Parameters and Structure of Neural Network Databases for Assessment of Learning Outcomes

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Abstract: The purpose of this study is to determine the methodology, develop a theory of construction, put into practice algorithmization and implement the functionality of a hybrid intelligent system for assessment of educational outcomes of trainees on the basis of the identified keyword parameters and structure of the artificial neural network using expert systems and fuzzy simulation; to develop a methodology for the construction of structural-logic, hierarchical, functional and fractal schemes for structuring databases of the didactic field of learning elements; to determine the content, structure of parameters and database components, selection criteria and the content of complexes of educational standards. The methodology of introducing intelligent systems into mathematical education is on the basis of the Hegelian triad: thesis (implementation of the coherence principle) – antithesis (implementation of principles of the fractality and historiogenesis) – synthesis (implementation of the principles of self-organization and reflection of the complex system inversion integrity). Requirements for the organization and construction of the artificial neural network for assessment of personal achievements on the basis of fuzzy simulation have been developed. In the direction of using elements of fractal geometry, the technological structures of clusters that constitute the basis of generalized structures have been developed. In particular, it is revealed that the didactic field of learning elements is equipped with a system of multi-level hierarchical databases of exercises, motivational-applied, research, practice-oriented tasks using expert systems and integration of mathematical, information, natural-science and humanities knowledge and procedures.

Keywords: Classification of learning outcomes, neural network, evaluation.

INTRODUCTION

The use of hybrid neural networks based on the implementation of fuzzy sets and fuzzy logic described in the monograph (Zadeh, 2012), expert systems with fuzzy logic, step-by-step data analysis with elements of stochastic methods, structural-logical, hierarchical, functional, and fractal schemes as well as models of data structuring of the didactic field of learning elements is an efficient tool for solving complex, multi-component, multifunctional problems. Such tasks should include the design of knowledge and competence assessment systems, which are a key component of the implementation of learning intelligent systems based on extensive use of computer and mathematical modeling, according to paper (Romero and Ventura, 2010). At the same time, according to the classification of Ostroukh and Surkova (2020), as demonstrated in their monograph, the system that is developed by the authors should be soft and hybrid, with an intellectual interface, with expressed features of expert, self-learning, and adaptive systems. The use of the new technology implies taking into account the specifics of the following set of the system synergistic features: the quality and operability of decision-making; the fuzziness of goals and institutional boundaries; the multiplicity of subjects involved in solving the problem; the randomness, fluctuating and discrete behavior of the environment; the multiplicity of mutually influencing factors; the weak formalizability, uniqueness, and irregularity of situations; the latency and implicitness of information; deviation of plan implementation and the importance of small actions; paradoxicality of decision logic, as is proven in works (Dvoryatkina, Melnikov, and Smirnov, 2017; Dvoryatkina, Smirnov, and Lopukhin, 2017; Dvoryatkina and Shcherbatykh, 2020).

The quality assessment system of trainees' knowledge on the basis of neural networks has been proposed by Zhuikov (2014). Development of methods and quality models of educational activity at school and university with the application of modern digital technologies was carried out by Kozlov and Kozlova (2012), Kozlov, Mikhailov, and Vershinina (2017), Makhnytkina (2011), Monakhov (2014), Rudinskiy and Davydova (2014), Robert (2016), Uglev (2010), Guner and Pyatkovsky (2012) studied issues related to the competence assessment of trainees. The issues of computer control in adaptive learning systems on the basis of fractal modeling, as well as methods of fuzzy logic were studied by Dvoryatkina, Smirnov et al. (2017), Dvoryatkina and Shcherbatykh (2020), Dvoryatkina and Smirnov, 2016; Dvoryatkina, Masina, and Shcherbatykh (2017).

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Methodologies for evaluating the quality of trainees' knowledge using the methods and tools of the Fuzzy Logic Toolbox of MatLab system in the form of Adaptive Neuro-Fuzzy Inference System (ANFIS) described in the paper (Tahmasebi, 2012) are proposed. At the same time, the hybrid ANFIS system is a combination of Sugeno's neuro-fuzzy output method with the ability to train a five-layer artificial neural network (ANN) of direct propagation with one output and several inputs, which represent fuzzy linguistic variables, according to works (Kamal, Mendis, and Wei, 2018; Karaboga and Kaya, 2018; Kasabov, 2019; Tahmasebi, 2012).

