Fuzzy Interface for Historical Monuments Databases

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Abstract. Issues concerning the conservation of historic monuments can be be supported by information systems. Databases offer significant opportunities for structuring knowledge, but they need to provide the users with effective tools. Efficiency of these tools depends largely on functionality and flexibility of the interfaces. This paper presents a proposal for a new interface access to databases of historical buildings using fuzzy sets.

Keywords: historical monument, database, fuzzy set, interface.

1 Introduction

Nowadays, various dangers affect national heritage in a broad sense, and this is the reason why special attention is given to its protection. The threats include air pollution, natural disasters, as well as exploitation. Many countries have extremely rich and highly diverse historical legacy, of which one of the more obvious components are the historic monuments. The problem of monuments protection is very complex due to the diversity of objects classified as monuments, and it requires the use of different approaches, techniques and solutions depending on the needs.

In Poland, there is over 65,000 historical monuments (divided into 14 major categories) [15], and their number is still growing. Due to the complexity of the matter, and the number of monuments, this paper focuses on the historical tenements (one of the types of historic residential buildings, which number exceeds 17,000).

The role of information systems in the monuments conservation may be very important. The complexity of aspects of the restoration and maintenance requires a structured approach. That is why considerable attention is given to applications that use the databases. Numerous studies are conducted on the use of such solutions [2]. However, these works are usually related to a single issue, such as specialized and detailed description of the materials that are made of elements of historic buildings [6] or encompass the wide range of topics that describe the multimedia and the GIS data [7]. Many problems still remain unsolved and research in many aspects seems not to be carried out.

A bibliography review and consultations with experts in conservation studies showed no complete solutions in this field. Simultaneously, there is great need

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for the availability of such tools. Existing applications are fragmentary, covering only some aspects of the problem and do not represent sufficient support for the wider protection of national heritage. This work presents optimal solutions, which allow efficient retrieval of information from large data sets.

2 Searching Similar Objects

The usefulness of the system that collects information largely depends on options in the searching process. The method of extraction of information determines whether the application meets the requirements [11]. In the protection of monuments, it is particularly important aspect. Majority of this systems users do not have any knowledge in programming. Often they are not even the engineers, and a large part of them can be artists.

The historical subject matter is always fraught with a lack of complete precision. As an example the issue of objects dating may be consider. A complete and documented history of an object or element is rarely available. Even if the complete data is given, it may still be the subject of discussion [11]. Also other, seemingly more tangible aspects, are not entirely clear. For example, there is a problem with the dimensions of individual components. Although it is easy to measure, the use of precise results will be useless if there is a need to search the corresponding object. In the past, many (if not all) elements were performed by different masters using their own developed methods and techniques, making it impossible to accurately compare the results of their work. In the case of dimensions of objects and their comparison, paradoxically, the greater the accuracy, the less effective search. In modern building techniques, it is significantly easier to use the precision data. Nowadays, objects are usually constructed with typical materials of defined characteristics, their components are standardized, cataloged and only minor deviations from standards are admitted. Quite different is the case of historic structures. The older objects are considered, the less precise criteria are assumed.

In summary, it is impossible to accurately compare data that are either of debatable precision (such as creation date, modification, repair, maintenance), or unique (dimensions of structural elements). Searching the database have to be characterized by inexactness in the formulation of questions, because that is the nature of the data.

The necessity of development of that kind of technology is undeniable [4,3]. Many examples of its usage can be enumerated. For instance, if there is a need to renovate a particular architectural element which, in the case of a given monument, has been destroyed, it can be very useful (especially in the absence of full documentation) to rely on other objects of similar structure, construction time, dimensions and purpose. Another example would be a situation in which conservators join their work to prevent further degradation of the monument and they would like to have the possibility to choose the best method of preservation. Relying on methods that have worked well with other objects (because of the chosen technology, materials, etc.), is always extremely valuable. Again, the key is to find similar objects (similar in different points of view) and verify the methods used in their maintenance. Different example is a situation where the conservator would like to explore the risks concerning specific elements, because of their design or the materials that they were made of. Analysis of other similar objects can give important clues in this regard.

