CREATION OF HYBRID INTELLIGENT SYSTEM FOR NONLINEAR RELATIONS IDENTIFICATION

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Abstract

There is usually no opportunity to form simple sufficient symbolic-form models for complex processes defined as indeterminacy (inaccuracy, unstochasticity, incompleteness, fuzziness) in the background information and situations of external and internal environment. Information on parameters of such processes is expressed by experts in words and statements, i.e. in linguistic form. In these cases, it is advisable to apply such systems as modelling, decision-making and regulation that use technological tools of soft computing (Soft Computing). In view of this, the methods of nonlinear relation identification based on hybrid intelligent system formation are examined in the current article.

***Keywords**: linguistic form, intelligent system, hybrid intellectual system, fuzzy logic.*

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1. INTRODUCTION

At present the main components of Soft Computing are Fuzzy logic (FL), the theory of Neural networks (NN), Probabilistic reasoning (PR) that include Genetic algorithms (GA) and Chaos theory (CT). FL as part of Soft Computing deals mainly with inaccuracy and approximate reasoning, NN – with learning and PR – with indeterminacy. Essentially, FL, NN, and PR complement each other than use alternative approaches [5,6].

Soft Computing components may be applied independently, for example, as in fuzzy computing, neural computing, evolutionary computing etc., and in combination very often [1-5,9]. Nowadays relying on self-dependent application Soft Computing constituents as fuzzy technology, neural network technology, chaos technology etc. are used extensively as new technologies and in the industrial and other spheres.

The leading constituent of Soft Computing is fuzzy logic. Fuzzy logic (FL) plays a peculiar role in Soft Computing. FL secures verbal expressiveness and computing interpretability [5]. The fuzzy logic has been actively applied to many industrial fields: robotics, inverted pendulum system, complicated systems of decision-making and diagnostics, data compression, TV and other fields.

We are in need of a fuzzy model system for designing of system processor for knowledge management presented in a linguistic form or in a form of fuzzy digital data. The fuzzy sets can be used as cross-functional approximators which are of critical importance for the modelling of the unknown objects. Furthermore, if operator cannot say what type of operation he/she is creating in that particular situation it is helpful to design its control activity using digital data.

However, the fuzzy logic in so called pure form is not always applicable for intelligent systems designing. In particular, when programmer does not have sufficient apriori information (knowledge) on system, it is impossible to form an appropriate fuzzy rule base. When there is an increase of system complexity, a similar difficulty arises in connection with determination of well-formed rule set and membership function for appropriate description of system behaviour. Moreover, the fuzzy systems suffer from the extraction drawbacks of extra data by the results of experiment and correction of fuzzy rules for the quality improvement of system operation.

The other significant Soft Computing element is neural network. Artificial neural networks are simultaneous computing models representing parallel fine-grained implementation of nonlinear statistical and dynamic systems. The most important feature of these networks is their adaptive nature where "learning from examples" replaces traditional "programming". Another crucial feature is a built-in parallelism that allows implementing of fast working decision circuits on the basis of parallel digital computers. The artificial neural networks are the essential computing models for the solution of wide range of problems such as recognition, curve fitting and functional relations, data compression, associative memory, modelling and control of nonlinear unknown systems [6,7].

The neural networks have the advantage of numerical efficiency and their effective hardware implementation. They have the ability to summarize – the capability to new correct pattern classification. The disadvantage of neural networks is a poor interpretability. Noting the deficiencies of neural networks, they are compared with the "black box" [5].

Evolutionary computing (EC) is a revolutionary approach to optimization. A compound part of EC - genetic algorithms are the algorithms of global optimization based on mechanisms of natural selection and genetics [8]. One of the great preferences of genetic algorithms is the ability of their effective realization in terms of parallel multivariable search.

The mechanism of genetic algorithm implementation is very simple. The simplicity of operations and powerful computing effect are the two primary virtues of genetic algorithms.

2. HYBRID INTELLIGENT SYSTEM

As it has been mentioned above Soft Computing components such as fuzzy logic, neural processing and probabilistic reasoning complement each other rather than compete. It is becoming increasingly clear that it is advisable to apply FL, NN, PR with GA in combination but not independently. As it was noted by L.Zadeh, "today term Hybrid Intelligent System becomes usual with regard to systems where FL, NN and PR are used in combinations. From our point of view Hybrid intelligent systems are the fast developing systems of the future" [5].