Neural networks, genetic algorithms, and fuzzy systems as applied to the assessment of knowledge and the development of learning systems were studied by Averkin and Yarushev (2020), Binh and Duy (2017), Brusilovsky, Somyürek, Guerra, Hosseini, Zadorozhny, and Durlach (2016), Fominykh, Eremeev, Alekseev, and Gulyakina (2020), Hadzhikolev, Yotov, Trankov, and Hadzhikoleva (2019), Crockett, Latham, and Whitton (2016), Chaira (2019), Kasabov (2019), Kolesnikov (2017), Kuchinskaya-Parova (2013), Kuchinskaya-Parovaya and Gulyakina (2013), Rutkovskaya, Pilinsky, and Rutkovsky (2013), Lavrov, Barchenok, Lavrova, and Savina (2019), Lisov and Bain (2012), Pokalitsina (2006), Gaaze-Rapoport and Pospelov (2011), Popov and Lazareva (2015), Dubois and Prade (2012), Petrushin (1993), Saxena, Shinghal, Misra, and Agarwal (2019), Tuktarova, Kamalova, and Daukaeva (2014), and others. The researchers have found that the accuracy and objectivity of assessment of learning outcomes depend on the dynamics and operational efficiency of use of diagnostic tools, the integrity of accounting and the nature of changes in parameters and indicators, the validity of quality criteria for the individual's mastering the content of the subject area of knowledge and the state of personal characteristics.

The conducted comparative analysis of the scientific literature related to this topic and all the above-mentioned have determined:

– *The research problem*: what are the methodological and technological bases for the development and functioning of the knowledge and competence assessment system using hybrid intellectual systems?

– *The author's goal of research*: to develop a theory of construction, carry out algorithmization, and to implement the functionality of a hybrid intelligent system for evaluating the learning outcomes of trainees on the basis of the identified keyword parameters and structure of the artificial neural network using expert systems and fuzzy simulation; then to develop a methodology for constructing structural and logical hierarchical functional and fractal schemes for structuring databases of the didactic field of learning elements, as well as to determine the content, structure of parameters and components of databases, selection criteria and the content of complexes of educational standards.

The novelty of the research is determined by:

– The feature of interactive communication (person – intelligent system – expert (teacher)) during the evaluation activity of quality conformance of recognizable learning elements to the a priori standard;

– The development of basic requirements for the organization and construction of the artificial neural network for assessment of personal achievements based on fuzzy modeling;

– The development and justification of the intelligent management methodology in assessment activity of schoolchildren learning outcomes on the basis of the characterization of stochastic, threshold, bifurcation, and fluctuation transitions of search and creative procedures of the cognitive activity content of a secondary school student and implementation of expert systems with fuzzy logic and hybrid neural networks;

– Peculiarities of the hybrid intelligence system for evaluating learning outcomes of trainees with dynamic random selection on the layers of an artificial neural network;

– The set of fuzzy rules, boundary conditions, and their characteristics for the use in expert systems with fuzzy simulation.

Construction of the evaluation process on the basis of the implementation of a hybrid intellectual environment of support will introduce clear elements of objectivity of evaluation activities both at school and university and create conditions for the modernization of educational programs in the developing digital environment.

MATERIALS AND METHODS

During the last decade, interest in the apparatus of artificial neural networks in the context of the quantitative and qualitative increase in its practical application in education has significantly increased (Hamoud and Humadi, 2019). The issues of personalization and automation of learning with the use of hardware and software tools, the work of which is based on neural network algorithms, have long been successfully solving (Brusilovsky *et al*., 2016; Crockett *et al*., 2016; Cetintas, Si, Xin, and Hord, 2009; Romero and Ventura, 2010; Tahmasebi, 2010; Truong, 2015). The researchers have been dealing with the issue of application of intelligent computer systems in education on the basis of neural network technologies. These are researches in the area of adaptive testing, application of computer neural network technologies as a means of individualized learning, intelligent management of educational process organization, and the smart support of educational process management and others. Intelligent computer learning systems are developed within individual universities for clearly defined disciplines and groups of students. More inclusive integration into educational activity, in particular, in conditions of the general education, was not carried out earlier.

