# Generation of emergency scheme for urban rail transit by case-based reasoning

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## Abstract

Case-based reasoning (CBR) is a method that uses previous experiences to solve new problems. The characteristics of CBR make it suitable for complex problems related to knowledge reuse. Based on the analysis of the characteristics of emergency events in urban rail transit, a generation method using CBR for emergency scheme is proposed. Certain related technologies, such as case representation, case retrieval, case adaption, case revising and case retaining, are conceived and discussed. A numerical example is used to illustrate the application and efficiency of the proposed method, which can take full advantage of historical correct experiences and benefit to the intelligentization of emergency scheme generation for urban rail transit.
*Keywords: urban rail transit, emergency scheme, case-based reasoning, case retrieval.*

## 1 Introduction

Accidents, failures, unpredictable disasters, and sudden increase of passenger flow due to special events happen in urban rail transit (URT) now and then. These emergency events, which impact widely and long and evolve uncertainly, will bring negative impact on the whole rail network unless properly dealt with. In terms of URT, on one hand, operation organization and passenger evacuation are constrained by the spatial layout because of the relatively closed space in URT system. On the other hand, emergency response process for URT actually is a process of interaction and cooperation between different departments, which is difficult to do well due to the distinct differences existing in the communication, coordination and authorization. Therefore, it is visible that the emergency decision in URT is complex and difficult.

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In recent years, a lot of researches have been carried out on the safety and security of URT, most of which studied the construction of emergency response system and the disposal method for specific emergency events, while few aim to the generation of emergency scheme. Zhang and Liu [1] designed the management mode of emergency plan based on case-based reasoning and rule-based reasoning, but did not give the specific reasoning algorithms. Cui et al. [2] constructed a framework for the multi-agent-based emergency response in the subway, but did not study generation of emergency scheme. Wang [3] proposed a generation method of emergency scheme based on emergency planning, but the emergency plans were compiled according to the type and level of emergency events before emergency events occur. It is hard to directly apply pre-established plan to emergency response, and specific plan still involves many unstructured problems. Therefore, it is necessary to generate emergency scheme according to emergency status and characteristics.

Case-based reasoning (CBR) is one of the well-known AI methods. It solves new problems by finding and reusing solutions from similar problems successfully solved before and often shows significant promise for improving the effectiveness of complex and unstructured decision making [4]. Based on the analysis above, this paper applies case-based reasoning (CBR) methodology into the generation of emergency scheme for URT. Certain related technologies, such as case representation, case retrieval, case adaption, case revising and case retaining, are conceived and discussed.

## 2 CBR in emergency scheme generation

Those previous experiences in emergency disposal in URT consisting of emergency characteristics descriptions and relative solutions are called cases and are stored in a case base in a certain pattern. The process of emergency scheme generation using CBR can be divided into four stages that is retrieval, adaptation, revising and retaining (fig.1) [5]. When an emergency event occurs, the system matches the new problem against cases in the case base using a specific retrieval method, and finds the most similar case from the case base. And then, aiming to the differences between the current problem and the retrieved case, the system revises the retrieved case using professional knowledge of emergency disposal. The revised solution can be confirmed as the emergency scheme for the current problem at that time. Subsequently if necessary, according to the performance of the emergency scheme and experiences and lessons learned in the disposal process, the proposed solution could be modified to avoid the same mistakes. The description of the emergency and the modified solution could be saved as a new case in the case base with the aim of reusing in the future.

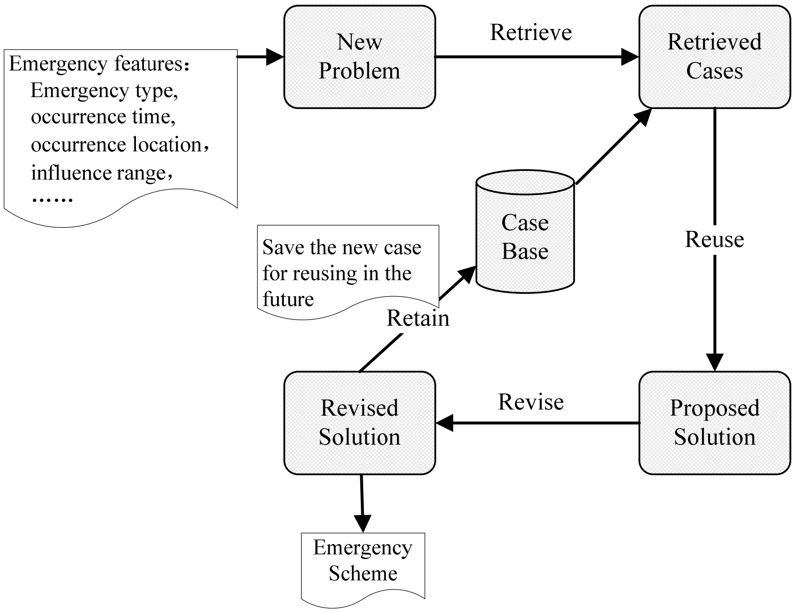


Figure 1: Case-based reasoning cycle in emergency scheme generation.

