Decision-making Support Based on the Combination of CBR and Logic Reasoning

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ABSTRACT

In recent years, various crises arise frequently and cause tremendous economic and life losses. Meanwhile, current emergency decision models and decision support systems still need further improvement. This paper first proposes a new emergency decision model based on the combination of a new case retrieval algorithm for Case-Based Reasoning (CBR) and logic reasoning, and then address a sample flood disaster emergency decision process to explain the application of the model in practice.

Keywords

Case-Based Reasoning, Logic Reasoning, Crisis, Emergency Response.

INTRODUCTION

Since the 90s of last century, the management of emergent crises has become an important problem which causes global concern. Continuing natural disasters and terrorist activities have become the reality that human beings have to face. China in recent years has in particular suffered from many crises. Severe Acute Respiratory Syndrome (SARS), the coal mine accident in Shanxi, the flooding in Sichuan, and other unexpected crises has caused an immeasurable loss to the country's economic and social development. Due to the high degree of geographical irregularity, the huge population, and the numerous rivers, flooding happens very often in history and is one of the most severe crises in China. Over the years, China has invested a lot of manpower, resources, and money to carry out river maintenance and strengthen hydraulic engineering construction in order to reduce the various losses caused by floods, but still cannot effectively prevent the occurrence of floods. Floods such as the one in Chongqing, Sichuan in 2007 still caused huge economic losses and casualties. In this context, the use of information technology to improve the speed and correctness of disaster information collection, transmission, processing and decision-making, so as to strengthen human beings' ability to fight against such disasters has become an important means of emergency response.

Existing research on emergency response decision-making mainly focus on the following aspects: (1) the emergency decision-making model. Some scholars have studied some emergency decision-making models adapted from other areas (She and Wu, 2005). For example, the Irish scholar Cosgrave addresses the characteristics of emergency decision-making and builds a theoretical model of emergency decision-making based on the normative model of leadership by Vroom and Yetton. In his approach, decision-makers are assigned different levels of authority to make decisions on the incident. (2) the emergency response decision-making methods. A number of solutions based on applied mathematics and risk management have been proposed (She and Wu, 2005). For example, Pauwels et al. use utility analysis and sensitivity analysis methods to analyze the withdrawal solutions for the nuclear leaking incident. Tamura et al. apply decision tree into the analysis of disaster risk. (3) the emergency decision-making patterns, which include the rational decision-making pattern based on statistical analysis, the constraints satisfaction decision-making pattern focusing on the actual environmental constraints, the progressive decision-making pattern based on group consultation, and so on. The most popular emergency decision-making pattern is the RPD (Recognition-primed Decision) pattern proposed by Klein (1991). (4) the emergency decision-making process. Yuan divides the emergency decision-making process into five stages: problem definition, goal setting, solution design, alternative selection, organization, and implementation (Yuan, 1996), while Wu argues that the decision-making process should consist of the following five steps: targeting setting, alternative programming, alternative assessment, alternative

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selection and alternative implementation (Wu, 2007).

Classical decision-making methods cannot satisfy many special requirements of the management of emergent crises. CBR and logical reasoning are two important knowledge-based problem solving and learning methods in AI. This paper studies these two methods and puts forward an emergency decision-making model based on the combination of the two methods. Based on the case study of flooding disasters, we show that the combination approach can take full advantage of the easy knowledge acquisition, fast reasoning speed and good learning ability of CBR while retaining the advantages of logic reasoning, including clear representation structure, strong explanation ability, and knowledge discovering ability, and thus can provide strong support for the decision-making in emergency response and help decision-makers conduct the most effective decision-making in the shortest time. We hope our research on the combination of CBR and logical reasoning in the context of emergent crises will enrich both existing DSS theory and application systems.

KNOWLEDGE REPRESENTATION FRAMEWORK

This section explains the knowledge representation structure of cases and rules in detail.