In modern psychological and pedagogical research, education is considered as an intellectual process that makes it possible to design and implement individual educational routes depending on the level of subject training and individual psychological characteristics of trainees in a hybrid learning environment (Basalin, Kumagina, Neimark, Timofeev, Fomina, and Chernyshova, 2018; Alasmri, Onn, and Hin, 2019). New interdisciplinary research directions in the study of complex self-organizing systems are promising. The leading role in the analyzed aspect is played by a synergetic approach in education, which determines the design of individual educational environments, which are formed by learning elements of different levels based on the processes of self-organization of its subjects. The synergetic approach is based on the mechanisms of interdisciplinary interaction to develop new, more complex structures with a new level of quality.

Intelligent management in the mathematical education of trainees is the use of the functionality of intelligence systems (including hybrid artificial neural networks) in conditions of openness (to external impacts and factors) and synthesis of mathematical and computer modeling to reveal of essence and efficiency of evaluation procedures on the basis of individualization of learning in mathematics and actualization of personalized and computerized feedback of cognitive and evaluation processes. It is characterized by:

– Functioning of stochastic, threshold, bifurcation, and fluctuation transitions of search and creative procedures of the cognitive activity content of a secondary school student;

– Assessment of learning outcomes on the basis of the implementation of expert systems with fuzzy logic and hybrid neural networks;

– Multiple goal-setting of the functionality and content of computer modeling of processing and accounting of personalized databases of images, texts, signals, and tabular data on the basis of the efficient feedback;

– Dialogue of mathematical, informational, natural science and humanitarian cultures and the end result of synergy and self-organization of schoolchildren in research activities and assessment of the quality of knowledge and competencies;

– Optimization of the results of intelligent systems functioning towards their classification, clustering, segmentation, regression in accordance with the standards and samples of intelligent management of cognitive activity and assessment of the results of mathematical education.

The hybrid intelligent system of knowledge and competence assessment is based on the dynamic random selection of parameters on layers of artificial neural networks with the implementation of fuzzy rules and their characteristics using expert systems and fuzzy simulation. In the course of recognition of the results of mastering complex didactic field of learning elements of KSEMA (knowledge, skills, experience, mathematical methods, algorithms, and procedures), direct-acting neural networks with reverse propagation of action error and fuzzy simulation of rules of input variable phasing, including those on hidden layers, are used. The value of the activation function is determined by a generalized Gauss function or a sigmoid function based on fuzzy simulation. The structural-logical, hierarchical, functional, and fractal scheme of the didactic field structuring of the learning elements is

updated through visual modeling and determination of local attractors with incomplete information and attraction basins of background information. Technological constructs of clusters of the foundation of generalized construct components towards using elements of fractal geometry have been developed. In particular, tooling of the didactic field of KSEMA learning elements with a system of multilevel hierarchical databases of exercises, motivational-applied, research, and practice-oriented tasks using expert systems and integration of mathematical, information, natural science, and humanitarian knowledge and procedures is identified.

Polyvalence, multiplicity, multi-polarity, unpredictability, emergence and disequilibrium of the modern world cannot but be connected with the categories of development of the essence of objects, phenomena, and processes through the manifestation of transition regularities to higher levels of complexity as components of the specific general theory of development (V.V. Orlov, St. Beer, N. Wiener, J. von Neumann, etc.). Since the essence reveals its reality in the aggregate of external characteristics of the subject in its manifestations, disclosing the essence through philosophical categories of internal, general, content, reasons, necessity, and law, let us determine, first of all, the component composition of the content and procedural characteristics of the essence manifestation in the process of evaluation activity. *The informative mode* means sign-symbolic, verbal, figuratively-geometric, and tactile-kinesthetic manifestations. *The procedural mode* means historical-genetic, specific-activity, experimental, and applied manifestations. Comprehension by trainees of the essence of the subject in a particular categorical field of knowledge and work methods sufficient for the success and efficiency of operation with it does not necessarily coincide in content and expression of the necessary essential communications. Moreover, it is possible to attach additional communications which, in combination with necessary communications, create the integrity and hierarchy of the essence in this categorical field. This variability and mobility of the subject essence requires the actualization of a step-by-step progression to its cognition and sets the third dimension of the essence – personal-adaptable one in its characteristics, thus defining the three-component integrity of the subject essence as an object of cognition during cognitive activity.

