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CONTEMPORARY METHODS OF ARTIFICIAL INTELLIGENCE IN THE FUNCTION OF WATER RESOURCES MANAGEMENT

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Abstract: The subject of the research in this paper is the artificial intelligence models through a modern methodological approach to solving complex water management problems. Fuzzy logic as new mathematics, neural networks and fuzzy expert systems open up great opportunities in simulating and solving real problems related to the division of water and water resources. When decision-makers seek optimum, in addition to technical and economic criteria, sometimes the decisive influence belongs to the low, ecology, political, territorial, social, religious or cultural criteria. The developed theoretical model was tested and confirmed by the development of an expert system for the selection of an optimal solution for the management and distribution of the water potential of the Drina River, in the zone of different entities, between the cities of Foča and Goražde. Holistic approach and synergy appreciation of all relevant criteria resulted in the fact that the solution found by the expert model was also implemented in practice, which is confirmation for the expert system developed.

Keywords: artificial intelligence, methods, fuzzy logic, expert system, water management, water resource.

1. INTRODUCTION

The artificial intelligence as a modern methodological approach opens the possibilities for solving complex problems from the real life, for example cross border distribution of water zones, potential and other water management problems. Cross border issue is very delicate subject [18], especially when large questions of surface water zones distribution, or underground water, or other potential distribution between the entities are opened. Range of mathematical supports for searching the prosperity optimum appears in the literature [23−30].

This paper presents the methodology which enables the quantification and incorporation of all relevant decision criteria (legal, environmental, political, territorial, social, religious or cultural) into a mathematical model in order to select the correct sustainable technical and economical solution [21] of an optimum construction degree. The environmental impact parameters [22] and other non technical criteria are quantified by the Delphi method and represented by the fuzzy input variable, together with technical and economic input variables.

Theoretical basics of fuzzy logic, neural networks and expert systems are given, as well as real case studies, selection of optimum technical solution of the hydro energy utilization at the Drina river within the section Foca-Gorazde, where the applying methodology of modern technical solution of artificial intelligence is certified and confirmed.

The Drina river is a water course with significant hydro potential and it is not irrelevant in which way the construction sustainability of the facilities for the production of valuable, renewable and pure energy is researched and proved. The necessary investments in designing such huge strategic facilities are not irrelevant and the methodologies in selecting optimum technical solutions as well as the support of the decision maker are of the same importance.

The previously applied evaluation methods of optimum hydro energy utilization concept and construction of dams and hydro power plants [10] are generally based on models of standard technical-economic and financial analysis. Parameters such as negative influence of dam constructions and creation of accumulations on the natural and social-political environment cannot be easily incorporated into such a system [4].

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Multicriteria decisions are requesting exact numeric quantificators for each of the input variables, while the corresponding weighted coefficients are representing the objective rating by the expert, who will design the expert system [8]. The fuzzy expert system is enabling a linguistic characterization of the mentioned impacts and their presence within the decision system. A numeric evaluation (rating) of each possible technical solution of the output is acquired by a corresponding dephasification process.

2. ARTIFICIAL INTELLIGENCE POSSIBILITIES

2.1. Fuzzy logic

The word „fuzzy“ has appeared for the first time within the world of science and technology in the report „Fuzzy sets“, published in 1965 in the prestigeous international journal „IT sciences“, by professor Lotfi Zadeha from the Berkley University. Fuzzy and neural technologies experienced a boom in Japan and thanks to its emphasized feasibility and new approach in solving problems within the engineering practice, they spread among mathematicians, philosophers, scientists, managers and engineers. Fuzzy and neural technologies enable us to make our computers „more intelligent“ and make them our virtual partners.

Due to the fuzzy approach, non-precise qualifications and especially descriptive linguistic qualifications (for example: partial environmental threat, low/high disturbance, low/high influence ...) can be represented by synthetic quantificators and processed by computers. The new fuzzy technology is a new computer technology bringing mankind and computer together.

The next stage in the fuzzy technology development is the setting of these technologies with neural networks. This setting is adding one more characteristic of intelligent systems to fuzzy systems meaning the ability of adoption to variable environmental conditions. The fuzzy sets [13] are introduced with the basic aim to initiate and mould an indetermination within the linguistic in a mathematical formalized way and thus defined settings can be considered as generalisation of the classic set theory.

2.2. Fuzzy neural networks

The fuzzy systems are adapting to the applied situations in a corresponding way. This was already emphasized by *Lotfi Zadeh* when defining the fuzzy sets, with special remark that each domain can be fuzzed and that the previous conventional (*crisp*) set theory approach can be correspondingly generalized.

In such a way, out of on neural networks, genetic algorithm, stability theories, shape recognition and mathematical programming, you can obtain fuzzy neural networks, fuzzy genetic algorithm, fuzzy stability theories, fuzzy shape recognition and fuzzy mathematical programming and determining.

The advantage of such a fuzzification is within a lighter level of generalization and expression with higher ability of modelling real case problems with a specific methodology in analyzing tolerances within inaccuracies.

When qualitative descriptions of phenomena are used together with learning through practice, it is possible to obtain a system, which is able to learn and qualitatively describe its knowledge. The qualitative component of such systems can be realized through a fuzzy approach. The learning component can be realized through neural networks. When such systems are developed in the shape of computer programs, than we can talk about fuzzy neural technologies or fuzzy-neural computing.

