APPLICATION OF FUZZY MODELS FOR GEOGRAPHICAL INFORMATION SYSTEMS

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Abstract

This paper deals with the designing of fuzzy models for application in geographical information systems (GIS). Geographical information necessary for creating operative ecological maps such as: influence of industrial and power installations on environment, atmospheric condition, condition of water bodies, condition of population's health etc. is observed here.

1 Systematic approach of map simulation

In the process of perspective planning of industrial development of a region various types of cartographic materials differing in contents and dimensions are used, which reflect the environmental conditions in that region and their interaction with the industries there. During the process of planning the necessary knowledge about the present conditions and perspectives for development of the researched territory can be got from cartographic materials. Such information is usually got from maps visually, but for creating such maps it is necessary to translate the contents of GIS in to a mathematical model with the use of computers.

This gives us possibilities to receive profound and complex ecological information, during the design stage, since GIS stores results of various complicated research works, like for example agrochemical parameters (properties, norms, constituents etc) of soil, constitution of pollutants influencing the ecological equilibrium.

As it is known, that cartographic objects and phenomena are very complex and multifaceted, they are characterized by a set of indices and are created in accordance with a definite group of laws. Cartography of such phenomena requires a systematic approach, therefore they must be clearly systematised. For this it is advisable to develop and use a unit structural model of cartographic phenomena. Such parameters of objects as "quality of water", "degree of atmospheric pollution", "degree of underground water

pollution", "concentration of natural resources" etc. can be represented by hierarchy structure. Majority of geographical information systems represent objects and phenomena on lower level, that is their parameters are expressed in absolute (points, mg/dm3 etc) or in relative (ppm) units of measurements. However, on higher level (the level of human evaluation) they are represented in fuzzy and linguistic forms which, when used in the creation of the above mentioned maps give rise to certain fundamental difficulties. Due to this it is necessary to apply fuzzy logic and linguistic variables.

2 About fuzzy logic

Today attempts are made to automate various types of human activity from technological objects design to diagnosing a patient.The methods using which a computer reasons and a human being reasons differ in the way they interpret the input data. When taking decisions, computers usually ask for precise and concrete information.

Humans don't generally reason in such a precise manner.Actually most human decision making processes are characterized by notions, which overlap each other.For example in our case :quality of water is very high or normal or normal or low. With the help of fuzzy models human notions like those mentioned above can be made understandable to computers. Indeed, fuzzy sets and fuzzy logic are finding wider and wider application in a broad range of problem solving, from industrial process control and pattern recognition to weather prediction, medical diagnosis and agricultural planning [1].

The base for fuzzy set theory is that, that the switching from one fuzzy set to another fuzzy set is not a step function but a continuous one. As history shows, man's ability to discern mathematical base started with real arithmetic. Processing of information using computers on the basis of real arithmetic continued till early 80s, when mankind recognized the latest discoveries in mathematics (1965-L.Zadeh, 1966-R.Moore).

Talking about somebody or something it is incorrect to see only as "good-bad, black-white, yes-no etc" based on Boolean algebra. Generalized view of information by human brain is necessary for proper understanding of problems in making decision in the analysis of cartographic phenomena is shown in figure 1. The papers [2,3] have shown the necessity and possibility of using of fuzzy and interval representations in many areas of human activity.

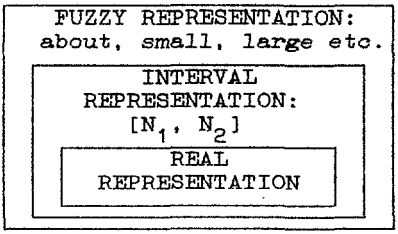

Fig.1:Representation of information

3 Proposed methodology

The basic notion in fuzzy logic which plays a key role in it's numerous applications, especially in expert systems is the linguistic variable. The linguistic variable is a varying quantity whose values are usually words or sentences of human language. Such representation of information about objects very well get along with the knowledge of experts, formulized with the help of rules like "IF <<fuzzy condition>>, THEN <<fuzzy inference>>" in expert systems. In the process of presenting and applying specialist's knowledge in simulation of maps, some of the parameters are determined in the form of linguistic variables, that is their values are fuzzy variables like "normal", "acceptable", "hazardous" etc. For example, "quality of water" based on its constituents and properties can be expressed through values like "bad", "good", "very good". But the meanings of these parameters are expressed by membership functions, for example "degree of atmospheric pollution"(Fig. 2).

