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Decision Support Based on the Evaluation of Residential Buildings

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Abstract: From the point of view of the sustainability of the building stock it is significant to be aware of the condition of the load bearing structures. In general the assessment of condition is done by visual inspection in the case of residential buildings therefore the experts assessing the condition of buildings have only limited information. Thus the assessment of an expert is subjective, which might cause the inaccuracy of the assessment. Two fuzzy logic based models have been created for qualifying the buildings. Sensibility of buildings was examined, to see to what extent the final assessment changes upon slight changes of input values.

Keywords: decision support, fuzzy signatures, real-fuzzy sets

1. Introduction

From the point of view of the safety and sense of comfort of those who live and work in the buildings, as well as of the sustainability of buildings it is an important task to carry out the status analysis of the existing stock of buildings and support the decision-making on interruption related to the renovation of buildings. From time to time it is reasonable to prepare expert opinions wherein the expert describes the condition of the structures of buildings and the detected impairments. In case of inhabited buildings the condition is more or less determined by visual inspection, it is only rarely possible to carry out destructive testing of structures and laboratory analysis of samples taken at the spot. Therefore it is often impossible to detect the hidden (covered) deteriorations existing in the structures. In such a case the expert has to make his decision related to the status of the structures of buildings based on limited information. In addition the subjective evaluation of the expert also influences the result of assessment.

It is highly probable that two different experts would not evaluate the quality of the same building structure in [0,1] interval to be totally the same (even if there is a precise description how to assess the given building structure in case of given arrangement and material of structures, and type and rate of impairments).

To assess the status of and rank the existing buildings and to model the decision-making a fuzzy singleton signature-based method was elaborated. Moreover by using fuzzy sets of real set of values (R-fuzzy sets), a model has been created, which in addition to the impairments detected in the structures, also takes into account the factors, which influence the condition of the structure. Since the membership values, characterising the status of a given building structure, are determined on the basis of the expert evaluations, they are partly subjective due to reasons mentioned above, that is may include discrepancies, errors, because of which they are not fully reliable.

The sensitivity of fuzzy signature-based method was tested, which shows the reliability of the obtained results. It was checked how the obtained results would change if the input data are slightly changed.

2. Fuzzy singleton signature based model

A fuzzy singleton signatures based model was created to determine the condition of buildings as well as to support the decision making. The set up of the fuzzy singleton signature structure in the format of tree structure can be seen on Figure 1.

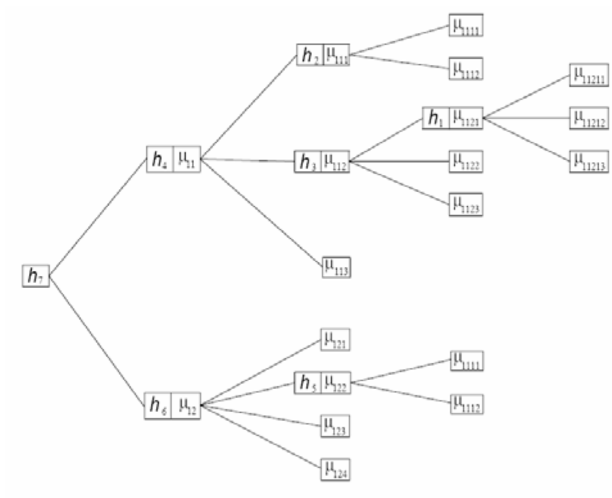

Figure 1. Set up fuzzy singleton signature structure

On the peak of the structures fuzzy membership values were defined on the basis of the formerly prepared data base. It is a requirement towards the fuzzy membership values (μ) to have their values within the interval of [0,1].

The role of the aggregation operators is to modify the structure of the fuzzy signatures. In such a case a sub-tree of the variables is reduced to the root of the sub-tree. The relevance weight shows the relevance of the peak, related to the root of the sub-tree. The applied aggregation operators were created by using the membership values and the relevance weights.

The aggregation operators and the relevance weights were defined based on expert evaluations. For example the relevance weight related to the cellar floor (ϕ_{11211}) and the aggregation operator, related to the vertical load bearing structures (h_2) can be seen in the following formulas (m is the extent of the cellar built, n is the number of the storeys of the building).

$$\varphi_{11211} = \frac{0{,}35 \cdot m}{0{,}2 + 0{,}45 \cdot (n-1) + 0{,}35 \cdot m} \tag{1}$$

$$h_2 = (0{,}50 - 0{,}05 \cdot (n-1)) \cdot \mu_{1111} + (0{,}50 + 0{,}05 \cdot (n-1)) \cdot \mu_{1112} \tag{2}$$

For each member of the examined residential buildings a value can be computed which refer to the status of the building. Values fall in the interval of [0,1].

3. Defining the membership values by using real-fuzzy sets

The method was elaborated using the “real fuzzy values” (R-fuzzy sets), an extension of the concept of classic fuzzy sets, the former being suitable at the same time taking into account various aspects.

To determine the membership values, featuring the examined structure, factors influencing the membership value (and so the condition of the examined load bearing structure) were defined. These factors show the size of the investigated effect exerted on the status of the examined structure.

Factors affecting the status of the structure in a positive direction will be called *status improving factors* (μ_i) and the factors affecting the status of the structure in a negative sense will be called *status deterioration factors* (α_i).