Thus, we present the following *structural and functional model of the essence of mathematical learning elements* (Figure **1**), according to paper (Smirnov, Tikhomirov, and Dvoryatkina, 2020):

In this case, the procedures of mastering the generalized essence and transition to the processes of individualization in the areas of the nearest development of trainees will be more pronounced and

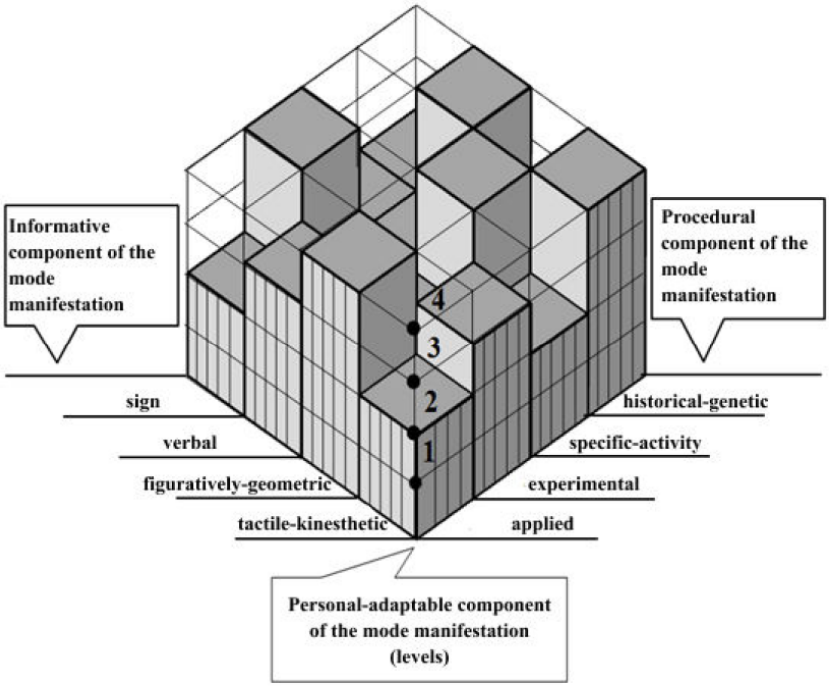

Figure 1: Cube of essence of the generalized construct of modern scientific knowledge.

directed if the orientation and information basis of learning activities of trainees are cemented by specially designed learning content visually simulated in the form of spirals or clusters of the foundation of primary learning elements. *Thus, experience foundation as an innovative mechanism of personal development, manifestation and comprehension of the essence of the generalized construct of mathematical education in the course of evaluation activities can be developed in three educational niches: the content of school mathematics training, technology of implementation of adaptation processes and development of personal qualities of trainees.*

Individual experience foundation becomes especially relevant in the modern period when there are increasing tendencies towards the development of the motivational sphere, metacognitive experience, processes of self-actualization, and personal self-fulfillment. It happens against the background of the deployment of adequate pedagogical conditions, subject content, means, forms, and technologies of teaching subjects of the natural science and humanitarian cycles, as demonstrated in the paper (Smirnov, Tikhomirov, and Dvoryatkina, 2020). The foundation procedures for the transition from the present state of the essence and its actual presentation to the generalized potential development of the essence in the form of an ideal object (process or phenomenon, state of personal qualities) are multistage, multifunctional, directed, and integrative for the actualization of intrasubject and intersubject communications. The design of local attractors of the didactic field of school mathematics learning elements can be an efficient tool for revealing the processes of mastering complex knowledge on the basis of personal experience foundation.

The methodology of introducing intelligent systems into mathematical education and knowledge and competencies assessment is based on the Hegelian triad: thesis - antithesis - synthesis:

The thesis is the implementation of the coherence principle (coordinated action of different foundation and efficient feedback) in the integrity of the educational content and the foundation structure of internal and external communications of a complex system or object;

The antithesis is the implementation of principles of the fractality and historiogenesis of revealing the essence of research objects and procedures of "problem zones" or integrity of reflection of local attractors in the complex system (knowledge and procedures) in the processes of development or assessment of activity quality;

The synthesis is the implementation of the principles of self-organization of the trainee's creativity and reflection of the inversive integrity of a complex system or object in the processes of mastering or assessing the quality of mathematical activity using intelligent systems on the basis of fuzzy modeling.

