Tatiana Tretyakova
West Pomeranien University of Technology, Szczecin, Poland
ttretiakowa@wi.ps.pl

Estimation of rule base's quality of fuzzy models of intelligent decision support systems (IDSS)

Abstract

Some problems of design of the rule base of fuzzy system for Intelligent Decision Support System (IDSS) are considered. The rule base of the fuzzy system used at decision making about an accommodation of industrial and social objects in territories, dangerous from the point of view of hydrometeorological factors is considered as object of research. The approach to determination of the parameter of rule base completeness of fuzzy model is submitted. Influence of an input vector's structure of fuzzy model on the decisions that are offered by IDSS is investigated. Research is carried out with use of package Matlab Fuzzy Logic.

Keywords: rule base, fuzzy environment, linguistic variable, intelligent decision support system, hydrometeorological information

1. Introduction

In the modern conditions the use of different type of information technologies in management significantly influences on the quality of accepted decisions. The special attention is given to the creation of *Intelligent Decision Support Systems (IDSS).* They can be built in structure of information systems of controls of regional and local level. The *Intelligent Decision Support Systems* can function as local subsystems, or can be integrated with other information technologies (GIS, OLAP) and with internal and external sources of the data.

Acceptance of strategic decisions on accommodation and protection of industrial and social objects in territories, which are subject to influence of the dangerous natural phenomena, always is carried out in view of the hydrometeorological information.

It is necessary to notice, that the hydrometeorological information is usually characterized by incompleteness and illegibility. For this reason results of the decisions accepted on the basis of this information are difficult for estimating because of absence of clear algorithms of decision making. In such cases IDSS can serve for increase of confidence of correctness of the decisions accepted in view of this type of the information [5].

At creation IDSS the problem of preparation of contents of their knowledge bases is playing the major role. At formation of knowledge base the fact should be considered, that decisions making in view of the hydrometeorological information occurs in fuzzy conditions. It is reaching by means of accommodation of fuzzy models in contents of knowledge bases of IDSS. In work [2] approach of Bellman and Zadeh [1] to the description of fuzzy conditions is submitted. According to this approach fuzzy conditions develop from the fuzzy purposes, fuzzy restrictions and fuzzy decisions. Thus, fuzzy models should represent the fuzzy purposes (for example, reduction of negative consequences of influence on economic objects of hydrometeorological factors) and fuzzy restrictions (for example, force of the hydrometeorological phenomenon etc.).

Also fuzzy decisions (for example, an opportunity of accommodation of object in the given territory) should be submitted. At creation of fuzzy systems the important place will be occupied by fuzzy linguistic models, which contain fuzzy linguistic variables, the fuzzy sets and the fuzzy rules, which are taking into account input-output functional dependences of system. The rule base of fuzzy model is the central component of this system.

The question of quality of rule base always arises at design of fuzzy models for knowledge base of IDSS. Quality of rule base, as is known, can be estimated with the help of different characteristics, for example, such as completeness of rule base, characteristics of an input vector of fuzzy model etc. [4]. Analyzing all these characteristics, it is possible to evaluate quality of created rule base, and accordingly, of knowledge bases of IDSS.

The purpose of this article is representation of the approach to determination of completeness of rule base of fuzzy model in case, if terms - sets of linguistic variables are characterized by different number of elements. Other purpose is representation of results of the analysis of influence of structural and quantitative characteristics of an input vector of fuzzy model on decisions of IDSS. Research was carried out on an example of rule base of the fuzzy model IDSS, which is intended for support of decisions on an opportunity of accommodation of economic objects in territories, that subject to influence of the dangerous hydrometeorological factors. Such decisions should be considered at a stage of a tentative estimation of projects which financing is supposed to be carried out from means of regional funds of development. During research technology Matlab - Toolbox Fuzzy Logic was used.

2. Research of influence of some characteristics of rule base of fuzzy model on the decisions of IDSS.

At elaboration of fuzzy models for systems of class IDSS accuracy of decisions offered by them play the paramount role. Obviously, accuracy depends on characteristics of rule base of fuzzy systems. To these characteristics belong the structural and quantitative characteristics of an input vector of fuzzy model: the content and amount of input's linguistic variables, and also amount of elements of terms - sets of each linguistic variables; completeness and consistency of inference rules, the structure and parameters of membership function of input and output linguistic variables; methods of fuzzification and defuzzification.