2.3. Fuzzy technologies applications

The fuzzy technologies can have a wide spread application area. That is why the fuzzy technology is not just a technology, but a certain approach to problems and a way of observing and studying phenomena. Fuzzy is a new prospect [17]. During the last ten years, the fuzzy systems have become a substantial replacement of conventional tehcnologies in a great number of scientific applications [13] and engineering systems, especially within the domain of systems managements and shape recognitions.

The fuzzy tehnology has been found in the shape of approximative comprehension of its appliance within IT technologies, where it is used as a backup in determining and within expert systems, which will be theoretically further processed also on realistic examples from engineering practice.

One of the most important characteristics of the fuzzy logic is its ability to express the indetermination degree in human apprehension and subjectivity. The most often situations when there is a demand on fuzzy logic are the cases and situations when an expert system is designed, where the belonging functions have to describe the validity of particular characteristics in a corresponding way. The fuzzy logic has found its application within the management theory, shape recognition, quantitative analysis, expert diagnosis systems, planning and prediction, IT systems etc.

2.4. Introducing the fuzzy logic into expert systems

The fuzzy logic by its nature is very appropriate for shape recognition methods and for expert determinations, simply because the terms of classes, clusters and classifications are most often of a subjective nature, defined by non-numeric attributes [16].

The fuzzy logic can be introduced into the shape recognition process and expert determination in two ways. The first way is phasification of the space within which the characteristic vector is defined, and the second one is concerning the phasification of classificators. The accentuation is on the general character of the classification method, based on fuzzy logic, as well as the method called *fuzzy min-max classificator with neural network* [17].

2.5. Neural networks and expert systems

Due to utilization of new technologies, systems are developed which are adoptable to the environment and accessible to mankind. The learning process using neural networks is derived to changing parameters within the computer program, which is representing this network and in such way that exiting the program is satisfying certain criteria. After setting the neural networks with the fuzzy systems, the learned knowledge can be expressed qualitatively.

Training of the computer systems is possible due to utilization of fuzzy and neural technologies and the knowledge of the experts can be described and represented within the computer. The expert system is a program with an expert behaviour for a certain problem domain. The expert system has mainly two basic functions.

The first function is the so called *problem-solving* function, i.e.ability to use knowledge from a certain domain. Within this function, the expert system is expected to be able to function within indetermination conditions or lack of informations. The second important function is the possibility of interacting with the user, meaning explanation of intensions before and after the problem solving process. The basic structure of the expert system involves three blocks: knowledge basis, inferention machines and user interface.

The knowledge basis implies the specific knowledge of the given application domain, including facts regarding rules and relations, which exist within this application domain. IF-THEN rules are the most popular formalism. It is a form of fuzzy rules, which are representing this knowledge.

The inferention machine, i.e.the determination algorithm has the task to apply the knowledge basis and to answer the questions asked by the user. The user interface means the communication between the user and the knowledge basis, i.e.the inferention machine.

The ability of the expert system to handle inaccuracies is of great importance. Prior to introducing the fuzzy system, the most used possibility to master inderminations was based on the probability theory. However, the fact is that the experts are mostly not cogitating within the probability space, their knowledge can be expressed most often by descriptions as “low impact”, “expressive impact”, “much”, “always” etc. In such way, the fuzzy expert system offering fuzzy comprehension and linguistic expressions for describing objects and relations is becoming the usable and good alternative.

The main goal of this report is the design of a determination expert system, which based on objective (numeric, quantitative) or some more linguistic (qualitative) parameters will decide on the solvency of a potential hydro power plant at the given location, this is not a classic expert system, but a determination expert system.

2.6. Delphi method

The Delphi method as an expert rating method is belonging to the group of exploratory methods [16] and is using the advantage of an expert group comprehension. The method is named after the old Greek temple. It is based on statistic processing of collected opinions given by experts in certain domains. The utilization of expert knowledge is methodologically organized in order to evaluate and quantificate certain impacts.

The method is suitable for defining criteria, parameters and quantities used in determinations related to selecting designs. It has numerous modifications depending on studied issues, but briefly reviewed the conclusion is that the application process is involving following phases: Definition of requested rated issues;

− Creation of an expert team (10-15 members), specialists on the defined problem;
− Determination of the rating horizon;
− Within the first questionary series each expert is requested to give a forecast and arguments;
− Obtained evaluations are arranged into an increasing sequence and the median and lower and upper quartile are determined;
− Within the second questionary series the experts are receiving information on all obtained values and they are requested to revise and possibly correct their forecasts, having in mind the obtained information;

− Within the last questionary series (3-4 series) the experts are requested to give final rates.

The median is a medium rate, i.e.such rate value for which the number of experts whose rate is higher than this value is equal to the number of experts whose rate is lower than this value. This is the medium value of a sequence of objective rates.

The quartile is the range of limits, which is describing the rate variation about the medium value. It is practically representing the precise rate measure. The lower quartile is the rate for which the number of experts whose rates are lower than this value is amounting ¼ of the total number of experts. The upper quartile is the rate for which the number of experts whose rates are higher than this value is amounting ¼ of the total number of experts.

