Expert system for assessing the labor professions complexity

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Abstract. The problem of building a model of professional activity (working specialties) is an urgent scientific task due to the need for a clear formalization of tariff assessment levels, built on indicators of work complexity. The article deals with topical issues of formalizing the factors characterizing the complexity of the work, the task of developing an expert system designed to automate the calculation of estimates due to the weak formalization of the developed factors of the work model. Also motivational indicator of work formalized.

Keywords: work complexity, expert system, motivational indicator of work.

1 Introduction

Labor (professional activity) - conscious deliberate activities of people, aimed at changing the subject of labor with the tools of work in certain organizational forms work. The main content and components of labor are work performed by the employee. Work - certain tasks and duties that are performed, are been performing or should be performed by one person.

The job (work) complexity is an objective characteristic that reflects the content of the labor process and manifests itself in the requirements for worker qualification. Analytical evaluation of professional activity involves the allocation of the upper level characteristics of the model structural elements (entities) (Fig. 1) [1, 2], which, in turn, combine the characteristics of individual operations with certain features: educational-qualification level, methods, means of operations etc., i.e. expand and combine elements of models.

Professional activity is seen as the application of efforts and knowledge, skills and abilities to achieve the goals of the organization. The meaningful analytical evaluation of professional activity involves the presentation and processing of quantitative data using the theory of information and methods of mathematical apparatus and modeling, which involves the development of an ideal design, the so-called conceptual (content) model. The conceptual model is used to formalize the boundaries of the research object and needs further detail for the transition directly to the subject of research within the framework of the corresponding structural and functional-logical (information) models, detailed to a level sufficient and necessary for the analysis of professional activity - the level of entities and their attributes [3, 4].

2 Professional activity model

The proposed method of allocating professional activity structural elements and combining them with a clearly defined feature in groups allows to obtain a professional activity structural model at a more detailed level, in which the main emphasis is on the entities characteristics and the connection between them as elements of a complex system (Fig. 1).

Thus, professional activity consists of the number of successive or parallel operations and procedures, which in general constitute the technology of work, determined during the division of labor.

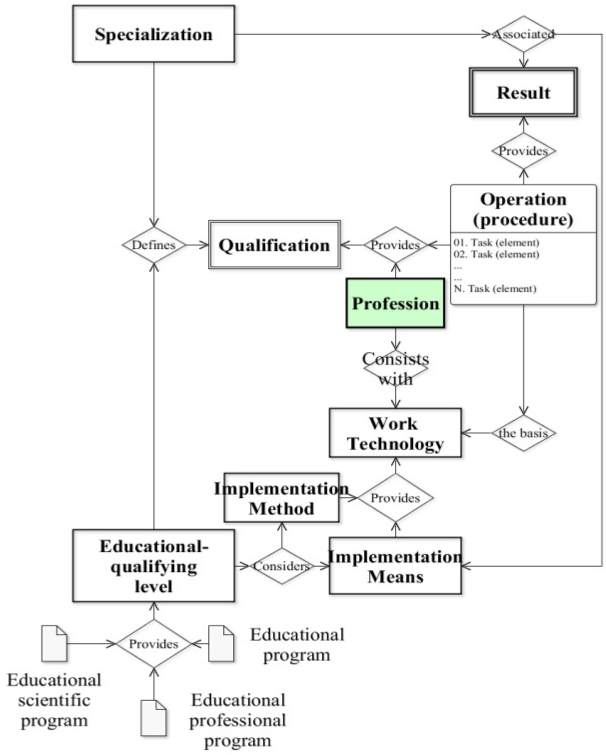

Fig. 1. Professional activity model.

The technology of work is a rational sequence of operations and procedures that are performed using specific means and methods of production in order to influence the object of management. The basis of the technology of work is the operation (Fig. 1).

Operation is any action, event (or system of events) that is united by a single plan and aimed achieving a corresponding goal. The complex of actions performed within the framework of one operation may consist of several elements (tasks), therefore the operation can be considered as a set of elements (tasks) of labor processes performed by employees. Target completeness of action with respect to the performer is considered as the basis for the construction of the operation.

Thus, the operation (task) is a basic element of professional activity, which is subject of formalization in the form of a structural model for further functional-logical modeling within the framework of developing the theoretical foundations of analytical evaluation of professional activity.

The generalized structural model of professional activity in the annotation "entity – connection" [5] (Figure 2) describes the conceptual structure of a complex socio-technical system, which is used for further detail through parametric studies.