The type of modeling of the generalized construct, content and structure of the didactic field of learning elements (search for local attractors and fractal constructs) to be evaluated based on the revealed essence can be phenomenological and genetic. Following D.B. Elkonin and V.V. Davydov's concepts, it is possible to note that the phenomenological type of modeling corresponds to attributes and properties of the empirical thinking formation. In this case, there take place a designation of sensible properties of objects and their communications, the abstraction of these properties, their classification, and generalization on the basis of the formal identity of their separate properties and their external changes in interaction. The genetic type of modeling corresponds to the attributes and properties of the formation of theoretical thinking when the unobvious hidden essential communications of objects, processes, and phenomena of the role and functions of the component relationship within the system, the conditions of their origin and transformation take place. After analyzing the essence identification and the most ideal object, the ascent to the real sensually-specific integer takes place. Therefore, the technology of manifestation of synergy and foundation procedures in the processes of evaluation activities of schoolchildren and structuring the didactic field of learning elements can be oriented respectively to the phenomenological or genetic type of revealing the essence of the generalized construct of scientific knowledge.

The foundation procedures for the transition from the present state of the essence and its actual presentation to the generalized potential development of the essence in the form of an ideal object (process or phenomenon, state of personal qualities) are multistage, multifunctional, directed, and integrative for the actualization of intrasubject and intersubject communications. In this case, the transition procedures in the areas of the nearest development will be more pronounced and directed if the orientation and

information basis of the learning activities of trainees are cemented by specially designed learning content visually simulated in the form of spirals or clusters of the foundation of primary learning elements.

Let us highlight a number of technological stages of the deployment of foundation and fractal procedures *in the processes of construction of the didactic field and local attractors of learning elements* of school mathematics, subject to evaluation activities using hybrid intelligent systems with the manifestation of synergetic effects and reflection of the phenomenological type of simulation of the essence of the generalized construct:

– *The motivational* stage *(self-actualization – "I'm interested")* is manifested in the expression of value and personal-adaptation characteristics of cognitive activity of trainees to master the standards and samples of the phenomenology of visual simulation of the generalized construct and the results of diagnostic procedures. This expression is directed towards the importance and values of the method choice of activity for revealing a separate quality of manifestation of the generalized essence (informative or procedural component); search and analysis of identification of the stages of scientific cognition, research methods, and mechanisms of implementation of intrasubject and intersubject communications on the basis of professionally oriented and research approaches; the attitude of the individual to self-determination and self-organization, mastering the principles and styles of scientific thinking such as induction, deduction, insight, analogy, inversion, and anticipation;

– *The tentative information saturation stage (self-determination – "what can I do")* is carried out in the implementation of empirical samples and design of visual models of foundation procedures for the presentation of particular manifestations of the generalized construct essence based on cognitive independence and actualization of actions, competencies, and characteristics of personal qualities. It includes the implementation of the process of revealing essential communications and continuity of empirical generalizations, comprehension of the functionality of the mathematical content level of the essence manifestation of the generalized construct and correction of the state of its parameters and conditions, adequacy and effectiveness of the "goal-result" orientation correlation, basics and integrity of the constructs under design as an orientation and information basis of purposeful and variable educational activity;

– *The procedurally-active stage (self-organization – "I am able to control the process")* appears in the design and organization of mastering technology by trainees of research procedures of mastering of innovative manifestations of the essence of the generalized construct during deployment of its foundation stages and based on actualization of techniques of creative cognitive self-activity and dialogue of mathematical, information, natural science, and humanitarian cultures. At the same time, forms, methods, and means of mastering the generalized construct are developed and implemented, which are adequate to their local, modular, and global manifestations of the deployment of foundation procedures;