3. WATER ZONES BETWEEN ENTITIES

The locality subject to this analysis are water zones between entities at the Drina river basin between the cities of Foca and Gorazde. During the seventies of the previous century, this river section has been suggested for building one dam, which would have the greatest energy-economic effects, but also very adverse environmental impacts. For a long time, the adopted solution could not be realized as it has not actually reflected the complex optimum selection issue.

Modern technics of artificial intelligence, which are enabling the incorporation into optimisation models of valorized, quantificated and functionally expressed environmental factors, are offering the possibility of revising an optimum solution and searching for a new one, which will not endanger the environment. Conceptual desings are made for profiles where the creation of 6 schemes of alternative technical solutions in hydro energy utilization of the river is possible, respecting geological [19] and other relevant conditions, representing the combination of 7 different scheme elements.

Following HPP technical systems at the Drina river are represented as varieties from A to F:

A – HPP Gorazde 375: one concrete dam at the profile Gorazde II, with a dam side hydro power plant with retention level 375,00 m.a.s.l.

B – HPP Gorazde 383: one concrete dam at the profile Gorazde II, with a dam side power unit and accumulation at the normal retention level 383,00 m.a.s.l.

C – HPP Gorazde 352, HPP Sadba 362, HPP Ustikolina 373, HPP Paunci 384: four concrete spillway dams, cascade series, accumulations with belonging retention levels, respectively.

D – HPP Gorazde 375, HPP Paunci 384: consisting of two hydro energy facilities at profile Gorazde II and Paunci, with retention levels 375,00 m.a.s.l. and 384,00 m.a.s.l., respectively.

E – HPP Gorazde 362, HPP Ustikolina 373, HPP Paunci 384: this alternative has a cascade of three concrete dams with flow hydro power plants: Gorazde II, Ustikolina and Paunci, with accumulations at levels 362,00 m.a.s.l., 373,00 m.a.s.l. and 384,00 m.a.s.l., respectively.

F – HPP Sadba 362, HPP Ustikolina 373, HPP Paunci 384: this possible technical solution is a cascade of three uniform hydro energy facilities within the Drina river bed at profiles: Sadba, Ustikolina and Paunci with levels at 362,00 m.a.s.l., 373,00 m.a.s.l. and 384,00 m.a.s.l., respectively, with 11,00 m cadence each.

The basic techno-economical characteristics of the hydro power plants at the Drina river section between the cities Foca and Gorazde are given in table No.1.

Tabel No.1: Techno-economical indicators of possible hydro power plants at Drina river within the research section

	Gor.383	Gor.375	Gor.362	Gor.352	Sadba362	Ustik.373	Paunci384
Q_i (m^3/s)	500	500	450	450	450	450	450
H (m)	35.8	27.8	15	5	9.5	10	10.6
N_i (MW)	166.5	130.8	61.5	20.7	43.2	43.2	43.2
E_{god} $(GWh/g.)$	501.7	407.2	223.8	73.2	140.4	147.4	156.3
E_{vrsno} $(GWh/g.)$	308.3	251.1	126.3	41.3	79.2	83.2	88.2
Investments (mill. $)	302.7	246.3	105.2	79.5	79.5	77.8	85.5
B/C	1.57	1.53	1.73	0.74	1.44	1.5	1.45
Inv. quant. ($/kWh)	0.603	0.605	0.47	1.084	0.566	0.528	0.547
Spec. inv. ($/kW	1.818	1.881	1.711	3.842	1.841	1.801	1.98

4. EXPERT SYSTEM FOR SELCETION OF THE OPTIMUM TECHNICAL CONSTRUCTION CONCEPT OF HYDRO ENERGY FACILITIES

The classic energy system structure is adopted, found in literature [13] and given in figure No.1. The expert system is a program with incorporated expert knowledge meaning to be trained on an example out of 11 different hydro energy facilities. Balanced and varified on a real case example from the practice. This is a selection of an optimum of water zones distribution and construction concept for hydro energy facilities at Drina river within a defined section, with 6 varieties of different possible constructed dams and hydro power plants with higher and lower retention levels.

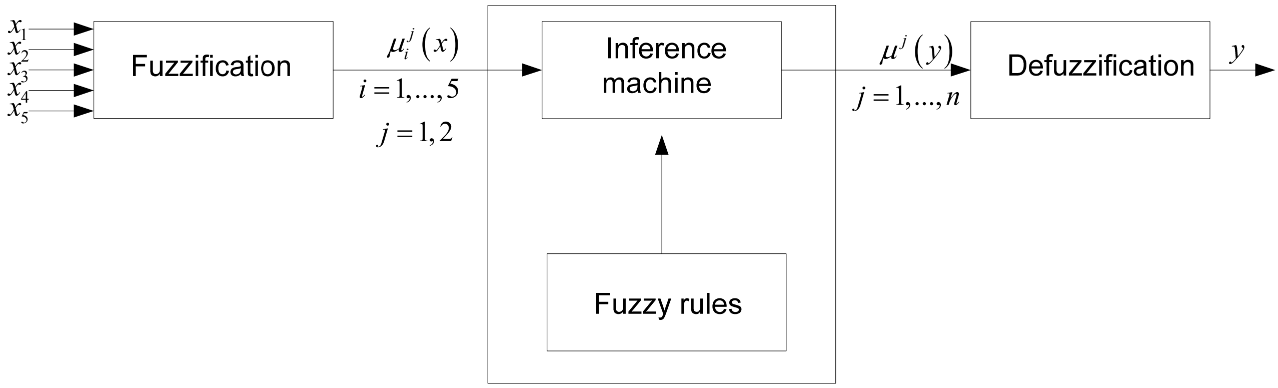

Figure 1. Structure of expert system for selection of the optimal water zones distribution

