An Event-Driven Scheme of Scenario Deduction for Railway Emergency

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Abstract: Railway emergency management is currently transforming from plan management to scenario management. Firstly, an event-driven model of scenario deduction for railway emergency was established. Then, according to the evolution process of scenarios for railway emergency, the emergency scenarios were divided into initial scenario, middle scenario and final scenario, among which the mutual relationships were analyzed. Furthermore, using Bayesian network inference algorithms, the specific process of scenario deduction for railway emergency was elaborated. Finally, taking train derailment accidentals for example, the states of node variables in scenario network were deduced. The scenario deduction results are in line with the real thing, which prove the proposed scheme feasible and effective.

1 INTRODUCTION

Railway has played an important role to ensure the smooth operation of economy and social stability. Due to the extremely high requirements of high-speed, high-density and heavy-load railway, the management tasks of railway transportation are increasingly arduous. Thus, the possibility of unexpected events is also increasing. At present, all kinds of railway emergency plans are improved and published, such as, flood protection, fire accidents, network and information security incidents and so on. Combined with geography, physiognomy, climatic characteristics in every railway administration, emergency plans have been consummated, which conforms to the characteristics and requirements of the region to make the operation program specific. Foreign railway companies also use the safety management system to provide dangerous source management, emergency investigation, information of track quality and standard degree and so on. It provides effective information for the timely prevention and timely setting of emergency plans for railway accidents. By comprehensively analyzing the relevant data, it can provide auxiliary decisions for the maintenance, supervision, accident prediction, and emergency rescue of the railway line.

The evolution of emergencies itself has strong dynamic, complexity and uncertainty, it determines the problems that emergency decision of the emergencies are also uncertain and complex(Wang, et al, 2011). At present, the decision-making method based on experience depends on the current information and experience which has been analyzed. Therefore, it has strong subjective randomness, and the incomplete analysis of information may seriously affect the decision-making results of decision-makers, so it is difficult to ensure the correctness of decision-making results. The emergency decision-making method of current emergency has begun to change from subjective decision-making based on experience to scientific objective decision-making based on comprehensive data analysis. It combines the expert knowledge and mathematical model.

In the field of emergent evolution and emergency decision-making research, She Lian put forward the theory of traffic disaster early warning management, Huo Ran had done a lot of careful research on the construction of fire emergency scenario and the analysis of incident evolution. Jiang Hui made a preliminary analysis of the concept and connotation of the scenario evolution in the real time decision making of a rare emergency, divided the evolution of the event stage. According to the limitation of the traditional “prediction - response” and the characteristics of various stages of unconventional emergencies, he put forward corresponding measures and countermeasures. The research of scenario

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inference process is an important means of emergency decision support for railway emergency. This paper will establish an event driven model of railway emergency scenario inference, study the function of event driven by analyzing of the process of deduction.

2 SCENARIRESPONSE MODE OF RAILWAYEMERGENCY

The scenario coping model is a solution, which is made by the decision maker. They analyze the existing information and data, integrate them, complete the scenario construction, analyze the situation by the experience information, evaluate the evolution of scene situation and then obtain the corresponding solution according to the evaluation results(Li, et al, 2012). The starting point of the scenario coping model is that the scenario is not static, but dynamic. As the emergency process goes on, the content of scenario element description also changes. Emergency decision makers can predict the evolution of events and trends based on scenarios. According to the results of the prediction, the corresponding measures are taken to control the development of the events, and change the direction of a sudden event to a good aspect.

3 UNCERTAINTY OF SCENARIO DEDUCTION

After the failure of the early warning of the railway incident, the event scene will enter the evolutionary stage. Aim at the dynamic characteristics of the event, decision makers must make real time decisions on the basis of the process of scene evolution. The current state of the situation changes with uncertainty, so it will inevitably make the scenario deduction and the evolutionary path uncertain. The situation of railway emergencies is a process of dynamic evolution. The process of evolution is shown in Fig. 3.1, which may change almost at any time. The key to influencing the decision-making subject's important decision is the state of the railway emergencies' scenario factors.

According to the whole emergency management process of railway emergencies(Rong, et al,2012), this paper divides the situation of railway emergencies into the initial scenario, intermediate scenario and ending scenario. The initial scenario is a description of the state of the scenario factors when the railway incident occurs. For a specific railway emergency, the initial situation is determined. The middle situation is caused by the influence of the initial situation through various scene elements or the interference from the outside world. The impact of different factors will lead to the evolution of the scenario path. The ending scenario is the state of the system after the emergency response of the railway emergency. The evolution of railway emergency scenarios may be affected by different factors, which may lead to multiple evolution paths. Therefore, there may be many situations when the scene ends.

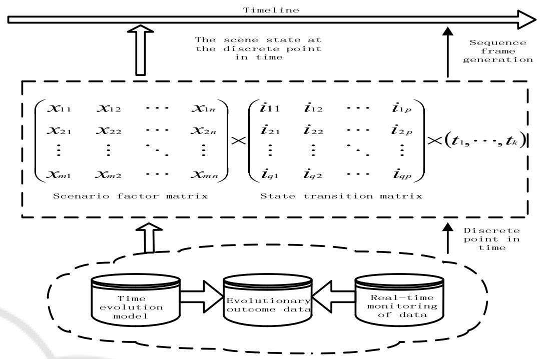

Figure 3.1: Process of scenario evolution.