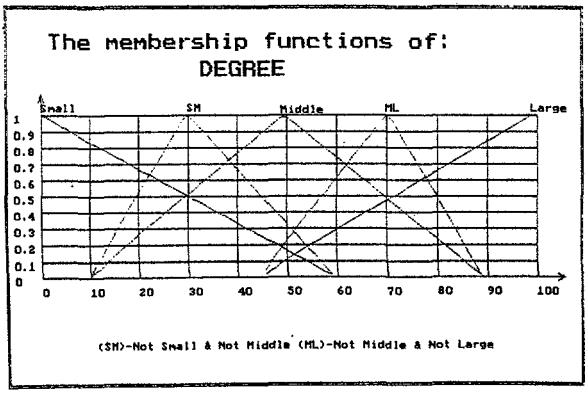

Fig.2:Degree of atmospheric pollution (ppm)

Knowledge is presented as a system of rules on the basis of which inferences are realized (Fig.3).

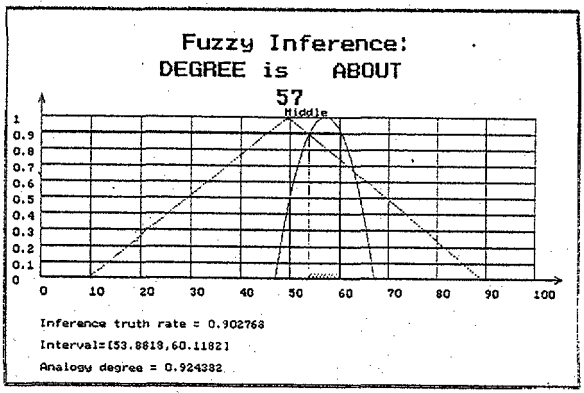

Fig.3:Fuzzy inference

Inference rules in fuzzy logic can be classified by various methods. In this work generalized modus ponens has been applied (†).

X is A (1)
Y is C if X is (2)

Y is A • R (3)

In this rule X,Y are variables ranging over specified universes of discourse (U,V), and A is fuzzy predicate or, equivalently, fuzzy relation; A • R, the composition of the unary relation A with the binary relation R, is defined by

$$\mu_{A\bullet R}(v)=\sup_{\mu}(m_A(u) \wedge \mu_R(u,v)) \qquad (4)$$

where μ_A and μ_R denote the membership functions of fuzzy fact (1) and selected rule (2), respectively; and $\wedge$ denotes the operator min.

Such an approach enables us to transact from fuzzy notion to interval representation (variable INTERVAL,Fig.3), in accordance with which is executed the simulation of selected cartographic objects.

In the expert system proposed by the authors a knowledge base, consisting of 15 rules (for three linguistic variables) with fuzzy conditions is used. For example the

linguistic variable "degree of atmospheric pollution" is represented by five fuzzy variables (Fig.2): "small", "not small & not middle", "middle", "not middle & not large", "large". This expert system processes fuzzy conditions such as 'A' from (1): "about", "almost", "slightly more", "slightly less", "approximately", translating them into interval form on the basis of initial estimation done by specialists.

The proposed method has found application in verious information systems where arises the necessity to search for information in undefined fuzzy conditions [4,5]. Besides, the application of fuzzy models for monitoring the environment enables us to recognize the areas of uncertainity (for example level of atmospheric pollution and to take corresponding decisions. In this case it is required to look into the specialities of membership function construction, especially in the areas of negative deviation (below the norm) for the values of the selected parameter.

Therefore, such an approach to simulate cartographic phenomena in perspective planning or in the earlier stages of industrial installation design, which is characterised by fuzzy information, enables us completly take into account the consequences of man's influence on environment and to take corresponding precautionary measures. This serves as a base for fuzzy decision support systems in map's simulation and environment monitoring.

References

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