Using the fuzzy disjunction the expression of factors μ_P and α_N are given as follows (in case of arbitrary n positive, and m negative factors):

$$\mu_P = 1 - \prod_{i=1}^{n} (1 - \mu_i) \tag{3}$$

$$, \alpha_N = 1 - \prod_{i=1}^{m} (1 - \alpha_i) \tag{4}$$

After that the membership values of the examined structure were determined. The extreme values of the fuzzy interval values are λ_{SUP} and λ_{INF} (optimistic and pessimistic case) while the arithmetic mean of the estimated overall membership value is λ_{AVG}.

$$\lambda_{SUP} = \frac{\mu_P \cdot (1-\alpha_N)}{1-\mu_P \cdot \alpha_N}, \tag{5}$$

$$\lambda_{INF} = \mu_P \cdot (1-\alpha_N) \tag{6}$$

$$\lambda_{AVG} = \frac{\lambda_{INF} + \lambda_{SUP}}{2} = \left(1 - \frac{\mu_P \cdot \alpha_N}{2}\right) \cdot \frac{\mu_P \cdot (1-\alpha_N)}{1-\mu_P \cdot \alpha_N}, \tag{7}$$

The structures in very good and in very bad state, the difference between the upper and the lower values of the membership value is generally rather small while the scissors open up more for median state buildings.

4. Sensibility and validity of the applied models

A mathematical analysis was performed to identify the sensitivity of the calculated condition of the examined residential buildings. The applied fuzzy singleton signatures related to the changes of membership values at the end nodes of graph was conducted.

The analysis investigates the validity of the results of the elaborated methods which takes into account the possible subjective discrepancy and uncertainty in the evaluations.

The upper estimation of the change of the output and the conclusion is the follow.

$$|\Delta f| \le \sqrt{\sum_{i=1}^{13} p_i^2 \cdot \sum_{i=1}^{13} \Delta^2 x_i} \le 0.4 \cdot \sqrt{\sum_{i=1}^{13} \Delta^2 x_i} = 0.4 \cdot \|\Delta \underline{x}\|_2, \tag{8}$$

$$|\Delta f| \le \sum_{i=1}^{13} |p_i| \cdot |\Delta x_i| \le 0.28 \cdot \sum_{i=1}^{13} |\Delta x_i| = 0.28 \cdot \|\Delta \underline{x}\|_1 \tag{9}$$

Examining the optimistic case it can be established that the upper estimation of $|\Delta f|$ with the euclidean norm of the input is the following:

$$|\Delta f| \le \sqrt{0.48} \cdot K_{2\max}(a,b) \cdot \sqrt{\sum_{j=1}^{13} \sum_{i=1}^{3} \left(\Delta^2 \mu_{ij} + \Delta^2 \alpha_{ij}\right)} \tag{10}$$
$$\text{where } K_{2\max}(a,b) = \max\{K_{2j}(a,b)\}.$$

The estimation with the sum norm of the input values is the following:

$$|\Delta f| \le 0{,}28 \cdot K_{1\max}(a,b) \cdot \sum_{j=1}^{13} \sum_{i=1}^{3} \left(|\Delta \mu_{ij}| + |\Delta \alpha_{ij}|\right), \tag{11}$$
$$\text{where } K_{1\max}(a,b) = \max\{K_{1j}(a,b)\}.$$

The estimation with the euclidean norm of the input values in the pessimistic case is the following:

$$|\Delta f| \leq 0{,}96 \cdot \sqrt{\sum_{j=1}^{13}\sum_{i=1}^{3}\left(\Delta^2\mu_{ij} + \Delta^2\alpha_{ij}\right)} \tag{12}$$

The estimation with the sum norm of the input values is the following:

$$|\Delta f| \leq 0{,}28 \cdot \sum_{j=1}^{13}\sum_{i=1}^{3}\left(|\Delta\mu_{ij}| + |\Delta\alpha_{ij}|\right), \tag{13}$$

The model has very advantageous mathematical property, but in practice the sensitivity depends on the precision and partition of the scale applied by the expert. The question is that how large changing of the output value can be caused by small changing of the input values. It can be determined that a small change of the input values could not cause a large change of the final decision.

5. Conclusion

After the investigation of the complex model it can be concluded that the possible subjective deviation and uncertainty in the expert evaluation (a small change of the input values) not cause a large change of the output.

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References

[1] István Á. Harmati, Ádám Bukovics, László T. Kóczy: *Sensitivity Analysis of the Weighted Generalized Mean Aggregation Operator and its Application to Fuzzy Signatures*. 2014 World Congress on Computation Intelligence. Beijing. China. 2014. p: 1327-1332

[2] Ádám Bukovics, László T. Kóczy: *Modeling the Condition of Buildings by Real Fuzzy Sets*. 39th IAHS World Congress on Housing Sciences. Milan. Italy. 2013. p: 817-824

[3] Ádám Bukovics, László T. Kóczy: *Fuzzy signature-based model for qualification and ranking of residential buildings*. IAHS XXXVIII. World Congress on Housing Sciences. Istanbul. Turkey. 2012. p: 290-297

[4] Adam Bukovics: *Pathological analysis of suspension corridor and floor structures of residential buildings*. CIB World Congress. Salford Quays. Manchester. UK. 2010. p: 98 (code: 626)

[5] Kóczy L. T., *Fuzzy graphs in the evaluation and optimization of networks*, FUZZY SET SYST 46: (3), 1992, pp. 307-319