We understand that poor interpretative capability of neural networks, on the one hand and difficulty of knowledge acquisition in fuzzy systems, on the other hand are the reasons of FL&NC hybridization. The neural and fuzzy systems are hybrid systems which try to solve this problem using combination of teaching abilities of connectionist models with the properties of fuzzy system interpretability.

As indicated above automatic correction of knowledge base in fuzzy systems becomes vitally important in case of dynamic working environment. On the other part, artificial neural networks are successfully used in the problems associated with knowledge extraction for managing and optimization processes with desired degree of accuracy based on concept formation. The usage of neural training concept for optimization of curve shapes of membership functions in fuzzy rules as well as minimization of the number of used rules for required accuracy achievement is the main point of neural and fuzzy approach.

The combination of the fuzzy rule-based systems which design empiric intuitive strategy used by a man in the decision-making enabling genetic algorithms to implement the global optimum seeking of a wide range of functions (yield surface) and gives an opportunity to form an effective, robust adaptive control system.

The membership functions in the fuzzy rules of the fuzzy system knowledge base are often presented in the form of fuzzy numbers like LR-type, for instance, as trapeziums, triangles and so on. The usage of gradient methods for correction of fuzzy knowledge bases, i.e. for detection of centre meanings and types of the membership functions have proved unsuccessful. The efficient mean in this case is GA.

The combination FL and GA permits optimizing fuzzy knowledge base of fuzzy controller using the optimal quantification of the rules in database and optimal knowledge centres and types of the membership functions. At the same time, the GA is applied for designing of relational matrix and membership function of the fuzzy system under design.

In turn, the FL and GA theory of fuzzy sets in fusion can be used for the improvement of operator's genetic behaviour and genetic algorithms on the whole. In other words, it is possible to create fuzzy tools for the perfection of effectiveness GA, i.e. the development of fuzzy genetic algorithms.

The fusion of the genetic algorithm with neural network gains the effective results as well. It is known that one of the main tasks of artificial neural system design is a choice of the appropriate learning method for parameter setting of the neural network (weight functions, rapids etc.). The most popular method is the «backpropagation» algorithm. Unfortunately, there are some difficulties with backpropagation. The first thing is that the effectiveness of training radically depends on the initial weight setup of the neural network which is identified in a random manner. The second thing is that backpropagation as well as any of the gradient methods do not allow avoiding of local minimums. Thirdly, if the training rate is too low this requires a lot of time to find a solution. Fourthly, the backpropagation requires activation functions to be differentiable. Many types of the neural networks do not fulfil this condition. The genetic algorithms are used for optimization of many tasks when "powerful" methods cannot find a good solution and they are applied for neural networks training being free from the previously mentioned deficiencies.

3. COMPUTING EXPERIMENT

The objective of the experiment was in the examination of capability to identify nonlinear relations with the help of neural and fuzzy network in comparison of this new approach with traditional methods of neural identification [8-14]. The experimental technique consisted of the following: The nonlinear object has been set as a sample in the form of analytic dependence. Observing the dependency diagram the expert formed fuzzy knowledge base on which the appropriate neural network has been under construction. The training has been carried out with the help of input-output pair that has been generated from the sample equally covering the whole range of input variable modification and lasted until the dependency diagram supported by neural and fuzzy network has become sufficiently close to the reference model. The reference model of the second order has been used in the experiment:

$$Y = \bar{Y}\,(1 - 0.01\rho_1(1 - x1_i)(1 - 0.3x2_i - 0{,}7x3_i) + 0.01\rho_2(1 - x3_i) +$$
$$+ 0.01\rho_4(1 - x2_i)(1 - 0.4x3_i - 0.2\tilde{o}1_i) + 0.01\rho_3(1 - \tilde{o}4_i)),$$

where

Y - cotton yield;

$\bar{Y}$ -potentially possible yield;

x_1 -weather conditions at the seeding time;

x_2 -water supply;

x_3 -weather conditions at the vegetation;

x_4 -weather conditions at harvesting.

Here the effect of impact factor on reduction in yields is caused by weather conditions at sowing at ρ_1%, at vegetation - ρ_2%, at harvesting- ρ_3% and at water insecurity - ρ_4 %.

