.050292398
1994	5685348	4548278.4	6822417.6	2.187261146
1996	37890050	30312040	45468060	2.245989305
1994	8907992	7126393.6	10689590.4	2.266029724
1998	8099891	6479912.8	9719869.2	2.648538012

Table 7. the interval of total evaluation index, κ

interval	*L_L(20%)*	*Economic loss*	*L_U(20%)*
2.0~2.09	9791424	12239280	14687136
	6001178	7501473	9001768

2.1~2.19	4548278	5685348	6822418
2.2~2.29	30312040	37890050	45468060
	7126394	8907992	10689590
2.3~2.39	0	0	0
2.4~2.49	0	0	0
2.5~2.59	0	0	0
2.6~2.69	6479913	8099891	9719869

Table 8. Interval of membership function and the module output code

interval	LL(20%)	Economic loss	LU (20%)
2.0~2.09	7896301.2	9870376.5	11844452
2.1~2.19	4548278	5685348	6822417.6
2.2~2.29	18719217	23399021	28078825
2.3~2.39	0	0	0
2.4~2.49	0	0	0
2.5~2.59	0	0	0
2.6~2.69	6479912.8	8099891	9719869.2

Table 8. Interval of membership function and the module output code

interval	Lowest level in the interval	Highest level in the interval	Module output code
	of membership function	of membership function	
2.0~2.09	0.142	0.31	3
2.1~2.19	0	0.097	1
2.2~2.29	0.602	1	4
2.3~2.39			
2.4~2.49			
2.5~2.59			
2.6~2.69	0.082	0.22	2

Table 8. the prediction results by fuzzy theory

Typhoon to be predicted	JANGMI	SINLAKU	HAITANG	MINDULLE
Corresponding typhoon	ABBY	TIM	DOUG	TIM
Typhoon to be predicted	TORAJI	NARI	BILIS	XANGSANE
Corresponding typhoon	WAYNE	TIM	ABBY	TIM

4. Conclusions

The results for the successful rate for the three scenarios are 12.54%, 37.5%, and 57%, respectively. The result of scenario II is better than scenario I. it shows that the CBR can be improved by the addition of appropriate parameters. The selected parameter also provides the reasonable physical meaning of the economic loss and the natural characteristic of typhoon. The newly added parameter can complete the lack of CBR for the statistically relevant data for backing and implicit generalization.

The CBR method is a method which depends on the amount in the data base. In this study, there are only six cases in the database. Therefore, it is very difficult to obtain a close estimation of the economic loss. If more data were included, the results could be increase.

The scenario III is the best among the three scenarios. It reveals that the fuzzy theory is better than the CBR in predicting the typhoon loss. The reason may comes from the fact that the typhoon is a very vague phenomenon, in such condition fuzzy theory has a better capability for identify the result than other calculation method.

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