– *The control and correction stage* (evaluation of empirical verification of results) manifests itself in the design of functions and steps of monitoring and diagnostic procedures for measuring the state and expansion of experience, the development of psychical functions, synergetic effects, and characteristics of personal qualities of trainees. It includes definition and optimization of technological procedures and the subject content of education, the level of mastering the essence and stages of deployment of spirals and clusters of foundation experience of the personality in the course of the mastering the essence of the generalized product as necessary component of the didactic field and basis for the variability of adaptation processes of modern achievements in science*;*

– *The summarizing and transformative stage (self-development of personality – "I can do something new")* is characterized by the content and characteristics of the innovation transfer in the mass practice of school mathematics mastering; integration of individual and social in the design of innovative generalizing constructs; information exchange, socialization, and verification of the innovation activity; characteristics, parameters, and indicators of formation and expression of individual educational trajectories of schoolchildren.

RESULTS

One of the most important properties of human intellect is the ability to make correct decisions in conditions of incomplete and unclear information. The questions of translation of our approximate reflections into the mathematical basis, construction of corresponding control algorithms and models, and their use in computer systems are a subject of the scientific discipline called fuzzy logic. In fuzzy logic, as opposed to classical logic, instead of values such as truth and lie, the truth degree is used. Currently, the scope of application of these opportunities is extensive and diverse; they are used in various expert systems, such as systems for assessing global processes (for example, air pollution) and earthquake prediction, as well as in the management systems of large business and production (for example, in the automated control systems of factory workshops), in transport, the military field, for the study of the environment and natural resources, etc. A number of systems support the construction of fuzzy cognitive maps, which are used to simulate and represent the causal relationships identified between the concepts of some area, taking into consideration the degree of their impact.

Thus, within the framework of the ongoing long-term study of the intelligent system development to support evaluation activities, it can be stated that ensuring the integrity of the didactic field of the learning elements to be evaluated is determined by the following factors, stages, and design methods:

1. Construction of the structural and logical (functional, fractal, hierarchical) model of the learning information block (relation of order, selection of basic learning elements (knowledge, skills, mathematical methods, and procedures – KSEMA)), construction of hierarchies and levels of achieving completeness, coding of information, etc.);

2. Construction of a functional model of external communications and generalization of objects (spirals and clusters of foundation, coordination graphs, structural and logical analysis of learning elements, etc.) of learning information blocks on the basis of the layered structure;

3. Tooling the units of educational information with knowledge bases, task banks (motivational-applied, research, professionally-oriented, standards, exercises, etc.) of different levels and information and time saturation;

4. Identification of boundaries of critical essential parameter variations of the object integrity, exceeding which leads to a violation of integrity, destruction (loss of substantial communications)