Based on numerical values of input variables x_i, $i=1,2,...,5$, fuzzification process calculates the values of membership function $\mu_i^j(x_i), i=1,2,...,5,\ j=1,2$ (where index *i* denotes the variable and index *j* the attribute addressed to that variable). These membership functions values represent the inputs for the inference decision machine. Based on the set of fuzzy rules, inference decision machine generates the values of membership functions adjoining the output variable called the *grade* of hydropower solution.

The suggested expert system has the possibility of interacting with the user. The basic knowledge built into this expert system, relating to the evaluation of the hydro energy facilities, is not only included into the interferent machine and fuzzy rules basis, but into the very structure of phasificators and dephasificators, selection of input and output variables and selection of corresponding belonging functions.

Five input variables x_i, i=1,...,5 are impact factors of solutions within suggested expert system. The idea was to involve three techno-economic parameters: facility pick production expressed in *GWh/year* with standardized value identified as (x_1), quotient B/C expressed as non-dimensioned quantity and identified with standardized value x_2, standardized investment quotient *$/kWh* identified as x_3.

The fourth input variable $x4$ is representing the environmental impact of selected technical solution and this variable is calculated based on objective rates, i.e. synthetic quantificator – median of the Delphi method [16]. The last, fifth variable $x5$ is nominated as the historical-political factor with the basic idea to indicate and include issues appearing when the hydro energy facilities are constructed within areas stretching over different national entities.

The input quantities are the result of conceptual designs made with 6 various technical solutions of hydro energy facilities [15]. In order not to favorize any of the mentioned variables, each of them is normalized within the range [0,1] according to the maximum and minimum values of single considered technical solution parameters. The table No.2 is created to define explicitely the normalisation process results.

Linguistic variables with corresponding affiliation functions are associated with each input variable. It was decided to define two linguistic variables for each input variable (changeable) xi, i=1,...,5, where the affiliation function parameters are selected in such way to really reflect the expert expression estimation of the observed characteristics.

Tabel No. 2: Normalisation factor values of different input variables

Input value	Maximum value	Minimum value	Normalized variable
V=Facility pick production (GkWh/year)	41.3	308.3	$x_1 = \frac{V-41.3}{308.3-41.3}$
B/C quotient	0.74	1.73	$x_2 = \frac{B/C-0.74}{1.73-0.74}$
IK=Investment quotient ($/кWx)	0.47	1.084	$x_3 = \frac{IK-0.47}{1.084-0.47}$
UE – Environmental impact (objective rate)	1	5	$x_4 = \frac{UE-1}{5-1}$
PI – Political-historical factor (objective rate)	1	5	$x_5 = \frac{PI-1}{5-1}$

The selected input variables are representatives, which have the strongest impact on the optimum construction concept selection and are the most important factors for the decision maker. It is clear that, if merely the technical-economic indicators would be analyzed, then the optimum solution would be represented only by one, highest dam and dam side HPP with maximum cadence.

However, as the indicators on environmental quality are involved in the input variables, as well as the historical-political factors, the arguments are extended and the concept composed of a series of low cascade dams and small accumulations has become a topical. The solution of the expert system will show us the optimum number of construction facilities and allowed flooding levels.

The expert system solution is searched in any case within the range of one hydro power plant and a high arch dam with belonging accumulation and four spillway dams within the river bed with smaller accumulations and thereby lower floodings and smaller energy-economic effects. The technical solution with one large hydro energy facility would have high financial and economic results.

At the same time, there are maximum environmental and social disturbances. For that reason, five input variables are selected, within which the technical, energy, economic, social and environmental performances have been considered equally and with the same weight factor.

Two lingusitic variables are defined for the pick production input variable: medium and high pick production. Affiliation function, for the linguistic variable, the medium pick production is as follows:

$$\mu_1^1(x) = \exp\left(-0.5\frac{x^2}{0.4^2}\right) \quad (1)$$

whereby the affiliation function is associated with the linguistic variable „high pick production“:

$$\mu_1^2(x) = \exp\left(-0.5\frac{(x-1)^2}{0.4^2}\right) \quad (2)$$

These two affiliation functions, representing the facility pick production, are given in figure 2.

