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Construction of Geological Knowledge-based Systems of Railway Route Selection

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Abstract

According to the diversity of geological conditions involved in railway location design, different types of geological objects were classified and indexed, and proposed the modeling method based on multiple sub-bases. It used the computer's internal and external representation in geological knowledge representation. In computer external, it used object-oriented class-rules knowledge representation model, added credibility to the object-oriented knowledge representation model, and then achieved fuzzy representation of knowledge. In order to achieve visual representation of external knowledge representation, text, images and three-dimensional virtual reality technology were used. According to the ambiguity of geological knowledge, it realized uncertainty reasoning of the part based on rule condition and conclusions.

Keywords: *geological knowledge base, railway route selection, reasoning construct*

1. Introduction

Decades of engineering practice proved that it is necessary for constructing a modern railway with high quality to select railway lines reasonably in railway construction according to geological conditions [1]. In mountainous areas and those areas with complex engineering geological conditions, engineering geology line selection plays an important role in the railway line selection. How to select a reasonable route according to the geological conditions? In addition to depend on regular route design standards, it depend more on route designers' experience [2]. But the experience and knowledge cannot be got overnight. Through the establishment of geological knowledge base of route selection, it offers geological knowledge required to route designers, automatically searches related line-selection geological knowledge in the line-selection process, and then provides engineers real-time help and reference. It also provides geological basis for railway line selection by reasoning and makes it possible for building a full range of intelligent route selection geological environment for railway line selection and achieving remote sensing geological route selection in three-dimensional environment.

2. Design of Knowledge Base

Structure of knowledge base plays an important role in knowledge base itself. An inconsistent or incomplete knowledge base could greatly reduce the efficiency of reasoning. Expression and organizational model of knowledge will influence reasoning efficiency of inference engine, affect updating and enriching knowledge at the same time, and affect intelligence level of the entire knowledge base. A variety of geological conditions are involved in line selection and design, so there is a large number of knowledge in the route geological knowledge base. If all lines-selection geological knowledge is listed in a knowledge base, it not only increases the difficulty of managing knowledge, but also directly leads to decreased availability and effectiveness of selected lines geological knowledge base. Therefore, according to its related different geological conditions, the knowledge in the knowledge base is divided into a series of knowledge sub-space, such as special geotechnical sub-base, sub-base of geological disasters. Every knowledge sub-space can also be divided into a number of relatively independent knowledge elements according to different geological objects it contains. In every

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knowledge element, corresponding element-rules are saved. When guiding the work of inference engine, appropriate rules will be found in these knowledge elements as quickly as possible. In addition, the knowledge of every knowledge cell is stored in the light of knowledge notes. This constitutes class hierarchy tree of line selection and design knowledge and the system structure is shown in Figure 1.