High accuracy of fuzzy model and little number of an inference rules is rather difficult for combining. At aspiration to increase of accuracy of fuzzy model it is impossible to avoid increase of number of rules. In this connection the search of the appropriate compromise is one of the problems, which must be decided at designing of any fuzzy systems.

It is possible to assume, that there are no objective mathematical ways of grade estimation of such type of systems. However comparison of characteristics of different variants of fuzzy models, such as completeness of rule base or type of membership function, allows choosing variant of rule base of necessary quality. In this article the results of the analysis of influence of some characteristics of rule base of fuzzy model on decisions IDSS are submitted.

2.1. Structure and amount of linguistic variables in fuzzy model

At designing of fuzzy model for knowledge base of IDSS it is necessary to create the rule base in which fuzzy linguistic variables will be used. The structure and amount of linguistic variables in the fuzzy model included in base of knowledge IDSS, obviously, influences on the decisions of this system.

According to the aim of the article the variants of structure of fuzzy model are compared at different characteristics, such as dimension of an input vector of system and amount of elements in terms - sets of input linguistic variables.

In article the procedure of defuzzification of output linguistic variables is not considered, as it does not influence essentially on decisions.

As an example the system with the following input and output linguistic variables was chosen:

- S - social and economic significance of economic object for the given region,

- U – utility of territory for accommodation of the given object,
- M - influence of hydrometeorological factors on functioning of the economic object placed on territory,
- E - expedience of object's accommodation in the given territory.

The block diagram of this system is shown on fig. 1.

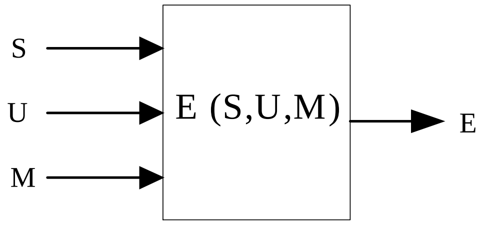

Fig. 1. Structure of fuzzy model IDSS

During inference IDSS should give the answer (linguistic variable E) to the question: whether is possible (and in what degree) accommodation of the given economic object on the given territory at taking into account of all input factors. The answer should be submitted on universal set T_E of values of this linguistic variable in the form of separate fuzzy variables E_I for which area of search of values is the universal set X_E = [0,100].

Researches have an object to find an influence of completeness of rule base and structures of input's linguistic variables on the characteristics of decisions IDSS, which received at simulation on fuzzy model.

Before to analyse results of these researches, we shall present the approach to an estimation of completeness of rule base.

2.2. Estimation of completeness of rule base of fuzzy model

The problem of an estimation of completeness of rule base is considered in detail in work [4]. In this work is emphasized, that the rule base is the major part of fuzzy model, and characteristics of rule base of this model are submitted.

One of the basic characteristics of rule base is its completeness. According to the definition submitted in work [4], the rule base of fuzzy model is linguistic complete in the event that to each linguistic state of each input vector there corresponds, at least, one linguistic state of a output vector.

Formalizing process of estimation of completeness of rule base, we shall present a parameter of completeness as follows:

$$C = \frac{N}{P} \tag{1}$$

where:

C - an index of completeness of rule base,

N - number of the rules, which are taken into account in the output mechanism,

P - the greatest possible number of consistent rules

Parameter P is defined by the formula:

$$P = \prod_{j=1}^{m} p_j \tag{2}$$

where:

m - dimension of an input vector of fuzzy model

pj - number of elements of term-sets of an input linguistic variable with the appropriate index ***"j"*.**

In works [3, 4] a little bit other formula for estimation *P* is submitted:

$$P = Z^{w} \tag{3}$$

where:

w - dimension of a vector of model’s input,

Z - number of elements of term - set of each linguistic variable.

It is easy to notice, that results of calculation of size *P* under formulas (2) and (3) coincide in case when terms - sets of all linguistic variables of an input contain identical number of elements. Formulas (1), (2) allow to carry out calculation of an index of completeness of rule bases at any number of elements in terms - sets of linguistic variable of fuzzy model. It is obvious that the parameter of completeness of rule base ***C*** should be equal to 1, if it is possible

2.2. Research of influence of structure of input's linguistic variables on decisions IDSS.

Research was carried out for two variants of the model submitted on fig. 1. As the first variant the structure of terms - sets of the linguistic variables, submitted in table 1 was considered.