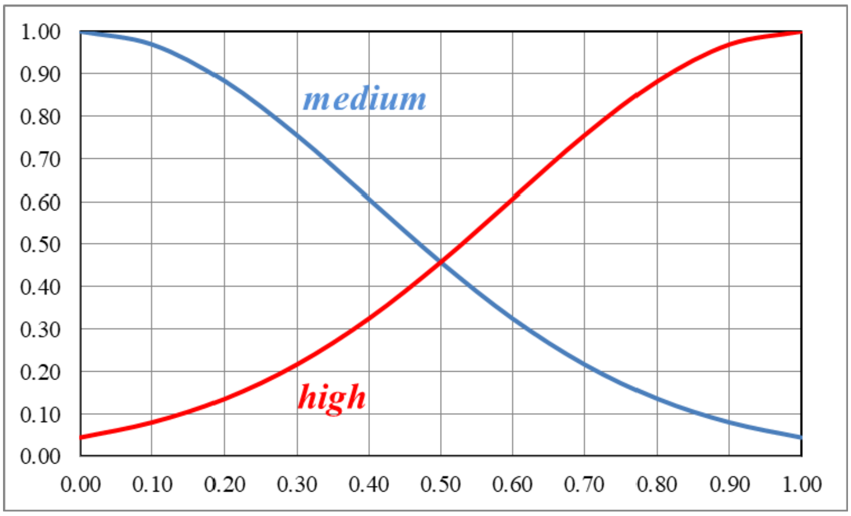

Figure 2. The belonging functions associated with linguistic variables of medium and high pick production of hydropower plants

The input variable *B/C* is defined by two linguistic variables: profitable and non-profitable facility. The belonging function of the profitable relation *B/C* is as follows:

$$\mu_2^1(x) = 1 - e^{-x/0.26} \quad (3)$$

while the belonging function of the non-profitable relation *B/C* is as follows:

$$\mu_2^2(x) = \frac{1}{1+\left|\frac{x+0.23}{0.43}\right|^{8.2}} \quad (4)$$

The formation of these belonging functions is shown in figure 3.

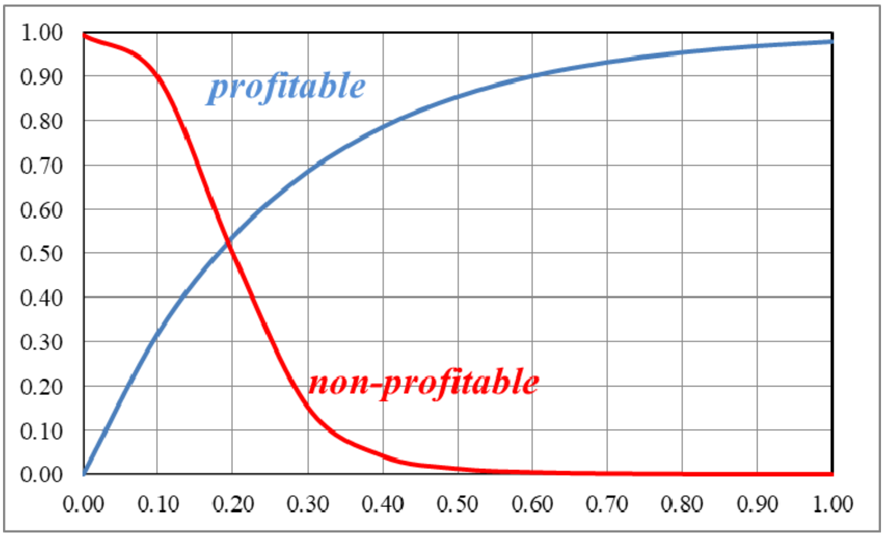

Figure 3. The belonging functions associated with linguistic variables of profitable and non-profitable technical solution, according to the relationship B/C

The third input variable is the relation USD/kWh. Two variables are associated with it: low cost and expensive technical solutions with corresponding functions $\mu_3^1(x)$ и $\mu_3^2(x)$ respectively, with:

$$\mu_3^1(x) = -0.34x^3 - 0.38x^2 - 0.28x + 1 \quad (5)$$

$$\mu_3^2(x) = e^{-0.5\left(\frac{x-1}{0.25}\right)^2} \quad (6)$$

The formation of these belonging functions is shown in figure 4.

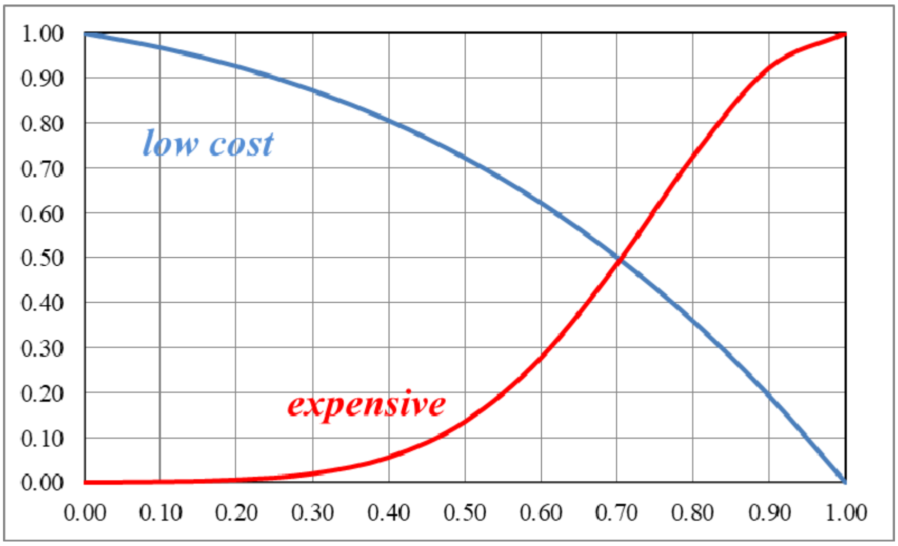

Figure 4. The belonging functions associated with linguistic variables: low cost and expensive technical solutions according to the investment quotient criterion USD/kWh