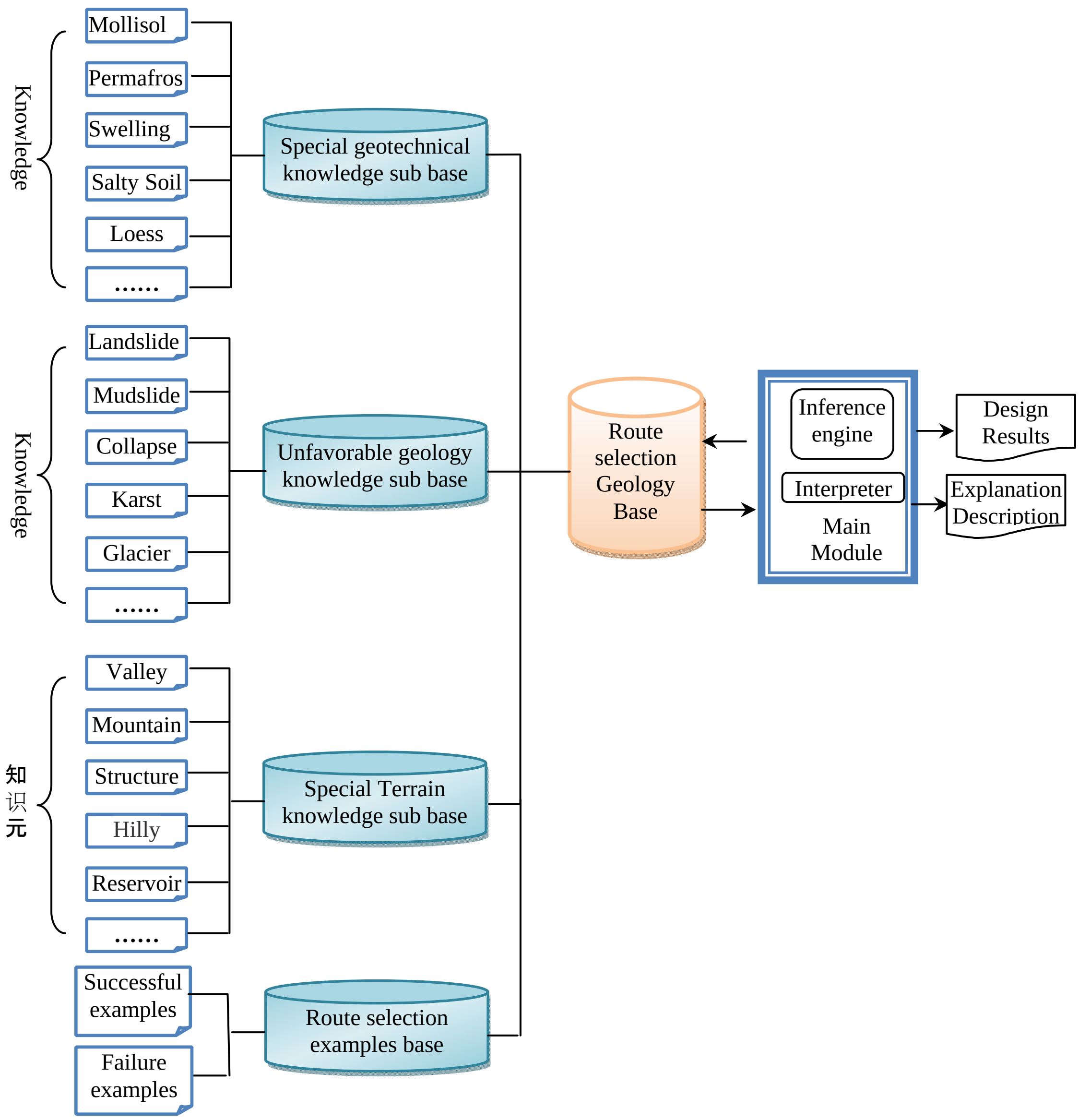

Figure 1. System Structure Diagram of Knowledge Base

As is shown in Figure 1, knowledge base is divided and saved into multiple sub-bases according to the characteristics of the line selection and design geological knowledge. On the terms of knowledge types, it can be divided into geological knowledge of line selection field and example knowledge. The entire knowledge base consists of several sub-bases and the knowledge cell consists of knowledge cells. Each node stores 3 types of knowledge of corresponding cells. These are related knowledge of existing norms, expert experiences and examples of existing designs. The storage structure of knowledge cell is shown in Figure 2.

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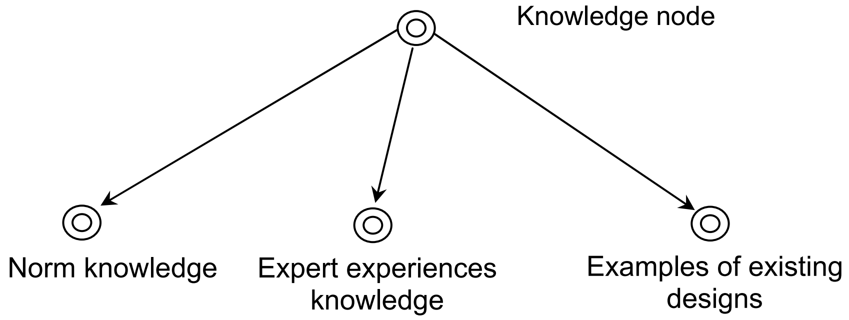


Figure 2. Knowledge Node of Knowledge Cell

According to different geological types, every knowledge sub-base corresponds to different types of geological objects. Geological objects in each category is made as a class and described using multiple keywords. At the same time, examples corresponding to each category are also included in its class. A class may conclude many instances and an example may correspond to multiple classes. Thus, whether beginning from classes or from keywords having actually retrieve significance, we can easily retrieve knowledge and their instances. Class's keywords and instances constitute the expression pattern of each type of geological knowledge. E-R relationships among them are shown in Figure 3.