Based on this, it is easy to describe the knowledge base behaviour:

IF X1=L AND X2=L AND X3=L AND X4=L WEIGHING 0.5

OR X1=M AND X2=L AND X3=L AND X4=L WEIGHING 0.5

THEN У=L

IF X1=L AND X2=L AND X3=L AND X4=M WEIGHING 0.09
OR X1=L AND X2=L AND X3=L AND X4=H WEIGHING 0.09
OR X1=L AND X2=L AND X3=M AND X4=L WEIGHING 0.09
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OR X1=H AND X2=L AND X3=M AND X4=L WEIGHING 0.09
OR X1=H AND X2=M AND X3=L AND X4=L WEIGHING 0.09
THEN У=LM

The membership functions of fuzzy terms used in this knowledge base were carefully selected (fig.1). The neural and fuzzy network selected by these membership functions provides with rough approximation of the object graphically represented in the fig.2.

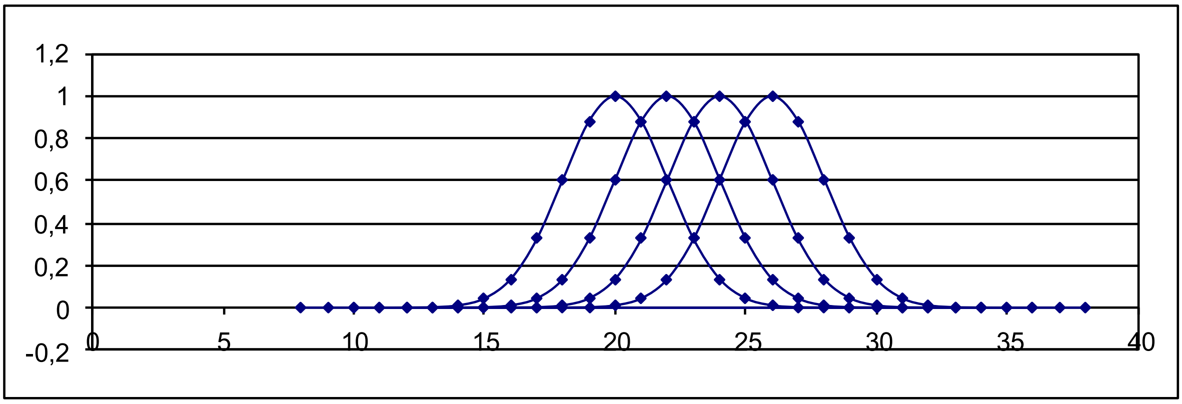

Fig 1: The membership function of the output terms before training

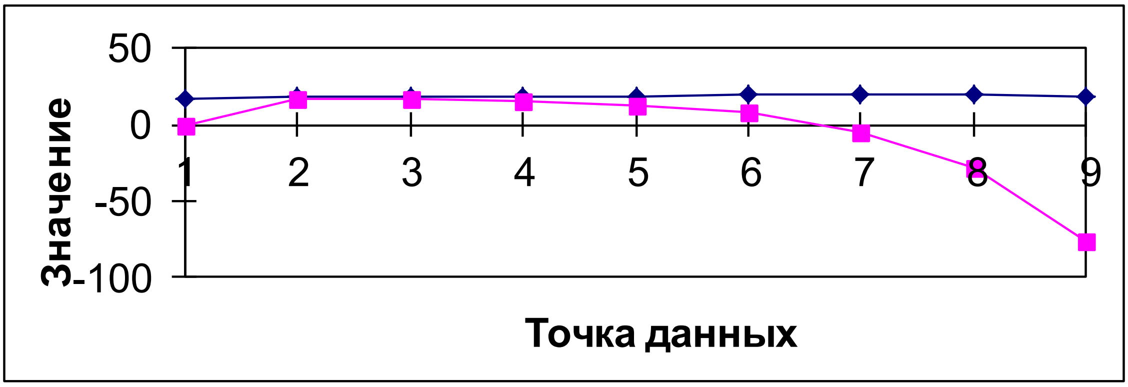

Fig 2: The model of the investigated object before training

As the result, the network training has been gained the model object which is presented in the fig. 3.

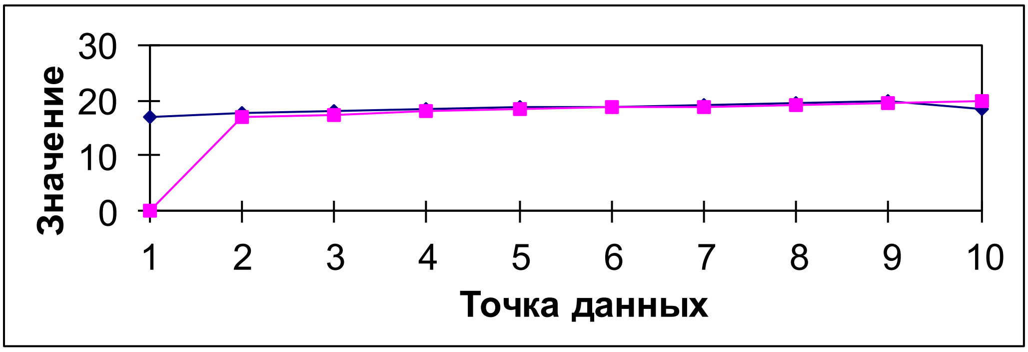

Fig 3: The model of the studied object after training

The membership function of the fuzzy terms after training are specified in the fig. 4.