(1) The case structure

A case is a record of problem specification and expert decision-making experience. Existing case-based reasoning research usually uses a pair of elements < problem description, solution description >, or sometimes uses the form of a triple < problem description, solution description, effect description> to represent a typical case. Case representation is to make the computer system recognize and understand the historical issue of the problem and expert knowledge in decision-making. Inspired by the modularity, inheritance, and ease of maintenance of object-oriented encapsulation method, this paper proposes an emergency case representation framework based on the hierarchical structure of object-oriented representation. Such a case framework can achieve flexibility and scalability. Specifically, for a case C, we express it in the form $C = \{T, P, S, R\}$. The case type description T primarily describes the type of an emergent crisis, which can be used to determine the choice of cases and rules in decision-making and is expressed in multi-leveled type attributes; the case problem description P mainly describes paradigm environment and specific characteristics, and is expressed in multi-levels with each level being a sub-problem description; similar to the case problem description, there are multiple solutions correspond to the problems. Therefore, the case solution description S is a collection of various sub-programs, and each sub-program has own specific description; the case result description R primarily evaluates the results of the decision-making so as to determine whether the case has a positive reference value. Such an evaluation can be based on various attributes from different aspects, such as property protection, personnel protection, the overall evaluation level, and so on. With this hierarchical case representation framework, a case can be clearly described and defined. In addition, the hierarchical structure is easy to be described in object-oriented language and will help improve the independence of knowledge and the flexibility of case maintenance.

An exemplified case based on the above case representation structure can be found in (Zhao and Shen, 2009) and is omitted here due to space limitation. The knowledge representation of a case is divided into six components, including basic information, types, environmental description, event description, solution description, and evaluation. The basic information includes some tags facilitating case retrievals; the type information can serve as retrieval index and make the retrieval process more efficient; environmental and event description record various aspects of the given case; the solution stores activities adopted in the advent of the given disaster; and the evaluation component stores comprehensive evaluation information of the given solution. In addition, each case has precise numerical attributes (CN), precision symbol attributes (CS), and fuzzy attributes (FN).

(2) The rule structure

Knowledge with clear logical relations can be represented in the form of rules. In the context of emergency decision-making, there are mainly three types of knowledge that can be used in the form of rules: emergency plans, expert experience, and decision-support knowledge. Emergency plans usually have clearly defined triggering conditions, that is, they specify what to do in the event of specific problems. If represented as a case, then the similarity between a plan and a current problem may become very low and the plan won't be retrieved because of the strict restrictions of the plan. Therefore, This paper argues that emergency plans should be broken down and represented in the form of rules, rather than stored as a whole case, to better guide decision-making. Specialist expertise is knowledge of dealing with problems or predicting event developments, acquired by experts through long-term accumulation. Such knowledge can often be described as "conditions-results". The decision-support knowledge, such as assistant rules for case retrieval, secondary rules for case modification, evaluation rules for case values, and so on, is often derived from systems engineers, and used to improve the effectiveness and efficiency of the reasoning process and decision-making system. This paper will also deal with such knowledge as rules and apply these rules into our decision-making model.

Knowledge expressed with production rules are generally with the basic form "if ... then ...". This paper adopts a hierarchical structure of the triples to represent rules. More specifically, a rule R can be expressed as $R = \{T, C, A\}$, where the rule type description T gives an overall description of the origin and applicability of a rule with the form $T = \{S, A, D\}$, S defines the rule source, A defines the rule applicability, while D gives other detailed description of the rule; the rule condition description C mainly defines the conditions and states that trigger the rule and can be expressed as $C = \{S_1, S_2, ..., S_n, R\}$ with $S_i = \{O, V, U\}$ representing a certain condition or state, O being the subject of the condition, V indicating the critical properties of the condition, U being the relationship between the critical properties and the subject, and R being the relationship between these conditions with a value from {AND, OR, NOT}; the rule result description A focuses on defining the activities to be undertaken when the conditions are satisfied. The representation form of A is similar to that of the rule condition description C.