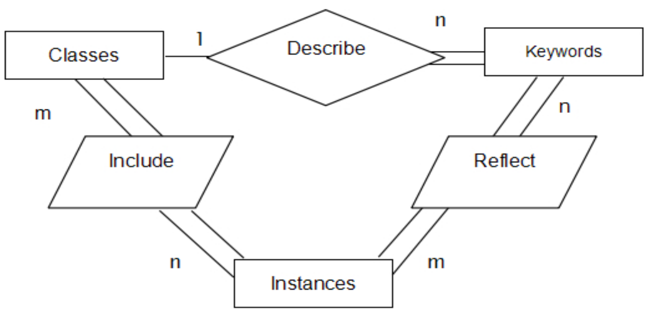


Figure 3. The Relationship among Classes, Keywords and Instances

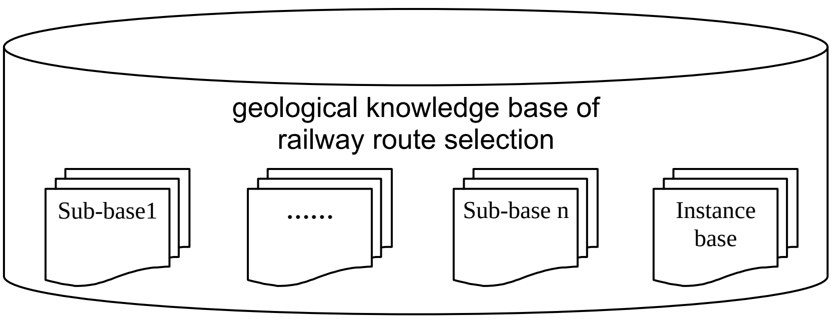


Figure 4. Physical Storage Structure of Knowledge Base

The main module geological knowledge base of route selection consists of inference engine and interpreter. According to different geological conditions, corresponding knowledge sub-base is invoked. Inference Engine makes decision inferences. Interpreter is responsible for explaining reasoning decision results and scheduling appropriate instances and shows reasoning decision results using some form. Overall physical storage structure of knowledge base is shown in Figure 4.

3. Knowledge Acquisition Method

Knowledge acquisition is a process that it extracts expertise which is used to solve problems from the knowledge sources which has this knowledge and converts them to specific computer representation. Geological knowledge base of railway route selection mainly contains norm knowledge, expert knowledge and instances knowledge (Shown in Figure 5).

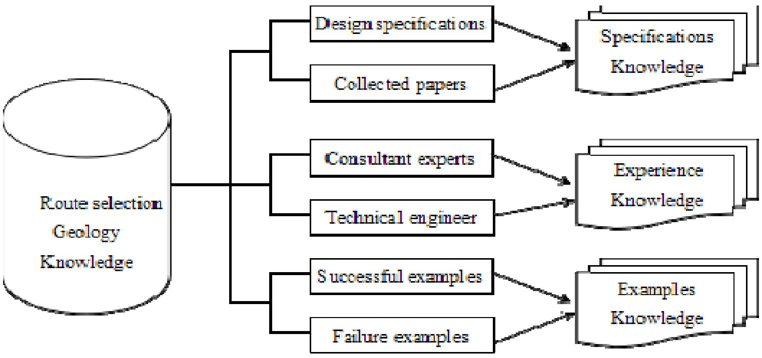


Figure 5. Source and Composition of Railway Route Selection Geological Knowledge

Knowledge acquisition method can be divided into automatic acquisition methods and non-automatic acquisition methods. Automatic knowledge acquisition relates to many problems of speech recognition, text recognition, natural language understanding and other aspects. Thus, according to characteristics of geological knowledge base of route selection, the knowledge acquisition mode that combines raw mode with advanced mode is used. The process of knowledge acquisition is shown in Figure 6.