The fourth input variable within the formed expert system is changeable, marked as the environmental impact. Similar to the previous input variables, it is characterized by two belonging functions with following analytical values:

$$\mu_4^1(x) = e^{-0.5\left(\frac{x}{0.4}\right)^2} \tag{7}$$

$$\mu_4^2(x) = e^{-0.5\left(\frac{x-1}{0.4}\right)^2} \tag{8}$$

The formation of these functions, marked as bed or acceptable, is shown in figure 5.

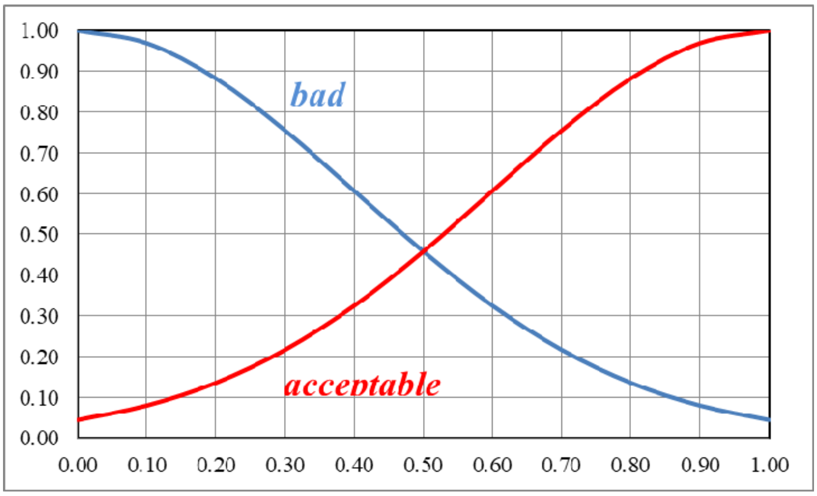

Figure 5. The belonging functions of the fifth input variable: environmental impact

The last input variable is representing the historical-political factor related to locality and taking up space of the considered technical solutions. Regarding the delicacy of the interethnic relations within the considered locality, the historical-political factor is of significant importance and its impact on the selection and realisation of the design in some cases can be eliminating.

Regarding this variable, it has been decided to define two belonging functions marked as unacceptable and acceptable solution while the belonging function formation has been selected within the domain of the Gaus' functions [17], with corresponding parameters:

$$\mu_5^1(x) = e^{-0.5\left(\frac{x}{0.4}\right)^2} \tag{9}$$

$$\mu_5^2(x) = e^{-0.5\left(\frac{x-1}{0.4}\right)^2} \tag{10}$$

The formation of these belonging functions is shown in figure 6.

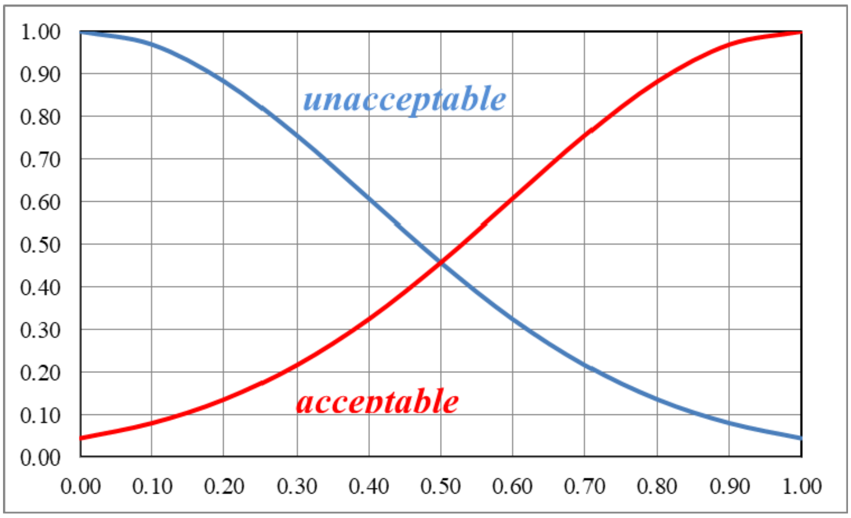

Figure 6. Belonging function associated with the fourth input variables: historical and political factors

The variable marked as *solvency* of the technical solution is representing the exit from the fuzzy expert system. This is again the fuzzy variable characterized by 10 belonging functions type *singleton.*

The positions of these *singletons* are determined according to the given delicacy of the whole determination system, but at the same time with the fuzzy rules structure. The position of the *singletons* within the exiting changable *solvency* is shown in figure 7.

The *singletons* are marked with ca s_i, i=1,...,10, where the positions of these singletons are {0.05, 0.07, 0.1, 0.15, 0.3, 0.6, 0.7, 0.75, 0.9, 0.95}. In this case, the dephasification was made by the centroid method [17].

