INTEGRATION OF A FUZZY SYSTEM AND AN INFORMATION SYSTEM FOR THE TERRITORIAL UNITS RANKING

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Abstract: For ranking and classification of the territorial units, up-to-date and precise data as well as ranking tool are needed. The advantage of fuzzy systems (FS) in these tasks is in definition of a problem by linguistic terms. The disadvantage is in universality and complexity of the fuzzy systems for end users. This disadvantage comes from usage of FS to solve a wide area of different tasks. The advantages and the disadvantages, as well as constraints of FS are analyzed. The aim of this paper is to show the information systems about territorial units of the Slovak Republic and possibilities of integration fuzzy system for ranking territorial units with these information systems. This approach enables creation of the model, importing the input data, processing of the rules and presentation of the solution in a usable and understandable form. In this case solution is presented on a thematic map too.

1 INTRODUCTION

The elements of significant importance for the ranking and classification of the territorial units are adequate number of indicators, their precise and up-to-date collection and qualitative usage of data for ranking. The support for ranking can be attained only with the design and implementation of an accurate information system and an adequate system for the territorial units ranking.

The aim of the research presented in this paper is to illustrate how this amount of data and FS can be used in classification and ranking problems. The classification and ranking of the territorial units is of significant importance for the regional development planning. The paper aims to present abilities of FS as an alternative approach to classical statistical methods for the classification and ranking tasks.

The collection and storage of data, even if exist a prefect information system for collect all possible indicators for all territorial levels, is an excellent basis but without reference to usage them in research and decision process is unuseful.

This paper briefly describes information systems for territorial units in the Slovak Republic. This paper also discusses some advantages and disadvantages of the fuzzy approach for the territorial units ranking and suggests the integrated FS (IFS) with statistical information systems.

2 INFORMATION SYSTEMS FOR TERITORIAL UNITS

The MOŠ/MIS (Urban and municipality statistics/ Urban information system) is officially used in the Statistical Office of the Slovak Republic. The INFOREG (Information system for support of the regional development) is in the phase of pilot application. The data from these two systems can be used for ranking of territorial units.

The MOŠ/MIS is developed according to the Nomenclature of Units for Territorial Statistics (NUTS) which defines hierarchical and geographical dividing of territory in a country. NUTS classification is important in the harmonization and comparing of regional data between countries that have implemented NUTS. All territorial units at the first three levels of NUTS have unique code in

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whole EU. The basic territorial units for the MOŠ/MIS are urbans and municipalities on level 5 of NUTS. This system covers collection of indicators for this level only. This system turned out to be successful in the municipality statistical area.

The INFOREG platform facilitates data collection, storage, management of data and their presentation for all NUTS levels. The structure of the INFOREG database consists of these dimensions: **indicator**, **territorial unit** and **period**. The structure of database is presented in three-dimensional cube in figure 1 (Priehradníková, Benčič and Hudec, 2005). In the intersection of dimensions is the indicator value. For example: 70 inhabitants/km^2 is density of population (source Statistical Office) for Bystrica region for 2003 year.

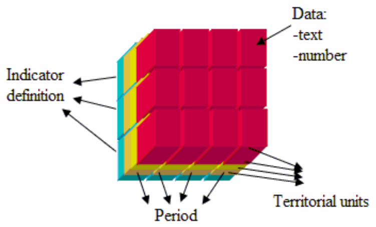

Figure 1: Structure of three-dimensional cube.

The **territorial unit** dimension is defined by NUTS classification. The **period** presents all possible periods of collecting indicator values. The dimension of **indicator** has the most complex requirements. The set of indicators is vast and there is the expectation that new indicators might be added according to requirements for information.

The main qualitative impacts of INFOREG are:

- effective support for research and development, strategy building, realization of the regional policy and investments during their decision making processes;
- development of sophisticated indicators system, which reflects the situation in municipalities and regions.

The next chapters present the FS use in ranking and classification tasks and the development of the integrated FS with the information systems mentioned above.

3 FUZZY APPROACH

The process of finding the best solution or ranking of the objects could be done using different methods. Classical methods usually use ponders to set importance for each attribute. Figure 2 shows situation when a system based on logic (an expert system) allows to obtain expected solution (point C) whereas by the method based on ponders is not possible to reach this solution. Depending of the changes in coefficient values for attributes X_1 and X_2 the object function f reaches solutions A or B.

