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Research Article

A Fast Environmental Pollution Emergency Plan Generation System Integrating Various Methods

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Abstract: Integrating methods and techniques of CBR, RBR, R-AHP and GIS etc. ,this study designed and developed a fast environmental pollution emergency plan generation system. The study analyzes the working principle and process that generate emergency plan combining CBR and RBR. In CBR system, R-AHP is used to construct the case index system of environmental pollution emergencies and calculate the weight of index; similarity between cases is measured by nearest-neighbour algorithm. Rule-based reasoning is performed in accordance with the rules in the knowledge base and GIS is used to achieve the visual expression of the dynamic emergency plan. Integration of various methods optimizes the response time and complexity of system, also enhances the practical operability. This study has great significance in researching of environmental emergency management and improving emergency response capability.

Keywords: CBR, environmental pollution, emergency plan, GIS, RBR, R-AHP

INTRODUCTION

In recent years, with the rapid development of Chinese socio-economic, environmental pollution incidents occur frequently, which have brought great harm and loss to the ecological environment, human health, socio-economic. Compared with the general pollution incidents, environmental pollution emergencies hold characters as short reaction time, low level of information, higher control costs. After the outbreak, responds need to de done at the first time, effective countermeasures should been taken to prevent the further expansion of the event. At present, China's environmental pollution emergency response system is still in the initial application stage and emergency plan almost exists as static text or simple management information system (Chang *et al*., 1997). Such emergency plan lacks of adaptability, operability and timeliness in the emergency response process. Therefore, research of fast emergency plan generation technique with the support of knowledge has important economic value and social significance.

The traditional method is using the expert system (Rule-Based Reasoning, RBR) to generate the decision method. However, this approach is often slow and it is also hard to generate the reasoning rules sometimes (Zhang and Liu, 2002). CBR (Case-based Reasoning) has broken through the bottleneck for knowledge acquisition. It is a reasoning mode for solving the current problem based on the experience got from the solving of similar problems in the past. CBR is particularly applicable to the areas in which a quick decision-making is needed but the mechanism is not entirely clear, or the situation is too complex to establish a rule model (Qu and Hao, 2004). However, due to the lack of deductive ability, the single CBR reasoning is the lack of systematic. In this study, the RBR and CBR are combined, supplemented by R-AHP (Reformed-Analytic Hierarchy Process) and with the expression technology based on GIS (Geographic Information System) for the dynamic plan.

STUDIES OF VARIOUS METHODS

The working principle and the process of the system: When a new emergency event happens, the case base of CBR system is first retrieved to find the similar solutions (Kolodner, 1992). If there is a suitable case, it can be applied directly or slightly modified as an emergency plan. Only when the solution cases cannot be obtained from the case base or the case solutions are not satisfactory, the RBR system is used to reason for a solution by users and then the reasoning result is stored in the case base for future use after evaluating of implementation results (Jiewen *et al*., 2007). The works and the process of the system are shown in Fig. 1.

With RBR system, users can simulate all kinds of events in advance and generates the appropriate plans, or in the process to solve the incident, record the results of reasoning. Accident report in the system can be used to keep records of the incident handling progress. The accident report and the case base have the same organizational structure. Therefore, the valuable

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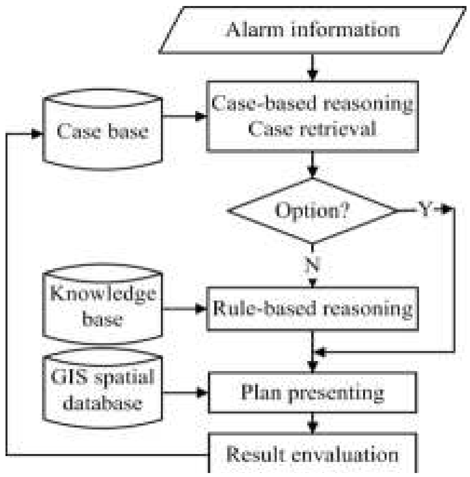

Fig. 1: The working principle and the process

accident report can be as a valid case to add into the case base after the end of the emergency.