The key in all these cases is the word “similar”.

3 Fuzzy Interface

Since the fundamental problem is the lack of ability to perform precise searches in the area of historical monuments databases, it is necessary to provide users with the possibility of formulating vague queries. In presented work, the theory of fuzzy sets [12,1] has been used. It is a starting point to model the interface that would find the usage in applications which support historic restorers, architects and artists.

There are also many papers that discuss design and implementation issues of solutions to formulate queries in natural language and processing them in relational databases [8,9]. Fuzzy sets theory has been used in the systems for monuments preservation, such as fuzzy number ranking in project selection [13] or reliability in archaeological virtual reconstruction [10]. It has not been used in the area of interfaces for calculation of similarity between monuments.

Our approach focuses on one category of historic buildings - a historical tenement. It is also possible to generalize the method, after its verification, to other types of buildings. Focusing on one category of objects enables simplification of the process of implementation, without losing the practical aspect.

As a part of a historic building five main types of structural elements can be distinguished [5]:

- The foundation
- The facade
- The roof
- Stairs
- Doors

This solution is a part of a larger project concerning the comprehensive system of historic buildings, and therefore each of those items in the database has a few or more instances, for example, two facades: the front and rear. The solution of the fuzzy search for similar objects is independent from the construction of given building, so the complexity of the building structure is not important.

For each structural element the following attributes are considered:

- The construction period
- The state of preservation
- Dimensions
- The material (that was used)
- The design (type or its properties)

The dictionaries have been prepared for each type of structural element. Various materials (including types of plaster, wood, roofing materials), types and characteristics of the structure (including resistance to weather conditions, load) had been taken into consideration.

The system has a set of various defined types of features. Each of them has assigned default values that can be edited by an expert. It is also possible to create new features to extend the functionality of the system. The features are based on fuzzy sets. The degree of belonging to the fuzzy set is the subjective assessment. Therefore, the possibility of free edition is fully justified. It should be taken into consideration that one of the experts may regard a similar period of construction within + / - 20 years, but the other one may consider a value of + / - 50 years. A similar situation is noticed in case of the strength of the structure, materials and all other features. The interface designed for the definition of features for the roof element is shown in Fig. 1.

The complexity of the interface is a compromise between the possibility of a detailed specification of the similarity by using multiple keywords, and the simplicity of the usage. We intentionally proposed a simpler interface, allowing the users to extend it for the creation of more precise criteria.

In case when the user searches for similar objects, and selects the characters by which the comparison should be carried out, then the degree of similarity should be determined (similar or very similar) - Fig. 2. Moreover, the user may indicate the importance (weight) of data characteristics.

The application that analyses the correlations between selected details of buildings is based on fuzzy sets. This solution allows searching the database for a pre-defined similarity. In presented application, the implementation uses a symmetric triangular membership function [12].

An example of calculation relative to the attribute “construction period” has been presented below.

1. A historical tenement built in 1600 has been selected as an input object (for which similar objects are searched). According to the opinion of an expert, construction period of tenements that are similar in terms of year of construction equals + / - 40 years.
2. One of the objects in database is the tenement built in 1590.
3. It is possible to calculate the wanted similarity of the tenement by using triangular membership function [12] and taking into consideration the values defined by the expert:

$$\mu\left(x : a, b, c\right) = \begin{cases} 0, & x \leq a \\ \frac{x-a}{b-a}, & for\ a < x \leq b \\ -\frac{x-c}{c-b}, & for\ b < x \leq c \\ 0, & x > c \end{cases} \tag{1}$$

where: a, b, c - parameters that define the similarity border and $(a < x \leq b < x \leq c)$