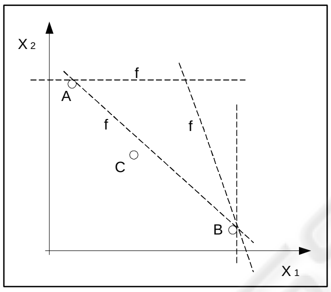

Figure 2: Finding of the best solution.

If is classical expert system widened with the fuzzy logic, fuzzy expert system or just fuzzy system based on the fuzzy “if-then” rules is attained. FS includes fuzzy sets and fuzzy logic into inference process and that gives significant advantages beyond the constraints of classical logic in many different tasks. The fuzzy logic possesses the ability to mimic the human mind to effectively calculate modes of reasoning that are approximate.

3.1 Advantages and Disadvantages

Despite the fact of important results in practical applications, fuzzy approach is not a total generalization of the Boolean algebra (BA) for the multivalued logic (Radojević, 2005). It means that the fuzzy approach is not capable to fulfill some of the axioms or theorems of BA. For example the sum of atomic functions $(a \wedge b, \bar{a} \wedge b, a \wedge \bar{b}, \bar{a} \wedge \bar{b})$ is not always equal to 1 and the excluded middle $(a \vee \bar{a})$ and the contradiction $(a \wedge \bar{a})$ laws are not satisfied always. According to these, it can be considered that fuzzy algebra: <[0,1], T, S, N> where T denotes T-norm, S is S-norm and N is complement, is not BA. It is possible to avoid these disadvantages and to exploit good properties of fuzzy approach by analysis of each task to keep staying in BA frame.

In case of using $(a \wedge b)$ rule, the min T-norm gives good output solution. Lukasiewicz T-norm gives more restricted output when membership degrees of a and b satisfy relation (a+b)<1, because the consequence of rule is always equal to zero. The advantage of Lukasiewicz T-norm is in the event of using complement in rules: $(a \wedge \bar{b})$ and when some of controlling rules, like contradiction $(a \wedge \bar{a})$ are used. In these cases Lukasiewicz T-norm satisfy Boolean axiom whereas min T-norm does not satisfy it. In case of softly ranking of municipalities by min

T-norm all municipalities that have sum of all membership functions in rule less than 1 can be ranked. If FS uses for example aggregation $(a \wedge b)$ and if min T-norm is used, what is usual case in real applications then FS is consistent with the BA.

If restrictions mentioned above are satisfied, the FS can be successfuly used in ranking and classification tasks because they:

- enables the creation of logical inference system based on human mind including uncertainities in membership degrees to the appropriate fuzzy sets.
- supports the inference process based on "IF-THEN" rules.
- enables accessible and understantable knowledge base for users.

The Sugeno model of fuzzy inference system (FIS) from the MatLab software is implemented for municipalities ranking according to needs for the road maintenance in winter. The data from the MOŠ/MIS were used. (Hudec and Vujošević, 2005).

The disadvantage is in the complexity of using FIS in software products (MatLab…) and non-existence of integration between FIS and databases for domain experts. The decision makers requirement for FIS is its simplicity for use to impose the obvious advantages of the FS. The FIS usually does not satisfy this criteria. The powerful software for FIS is produced for wide area of tasks and is complicated for users. In order to solve a task, the decision maker needs the assistance from an information system expert for preparing the input data from database into proper format for FIS and for presenting results in useful form. The decision maker also needs an operational research expert to set appropriate functions for aggregation, implication, accumulation and defuzzification in FIS. The FIS tools usualy offer variety of functions and fuzzy model could become unreliable if unparopriate functions are chosen.

3.2 Integrated Fuzzy System

The Integrated fuzzy system (IFS) was developed to avoid disadvantages mentioned above. Figure 3 shows the IFS for territorial units ranking. The interface to database enables the selection of territorial units and indicators which are important for ranking task. Selected territorial units and values of chosen indicators are converted into appropriate matrix form for the FIS.