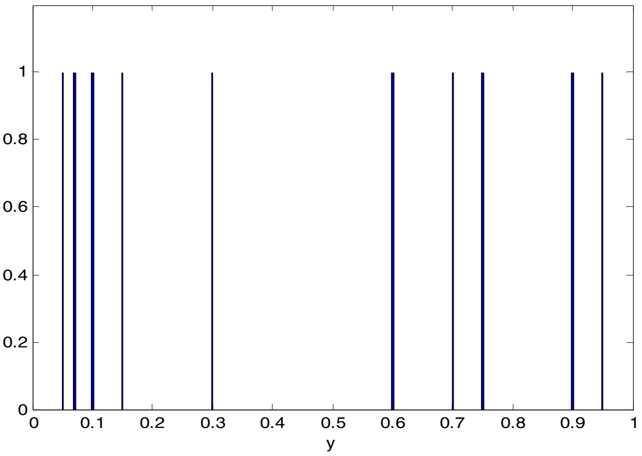

Figure 7. The belonging function of the output variables: solvency of technical solutions

5. FUZZY RULES AND THE TUNING OF THE EXPERT SYSTEM

The fuzzy rules are defined and shown in table No.3. It is proved that the optimum number of fuzzy rules is 10 for the specific expert system, having in mind that there are 5 different input variables. All rules are associated with the same weights, except the variable representing pick production, as it is not necessarily supposed that a hydro energy facility is simultaneously producing a large quantity of pick energy.

At this specific case, ten fuzzy rules are sufficient to reflect the real-world practice function within the expert system.

Tabel No.3: Table of fuzzy rules and their weight coefficients

Rule number	Fuzzy rule content	Weight coefficient
1	If (pick production is medium) then (solvency is s5)	0.8
2	If (pick production is high) then (solvency is s7)	0.8
3	If (B/C is not profitable) then (solvency is s1)	1.0
4	If (hist.-polit.factor is bad) then (solvency is s4)	1.0
5	If (hist.-polit.factor is good) then (solvency is s8)	1.0
6	If (environmental impact is bad) then (solvency is s2)	1.0
7	If (environmental impact is good) then (solvency is s6)	1.0
8	If (B/C is profitable) then (solvency is s9)	1.0
9	If (USD/kWh is super) then (solvency is s10)	1.0
10	If (USD/kWh is expensive) then (solvency is s3)	1.0

The listed rules are applied with the corresponding weights that are taken into account when deffuzification process is formed. Defuzzification is performed using the method of centroid.

The training of the expert system means the tuning of the adopted parameters that define the membership functions of the input variables and position of the singletons adjoined to the output variable and definition of the fuzzy rules set. The training process must fulfill two different criteria. The main one is the expert system to behave according to the experts' experience. The other one is more formal and it requires the quantified grade to be continuous function of each of the input variables excluding the first-type breakpoints.

For the training process, the particular hydropower systems given by Table 1 as well as the following hydropower systems were used: HPP Kozluk, HPP Drina I, HPP Drina II and HPP Drina III. The values of input variables, scaled to the interval [0,1] and obtained values for the final grades of these hydropower systems are given in the Table 4.

The obtained final grades given by the table 2 emphasize the fact that hydropower system Gorazde 352 is thoroughly unacceptable since it is very unprofitable plant with very small backwater level and high construction costs. On the other hand, the Kozluk and Drina III plants have very low grades regarding their bad environmental impacts. The plants Drina I, Sadba 362, Ustikolika 373 and Paunci 384 are noticeable with high grades because of their good technical-economic characteristics and acceptable environmental influence.

Table 4. Input variables and final grades, scaled to the interval [0,1], for the tuning set of HPP systems

HPP	*Input variables*					*Final grades*
	x_1	x_2	x_3	x_4	x_5	y
Gorazde 383	0.77	0.433	0.61	0.227	0	0.638
Gorazde 375	0.73	0.436	0.62	0.352	0	0.659
Gorazde 362	0.93	0.243	0.56	0.642	1	0.717
Gorazde 352	0	1	0.56	0.952	1	0.394
Sadba 362	0.64	0.38	0.56	0.885	1	0.726
Ustikolina 373	0.7	0.326	0.56	0.812	1	0.725
Paunci 384	0.65	0.353	0.56	0.815	1	0.724
Kozluk	0.93	0.624	0.539	0.15	0	0.584
Drina I	0.79	0.35	0.539	0.99	0	0.726
Drina II	0.6	0.428	0.539	0.97	0	0.714
Drina III	0.56	0.561	0.539	0.06	0	0.588

6. OPTIMUM CONCEPTUAL HOLISTIC SOLUTION OF THE EXPERT SYSTEM AT THE WATER ZONES BETWEEN FOCA AND GORAZDE

In defining the rules, which are representing the functional relation between single input variables and solvencies, total solvencies are obtained for technical solutions from the set for training the expert system, as a result of the fuzzy expert system in selecting the optimum concept for constructing hydro energy facilities, as shown in figure 7.

Total solvencies shown in table no. 5 are calculated for alternatives A, B, C, D, E and F, which are representing sets of possible water zoned distribution between the entities and possible technical solutions of hydro energy facilities at the Drina river, which satisfy all requested criteria, between the cities of Foca and Gorazde. Those criteria are the results of the analyses made by the attorney, environment, cultural, political, social, economy and engineering experts.