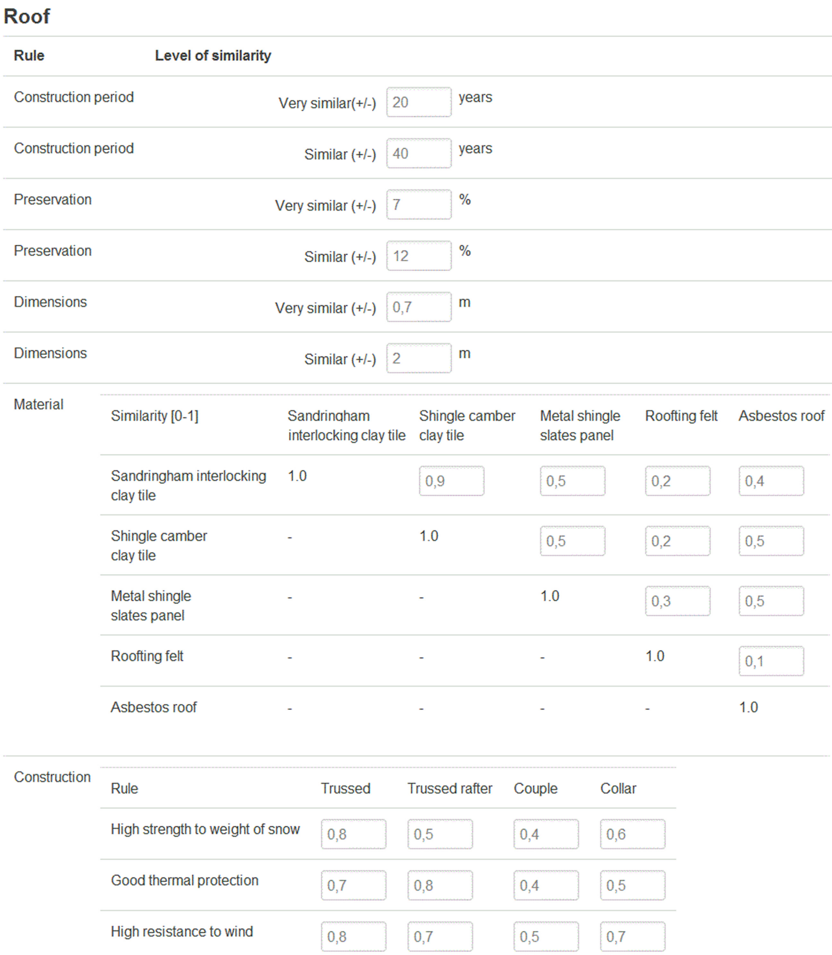


Fig. 1. Interface of features defining for the roof

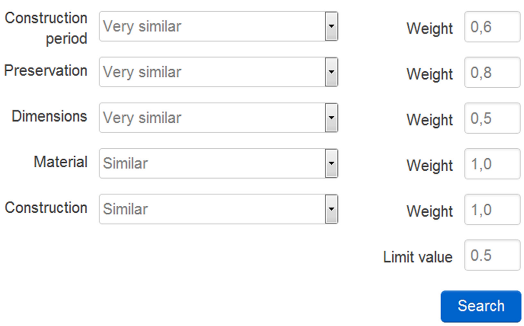


Fig. 2. Defining criteria for given monument

4. Supposing that we have the expert opinion ($1560 < x \leq 1600 < x \leq 1640$), the membership function takes the following form:

$$\mu\left(x : a, b, c\right) = \begin{cases} 0, & x \leq 1560 \\ \frac{x}{40} - 39, & for\ 1560 < x \leq 1600 \\ -\frac{x}{40} + 41, & for\ 1600 < x \leq 1640 \\ 0, & x > 1640 \end{cases} \tag{2}$$

5. Memberships of the tenement of 1590 equals 0.75.

The degree of belonging to a given fuzzy set determines the similarity to the reference element.