An exemplified rule based on this rule representation structure can be found in (Zhao and Shen, 2009) and is omitted here due to space limitation. The knowledge representation of a rule is divided into four components, including basic information, types, description of conditions, and description of results. The basic information includes some tags facilitating rule searching; the types information describes the source and type of a rule, and serves as retrieval index; condition description stores the conditions effecting the rule and the logical relations among the conditions; result description stores the results of triggering a rule and the logical relations among the results. The representation structure of basic information and type information satisfy all kinds of rules, but the structures of conditions and results have to be changed based on a given rule.

CASE RETRIEVAL ALGORITHM

Upon the completion of knowledge representation and organization, our emergency decision-making system starts reasoning based on user description of the problem. Case retrieval is the most important steps in the reasoning process. In this section, we present a case retrieval algorithm, which first applies specified pre-filters before starting the retrieval process so as to reduce the search range, and then combines fuzzy similarity calculation with auxiliary rules in order to achieve flexible and efficient case retrieval. The fuzzy similarity calculation method is omitted here due to space limitation. The case retrieval algorithm consists of four steps, based on the above calculation method of similarity as well as auxiliary rules.

(1) Classify the cases based on their type attribute. Given the type information of case q , only the cases belonging to the same category are retrieved to construct the initial candidate set so as to narrow the scope of the search. Other conditions specified by decision-makers specify can also be selected for further filtering in order to make the initial candidate set as compact as possible.

(2) Search the initial candidate set, calculate the similarities between each case in the set and the query case based on the method introduced in the above section, and select the cases with a similarity above a given threshold into an temporary table.

(3) Retrieve all the auxiliary rules from the Knowledge Base, apply each rule on the candidate set, and select eligible cases and rule information into another temporary table.

(4) Rank all the cases got from above steps by given rules and return the result.

CASE STUDY

In this section, we explain a case study on flood emergency decision-making. In order to establish the case base and rules for flood emergency decision-making, we collected useful data and information from various sources. First, we adapted the flood description information presented in (Jin, 2007) and represented the information in our knowledge representation framework. Second, we collected useful information from news press, government reports, commentaries, and official statistics, and added it into our case base and rule base. Finally we selected 10 flood cases, designed three retrieval auxiliary rules, 12 dynamically generated facts, and 20 logical reasoning rules. Due to limited space, the case base and rule base are not listed in this paper. Interested readers can refer to (Zhao and Shen, 2009) for specific information. The decision-making problem is to find a solution based on the following crisis description: One day, a rainstorm happened suddenly in a city in Anhui, China. The rainfall is about 250mm, the wind power is rated as level 5. Weather report predicts the probability of further raining within 24 hours is 70 percent. The population suffered from the storm has reached 5,500,000 and the death toll being reported has been over 100. The disaster is ranked the highest grade level I. The dam in Anhui is at risk as the water level is far above the limit and under very low controllability. The storm has resulted in moderate economic loss and affected water and electricity supply, and traffic.

Case Retrieval

Upon acquisition of the new case, the next stage is executing the reasoning process. First, the reasoning component in the decision support system conducts the following steps to finish the reasoning task. (1). Filter the case base according to the values of attributes Type1 and Type2. Only case 6 does not belong to the type Flood, so the rest 9 cases are retrieved to the initial candidate set; (2). Calculate the similarities between each case in the candidate set and the new case. The similarity calculation result is shown in Table 1. Assume the decision makers set the similarity threshold is 0.80, then the cases selected are case C0002 and case C0010; (3). Retrieve all the auxiliary rules from the Knowledge Base in [2], and apply each rule on the candidate set. No case satisfies rule 1, case C0009 satisfies rule 2, and case C0002 satisfies rule 3. So we have another two candidate cases C0002 and C0009; (4). Merge all the cases selected from the previous two steps based on given integration rules, we get the output C0002, C0009, C0010 and the explanation set 30.8120.690.80.