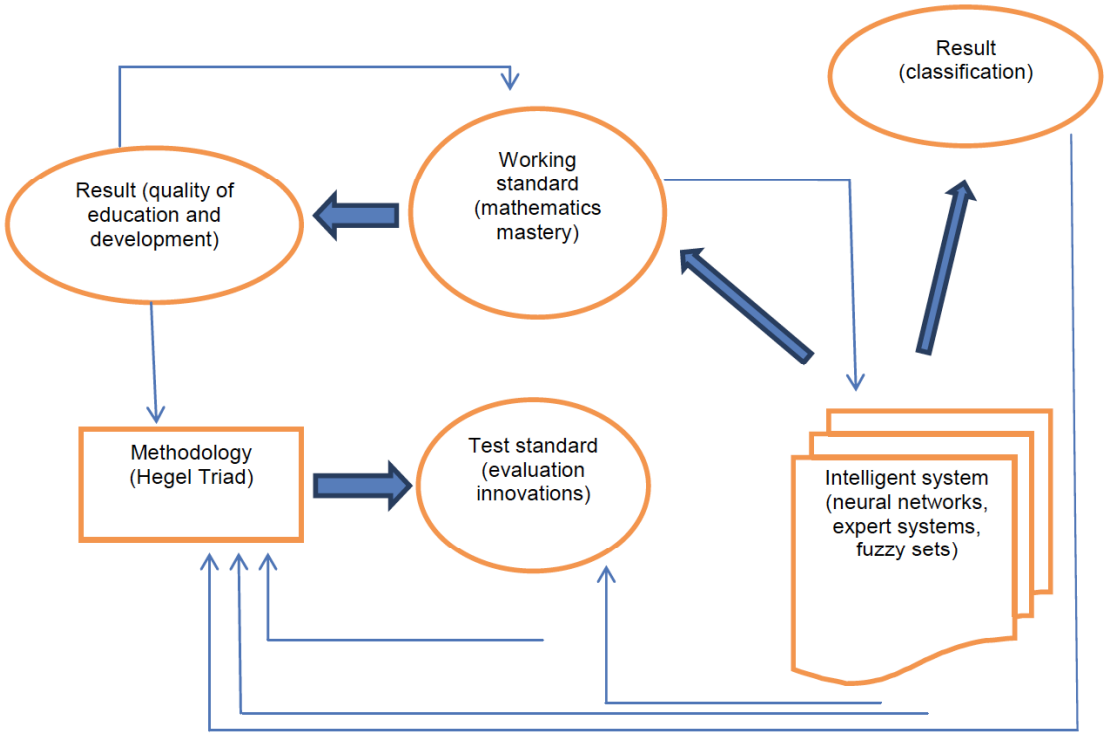

Figure 2: Logic of the intellectual system structure on the basis of fuzzy simulation.

of the object ("growth limits" (Meadows, Randers, and Meadows, 2015) as well as the development of the KSEMA base reflecting access to the "growth limits."

The main requirements for the organization and construction of the artificial neural network for the assessment of personal achievements on the basis of fuzzy simulation (Figure **2**) are as follows:

1. The artificial neural network should be a multi-layer network (consisting of input, output, and hidden layers) of direct action with backward propagation of errors on the basis of fuzzy simulation. The state of each neuron on the input layer is determined for linguistic evaluation by an expert (teacher) from 3 positions of the term set – 0 (bad), 1 (medium), 2 (excellent) during verbal communication with the examinee.

2. In the function of input variables x_i of the intelligent system (i = 1, 2,..., 10), we use assessments of three groups of interrelated factors V_j (j = 1, 2, 3) characterizing the parameters of knowledge and competence assessment which, respectively, determine the following qualities: V_1 – achievements of subject outcomes of the education content, V_2 – achievements of meta-subject outcomes of the education content, and V_3 – achievements of personal learning outcomes.

3. The neural network should include 2-3 hidden layers with an equal number of neurons (10 neurons per each layer). It should have the output fixation of the neuron state along the way through the hidden layers so that the output layer contains one active neuron and nine neurons with the output fixation on the hidden layers of the neural network. The sigmoid activation function on each hidden layer will be used (Figure **3**).

4. Weights on the hidden layers of the neural network are considered of two types. Internal weights are $w_{il}^{1}(V_j^k)$ (j =1,2,3, where k denotes the number of the hidden layer i,l ϵ {1,2.3,…., 10}), which are set a priori and can be corrected in supervised learning with a neural network teacher. In this case, the adder is Σ_1, and the external weights are $w_{lp}^{2}(V_j^k)$, where p = 1, 2 and p < 3, correspond to the asked additional questions (exercises, tasks) y_p from the databases according to the current fixation rates of the parameters on the hidden layer; in this case, the adder is Σ_2. The common adder on each hidden layer and neuron is $\Sigma = \Sigma_1 + \Sigma_2$. The weight of an additional question is determined by an expert (teacher) from 3 positions: 0 (bad), 1 (medium), 2 (excellent) during verbal communication with the examinee.

5. The expert (teacher) fixes the output state of a neuron in the hidden layers with a specific symbol. Further, the state of a neuron does not depend on the adder Σ2 of additional questions during the way through the hidden layers.

6. There must be multiple standards of the output layer vector state, which forms the basis of classification and recommendations for the final evaluation of the quality of learning elements mastering or competencies (on a 5-point, 10-point, or 100-point scale). Also, a set of learning samples should be developed, according to the run of which the neural network training with the teacher will take place.

7. Before the beginning of the examination procedure, verbal contact with the expert (teacher) and fixation of input layer neurons, the examinee incidentally receives a fragment of learning information with incomplete data from the databases of learning elements (local attractor KSEMA), as demonstrated in the paper (Bogun and Smirnov, 2018).