The problem of similarity of elements, such as the type of construction of foundation or roof, has been solved in a different way. Fuzzy sets that describe certain characteristics or properties of a given element have been defined in this application. The task of an expert is to determine the degree of belonging of a considered element to a selected set of structures. For instance, if a set is defined by the rule “the high durability on the weight of snow”, a specialist can evaluate that the trussed roof belongs to the set at 0.8 degree. However, trussed rafter roof considered as less robust, belongs to the set at only 0.6 degree.

The paper [14] gives a variety of methods for calculating the similarity between elements belonging to fuzzy sets. In most cases, the concept of geometric distance between these elements is used. The similarity between element A and B may,

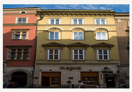
Name	Address	Monument class	Building date	Present usage	Photography		Similarity
Długosz House	Kanonicza Street No. 25	I	05-03 -1575	The Pontifical University of John Paul II in Cracow		Show report	0.724
Under The Angels	Florianska Street No. 1	II	01-30 -1486	Residential building		Show report	0.722
Dobrodziejskich House	Florianska Street No. 5	II	01-18 -1478	Jewelry factory		Show report	0.632
Under The God's eye	Grodzka Street No. 6	III	03-17 -1735	Residential building		Show report	0.614
Margrabska Tenement	Slawkowska Street No. 2	I	07-13 -1574	Residential building		Show report	0.547

Fig. 3. The list of tenements with degree of similarity

for example, be determined by the equation (3) for a fuzzy set defined by the class of triangular membership function.

$$S_{A,B} = 1 - \frac{1}{n} \sum_{i=1}^{n} |a_i - b_i| \tag{3}$$

where: A, B - fuzzy sets; a, b - elements belonging to fuzzy sets.

It is possible to compare the data structure under certain traits by using the expert-defined features visible in Fig. 1. If trussed roof and trussed rafter roof is considered by doing an analysis of their individual characteristics and then average the results is made, final similarity between structures is obtained.

In the query in Fig. 3 criteria were defined: construction period 1600 (weight 0,8), preservation 78% (weight 0,8), dimension very similar (referential: 12mx9m, weight 0,5). material similar (referential: roofing felt, weight 1,0). The final result of the application is a list of tenements arranged in descending order in terms of similarity of the selected elements. Apart from general information about building products, the list contains references to reports that precisely discuss the historic details.

4 Conclusion

The paper discusses the issues of information retrieval about historical monuments in the databases. In our solution, the theory of fuzzy sets was used to design the interface to such databases. The authors focused on developing the most universal way to formulate imprecise queries. An important assumption was the simplicity of querying and the possibility of relying on the characteristics of various kinds. Another important goal was to enable users such as preservationists, architects to redefine the fuzzy numbers as well as extend interface attributes. The authors focused on the development of the most useful interface to formulate imprecise queries for simple integration with existing database systems.

Approaches presented in [8], [9] are proposals of universal solutions which can be implemented in standard database environments. Universal implementation of fuzzy queries can be very useful and gives possibility to construct a lot of combination of queries to any data. However, such a solution requires implementation in given database server. Each database server vendor provides its own procedural language and each database can be hermetic environment with limited access to make such implementation. General solution could be a great improvement in given integrated system, for example in data warehouse [9].

As an alternative to such solutions, this paper presents dedicated approach. It is possible to identify some advantages of proposed solution. First, it is not necessary to add any extension to existing databases, which have own security policies, because the implementation is performed in the application layer. In case of the need to search for data in multiple databases, universal solution have to be implemented in each database, often from different providers. Finally, in approach presented in this paper, the change of database servers is very easy (for example: from open-source to commercial or vice versa), also there is no need to move the implementation of fuzzy queries.

Based on a review of literature, no available solution in this area can be found (even the consistent concept or prototype). In the aforementioned papers, only theoretical analysis of usefulness of fuzzy sets is presented. A few examples describe a ranking procedure among various conservational and enhancement projects that may be defined for an archaeological site [13] or in describing virtual models of monuments [10].

We have developed the application that verifies the approach presented in the paper. Tests performed with the use of the application confirmed the utility of this approach.

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