Case Name	**C0001**	**C0002**	**C0003**	**C0004**	**C0005**	**C0007**	**C0008**	**C0009**	**C0010**
Overall similarity	0.44	0.81	0.42	0.58	0.42	0.42	0.43	0.69	0.80

Table 1. Similarity Calculation Result

Logic Reasoning

After finishing case-based reasoning, the decision support system derives logic facts, and starts logic reasoning.

(1) The logic facts derived are list as follows:

crisis_type(current_case,rain_flood). crisis_level(current_case,high). affected_number(current_case,high).
water_over_limit(current_case). dike_endangered(current_case). rain_level(current_case,high).
infra_affected(current_case,communication). infra_affected(current_case,transportation). rain_possibility(current_case,high).
death(current_case,high). disease_possibility(current_case,low).

(2) The decision support system then add these facts into the knowledge base in Prolog, and then query each predicate in every rule, and then perform backward chaining reasoning on the knowledge base. There are seven rules applicable in this step with the following predicates:

restore_action(current_case,communication); restore_action(current_case,transportation);affection_range(current_case,high);
drain_flood(current_case);dike_rebuild(current_case);transfer_residents(current_case);broadcast(current_case)

(3) After getting the reasoning result, the DSS retrieves the values of attributes for the solution from corresponding rules. Retrieved attributes include *Residents transfer, Radio publicity, TV publicity, Waterlogging drainage, Communication restore,* and *Traffic restore*.

Result Integration

Next, after the reasoning process, the DSS merges and integrates the results generated from both case-based reasoning and logic reasoning, and set each value of the final solution, probably solve the conflicts sometimes, based on the preference order
$logicalreasoningresults \succ reasoningresultsfromauxiliaryrules \succ similaritycalculationresults$, which is specified by the decision makers. The final solution is shown in Table 2.

CONCLUSION

In this paper, we focus on the reasoning component in our DSS system for flood emergency decision-making. The reasoning component combines cased-based reasoning and logic reasoning. More specifically, the reasoning component adopts the following preference order. When logic reasoning can generate results on some attributes, these results contributes to corresponding attributes of the final solution. In case for some attributes, logic reasoning cannot generate their results, the DSS system retrieves the result generated by the similarity calculation method and auxiliary rules, and return the reasoning result to decision makers. If the decision makers are not satisfied with the recommended solution, they can specify further auxiliary rules, do another round of reasoning, or directly revise the final solution recommended by the DSS system.

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	CBR Rec1	CBR Rec2	CBR Rec3	LR Recommendation	Final Solution
No.	C0002	C0009	C0010	N/A	N/A
Date	2006-07	2007-07	2007-08	N/A	N/A
The number of disaster relief workers	2000	5000	1500		2000
The number of medical care workers	400	1000	300		400
The number of logistics supporters	600	1500	500		600
The number of facilities repairers	500	800	400		500
Residents transfer	Yes	Yes	Yes	Yes	Yes
Prevention of further hazard	No	Yes	No		No
Radio publicity	Yes	Yes	No	Yes	Yes
TV publicity	Yes	Yes	Yes	Yes	Yes
Waterlogging drainage	No	Yes	No	Yes	Yes
Ships back to port	No	No	No		No
Infrastructure inspection	Yes	Yes	Yes		Yes
Dam maintenance	Yes	Yes	No		Yes
Requests for assistance	No	Yes	Yes		No
Requests for donation	Yes	Yes	No		Yes
Water and electricity restore	Yes	Yes	Yes	Yes	Yes
Communication restore	No	Yes	No		No
Traffic restore	Yes	Yes	Yes	Yes	Yes
Scheduling emergency relief	A1	B1	C1		A1
Scheduling medical care	A2	B2	C2		A2
Scheduling logistics repairs	A3	B3	C3		A3

Table 2. The Final Recommended Solution

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