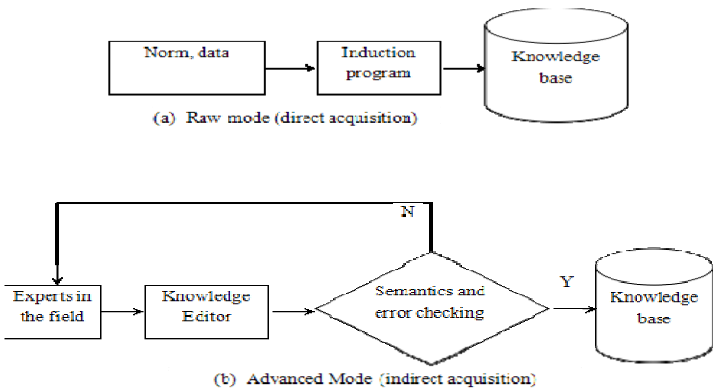


Figure 6. Process of System Knowledge Acquisition

4. Knowledge Representation of Geological Route Selection

Knowledge representation is how to show knowledge (rules, concept, and facts) in an acceptable form of computer and inform people processing results in a way that people can understand. This is the problem to be studied of knowledge representation. It can clearly be seen knowledge representation involves two aspects. They are the form of knowledge representation and knowledge management and utilization. Whether the form of knowledge representation is reasonable or not depends on whether this expression form is conducive to knowledge management and use of computer. Knowledge management and utilization is realized by programs, so the form of knowledge representation needs to meet the form and style of programming language. Base on this, this passage offers a kind of computer internal and external user-oriented knowledge representation form which is suitable for geological line selection knowledge.

4.1. Object-oriented Knowledge Representation Inside the Computer

Currently main knowledge representation methods using more are first-order predicate logic representation, production representation, frame representation [4, 5], semantic network representation and so on. Every method has its advantages and disadvantages. For example, first-order predicate logic representation cannot express uncertainty knowledge; frame representation is not good at procedural knowledge representation; semantic network representation expresses non-stringency of knowledge. Expressing knowledge with rules is widely used in intelligent engineering systems, and already has had a very solid theoretical foundation [6, 7]. And object-oriented representation is a mixed representation method that puts together conventional representation method such as production representation, frame representation and process representation. Object-oriented representation represents knowledge in knowledge base using objects and can abstract corresponding knowledge object class for knowledge objects with the same characteristics. It has four characteristics: encapsulation, modularity, inheritance and easy maintenance. Object-oriented representation is closer to the human mind, reflects the nature of the human thinking process better and is more suitable for knowledge representation [8]

For example, route-selection geological knowledge of permafrost regions can be expressed as the following objects:

Class name: permafrost line selection [Super class name] special geotechnical line selection

Attributes:	Methods:
Premise list;	InputAverageGroundTemperature ();
Premise weights;	InputLineTerrainFeatures();
Conclusion list;	InputPermafrostZoneType ();
Conclusion weights;	CalculateBeliefPropagationValue();
Number of Premise;	OutputRecommendationsConclusions()
Number of Conclusion;	OutputCorrespondingInstances();
……..	

In the figure above, attributes of classes represent factual knowledge and the methods of classes represent the process knowledge and control knowledge. Knowledge class methods include the knowledge for reasoning such as all kinds of heuristic knowledge, meta-knowledge, formulas and chart. Knowledge in classes has encapsulation and is not allowed operation out of the object to process its internal data. You can also use the inheritance of classes, decomposing complex knowledge and reducing redundancy of knowledge, to facilitate knowledge reasoning. Thus, the static and dynamic characteristics of the object as a whole exist in the object. The object becomes an entity with knowledge processing capabilities and can exist flexibly in the knowledge base.

Simultaneously, it can also represent fuzzy knowledge to add credibility to object-oriented knowledge representation. It is shown in two aspects. First, each precondition of production rules has different degrees of support to conclusions, that is, they have different degrees of importance. It makes different preconditions have different weights through assigning weighting factors to preconditions. Second, each rule has different credibility. It indicates the degree of certainty of human experts to this rule adding weighting factors to rules. Thus it adds the ability to blur represented to object-oriented knowledge representation on the basis of traditional production rules.

Rule is expressed as follow:

if $(P_1,\delta p_1)$ and $(P_2,\delta p_2)$ and …and $(P_n,\delta p_n)$ then C_1 and C_2 and …C_n with α
Among this, P_1, P_2, …, P_n is prerequisites; δp_1, δp_2, …, δp_n is right weight of prerequisites; C_1, C_2, …, C_n is conclusions of rules; α is credibility.

