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A Fuzzy Intelligent Decision Support System for Typhoon Disaster Management

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Abstract—**This paper presents the conceptual framework of fuzzy intelligent decision support system for typhoon disaster management. The typhoon risk management pattern was mentioned in the first section. Several types of database should be established in the decision support system. There are three steps to predict the typhoon risk. The first one is the feature extraction of typhoon pattern. The second one is the damage estimation by case base reasoning method. And the third one is the linguistic estimation of typhoon risk. An example of risk evaluation from the experiment data shows that the decision supporting system can be further improved if there is a complete and accurate dataset in this system.**

Keywords-component; fuzzy theory, decision support system, disaster management, risk analysis

I. INTRODUCTION TO TYPHOON DISASTER MANAGEMENT

Typhoon is one of the most worrisome natural disasters in Taiwan. Its management is related to the location because typhoon is a variable vector in the space. The concept of geospatial information system helps us to construct the geographic database. However, the prediction of typhoon must have large amount of observational data. The choice of these data is a process worthy of careful condition.

Typhoon disaster is a decision analysis process under uncertain condition. We need to concern about the combination of information on human identification and instrumental observation to make consolidated conclusion.

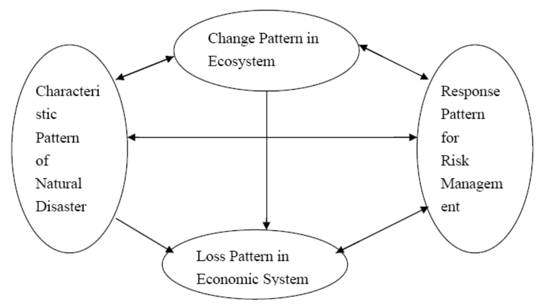
The aim of this study was to build a decision support system for typhoon mitigation. The system can provide the disaster prevention and rescue unit to temporary reduce risk and disaster preparedness. Besides, it can support the operations as decision making or disaster recovery. The system has to integrate with the function of geographical information system to incorporate the typhoon forecasting and analysis model. A model bank with the spatial decision support system was included in this system to obtain the necessary knowledge of typhoon risk management.

How to obtain the wisdom related to typhoon disaster management is an important issue in constructing the intelligent system. The theory of ontology can systematically organize the human knowledge.(Hadzic et al., 2009) Knowledge ontology allows us to share the wisdom and knowledge more easily. It can also quickly help us to find the required information and data. The knowledge ontology in this study also accumulates the technical results of typhoon risk prevention and assists the researchers to identify the topic worthy of further research. (Chang and Wang, 1996)

II. MATHEMATICAL MODEL

A. Feature extraction

Feature extraction of typhoon risk includes the image decomposition, pattern recognition and noise filtering. Many researchers have applied the Artificial Neural Network (ANN) model in feature extraction. ANN has capacity to simulate the brain's thinking process objectively and avoid the influence of the forecasters' subjective judgment.



Fug 1 the four types of pattern in the typhoon risk management system

Chen et al have used the multivariable method to clarify the relationship of typhoon pattern. (Chen et al, 2010) We may consider the feature of typhoon has the following four categories: (1) typhoon natural itself; (2) change in ecosystem; (3) loss in economic system; (4) response for risk management. (Chen, 2010) (Schuermann, 1996) (Richard et al, 2001)

B. Damage prediction

The typhoon damage can be estimated by the basic principle of case-based reasoning (CBR). CBR is one of the new reasoning methods of artificial intelligence, and it is the simplest way to perform fuzzy risk assessment and calculate the fuzzy expected value. Case base reasoning method can also convert the fuzzy risk into the non-fuzzy risk by converting it to a clear number. Decision support system of typhoon uses various risk factors of typhoon to analyze the damage by the case base reasoning method.

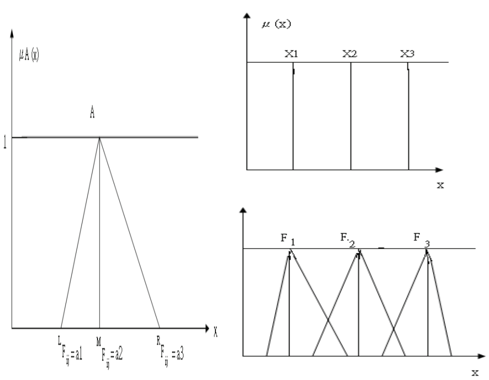
C. Risk analysis

Prediction of typhoon risk is difficult because the term “risk” is a very subjective work. Some people think that is very dangerous, but others believe that not dangerous. For example, if the damage of typhoon can be represented as: very safe, safe, medium, serious, very serious, then we can use fuzzy logic operation to convert it into an objective amount. The Triangle Fuzzy Number (TFN)r is often used in the representation of a vague amount. For example, the i^{th} damage of the j^{th} area, X_{ij}, the fuzzy equation can be written as $F_{ij} = (LF_{ij}, MF_{ij}, RFi_{j})$, where F_{ij} is the characteristic value of X_{ij}, LF_{ij} is the lowest value of F_{ij}, RF_{ij} is the maximum value of F_{ij}, MF_{ij} is the most probable value of F_{ij}, and ${}^{L}F_{ij}< {}^{M}F_{ij}<{}^{R}F_{ij}$.(Figure 2a)