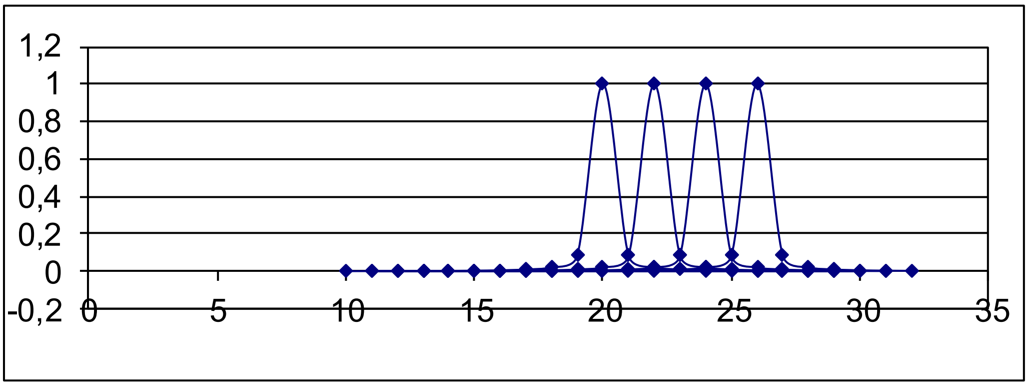

Fig 4: The membership function of the input terms after training

From the figures 1, 4 and table 1 it can be seen that the parameters of the ***c*** membership functions had been radically modified due to the training of the neural and fuzzy network $\mu(x_i) = \frac{1}{1+\left(\frac{x_i - b}{c_i}\right)^2}, i=\overline{1,n}$, when the other parameters stayed almost unchanged. It is explained that when forming the fuzzy knowledge base the expert sufficiently pointed out the position of the membership function maximums (***b*** *parameters*). The expert's choice of large values in the *c* parameters implies the considerable indeterminacy in the assessment of fuzzy terms. The values reduction of the *c* parameters during training has led to "concentration" (compression) of the membership function that shows the indeterminacy removal in the assessment of the fuzzy terms.

Thus, the method of linguistic knowledge representation about the identification object has been examined in the form of special neural and fuzzy network for which the recurrence relations of training have been gained. By means of the computer experiment it is proved that the application of the proposed neural network considerably decreases the training expenditures at nonlinear object identification. The training of the proposed neural and fuzzy network makes it possible to pass on to the new approach of experimental information processing: getting of the fuzzy rule base. The fundamental advantage of such method is the interpretation convenience of the gained results and the teach-and-learn capability of the fuzzy knowledge base in real time.

Table 1: A calculation fragment of neural and fuzzy approximation

Y	$\frac{\partial\mu}{\partial c}$	$\frac{\partial\mu}{\partial b}$	$\frac{\partial E}{\partial c}$	$\frac{\partial E}{\partial b}$	c	b
Before training						
16.75					2	0.33
17.09					2	0.31
17.43					2	0.30
17.76					2	0.28

18.09					2	0.27
18.43					2	0.26
18.76					2	0.24
19.09					2	0.23
19.42					2	0.22
19.75					2	0.20
After training						
16.95	0.23	1.21	-8.21	-41.87	0.30	0.31
17.32	0.13	0.94	-4.7	-32.48	0.30	0.29
17.72	0.05	0.61	-1.98	-10.29	0.30	0.27
18.09	0.23	0.29	3.28	4.11	0.29	0.26
18.43	0	0	0	0	0.30	0.24
18.78	0.01	-0.29	0.18	-4.11	0.29	0.23
19.02	0.04	-0.51	0.69	-8.87	0.29	0.22
19.38	0.10	-0.82	1.80	-5.11	0.29	0.21
19.71	0.18	-1.08	3.18	-5.11	0.29	0.19
20.04	0.28	-1.31	4.85	-5.11	0.29	0.25

The gained working data can be used in forecasting, diagnostics, situation control, multidimensional analysis, automatic classification and other tasks of the expert information processing.