Introducing a weighting factor of evidence to rules solves not only the representation problems caused by different degrees of importance of multiple evidences supporting to conclusions and different independences and dependences among evidences, but also uncertain reasoning problem with incomplete evidences. It makes object-oriented knowledge representation be capable of handling fuzzy knowledge through adding confidence spreading values and calculated confidence spread values to the knowledge object class.

4.2. Users' External Knowledge Representation Based on Visualization

Knowledge in knowledge base, on one hand, needs to be effectively stored, retrieved and identified with internal computer. At the same time, it requests to be shown to users in a more direct way. More than 80% of human knowledge and information is obtained through visual, so here we apply multimedia technology to external knowledge representation, using not only text messages, but also 3D virtual reality technology such as graphics, images, sound, video, animation, etc. and making comprehensive description of multi-angle to achieve visualization of knowledge of external representation. External visual representation of knowledge is shown as Figure 7.

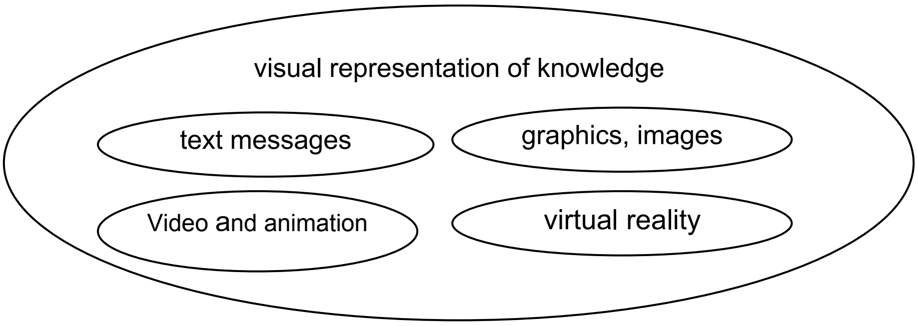
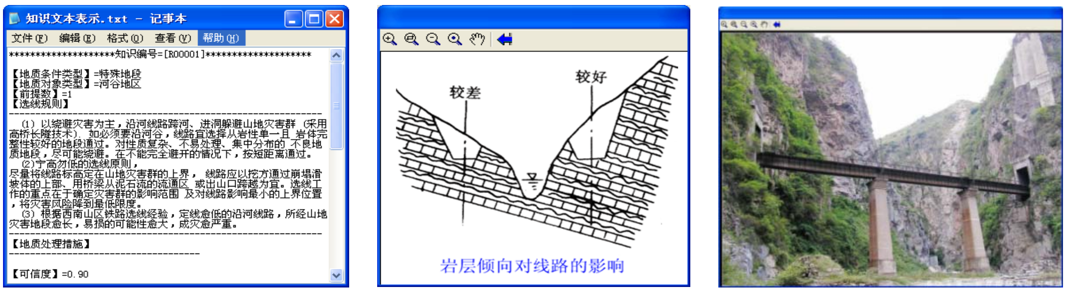


Figure 7. External Visual Representation of Knowledge

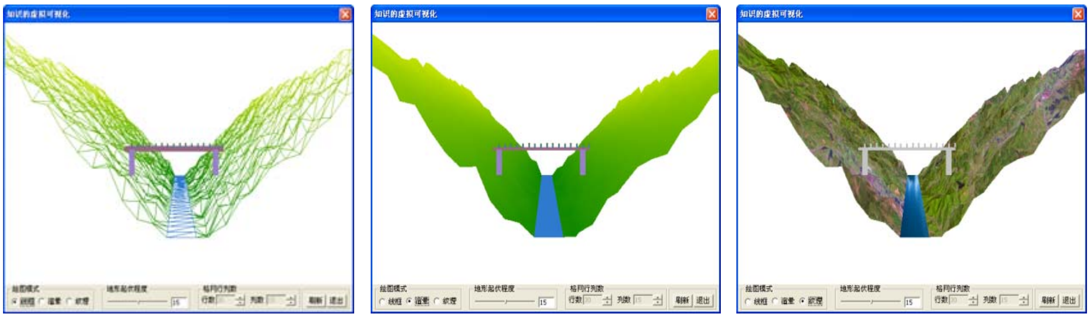


(a) Text representation of knowledge (b) Graphics representation of knowledge (c) Image representation of knowledge

Figure 8. Knowledge Representation Form

In Figure 7, text messages are used to describe the concept and types of knowledge, and other text information; graphics and video animations are more image representation for knowledge. Knowledge base provides interfaces for input of this information. Take knowledge representation of valley region line selection for example and is shown as Figure 8.