In suggested IFS the zero ordered Sugeno model of fuzzy inference is used. Unconditional fuzzy rules are not of interest in territorial ranking tasks so to use Mamdani model is not necessary. FIS can be expanded in future by Mamdani model to use non singleton fuzzy sets in the model output part.

Ordinary fuzzy sets as triangular, trapezoidal or bell shaped type are used in the IFS. These fuzzy sets are not complicated and in this case keep enough information for description of ambiguity from the decision maker point of view. The next step is the knowledge representation using inference rules that connect the input with the output. The rules are of the "if-then" form. Although determining of these rules is intuitive, it is very important to include all interesting cases in these rules. Antecedent part of the rule is connected by **and**, **or** or **not** operators. The fuzzy model for a ranking task is after these two steps defined. The next step is the processing of the rules for selected territorial units. Processing of the rules depends on selected functions for aggregation, implication and accumulation. Min T-norm is used for "and" aggregation. In order to support selection of proper T-norm for fuzzy model defined by user, integrated system would have to select appropriate T-norm according to selected type of fuzzy rules. For the implication, the Mamadani implication is used.

In order to solve a ranking problem within a knowledge-based fuzzy system it is necessary to provide results in a usable and understandable form. The result of ranking in a vector form is connected with code list of territorial units and exported into xls format for additional spreadsheet calculations. In territorial units ranking, providing the result in a thematic map is very useful too. For this purpose the result form the FIS is adapted for presenting results in a map. The rank for every territorial unit, obtained by the FIS and determined by territorial unit primary key, is connected across this key to the identification of the particular polynomial area of the vector map. The map shows territorial survey of municipality ranking. These two modes for presenting of the results are shown in the right part of Figure 3.

The FIS is under development in the VB.NET as well as other parts of IFS: the database interface and the export solutions to the spreadsheet calculations format and maps. The knowledge and experiences obtained from ranking of municipalities by existing FIS in the MatLab was used for IFS development.

More comparison to the other systems for estimation and ranking (e.g. DEA, or OLAP) will be done once the IFS is implemented. This comparison is interested in the obtained result as well as in

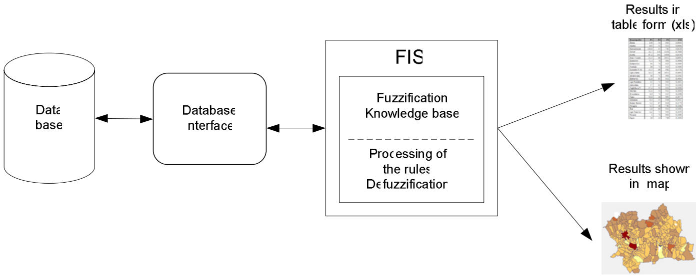

Figure 3: Integrated fuzzy system.

simplicity of use for end users. The second comparison means level of satisfaction of the system functionality for easiest creation of a model and for solving particular ranking task from decision maker point of view.

The IFS can be used in ranking tasks for territorial units in other countries too. This possibility is at this moment only theoretical. There are some more conditions that have to be satisfied. Hierarchical structures of territorial units in databases need to be compatible with the NUTS and adequate maps for territorial units need to be available for use.

4 CONCLUSIONS

The support for the ranking can be attained only with the design and implementation of an adequate information system and an adequate system for territorial units ranking.

The object of this research was to improve the support for decision makers during their work with the statistical data. In this area of work expressions like: low or high rate of unemployment, low pollution, etc. are frequently used. It was needed to adapt and include these expressions into inference process. Upon the obtained results from previous research in fuzzy ranking the IFS is suggested as a support tool for these decision makers.

It was proven in the previous research that the FS may be successfully used for municipalities ranking tasks. The results were reasonable and expected (Hudec and Vujošević, 2005). Disadvantages of the FS were found too. The aim of this paper was to avoid some of disadvantages and to exploit advantages mentioned above. Meanwhile, the INFOREG was developed. The possibility of the FS integration with the INFOREG enables more flexible using of the FS in territorial ranking tasks. Briefly, the use of the FS has given satisfactory solutions and the IFS provides better working environment.

Decision makers and domain experts obtain useful tool for their work. This tool exempts them from the help of information and fuzzy systems experts during preparing of a fuzzy model and the process solution.

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