## 3 Case representation

Cases should be represented in a standard structure and rules, so as to be retrieved and adapted. A typical case usually contains two parts: the problem and the solution. The problem that describes the characteristics of the problem and related information could be represented by pairs of feature-value; the solution expresses the measures, disposal process and related information to the problem. Currently, the main methods of case representation includes: logical representation, production representation semantic network method, frame method. There are various emergency events in URT, such as train fault, fire and so on, and the number and names of the referred features vary from one to another. Framework method is used to represent emergency and fire is taken as an example to describe case representation, as shown in table 1.

## 4 Case retrieval

Case retrieval is the core of CBR. Methods for case retrieval are nearest neighbour (NN), induction, and knowledge-guided induction and template retrieval. These methods can be used alone or combined into hybrid retrieval strategies [6]. In this study, we take NN to retrieval the similar case. It is the

Table 1: The description of fire case.

| Emergency feature or solution | Description | Value type |
|---|---|---|
| case ID | the order number of the case in the case base | numeric or ordinal |
| type of emergency | fire, electrical breakdown, etc. | nominal |
| occurrence time | peak or off-peak hours | nominal |
| occurrence location | coach, platform or station hall | nominal |
| duration | the expected duration | numeric or interval |
| casualties | number of injury and the death toll | numeric or interval |
| event level | description the severity of emergency | Nominal |
| burning area | the area of burning region | Interval |
| smoke components | the main components of smoke | Nominal |
| smoke concentration | the concentration of smoke | numeric or interval |
| safety facilities | the status of fire safety facilities | numeric or ordinal |
| cause | the cause of the emergency | Nominal |
| emergency scheme | measures, disposal process, et.al | |
| implementation result | good , bad | |

method for retrieving the most similar case or several similar cases from the case base. Similarity is a measurement of the degree of the similarity between the current case and the retrieved case. A complete case retrieval process using NN is generally composed of two steps: Firstly, calculate the similarity of features between the new case and the source case. Secondly, calculate global similarity according to the weights and the similarity of features obtained. The similarity of features between the two cases could be calculated as follows [7]:

$$sim(C_j^*, C_{ij}) = \begin{cases} 1 - |V_j^* - V_{ij}| & \text{if } V_j^* \text{ and } V_{ij} \text{ are numeric or ordinal} \\ 1 & \text{if } V_j^* \text{ and } V_{ij} \text{ are numinal and } V_j^* = V_{ij} \\ 0 & \text{if } V_j^* \text{ and } V_{ij} \text{ are numinal and } V_j^* \neq V_{ij} \end{cases} \quad (1)$$

where $C^*$ and $C_i$ are the new case and the $i$ th retrieved case respectively, $V_j^*$ and $V_{ij}$ are the values of the $j$ th feature for the two cases, and $sim()$ is the similarity function.

If the value of the feature is interval, the similarity function of features is shown in eqn. (2) [7].

$$sim(C_j^*, C_{ij}) = 1 - \sqrt{\frac{1}{2}\left[\left(V_j^{*-} - V_{ij}^-\right)^2 + \left(V_j^{*+} - V_{ij}^+\right)^2\right]} \quad (2)$$

where $V_j^{*-}$ and $V_j^{*+}$ are the lower limit and upper limit of the $j$ th feature for the current case respectively, and $V_{ij}^-$ and $V_{ij}^+$ are the lower limit and upper limit of the $i$ th retrieved case in the case base.

Global similarity is the weighted sum of the similarities of features, and it could be computed by the following formula.

$$sim(C^*, C_i) = \frac{\sum_{j=1}^{n} \omega_j sim(C_j^*, C_{ij})}{\sum_{j=1}^{n} \omega_j} \quad (3)$$

where $sim(C^*, C_i)$ represents global similarity between $C^*$ and $C_i$, and $\omega_j$ is the weight of the $j$ th feature for both the current case and the retrieved case, and $n$ denotes the number of the finally selected features in calculating similarity. The initial weights of features could be determined by using analytic hierarchy process or the experience of experts. It must be noted that all of features values should be normalized before similarity calculation.

