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FUZZY-ORIENTED SHELL OF AN EXPERT SYSTEM "LISAP" AND ITS APPLICATIONS TO PROGNOSES IN LANDSCAPE ECOLOGY

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An expert system shell LISAP (LInguistic Shell APplications) has been developed enabling to interpolate on account of its use of fuzzy terms in such cases when an unknown functional polyfactorial relation is described by noisy data or experiential knowledge which in both cases do not satisfy the conditions for being treated by classical exact methods. The feasibility of (very large) applications has been checked in ecological forestry and agriculture.

1. LISAP FUNDAMENTALS

LISAP uses the inference mechanism based on linguistic logic. It utilizes fuzzy relations and the generalized modus ponens rule (cf. [1]). The fuzzy definition of the linguistic value of a variable is that as given in [2] and [3]. No intermediate conclusions are being formed throughout the inference. Using suitable mathematical adjusting, as proved in detail in [4], its fundamentals may be expressed as follows (cf. [1], [5], [6]):

Let $X_1, \ldots, X_n$ be the input (independent) linguistic variables from the universe $U_j, 1 \le j \le n, Y$ the output (dependent) linguistic variable within the universe U_B. Let us assume that the knowledge base is filled with m rules r_i, $1 \le i \le m$, written in the general form

if (X_1 is A^i_1 and … and X_n is A^i_n) then Y is B_i having the rule weight w_i,
where $A^i_1, \ldots, A^i_n$ are the linguistic values of the variables $X_1, \ldots, X_n$, and B_i is the linguistic value of the variable Y.

Let Q_j be the linguistic values of the (independent) variables $X_j, 1 \le j \le n$; the question is formed by the conjunction of these values.

Then the degree of membership $B(b)$ of the linguistic value of the dependent variable Y in the point $b \in U_B$ the inference mechanism computes using the following formula

$$B(b) = \left[\max_{1 \le i \le m} (\min(B_i(b), \min_{1 \le j \le n} (\mathrm{con}(Q_j, A^i_j)))) \right] \cdot w_{i_o},$$

where i_o is the index of the rule providing for maximum in the formula and where con (the consistency) of two fuzzy sets F, G in an universe U is defined as follows

$$\mathrm{con}(F, G) = \sup_{u \in U} (\min(F(u), G(u))).$$

Let us denote $h_i = \min(\mathrm{con}(Q_j, A_j^i))$. Then

$$B(b) = \left[\max_{1\le i\le m}(\min(B_i(b), h_i))\right] \cdot w_{i_o}.$$

Let $B^1, \ldots, B^s$ be all linguistic values of the dependent variable Y. Let us denote $d_k = \max(h_i; B_i = B^k), 1 \le k \le s$. Then

$$B(b) = \left[\max_{1\le k\le s}(\min(B^k(b), d_k))\right] \cdot w_{i_o}.$$

The final form of $B(b)$ indicates that the values $d_k, 1 \le k \le s$, actually represent the validity of the linguistic value B^k. From the previous description it follows that the inference mechanism seeks to each linguistic value B^k a rule whose antecedent has the maximal consistency with the question and has simultaneously B^k as its consequent. This can be taken for a measure of "similarity". After the rule had been found and used, it is ranged out of the knowledge base. This procedure is repeated until there are no more rules available, having non-zero consistency with the question.

2. LISAP PROGRAMS

LISAP contains (excluding utilities) three functional programs: VARIABM, KNOWM, and ADVISOR.

VARIABM converts linguistically expressed definitions of variables into the form accepted by KNOWM and ADVISOR. Variables are defined in a separate program so as to enable to use them in several knowledge bases. LISAP may treat up to 20 variables, each having up to 100 values.

KNOWM reads both information about the choice of the active variables (one dependent variable must be specified) and the set of production rules, which confronts with the definitions of linguistic variables and stores it on a disc. A weight may is attributed to each rule and to each independent variable. A knowledge base can take up to 9000 rules for each problem-oriented case.

Incomplete rules are accepted by the system when some independent variables are not specified in some rules. This fact is interpreted as if the respective variable did not affect the result.

Generalized rules may also be introduced. In this case, more than a single linguistic value may be given for a linguistic variable in a rule. This denotes actually a union of the cases, represented by the connective "or". The rules in the final form required for ADVISOR run are re-written by the program itself. A typical generalized rule is shown below:

A1 and ($B1$ or $B2$ or $B3$) and … and ($J1$ or $J2$)
implies $F2$ with the weight w.

ADVISOR provides answers to users' questions giving information on what behaviour of the system may be expected under conditions not (exactly) examined, analyzed or experienced, which are not contained in the knowledge base as an exact analogy. Some analogy to some situations available in the knowledge base must exist, naturally. The computation procedure proper can be interpreted as the statement of a prediction based on incurring symptoms. Independent variables may be taken for symptoms, and their linguistic values as symptom validity. Single linguistic values of the dependent variable represent the actual prognoses.

3. LISAP IN LANDSCAPE ECOLOGY

The Shell is the basis of two ecological prognostic systems (see [7]). The FORELIS – predicting suitable forest structures for immission resistant compositions, and the AGRILIS – predicting ecologically sustainable farming. In both cases we have large metasystems.

FORELIS is composed of 7 interconnected expert systems, one of them having 5 partial ES's. It contains approximately 7000 rules. AGRILIS is a metasystem built in four hierarchical levels and in its recent form it contains about one million rules. Both systems have been verified successfully in practical applications, as shown in [8], [9].

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