Preliminary development of safety assessment and assistance decision system for old buildings

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ABSTRACT : Based on the results of visual inspection data and earthquake damage survey from old buildings, a safety assessment and assistance decision system is developed by using some new information processing technologies, including interval analysis method, fuzzy synthesis judgment model and expert system. According to its evaluation process (in-situ testing, data processing, expert evaluation), the system consists of three modules, which are data record and management module, grade evaluation module and expert evaluation module. It can not only help the building managers process large numbers of inspection data, but also give the best management scheme by the health condition of old buildings.

KEYWORDS: Expert system, Data management, fuzzy synthesis judgment, Safe Grade evaluation

1. Introduction

With the condition of environment, application conditions, earthquake and storm etc, those old building's healthiness status change continuously, the proportion of need security status appraisal's old building is rising greatly. For the aim that achieve the appraisal of old building's security, reasonable and effective distribution of fund, material, manpower and operation time, ensure the structure in a all right and security status, those management department hope could possess a special computer assistant system for comprehensive supervision and appraisal which can establish detecting plan and building's current using status, in order to advance warning and make a scientific management decision. Currently, the means which apply in computer assistant to appraise the security of construction [1-2] is still in its starting stage. Nowadays, EXPERT XYSTEM OF SEISMIC SAFETY EVALUATIONFOR EXISTING BUTLDINGS [3] and IASSAB [4] only appraise the construction security status after earthquake. Those above systems are applied in the idea of Classical Fuzzy Set which has some limitations in optimization solving, to establish data model during engineering practice. In this study, we based on current civil building's security appraisal, first introducing the interval analysis method which use for processing the floating-point operation in computer early time and now it also prevail in engineering practice. However, the interval number's operation is easy to cause the expansion of operation, so that the interval analysis method has limitation in engineering construction analysis application. Therefore, we introducing the fuzzy theory [5-7] which describing the interval number fuzzy set based on the fuzzy field which enclosure those uncertainty attribute data. It can shrink the expansion range resulted from the interval analysis method effectively. We establish the data model which have multi-level factors comprehensive appraisal combining with the above theory, improve the data that collecting in detection process method. It overcome those defects that only gain the local optimal solution with conventional planning method, and gain the all extreme value and global extremum about the practical engineering problems which need solved. Based on the above analysis method's theory, this study using the latest information processing technology such as fuzzy synthetic evaluation model and expert system ideas etc, and working out a suit of complete application system. It gathers mainly old building's apparent data or the result of aging test. Then we put forward the old building's security management countermeasures. This system will secure extensive foreground in practical engineering application.

2. The means of old building's security appraisal system

It is unavoidable that the construction will damage or aging, and has great significance that appraise and authenticate the security of building correctly towards the work of earthquake prevention and disaster relief.

Usually, the requirement against the dangerous building's authentication is very strong. It is unpractical inspect the building with carefully and completely, investigate, detect and checking calculation towards the construction accurately. Commonly, we use the celerity appraisal method based on the expert system's subjective quality. However, the authentication results always different result from experts different view in knowledge background, work experience and cognition. In this study, we combine with comprehensive appraisal theory of multi-level factors in interval fuzzy set, by the simulation of PC, and discuss the multi-level factors comprehensive appraisal based on interval fuzzy set solving model of this field problems appropriately. It fully reflects the evaluation idea of expert in this field.

2.1. The comprehensive appraisal method of multi-level factors based on interval fuzzy set

The attribute data of sampling point always not an accurate data, but an interval range (0.0-1.0). System modeling, analysis and reasoning for this interval data is based on spatial topologic relation model of classic fuzzy set and cut set [8]. Measured data provided by construction engineering always in the certain interval range $\{x-\Delta x, x+\Delta x\}$, where x is a theoretical value and △x is tolerance. We use fuzzy range enclosing by uncertain attribute data result from the interval value's fuzzy set describing, and operation properties based on interval value and interval fuzzy set [9]. We propose the analysis model of topological relation between the fuzzy ranges. There are many factors need to considered when we appraised complicated system or problem. However, these factors are contributed different level. First, we divided the system into several levels according to the logical relation. Secondary, divided all factors into several kinds according to certain attributes in every level. Thirdly, first-level comprehensive appraised in every kind range until to the top-level, at last we achieve the general appraisal of complete problem. That is the method of thinking of multi-level factors comprehensive appraisal based on the interval fuzzy set.

2.2. The model of multi-level factors comprehensive appraisal

While we appraising a complicated system, we divided the n factors into t subsets which mutually uncorrelated each other according to attributes in the universe $U=\{U_1, U_2, \ldots U_n\}$, that is $U=\{U_1, U_2, \ldots U_t\}$. Assumption the appraisal divided into m stages, we composed the appraisal range $V=\{v_1, v_2, \ldots v_m\}$. We comprehensive appraise the first stage in the range of $U_k(k=1,2,\ldots t)$ in each attribute set.