We can use the membership function $\mu_A(x)$ represented by (a_1, a_2, a_3) to express the triangular fuzzy number (TFN). Thus the characteristic number of the i^{th} damage of the j^{th} area is $a_1 = {}^{L}F_{ij}$, $a_2 = {}^{M}F_{ij}$, $a_3 = {}^{R}F_{ij}$. The membership function by TFN then becomes

$$\mu_A(x) = \begin{cases} 0 & , \quad x \langle a_1 \\ \dfrac{x - a_1}{a_2 - a_1} & , \quad a_1 \le x \le a_2 \\ \dfrac{a_3 - x}{a_3 - a_2} & , \quad a_2 \le x \le a_3 \\ 0 & , \quad x \rangle a_3 \end{cases} \tag{1}$$

Since the range of fuzzy interval for everyone is different, so the value of TFN is not the same. Figure 2b describe that there are various TFN value from different observer.



(a) (b)

Fig 2 (a) Membership function of the triangular fuzzy numbers (TFN) (b) Converting the original results into a normalized fuzzy number

III. SYSTEM DESCRIPTION

The knowledge bank of typhoon disaster management is shown as figure 3.

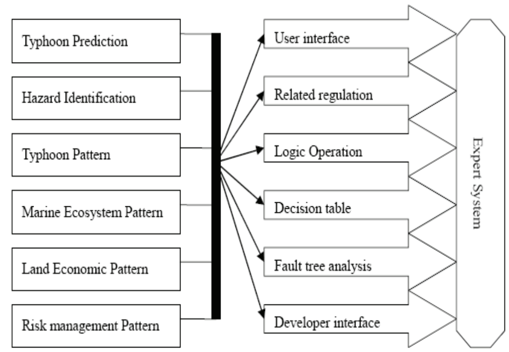


Fig 3 Intelligent knowledge-based expert system

A. Knowledge bank and data base design

The input data of typhoon disaster decision support system includes the following: real- time meteorological data, forecast typhoon data, historical typhoon data, and other basic typhoon information. There are two types of real time data, the real-time meteorological data and the forecast typhoon data. Therefore the system must have the real-time data loading capability in order to meet the “real time” feature.

The real-time meteorological data can be obtained from the government. The typhoon forecast data is also real-time information; however, it may not so complete as the general meteorological data. Most of this information is image base, such as satellite image, typhoon forecasting, or typhoon path map, etc.

B. Real-time and historical information query

The real-time information of typhoon includes the real-tine trend of typhoon. These includes typhoon the previous typhoon path and forecast typhoon path, satellite images, and related descriptive statistics information.

The historical information of typhoon provides the function of query. The query is through the configuration condition by name, landing time, landing location, and generating location, etc. the information available in this system are: landing data, landing time, generating location, generating time, typhoon grade, cumulative rainfall, total rainfall, satellite image, and disaster description.

C. Typhoon damage prediction

Typhoon damage prediction can be performed by the case base reasoning method as described in section 2.3. The major disaster of typhoon is flooding and landslides which were caused by the precipitation due to typhoon. The major function of typhoon damage prediction is to provide the real time rainfall data as for the risk analysis. It includes the spatial and temporal distribution of real time rainfall and accumulates rainfall.

D. Typhoon risk analysis

The results of risk analysis provide the decision maker the information about the loss of life and property. Typhoon risk prediction can be performed by the linguistic risk analysis as described in section 2.3. In this study, we selected five grades of typhoons in this system: 1.very strong; 2. strong; 3. medium; 4. weak; 5.very weak.

There are many variable for describing the degree of risk. These include: extent of flooding, number of death, number of disappear, number of injury, housing collapse(all), housing collapse(half), housing loss, and agriculture loss.

E. Scenario simulation and information display

The scenario simulation and information display of typhoon should consider the space and time characteristic of typhoon. Since the typhoon disaster is a space-time event, we define the event by the same equation. The scenario simulation was based on the historical typhoon information. The case base reasoning can help us to simulate the possible damage in order to prevent the disaster.

Typhoon can be represented by a mathematical vector. The space geographical information can be represented by the following equation:

$$I = \sum_{i=1}^{m}\left[\sum_{j=1}^{n}\begin{bmatrix} S_{ij}(T_{ij}) \\ A_{ij}(T_{ij}) \\ T_{ij} \end{bmatrix}\right]$$

$$T_{ij}(t_b, t_e)_{ij} \tag{2}$$

Where I is the collection of space geographical information; i is the individual vector for the i^{th} item, j is the state of this item; $S_{ij}(T_{ij})$ and $A_{ij}(T_{ij})$ represent the characteristics of this item in time t_b to t_e.