In order to improve the retrieving efficiency, the current case only matches with the retrieved cases with same type of emergencies because only the solution to the same type of emergency event may be suitable for current event. In the reasoning process, $\lambda$ is set as a threshold to ensure the number of selected cases is not too much. Only global similarity between the current case and the retrieved case is greater than $\lambda$, can the retrieved case be screened.

## 5 Case adaptation, revising and retaining

The emergency scheme of the most similar case could be regarded as the initial scheme for the current problem. In general, the most similar case, which is still different from the current problem, should be revised to fit the current situation. However, because case revising usually needs professional knowledge, there is no universal revise method. Cases are usually modified manually. The CBR system usually could retrieve several similar cases simultaneously. Operators could revise initial scheme by using the knowledge of other similar cases to improve the performance of emergency scheme.

Case retaining is also the process of learning for the CBR system. After emergency handled, the performance of the emergency scheme is evaluated. Combination of the description of emergency event, emergency scheme and implementation result is saved as a new case in the case base. The knowledge of the CBR system can be updated over time, which ensures the growing of system handling ability.

# 6 Example

In this section, a simple example is presented. Suppose a fire occurred in urban rail transit, and the description of the input case and related cases in the case base are listed in table 2. In table 2, $C^*$ denotes the current case, and the listed features are the important features selected in similarity calculation, and the values of the features has been already normalized. The initial weights of the selected features are presented in table 3.

Table 2: The new case and the retrieved cases in the case base.

| Case ID | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C^*$ |
|---|---|---|---|---|---|---|
| occurrence time | peak | off-peak | peak | off-peak | off-peak | off-peak |
| occurrence location | station hall | station hall | platform | station hall | coach | station hall |
| event level | level 1 | level 1 | level 2 | level 1 | level 1 | level 1 |
| burning area | 0.1-0.15 | 0.2-0.3 | 0.1-0.2 | 0.2-0.4 | 0.15-0.25 | 0.25-0.3 |
| safety facilities | 0.95 | 0.85 | 0.8 | 0.8 | 0.95 | 0.9 |
| scheme ID | scheme1 | scheme2 | scheme3 | scheme4 | scheme5 | |
| implement result | good | good | good | good | better | |

Table 3: The initial weights of the selected features.

| | Occurrence time | Occurrence location | Event level | Burning area | Safety facilities |
|---|---|---|---|---|---|
| weight | 0.05 | 0.05 | 0.1 | 0.1 | 0.15 |

Take $C^*$ and $C_1$ as an example to illustrate the calculation of case reasoning. The five similarities of five features pairs can be calculated by eqn. (1) - eqn. (2).

$$sim(C_1^*, C_{11}) = 0$$

$$sim(C_2^*, C_{12}) = 1$$

$$sim(C_3^*, C_{13}) = 1$$

$$sim(C_4^*, C_{14}) = 1 - \sqrt{\frac{1}{2}\left[(0.25-0.1)^2 + (0.3-0.15)^2\right]} = 0.85$$

$$sim(C_5^*, C_{15}) = 1 - \left|0.9 - 0.95\right| = 0.95$$

Then, the global similarity can be calculated by eqn. (3):

$$sim(C^*, C_1) = \frac{\sum_{j=1}^{n} \omega_j sim(C_j^*, C_{1j})}{\sum_{j=1}^{n} \omega_j} = 0.84$$

Finally, the global similarities between the input case and all related cases existed in the case base can be calculated, and the results are listed in table 4.

Table 4: The global similarity of each case.

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ |
|---|---|---|---|---|---|
| global similarity | 0.84 | 0.97 | 0.49 | 0.95 | 0.85 |

From table 3 we can see that the most similar case is $C_2$. If the threshold $\lambda$ is set to 0.9, $C_1$, $C_3$ and $C_5$ will be filtered out. The solution of $C_2$ can be selected as the initial scheme for the fire. $C_4$ can be served as a reference to operators for revising the initial scheme in order to make it more suitable to the current condition.

## 7 Conclusion

In this paper, the case-base reasoning (CBR) is introduced into the solution to existing problems in emergency decision-making of urban rail transit as a new approach. The procedure and methods of generating emergency scheme by CBR are analyzed in detail. The numerical example indicates that valuable knowledge in previous practice could be reused. However, generating emergency scheme successfully depends on a well-constructed case base which contains a large number of cases with the same type. Selecting appropriate features to improve retrieval's accuracy and efficiency is the issue that we plan to explore in the future.

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