After comparing the calculated solvencies, the conclusion was made that logic and authentic results are gained and the most acceptable optimum solution in constructing hydro energy facilities at the Drina river is the alternative F, i.e. a system consisting of three uniform hydro power plants: HPP Sadba with normal accumulation retention level 362 m.a.s.l., HPP Ustikolina with normal accumulation retention level 373 m.a.s.l. and HPP Paunci with normal retention level 384 m.a.s.l. They have the highest solvency amounting 0,724.

Tabel No. 5. Total solvencies of alternative solutions of Drina hydro potential exploitation

Possible alternatives	Total solvency
Alternative A	0,532
Alternative B	0,514
Alternative C	0,707
Alternative D	0,533
Alternative E	0,714
Alternative F	0,724

This construction concept within the area between Foca and Gorazde, with three approximately same facilities has 30% lower costs related to hydro-mechanical, machine and electricity equipment, because of the same type of equipment and common spare parts.

The facilities are consisting of low concrete dams with spillways being at the same time bottom outlets. Such solutions have a minimum environmental impact and they are perfectly fitting into the environment as single complexes within the territory divided between different entities. HPP Paunci is belonging to one entity and HPP Sadba and HPP Ustikolina to another.

The construction concept of the hydro energy facility within the Drina river section between cities Foca and Gorazde with a second rated solvency is representing the alternative E with solvency 0,714. This solution is consisting of following hydro energy facilities: HPP Gorazde with normal accumulation retention level 362 m.a.s.l., HPP Ustikolina with retention level 373 m.a.s.l. and HPP Paunci with retention level 384 m.a.s.l.

The third concept, i.e. alternative solution of the occupying space issue and construction of hydro energy facilities at the Drina river within the considered section Foca-Gorazde is representing the alternative C with solvency 0,707 consisting of following construction of hydro energy facilities: HPP Gorazde with retention level 352 m.a.s.l., HPP Sadba with retention level 362 m.a.s.l., HPP Ustikolina with retention level 373 m.a.s.l. and HPP Paunci with retention level 384 m.a.s.l.

7. CONCLUSIONS AND RECOMMENDATIONS

The determination of the optimum water zones utilization concept of the Drina river within the section between Foca and Gorazde with an extremly expressed conflict of all existing interests is representing a real case example from the practice, ideal for balancing the artificial intelligence model and suggested methodology.

The logic of calculated results and reality conclusions related to the selection of the optimum construction concept of hydro energy facilities at the Drina river between Foca and Gorazde is showing the following:

− the expert system based on the example of 11 (eleven) different hydro energy facilities with different technical-economic, historical-political and environmental parameters was correctly „exercised",

− the selection of 5 (five) relevant input variables has been representative and valid enough for the determination of an optimum alternative,

− the defined 10 (ten) interactive rules have reflected the real functional dependence of input variables and solvencies,

− weight coefficients have reflected precisely the importance and impact on solvency of input variables of the belonging functions.

The conclusion is, that the expert knowledge was reliably transferred to the computer. The computer is now trained to select the optimum utilization concept of renewable hydro resources, i.e.construction of hydro energy facilities at other water courses and related to similar complex problems.

A defined goal is realized. The conclusion is, that by using this artificial intelligence methodology, maximum possible technical-economic effects are obtained from one hand, and from the other hand the adopted technical solution is using the optimum of all resources, it is proportionally fitted in and it is not disturbing the low, the environment, the territory of entities, natural, cultural and social-political environment. Also, if it would have been constructed, together with upstream dam Buk Bijela, Republic of Srpska, Serbia and Bosnia would not have been flooding and landsliding during 2014[19]. The methodology mentioned in this report is recommended for further analysis and application, in order to facilitate and fastened the decision makers actions with the goal of preparing necessary documentations and investing in this constructions.

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САВРЕМЕНЕ МЕТОДЕ ВЕШТАЧКЕ ИНТЕЛИГЕНЦИЈЕ
У ФУНКЦИЈИ УПРАВЉАЊА ВОДНИМ РЕСУРСИМА

Сажетак: Предмет истраживања у овом реферату су модели вештачке интелигенције кроз савремени методолошки приступ решењу комплексних водопривредних проблема. Фази логика као нова математика, неуронске мреже и експертски системи отварају велике могућности у симулирању и решавању реалних проблема у вези са поделом зона воде и водних ресурса. Када доносиоци одлуке траже оптимум, поред техничких и економских критеријума, некада пресудан утицај имају правни, еколошки, политички, територијални, социјални, верски или културолошки критеријуми. Развијени теоријски модел је тестиран и потврђен израдом експертског система за избор оптималног решења за управљање и поделу водног потенцијала реке Дрине, у зони различитих ентитета, између градова Фоча и Горажде. Холистички приступ и синергијско уважавање свих релевантних критеријума, резултовао је тиме да је фази експертским моделом пронађено решење заживело и у пракси, што је потврда за развијени експертски систем.

Кључне ријечи: вештачка интелигенција, методе, фази логика, експертски систем, водопривреда, водни ресурс.