Table 1. Structure of terms - sets of linguistic variables in fuzzy model IDSS

The name of a linguistic variable	Term - sets of linguistic variables			
S - significance	S1 - high	S2 - middle	S3 - small	
U - utility	U1 - high	U2 - middle	U3 - small	
M - meteo	M1 - small	M2 - middle	M3 - high	M4 - very high
E - expedience	E1 - certainly possible	E2 - possible	E3 - doubtful	E4 - not recommended

According to the formula (2) maximal number of the rules submitted in the conjunctive form for fuzzy model in this case makes 36. Limitation of volume of article does not allow resulting completely the report of 36 rules. In table 2 are resulted only 3 of the developed system of rules.

Table 2. The fragment of rule base for the first variant of fuzzy model IDSS

	S1	**S2**	**S3**	**U1**	**U2**	**U3**	**M1**	**M2**	**M3**	**M4**	**E1**	**E2**	**E3**	**E4**
1	√			√			√				√			
2	√			√				√				√		
...			…			…					…			
36			√			√				√				√

For example, from table 2 follows what the rule 1 enter as: < if S1 and U1 and M1 then E1 >**.** Some results of simulation are submitted in tab.3.

Table 3. Results of simulation: variants of probable decisions E=f (M, S, U) for case U1=5

Significance S $<X_S = [0, 5]>$	Meteo M $<X_M = [0, 100]>$					
	0	20	40	60	80	100
High S1=5	83,5	68,2	59,8	40,2	33,9	33,7
Middle S2=3	63,7	46,3	36,3	36,3	31,5	16,2
Small S3=1	62,7	47,8	34,1	25,6	25,6	19,1

Further, in the second variant of simulation the number of terms of the input linguistic variables submitted in table 1 was reduced:

- for S: T_S = {S1 - high, S3 - small},
- for U: T_U = {U1 - high, U3 - small}
- for M: T_M = {M1 - small, M3 - high}.

In this variant the maximal number of the rules designed under the formula (2), has decreased up to 8.

Results of simulation on the data of this variant allow comparison with the previous variant as the number of terms of input linguistic variables is changed only, thus the structure of system is left without changes. Owing to limitation of article's volume the rule base is not shown here. Some results of simulation for the second variant are submitted in table 4.

Table 4. Results of simulation: variants of probable decisions E=f (M, S, U) for case U1=5 (the second variant)

Significance S <X_S = [0, 5]>	Meteo M <X_M = [0, 100]>					
	0	20	40	60	80	100
High S1=5	78,8	68,1	56,7	47,1	40,3	36,2
Middle S2=3	69,7	63,4	54,7	46,7	39,3	34,7
Small S3=1	64,2	59,6	53,1	43,7	32,9	25,1

Further on fig. 2 diagrams of dependence E=f (M) for two cases is submitted for comparison: at use of 36 rules and 8 rules (at S1=5 - the high significance of object and U1=5 - the territory is high useful).

Diagrams on fig. 2 shows evidently influence of number of elements in terms-sets of linguistic variables on character of decisions IDSS.