4 EVENT-DRIVEN SCENARIO DEDUCTION MODEL

4.1 Elements of event-driven model

The emergency response was immediately activated after the incident occurred. Emergency response events belong to the driving elements of the scenario, which is the emergency task that the emergency subject needs to implement in order to meet the emergency target, or the action of the emergency object, which will inevitably lead to the change of the state of the emergency situation. Therefore, we can indicate an emergency response event by a group of seven elements:

$$Event = \{ID, Name, Subject, Object, Action, Description, Previous\}$$

Among them, ID is the only sign of the event; $Name$ is the name of the event; $Subject$ and $Object$ represent the subject and the object of the event respectively; $Action$ is the action of the subject for the object; $Description$ is the description of the event; $Previous$ is the set of predecessor nodes for the execution of the event.

Scenario inference is a discrete visualization process of the emergency entity state and behavior in the specified space and time, which is the main line of the implementation process of the emergency task.

The emergency scenario inference process includes a series of scenarios. The scenario inference uses an event driven model. An event can be considered a function that maps time to a Boolean value, that is:

$$Event: t \to \{True, False\}$$

$$E(t) = \begin{cases} True & \text{if event happens at t} \\ Flase & \text{other} \end{cases}$$

4.2 Construction of the scenario model

In the scenario model of the railway emergencies, the change of the state of the event scenario has a great influence on the evolution of the situation, and there is a strong causality between them. Therefore, the deduction process can be expressed through the Bayesian network. According to the analysis of the evolution of railway emergencies, the sub-elements of scenario S_i are used as network node variables to construct Bayesian network for scenario deduction. The node of Bayesian network in S_i is divided into three categories according to its effect on the process of inference, that is, the scenario input variable, the state analysis variable and the scenario output variable.

(1) Scenario input variables: Describes the input elements for the situation analysis, which are the determined variables in scenario S_i. Scenario input variables mainly include the variety of factors that cause the situation or the collection of various measures in the process of situation response $P = \{p_i | 1 \le i \le m\}$, the set of state variables of the event scenario itself $IS = \{is_k | 1 \le k \le l\}$, and the set of response variables that control the events to change $R = \{CR, JR\}$,among them $CR = \{cr_j | 1 \le j \le n\}$, $JR = \{jr_j | 1 \le e \le f\}$.

(2) State analysis variables: Describes the state of the elements require scenario analysis. The development trend of the situation element state can be obtained through the analysis of the state of the event itself and the state of the disaster situation. In this paper, the state analysis variables are divided into two parts: the state variable set $IS = \{is_k | 1 \le k \le l\}$ and the event state of the disaster $ES = \{es_q | 1 \le q \le t\}$.

(3) Scenario output variables: Describe the next possible occurrence of Scenario S_{i+1}, including the affected external environment state and the loss state of the event scenario. Let $OS = \{os_w | 1 \le w \le h\}$ be the set of affected external environment state variables, and $FS = \{fs_z | 1 \le z \le x\}$ be the loss variable set caused by event scenario, among them $S_{i+1} = \{OS, FS\}$.

The key to determining the impact of the event's scenario input variables, state analysis variables, and scenario output variables is how to combine specific railway emergencies to collect event information and domain expert knowledge. Based on the analysis of the evolution of railway emergencies, the three-tier Bayesian network structure of "scenario input layer - state analysis layer - scenario output layer" is further constructed according to the causal relationship between the nodes, as shown in Figure 4.1.

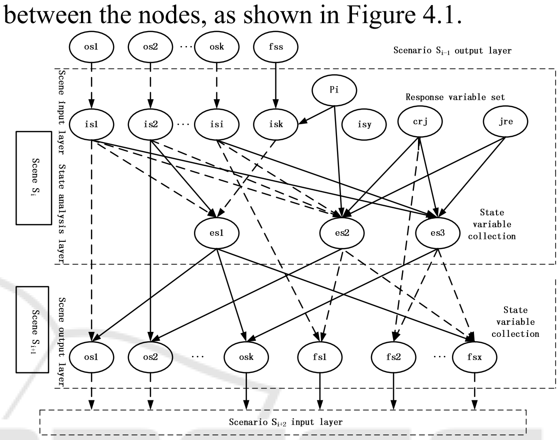

Figure 4.1: Scenario deduction model.

5 CASE ANALYSIS

Taking the derailment accident of a train as an example to make empirical analysis .When the freight train reached about 200m before the exit of a tunnel, the vehicle pulled behind the locomotive suddenly derailed and caused the leakage of the liquefied petroleum gas tanker. So train drivers take braking measures. The locomotive and 1-37 vehicles parked in the tunnel and 38-55 vehicles parked out of the tunnel. The leakage of liquefied petroleum gas spread rapidly and burn, that caused casualties in the tunnel, and the line interrupted.