Because incident information is incomplete, the case index system in the CBR system is constructed solely based on the necessary alarm information. R-AHP is used to represent the case index system and to calculate the index weight. The nearest-neighbor algorithm is used to measure the similarity of the cases. CBR system has a self-optimizing function. Therefore, the efficiency and accuracy of the system will also be greatly improved with the increase of emergency plans in case base.

Due to the combination of RBR, CBR, AHP and GIS, the system has the following advantages. Firstly, it improves the performance and solves the knowledge acquisition bottleneck of traditional RBR system. Secondly, it also solves the automatic acquisition of the initial case in CBR system. Finally, dynamic results of the emergency plan are plotted on the map of GIS, such as the atmospheric pollutant diffused region, affected sensing receptors, evacuation routes of receptor and the optimal route of the emergency rescue, etc. All of these provide strong support to deal with environmental pollution emergencies.

At present, the system has been used in a city emergency platform. The effect of implementation shows that it has obvious advantages in performance and operability.

Knowledge representation of the case base in CBR system: The system uses R-AHP to construct case index system and calculate index weight. The principle of AHP includes of analyzing of the main elements of the target, grouping the elements for establishing the hierarchy, determining the relative importance of the sub-layers and the various elements in the hierarchy, establishment of judgment matrix and getting the final weight of the element (Sunghoon *et al*., 2007). R-AHP amends inconsistent judgment matrix, which is prone to the AHP and adds the optimal transfer matrix, thereby makes the calculation of the weights is more objective.

Table 1: Index system and weight calculation

Sub-layer	Sub-layer index	Index weight	Attribute type
Contaminant	Name	0.5733	Character
	Quality	0.0637	Number
Event characteristics	Type	0.1457	Character
	Duration	0.0680	Number
	Deaths	0.0304	Number
	Injuries	0.0142	Number
Location	Source	0.0942	Character
	Company	0.0105	Character

Through the analysis of the emergency alarm information, the system constructs the index system of air pollution events, as shown in Table 1.

Weight is calculated as follows:

Step 1: Calculating sub-layer weight with 0, 1, 2 scale method. First, some matrixes can be constructed in the order of comparison matrix A_{ij}, judgment matrix B_{ij}, transfer matrix C_{ij}, optimal transfer matrix D_{ij} and quasi-optimal consistent matrix B'_{ij}. Then the eigenvectors of B'_{ij} are solved and normalization. Finally, the weight of three sub-layers can be calculated, as shown in Table 1. Each matrix is calculated as follows Eq. (1-5):
Comparison matrix A_{ij}:

$$A=\begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{21} & \cdots & A_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ A_{n1} & A_{n2} & \cdots & A_{nn} \end{bmatrix} \tag{1}$$

where, $A_{ij}=\begin{cases} 2 & \text{i is more important than j} \\ 1 & \text{i and j are equally important} \\ 0 & \text{j is more important than i} \end{cases}$

Jugement matrix B_{ij}:

$$B_{ij}=\begin{cases} \dfrac{r_i-r_j}{r_{max}-r_{min}}(k_m-1)+1, r_i \geq r_j \\ \left[\dfrac{r_j-r_i}{r_{max}-r_{min}}(k_m-1)+1\right]^{-1}, r_i \geq r_j \end{cases} \tag{2}$$

where, r_i is sorting index for the degree of importance,

$$r_i=\sum_{j=1}^{n} A_{ij},\ r_{max}=\max\{r_i\},$$

$$r_{min}=\min\{r_i\},\quad k_m=r_{max}/r_{min}$$

Transfer matrix C_{ij}:

$$C_{ij} = \lg B_{ij}, (i, j = 1,2,\cdots,n) \tag{3}$$

Optimal transfer matrix D_{ij}:

$$D_{ij} = \frac{1}{n}\sum_{k=1}^{n}(C_{ik} - C_{jk}) \tag{4}$$

Quasi-optimal consistent matrix B'_{ij} :

$$B'_{ij} = 10^{D_{ij}} \tag{5}$$

Step 2: Calculating sub-layer index weight respectively. Method of calculation is the same way as the step 1. The value of weight is shown in Table 1.