4. CONCLUSION

One of the main objectives of the present research has been an attempt of models development and realization of the faintly formalizable processes at the initial fuzzy information expressed in the form of logical linguistic statements. The following results have been received from the study:

1. The hybrid intellectual models have been developed for the designing of fuzzy models. The problems of optimization, management and decision-making have been examined from the perspective of the system approach that allows constructing of more adequate models of faintly formalizable processes.
2. The program system have been created to realize the proposed soft models and algorithms in relation to the specific practical objectives of optimization and decision-making.

The methods applicability of the fuzzy mathematics have been investigated in the cotton planting sphere. The best conditions of their use have been defined and proved in this study. The method promoting the solution to application-oriented tasks of the cotton planting has been formed on the basis of the fuzzy sets theory.

3. The knowledge base has been developed and the systems of the fuzzy logical deduction have been constructed that are similar to Sugeno and Mamdani. The way of the linguistic knowledge representation of the object identification has been developed in the form of special neural and fuzzy network. By means of the computer experiment, it is proved that the application of the proposed neural network considerably decreases the training expenditures at nonlinear object identification. The number of training iterations for the neural network is 9000, and time - 8 min.; the number of iterations for neural and fuzzy network is 1200, and time - 1,5 min.

REFERENCES

[1] Yager R.R., Zadeh L.A. (Eds.), Fuzzy sets, neural networks and Soft Computing, VAN Nostrand Reinhold, New York, 1994, 440p. (in English)

[2] Aliev R.A., Barak D, Chew G.at all, SOFT COMPUTING: Fuzzy Logic. Neural Networks and Distributed Artificial Intelligence. F.Amin zadeh. Jamshidi M. (Eds.), PTR Prentice Hall Englewood Cliffs, New Jer sey, 1994, 301p. (in English)

[3] Zurada Y.M., Marks R.J. Robinson C.Y. (Eds), Computational Imitating Life Piscataway. NJ:IEEE press, 1994, 448p. (in English)

[4] Pearson D.W., Steel N.C., Albrecht R.F.. (Eds.), Artificial Neural Nets and Genetic Algorithms: Proc. of the Inter Conference In Ales, France 1995.552p. (in English)

[5] Proceeding of the Second European Congress on Intelligent Techniques and Soft Computing, Aachen, 1994, 1750p. (in English)

[6] Aliev R.R. Soft Computing and MIQ enhancement, Scientists note AGNA № 1, 1997. (in Russian)

[7] Aliev R.A. Kenarangui. R. (Eds.). Applications of Fuzzy Systems University press of Tabriz, Tabriz, 1994, 420p. (in English)

[8] Wealstead S.T. Neural Networks and Fuzzy Logic Applications in C/C++, John Wiley Professional Computing, New York, 1994, 494p. (in English)

[9] Mukhamedieva D.T. Intellectual analysis of fuzzy solutions to ill-posed problems Publishing house «Palmarium Academic Publishing». AV Akademikerverlag GmbH&Co.KG Heinrich-Böcking-Str. 6-8, 66121 Saarbrucken, Germany. 2017. 327 p. (in Russian)

[10] Muhamediyeva D.T., Abduraimov D., Niyozmatova N.A. Metods of image preprocessing of text characters // BEST: International Journal of Management, Information Technology and Engineering (BEST : IJMITE); ISSN (Print): 2348-0513; ISSN (Online): 2454-471X; Impact Factor (JCC): 1.5429; (in English)

[11] Mukhamedieva D.T. Hybrid decision models for intelligent data analysis. // Publishing house "MUXR-PRESS". -Tashkent. 2016. 250 p. (in Russian)
[12] Mukhamedieva D.K. System of quasilinear equations of reaction-diffusion tasks of kolmogorov-fisher type biological population task in two-dimensional case// IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308 Impact Factor(JCC): 1.0174. Bangalore, India. 2014. Volume: 03 Issue: 07 | Jul-2014, 327-334 p. (in English)
[13] Mukhamedieva D.T. Development of fuzzy models of decision-making tasks. Publishing house «Palmarium Academic Publishing». AV Akademikerverlag GmbH&Co.KG Heinrich-Böcking-Str. 6-8, 66121 Saarbrucken, Germany. 2014. 190p. (in Russian)
[14] Mukhamediyeva D. T., Niyozmatova N. A. Application of Immune Algorithm for Constructing a Model of Fuzzy Inference // American Journal of Mathematical and Computational Sciences 2016; 1(2): 74-78. (in English) http://www.aascit.org/journal/ajmcs