(1) Scenario profile

The event is simplified as follows: the freight trains in the tunnel are derailed for some reasons and cause fire and explosion $IS = \{PIS, SIS\}$. The drive event is PIS and the current state of the event is SIS. At present, the emergency management department should take a variety of emergency plans and different emergency plans lead to different evolution paths of event scenario. Thus, the Bayesian network structure of the event scenario evolved is shown in Figure 5.1. In view of the current situation, emergency management departments may take a variety of contingency measures, and different emergency measures will lead to the evolution of event scenarios in different directions.

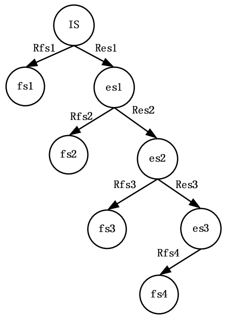

Figure 5.1: Instance of scenario deduction.

(2) Node probability assignment

First, we need to determine the probability of each situation and the probability of not happening. In this case, the expert specifies the conditional probability of the node according to the knowledge experience and the changing process of the event scenario, and constructs the conditional probability table of the event scenario. The conditional probability of each scenario is shown in Table5.1.

(3) Scenario deduction

Using Bayesian reasoning algorithm, we start from the top scenario node in Figure 5.1, and gradually calculate the state probability of the follow-up critical scenario to track the change process. The state probability for the event $es1$ is calculated as follows:

$$P(es1) = P(es1/S = True)P(IS = True) + P(es1/IS = false)P(IS = false)$$

Similarly, the probability of the state of the other critical scenarios is calculated from the conditional probability table, and the results are shown in Table 5.1.In the process of reasoning, we simplify the process of case scenario evolution, and the path of scenario evolution only takes into account two cases(Shu, 2012).Considering the actual situation of the evolution of the event scenario, the above reasoning results are basically consistent with the actual situation, which proves that the event driven railway scene scenario deduction method is effective and feasible. However, there are a variety of responses to the same scenario, so there are many ways of the evolution of the situation. Therefore, in practical applications, we must conduct a comprehensive and m-path reasoning analysis for specific events, and make the evolution of event scenarios more realistic and systematic.

Table 5.1: Probability of critical scenario state of events.

IS		*fs*1	
True	1	*True*	0.1*1+0*0=0.1
False	0	*False*	0.9*1+1*0=0.9
*es*1		*fs*2	
True	0.9*1+0*0=0.9	*True*	0.3*0.9+0*0.1=0.27
False	0.1*1+1*0=0.1	*False*	0.7*0.9+1*0.1=0.73
*es*2		*fs*3	
True	0.95*0.9+0.2*0.1=0.875	*True*	0.5*0.875+0*0.125=0.4375
False	0.05*0.9+0.8*0.1=0.125	False	0.5*0.875+1*0.125=0.5625
*es*3		*fs*4	
True	0.8*0.875+0.1*0.125=0.7125	*True*	0.9*0.7125+0.3*0.2875=0.7275
False	0.2*0.875+0.9*0.125=0.2875	*False*	0.1*0.7125+0.7*0.2875=0.2725

6 COMPARISON OF RELEVANT STUDIES

At present, the methods applied to scenario deduction are mainly based on contingency plans and case-based reasoning. These two methods can help to realize the scientific decision of emergency response of railway emergency, and can assist decision makers to make emergency decisions to a certain extent(Cheng, et al, 2012). They can use the existing knowledge to form a more scientific and auxiliary decision-making knowledge and improve the scientific nature of emergency decision-making. However, due to the differences and application characteristics between the different methods, there still have some limitations in practical applications, as shown in Table 6.1. Among them, ☆ is preferred, □ is medium, and △ is poor.

Through the comparison of the three kinds of deduction models, studying the applicability of them in the emergency response of railway emergencies, and theoretically analyzing the differences between them, we can conclude that: The event-driven deduction model is superior to the other two methods in terms of scope, flexibility and the level that need expert participation. It has great development potential.

7 CONCLUSIONS

Starting from the time law of scenario evolution of emergency events, the emergency scenarios were divided into initial scenario, middle scenario and final scenario, among which the mutual relationships were analyzed. The paper explicates how the event-driven model can play a role in the scenario deduction for railway emergency, and makes assumptions about the process of scenario deduction of events. Then, an event-driven model of scenario deduction for railway emergency was established. In addition, taking train derailment accidentals for example, the Bayesian network of scenario was set up and analyzed to further deduce the states of node variables in scenario network. The deduction results accord with the practical situation. The proposed scheme has been proved to be feasible and effective for railway emergency.

Table 6.1: Comparison of three models.

Project	Proposition - based deduction model	Derivation Model Based on Case - based Reasoning	Event - driven deduction model
Applicable scope	△	□	☆
Flexibility	△	□	☆
Processing speed	△	□	□
Targeted	☆	☆	□
Field expert Participation	△	△	□

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