Step 3: Sub-layer index weight multiply by a sub-layer weight and finally the index weight is shown in Table 1.

Case retrieval in CBR system: The nearest-neighbor algorithm is used to measure the similarity of the cases (López De Mántaras *et al*., 2005). The type of case index is shown in Table 1.

Step 1: calculating the similarity between indexes.

Defining X is a source case in case base, T is target case, then the similarity between X_i and T_i which are two values of the i index is expressed as:

$$sim_i(X_i, T_i) = \begin{cases} 1, & X_i = T_i, \text{character} \\ 0, & X_i \neq T_i, \text{character} \\ 1 - \frac{|X_i - T_i|}{\max_i - \min_i}, & number \end{cases} \tag{6}$$

where, $\max_i$ is the maximum value of all the index values of the i index and $\min_i$ is the minimum value of all the property values of the i index.

Step 2: Calculating the similarity between cases. The similarity between the cases is expressed as:

$$Sim(X,T) = \sum_{i=1}^{n} \omega_i \times sim(X_i, T_i) \tag{7}$$

where, n is the total number of case index, ω_i is the value of the i index weight.

The key technologies of the RBR system: Usually, RBR system consists of two parts: the knowledge base and inference engine. According to the rules in the knowledge base and the input parameters from the users, inference engine executes query, matching, calculation, reasoning and finally deduced in the emergency plan. On the one hand, this plan is as the decision-making of the event; on the other hand, it is stored in case base. Once a similar situation occurs, the plan can be directly retrieved from the case base without reasoning in RBR again.

Reasoning process of the inference engine of the system is as follows:

Step 1: Generating reasoning conditions *RC* according to the event. *RC* is expressed as $RC = (RC_1、RC_2、RC_3、\cdots、RC_n)$ and it is used to match with the prerequisite of the rules in reasoning.

Step 2: Selecting RC_1.

Step 3: Matching rules in knowledge case until RC_1 be to obtain.

Step 4: Implementing rules conclusions and storing the results.

Step 5: Repeat the second step to the fourth step until RC_n.

Step 6: Output the results of all the rules of reasoning. The results of the system are given in the way of text and GIS.

IMPLEMENTATION SYSTEM AND DISCUSSION

Architecture, design and development of the system are based on the technical specifications such as SOA (Service Oriented Architecture) and Web Services. The structure of the system is B/S and programming language is JAVA. The client is developed by JSP and AJAX, which supports the remote asynchronous calls and the server is developed by the Servlet and Hibernate. In addition, WEB GIS is used as an application support, to achieve a dynamic plan (Xin *et al*., 2008).

For example, an atmospheric pollution emergency was caused by chlorine leakage and the fast generation process of the emergency plan is shown in Fig. 2, 3, 4 and 5.

Plan generation speed of this system depends largely on the size of the case base. If only a small number of cases in the case base, we often cannot get the case with high similarity as a plan, so, we have to use the RBR method as a plan generation tool. With the accumulation of cases in case base, the success rate of the CBR method increase and the average time of the plan's generation be reduced accordingly. However, with the growing number of cases in case library, case retrieval time is getting longer and the response time of the system also grows. Therefore, the case base maintenance is an important factor to affect the efficiency of the system.