Because the decision support system is based on the core concept of geographical information system, therefore the information should fully demonstrate the characteristic of spatial information. It has to show the relationship between the space and spatial distribution. In addition, it has to integrate the traditional text, statistics, reports, and display mode.

F. Intelligent decision support system

Spatial Decision Support Systems is one of the major development item of Geographic Information Science. (Goodchild, 2005;Sengupta and Bennett , 2003;) The development of intelligent decision support system should include the intelligence and knowledge for this kind of decision making.

In this system, the database includes the real-time meteorological data, with this information and other data; it can provide the related table and figure for the decision maker.

To solve the decision making problem of typhoon disaster management, we need to utilize our information technology. Intelligent spatial decision support system (ISDSS), which is now the major research direction in geographic information science and decision makers, can help us integrate the data base in various types of information and knowledge.

IV. EXAMPLE AND DISCUSSION

An example of risk analysis was presented in this section to explain the importance of database. The prediction of typhoon risk has to use the available data. There are three different types of data for the prediction of typhoon risk. The first one is the value with definite quantity; the second one is the value with fuzzy interval, and the third one is the linguistic expression.

In order to compare the different types of data, we have to adjust these data into the same type. **W**e use three types of fuzzy degree to calculate the fuzzified number, 20%, 10%, and 5%. The fuzzified results were shown in figure 4. Then, the normalized risk was calculated and the aggregate results of total risk were shown in figure 5.

In figure 5, there are different fuzzy degree ranges with different type of typhoon, from very strong to very weak. If it is twenty percent fuzzy degree as figure 5(a), then there is a very wide range of risk interval; however, if the fuzzy degree is low, such as figure 5(c), then the range of risk interval will be decreased.

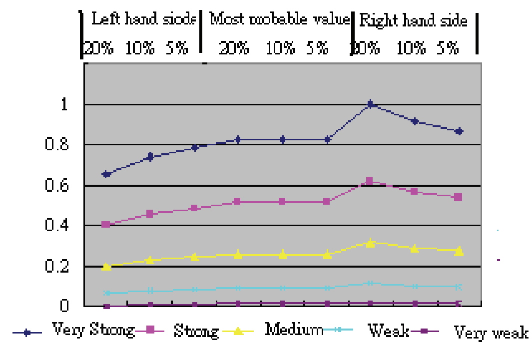
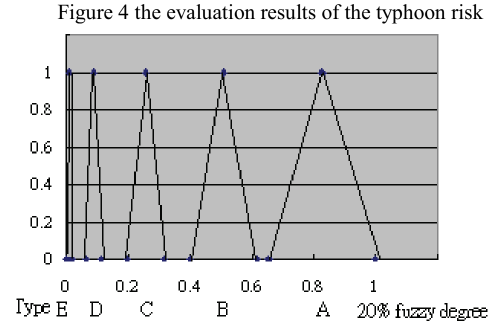
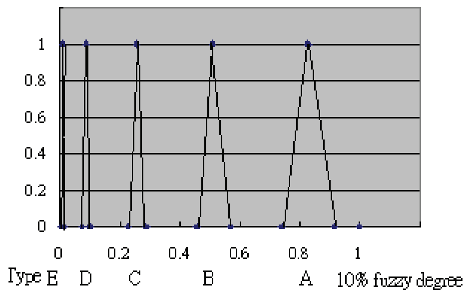


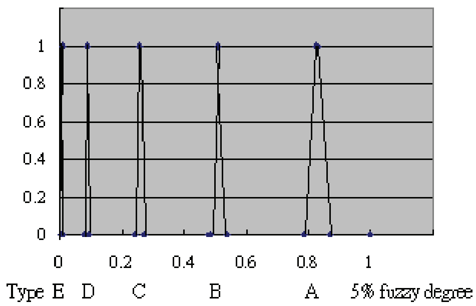
Figure 4 the evaluation results of the typhoon risk



(a)



(b)



(c)

Figure 5 Different fuzzy degree range with different type of typhoon,

A: very strong B: strong C: medium D: weak E: very weak

The reasons for the discrepancy of these results were due to the reliable extent of information. The damage prediction need adequate data to support the decision making process. However, the determination of the availability of information is very cumbersome. The decision maker does not have enough time to determine. Therefore, more unreliable information cause more credible decision-making. The best way to improve the efficiency of this decision support system is to increase the reliability completeness of the database.

The feature extraction and damage prediction help us to confirm the extent of harm by typhoon. In this article, there is not enough space to elaborate. Hope there will have more research appeared in this area.

V. CONCLUSION

This paper describes the framework of a fuzzy intelligent decision support system for typhoon disaster management. The development of spatial decision support system was introduced in this article. The mathematical model of the intelligent system includes the feature extraction by artificial neural network, damage estimation by case base reasoning, and risk prediction by fuzzy linguistic transformation. An example of the typhoon risk analysis show that the improvement of this system is depends upon the accuracy and completeness of its knowledge. And the development of feature extraction and damage estimation will be of great benefit of these results.

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