Thus, in the course of the research on the basis of integration and generation of scientific material trends and dynamics of knowledge and competence assessment methodologies using intelligent systems have been identified. In the same way, the innovative system of knowledge and competence assessment of trainees using artificial neural networks has been developed. These results have been achieved through the design of the author's methodology and implementation of mathematical and computer modeling of the software complex of the hybrid intelligent system for assessment of learning outcomes.

CONCLUSION

Original results and theoretical models of using a hybrid neural network on the basis of fuzzy simulation of teacher's evaluation activities in the context of computer and mathematical modeling using expert systems have been obtained. The peculiarity of the

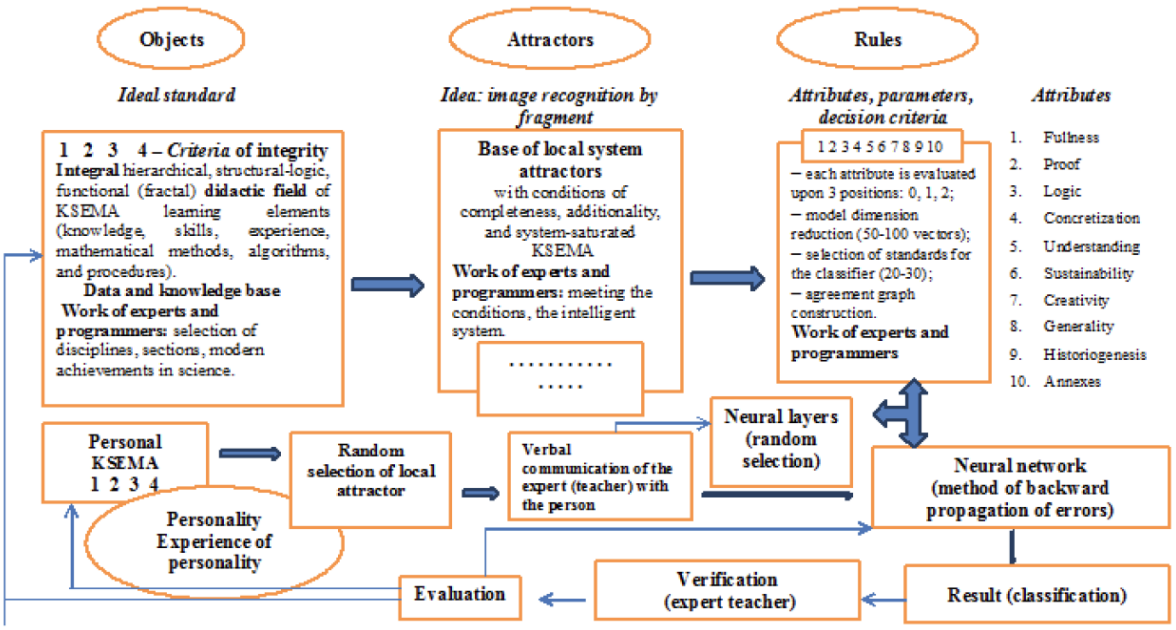

Figure 3: Intellectual hybrid model of quality recognition of learning elements mastering.

presented approach is interactive communication (person – intelligent system – expert (teacher)) during the evaluation activity of quality conformance of recognizable learning elements to the a priori standard. The structural-logical, hierarchical, functional, and fractal scheme of the didactic field structuring of the learning elements has been updated through visual modeling and determination of local attractors with incomplete information and attraction basins of background information. Technological constructs of clusters of the foundation of generalized structures components towards using elements of fractal geometry have been developed. In particular, tooling of the didactic field of KSEMA learning elements with a system of multilevel hierarchical databases of exercises, motivational-applied, research, and practice-oriented tasks using expert systems and integration of mathematical, information, natural science, and humanitarian knowledge and procedures has been identified. Structural and informative components of the design methodology of innovative didactic field of learning outcomes, as well as criteria for their selection and complexes of standards, were tested in a pilot experiment in schools and universities of Yelets and Yaroslavl in 2014-2019. Building the process of evaluation activities on the basis of the implementation of a hybrid intellectual environment of support will make it possible to introduce clear elements of objectivity of evaluation activities both at school and at university, and create conditions for the holistic development of educational programs. This method is innovative in pedagogy since the time of John Amos Comenius and requires further research by teachers, mathematicians, and specialists in the area of intelligent systems.

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