Fig. 2: Results of case retrieval in CBR

Fig. 3: Input of reasoning in RBR

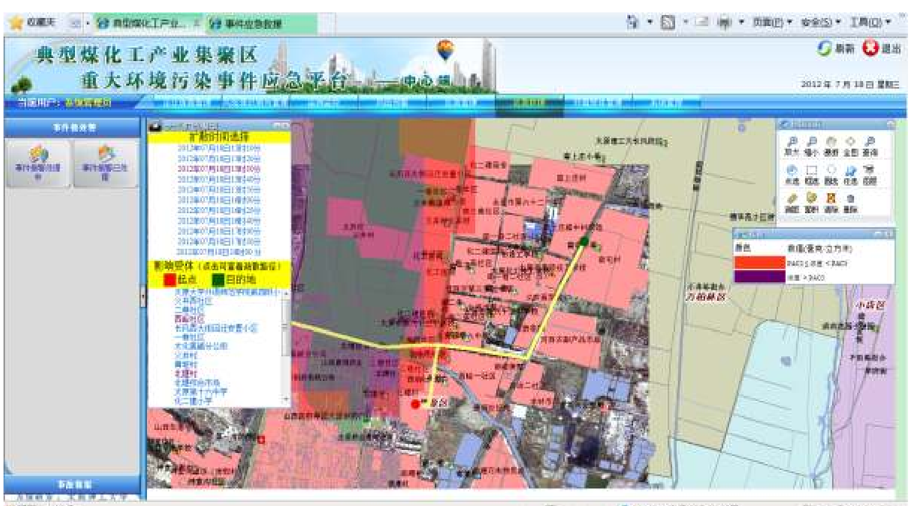

Fig. 4: Display of dynamic plan

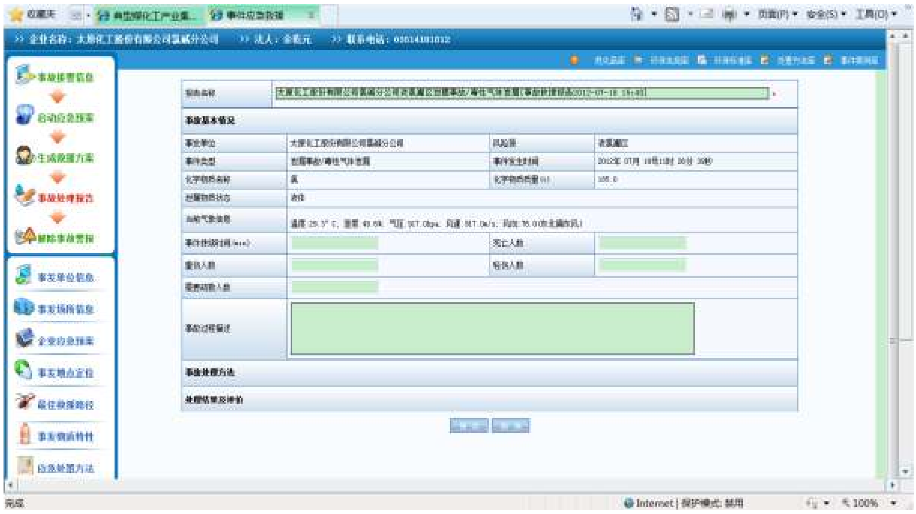

Fig. 5: Example of accident report or case

CONCLUSION

It is very important to generate response plan in the shortest possible time to deal with the emergencies, which will greatly reduce the loss of lives and property. This study describes the design and implementation of a fast environmental pollution emergency plan generation system from theoretical and engineering aspects, which integrates a variety of methods of RBR, CBR, R-AHP, GIS etc. in it. On the theoretical side, the system uses the alarm information as the retrieval conditions of plans, so it can reduce the complexity of CBR system and application. This system uses an R-AHP method to construct the case index system and the weight. The plan matching is realized with the weighted similarity retrieval method. On the engineering side, we construct a fast environmental pollution emergency plan generation system. This system combines the RBR system and the CBR system. GIS technology is used to do the visualization of the contents of the plan. And now the system has been applied to a city emergency platform. The effect of implementation shows that it has obvious advantages in performance and operability.

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