Definition: On the assumption that $a=[a^-, a^+]$, $b=[b^-, b^+]$ are two arbitrary interval numbers. We call the relative dominance of the interval number $a \succ b$ to $P(a \succ b)$ =

$$
\begin{cases}
1-\dfrac{1}{2\exp\{\dfrac{a^+-b^-}{a^+-a^-+b^+-b^-}-\dfrac{1}{2}\}} & \text{When } \dfrac{a^+-b^-}{a^+-a^-+b^+-b^-} \geq 12 \\
\dfrac{1}{2\exp\{\dfrac{1}{2}-\dfrac{a^+-b^-}{a^+-a^-+b^+-b^-}\}} & \text{When } \dfrac{a^+-b^-}{a^+-a^-+b^+-b^-} < 12 \\
1-\dfrac{1}{2e^{(a-b)}} & \text{When a and b are degradation interval numbers, and } a \geq b \\
\dfrac{1}{2e^{(b-a)}} & \text{When a and b are degradation interval numbers, and } a \prec b
\end{cases}
$$

On the Assumption that $H1=[H_1^-, H_1^+]$, $H2=[H_2^-, H_2^+]$, $\cdots$, $Hn=[H_n^-, H_n^+]$ are interval numbers of n scheme grade characteristics. We use $h_{ij}(i, j=1,2,\ldots n)$ for expressing the relative dominance $P(Hi \succ Hj)$ of interval number $Hi \succ Hj$. We can easily validate that judgment matrix $H=(h_{ij})_{n\times n}$ of relative dominance based on the element of h_{ij} is a fuzzy reciprocal matrix. We can secure the weight value

$A_i = \frac{1}{n(n-1)}[\sum_{j=1}^{n} h_{ij} + \frac{n}{2} - 1]$ of scheme A_i by using the sorting method of fuzzy reciprocal matrix. On the assumption that the first group of first level consist of s elements, we compose the appraisal matrix by using the appraisal result which appraised from the single factor firstly. If the membership degrees range from r_{i1} to r_{im} which result from the single appraisal evaluation index r_i compose the single factor evaluation vector, we will gain the relation matrix $R_i = (r_{i1}, r_{i2}, ..., r_{im})$.The weighted factor sets of the first group of first level and the second level are follows:

$$A_1 = (a_{11}, a_{12}, ..., a_{1s})$$
$$A^2 = (a^2{}_1, a^2{}_2, ..., a^2{}_t)$$

We secure the appraisal vectors every group by comprehensive appraise the subgroup in the first level firstly. That is: $B_1 = A_1 \circ R_1 = (b_{11}, b_{12}, ..., b_{1m})$

And we can yield with the same reason: $B_2 = A_2 \circ R_2 = (b_{21}, b_{22}, ..., b_{2m})$

$$B_3 = A_3 \circ R_3 = (b_{31}, b_{32}, ..., b_{3m})$$
$$\cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots \quad \cdots$$
$$B_t = A_t \circ R_t = (b_{t1}, b_{t2}, ..., b_{tm})$$

We synthesize the interval fuzzy relation matrix $R = (b_{s1}, b_{s2}, ..., b_{sm})$ as second level by using the appraisal vectors of every group result from the first level. Then we synthesize the second level secondarily and gain the follows appraisal set: $B^2 = A^2 \circ R = (b_1, b_2, ..., b_m)$

It strengthens the effectiveness of level assessment result and practicability of modules under the above theories.

On the assumption that the comprehensive appraisal vector is $B = (b_1 \quad b_2 \quad b_3 \quad b_4)$, therefore the concrete algorithm of above could be expressed as following the table 1 which describing the criterion of construction safety grade assessment:

① If $b_1 + \quad b_2 + \quad b_3 + \quad b_4 \succ 0.9$, it is called a safety building, otherwise it is called a un-safety building as D_{su};

② If $b_1 + \quad b_2 + \quad b_3 \prec \quad b_4$ while $b_1 + \quad b_2 + \quad b_3 + \quad b_4 \succ 0.9$, it is called a C_{su} kind safety building;

③ If $b_1 \prec b_2$ while $b_1 + \quad b_2 + \quad b_3 + \quad b_4 \succ 0.9$, $b_1 + \quad b_2 + \quad b_3 \succ \quad b_4$ and $b_1 + \quad b_2 \succ \quad b_3$, it is called a B_{su} kind safety building; otherwise called a A_{su} kind safety building.

Table 1 Identification of building safety conclusions

Grade	Based on
A_{su}	Identification Unit safety standards, if the load-bearing part of the maintenance system for Cu grade level or grade Du, the commentary by a lower grade or two, no less than Csu level
B_{su}	Identification Unit safety standards, if the load-bearing part of the maintenance system for Cu grade level or grade Du, the commentary by a lower grade or two, no less than Csu level
C_{su}	Identification Unit safety standards
D_{su}	Identification Unit safety standards, if there are dangerous buildings, and by direct threats, or tilt towards one side to speed up the pace, directly as Dsu level

Based on those above theories, we improve the efficiency of grade appraisal's results and enhance the usefulness of module.

3. The main function implementation and simulation system designing

3.1. Identification of safety standards and processes

To the national standard “building safety identification” (GB 18208.2-2001) and “Identification of civil reliability standards” (GB 50292-1999) as the basis, with test data on the safety of old buildings to be in class.