The system builds many types of VGE such as valley, permafrost, loess and so on for the particular environment of route selection. It automatically invokes the corresponding virtual geographic environment from virtual geographic environments library, expresses knowledge in the environment and then achieves virtual visual representation of knowledge. It allows users immersive, and makes them learning and use knowledge more effectively. The three-dimensional visual representation of knowledge of river segment's line selection in valley region is shown in Figure 9 (Using high bridges across valley). The system can see dynamically 3D knowledge representation model from different perspectives and depths and resize the virtual geographic environment.



(a) 3D virtual representation of Knowledge (Gizmos Mode)

(b) 3D virtual representation of Knowledge (Vertigo Mode)

(c) 3D virtual representation of Knowledge (Texture Mode)

Figure 9. 3D Virtual Visual Representation of Knowledge

5. Management and Maintenance

In geological knowledge base of route selection, the main functions of knowledge base management has to be done are basic management of knowledge (consists of addition, deleting and modification), knowledge demonstration, visual representation of knowledge and so on. In order to offer users more user-friendly interfaces, the work of knowledge management section is mainly focused on realizing visual representation of knowledge and simple decomposition of general knowledge input by users.

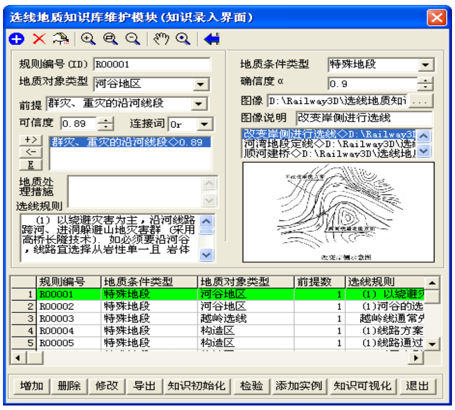


Figure 10. Input Interface of Knowledge

Figure 11. Input Interface of Examples

The interface that users input knowledge is shown as Figure 10. When initializing knowledge base, an expert or a knowledge engineer enters a rule using the user interface, and this rule is judged by the system. If the rule's premise or conclusion contains both "And" and "Or", the system will automatically convert it into a multi-decomposition rule and store into the knowledge base to facilitate future maintenance of knowledge base. The rules storage through this form is convenient for rules redundancy checking, contradictory rules checking and circulation rules checking. To achieve fuzzy knowledge representation, every prerequisite of a rule has own credibility input value and the maximum value is 1. After selecting a piece of knowledge, we can add instances to it through function 'Add an instance'. This process is shown in Figure 11.

6. Reasoning of Knowledge Base

6.1, Reasoning of Uncertainty

In engineering problems, there is much common knowledge which cannot use normal logic to handle, because they contain a great deal of uncertainty [9]. For example, observe the following pieces of knowledge: 'Relatively flat side of the river bank may have bad geological conditions', 'The terrain of valley sides is steep and it may cause geological disasters landslides, mudslides, etc.'. These pieces of knowledge contain a great deal of uncertainty. There are two classes of the uncertainty above. They are uncertainty of rule conditions and uncertainty of conclusions. Therefore, it is necessary to build some uncertain process of calculation and reasoning [10-12].

1) Uncertainty of rule conditions

When observing objects, the truth that we have seen usually owns uncertainty. Generally, uncertainty of a truth is described by a coefficient ranging from 0 to 1.'1' represents complete determination and '0' represents complete uncertainty. This coefficient is called credibility. When a rule has more than one condition, you need to calculate credibility of the overall condition according to credibility of each credibility[13-14]. There are two main ways as follow:

a) The approach based on fuzzy set theory

According to this approach, it regards the smallest credibility of all the conditions as credibility of the overall condition. For instance, this approach is used by MYCIN system. Set a rule containing m conditions, and $c_1, c_2, ..., c_m$ is each condition's credibility. Therefore, credibility of the overall condition c_t is $c_t = \min\{c_1, c_2, ..., c_m\}$. As is shown in Figure 12, there are 3 rules owning rules. Assuming that 0.9, 0.5 and 1.0 are credibility of the three rules, so take the minimum value 0.5 for the credibility of the total.