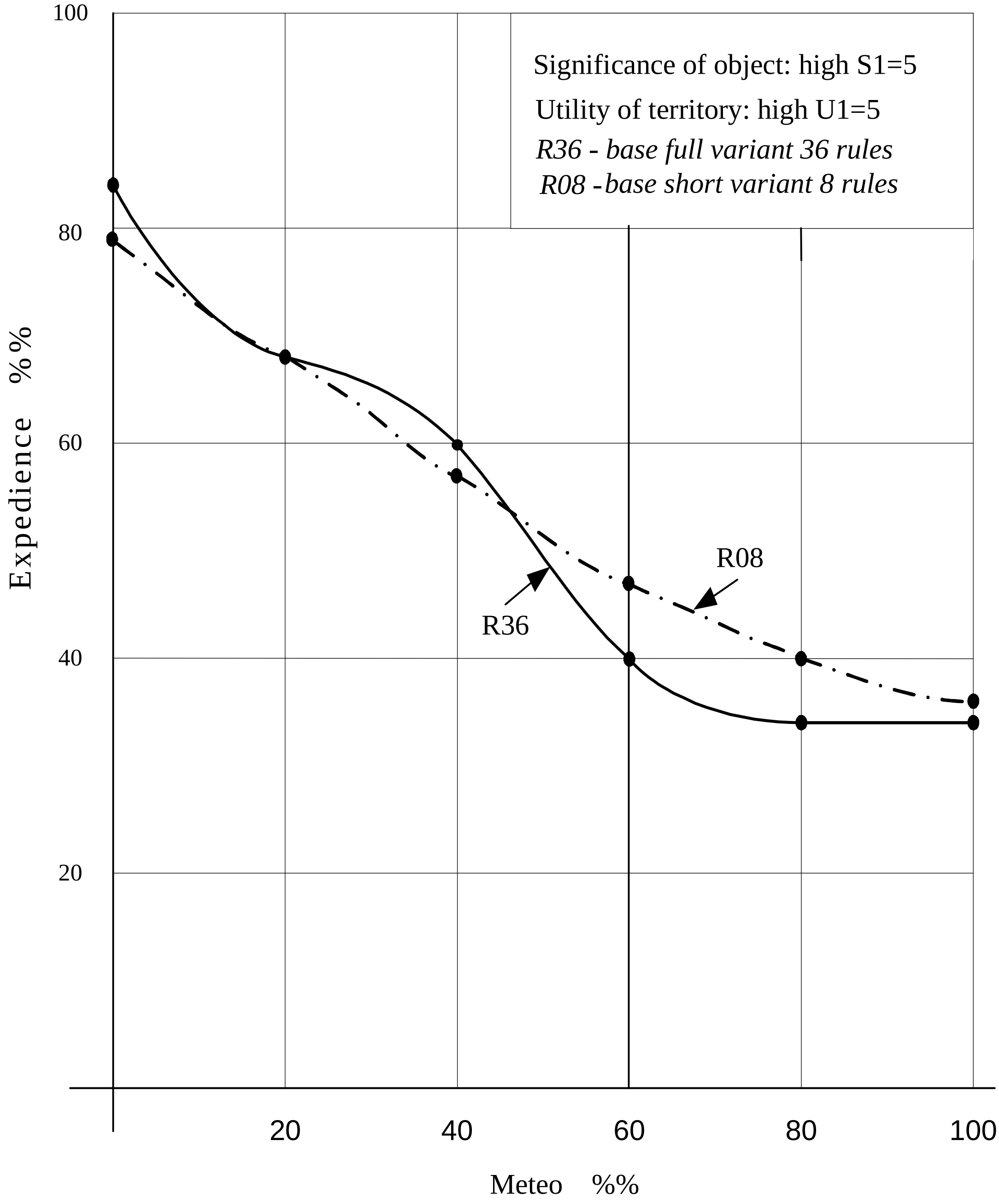

Fig. 2. Influence of number of terms on character of the decisions offered by IDSS

The analysis shows, that quality of decisions IDSS received at use of smaller number of input linguistic variables in fuzzy model, as a rule, can be sufficient at a stage of a preliminary estimation of projects. Reduction of number of input linguistic variables essentially allows reducing labour-intensiveness of creation of rule base of fuzzy model, thus quality of the decision remains at a satisfactory level.

Author of article also investigated systems with structure more a high level of complexity in comparison with submitted in the present article. For example, comparisons of two variants of systems with a scalar output and four input linguistic variables are investigated. In the first of compared variants the term-sets of three input linguistic variables contained three elements, and the term-set of one more input linguistic variable contained four elements. In this case the greatest possible number of rules according to the formula (2) makes 108. In the second variant the term-sets of all input linguistic variables contained two elements. In this case the maximal number of rules has made 16. The analysis of the results received at modelling in Matlab Fuzzy Logic environment, has shown, that the divergence of results has not exceeded 15 - 20 %.

3. Conclusion

In article the results of research of influence of rule base's characteristics of fuzzy model on the decisions, which offered IDSS are analysed. Researches are carried out with use Matlab Toolbox Fuzzy Logic on an example of rule base of the fuzzy model IDSS intended for support of decisions on an opportunity of economic object's accommodation in territory, which subject to threat of influence of dangerous hydrometeorological factors. In the article two variants of fuzzy models with different structure of input's- output's linguistic variables are compared. Reduction of number of terms of input linguistic variables allows essentially reducing number of rules in the rule base of fuzzy model. As a result of it the labour-intensiveness of creation of rule base can be reduced. Results of researches demonstrate that the quality of the decisions accepted in the fuzzy environment at reduced number of rules in fuzzy model, can be sufficient at a stage of acceptance of initial administrative decisions.

4. References

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