Identification of the basic processes shown in Figure 1: First, through visual inspection, testing and some simple apparent vibration testing by the testing data, and then these test data and old buildings to enter the basic information to support decision-making system, the system based on criteria that the building of the components of the sound (of injury), and then to a sound evaluation based on the results, judgment at this stage why the injury occurred, and gives the buildings a reasonable grade and expert recommendations.

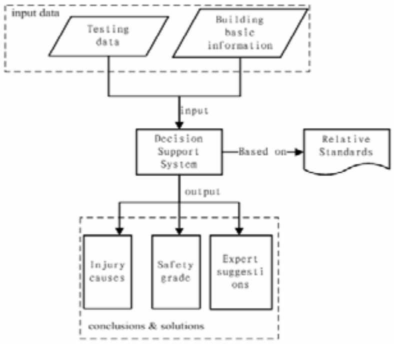

Figure 1 security identification of the basic processes

Based on these standards and procedures, steps to integrate the Building Management (site monitoring → data processing → expert evaluation), the system is divided into data entry and management, rating, the expert evaluation of three modules.

3.2. Data input and management module

Old building is mainly responsible for basic information and test data input, and provide information to the preservation, edit, query, and other functions, automatically record data generated by the old grading of building the necessary information related documents. Since the importation of large quantities of information, variety, to enhance operational convenience and ease of maintenance, use VB6.0 development of the visual graphics input and management interface, in Figure 2 below.

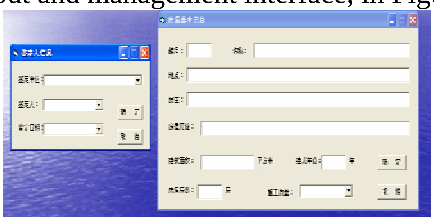

Figure 2-a Building the basic information management

Figure 2-b Building detection information management

3.3. Grade appraisal module

Module grading of the main features are: According to the environmental conditions, conditions of use, testing data, as well as national civil identification of existing standards for the reliability of components, sub-units, units from the bottom to the top of the building gradually damage the cause of the analysis and assessment through the security rating and identification of the normal use of the rating, the identification unit to make a reasonable rating, as well as follow-up to provide reliable data. There is rating of the treatment process, as shown in Figure 3.

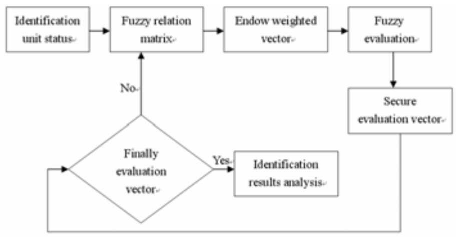

Figure 3 grade appraisal processing flow

3.4. Experts evaluation module

The module's main function is to: Based on input data (such as expertise, building the basic information, environmental conditions, the use of actual field conditions and testing data, etc.) treatment, comprehensive evaluation of the safety evaluation is given grades are given expert the proposal, and automatically generate the report identified, options shown in Figure 4.

Figure 4 Experts evaluate the results

4. Example of system operation

Example: Even the old school somewhere for the four-story brick masonry structure, prefabricated concrete floor, the scene of the damaged housing survey results are:

1) Support beams are cracking in the wall, serious cracks in the wall junction, large hand-layer shedding;
2) Decorating brick stack fracture falling;
3) Component concrete floor is damaged, beam, floor signs of loosening on the wall;
4) Pre-cast slab's interval between the prefabricated expansion has serious cracks;
5) Top-level conference room ceiling decoration decorative cracking down fall;
6) Non-structural cracks and even have a component part of the dumping occurred, fell;

The group of the housing site for the conclusion of the identification of unsafe buildings, and are not to use housing. Are identified through the old building security system to support decision-making in the construction of a security identification, the first major of the main parameters and information collection, then click on the menu in the identification process of identification of the security options, the system will provide information to users of housing for security identification, in the form of the final results show identification and expert advice. Example of this old building safety identification of decision-making system and the results of the group of expert identified at the scene identified the results match, the initial analysis proved the reliability of modules.

5. Conclusions

Old building safety appraisal decision support system is mainly for the construction of a large number of old test data or the apparent aging testing summary of the results, then gives the old building safety management measures. A range of methods and range fuzzy set theory, the use of neural networks, fuzzy comprehensive evaluation model of thinking and expert systems, such as the latest information processing technology, applications software development VB6.0 to a complete set of applications.

Some records from the system (data entry), to inform the part of (grades determine) and experts of the three parts. Records portion of the major responsible for data entry. Evaluation is based on the time of admission to some of the different data and identification of relevant standards, the building of the current security situation, can get through systematic analysis of the results: the use of old buildings and cause damage to the natural causes of earthquake damage, can also be given accurate building the security level. Some experts are mainly based on experts in the field experience, combined with data to inform the part of the identification unit is given the security level for the management of the maintenance programmed to provide a scientific basis.

The system works in practice has a broad application prospects for the development, with the building of the growing injury factors to determine the level of refinement to be further in-depth study.

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