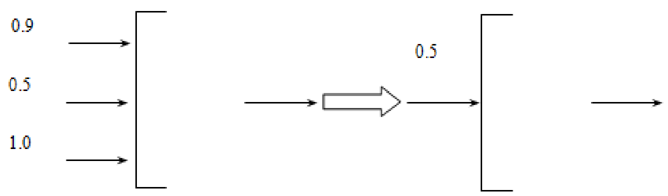


Figure 12. Fuzzy-set Processing Method of Condition Credibility

b) The approach based on probability

This approach also gives all evidences its own credibility. But credibility of the overall condition equals to the total product of every credibility. For example, this approach is used by PROSPECTOR system. Using the same rule as is shown in Figure 12, the overall credibility of part of the rules entering is 0.45, as is shown in Figure 13.

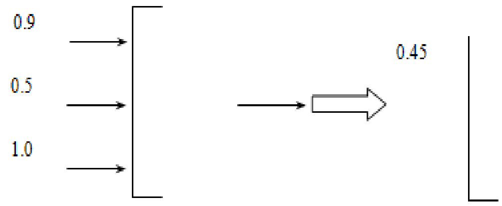


Figure 13. Probability Processing Method of Condition Credibility

For the same rule having m conditions, $c_1, c_2, ..., c_m$ is each condition's credibility. So credibility of the overall condition c_t is $c_t = \prod_{i=1}^{m} c_i$.

Therefore, this article provides two methods to determine the overall credibility of the rules section; you can choose one according to the actual situation.

6.2. Uncertainty on Conclusions

The uncertainty on conclusions is also called uncertainty of rules, and it represents uncertain degree of producing some conclusion when the conditions of the rule are fully completed. It is also represented by given rules coefficients between 0 and 1, that is, the coefficient is credibility of a conclusion. Determination method as follows:

Take conclusion credibility as the product of conditions credibility and rules coefficient $C_{out} = C_{in} \times \alpha$. As is shown in Figure 14, at this time conditions credibility is 0.5 and rules coefficient is 0.8, so conclusion credibility is $C_{out} = 0.5 \times 0.8 = 0.4$. The relationship between conditions credibility of rules and conclusion credibility of rules is shown in Figure 14. This relationship can be used to represent uncertainty of rules.

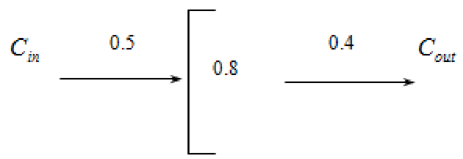


Figure 14. Calculation method of Conclusion Credibility

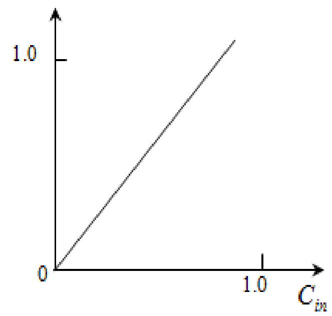


Figure 15. The Relationship between Conditions Credibility of Rules and Conclusion Credibility of Rules

7. Conclusion

According to the diversity of geological conditions involved in railway location design, different types of geological objects were classified and indexed, and proposed the modeling method based on multiple sub-bases. It used the computer's internal and external representation in geological knowledge representation. In computer external, it used object-oriented class-rules knowledge representation model, added credibility to the object-oriented knowledge representation model, and also can represent fuzzy representation of knowledge. Achieve visual representation of external knowledge representation using text and graphics 3D virtual reality technology. According to the ambiguity of geological knowledge, it realizes uncertainty reasoning of the part based on rule condition and conclusions and realizes reasoning based on instances. Geological knowledge-based systems of railway route selection builds a full range of route-selection geological environments for route selection and design, provides real-time help and reference for engineers and Better meets the requirements of railway geological route selection.

Acknowledgements

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