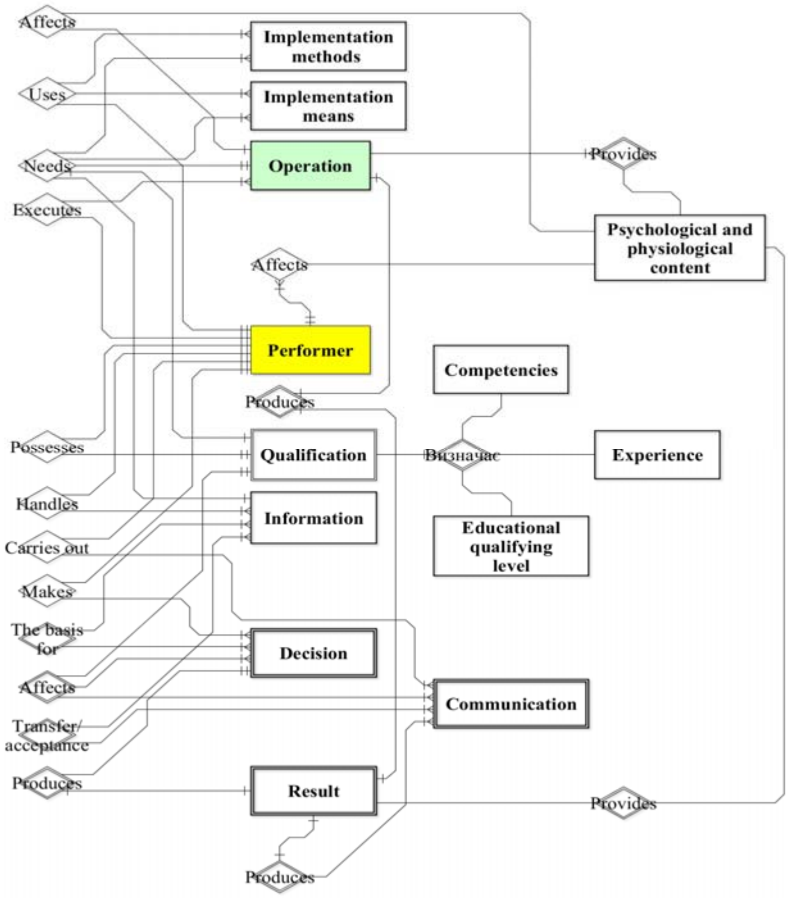

Fig. 2. Conceptual model of professional activity.

Existing methods for work complexity assessing consider professional activity in terms of certain efforts aimed at achieving the technological goal, and is determined by the combination of technical and organizational factors of the labor process: the complexity of equipment, its maintenance; the complexity of tools, etc.

The main factors determining the complexity of workers' work were grouped into four main groups [6]:

1. Technological factors.
2. Organizational factors.
3. Factors of responsibility.
4. Specific factors.

In addition, the complexity of labor is determined by the type of labor process, including the degree of its mechanization for the working professions:

Manual labor processes - executed manually with the help of mechanized tools of labor. Within the framework of this type of labor processes, it is necessary to distinguish separately hand-made creative work, which differs from most hand-made works by the increased content of creativity elements, artistic imagination, individual author's character of performance and other qualities inherent in, for example, work on the manufacture of folk arts products, jewelry-filigree production etc.

Machine labor processes - the main work is performed by machines, and elements of auxiliary work - manually or with the help of mechanisms. For example, machining of parts on mechanized feeders.

Machine-manual labor processes - performed by machines or mechanisms with the direct participation of the worker, when both the energy of the machine and the efforts of the performer are used simultaneously.

Automated labor processes - the main work is mechanized completely, and the auxiliary - partly (semiautomatic) or completely (automatic). In this case, the management of the work of the mechanisms is carried out automatically. In such cases, the function of the workers is reduced to the installation of machines, monitoring their work, eliminating defects, and on semi-automatic machines - to periodically present raw materials and the removal of finished products.

Hardware (instrumental) labor processes - carried out with special equipment (apparatus) by influencing the subject of work of thermal, electrical or chemical energy. In this case, the workers regulate the course of such processes. For example, iron melting, heat treatment of parts, most processes in the chemical and petroleum industries, etc.

The distinction between the types of labor processes affects the evaluation factors for each specialty. The essence of the assessing the complexity of labor analytical method is in a consistent, factor-to-factor assessment of the complexity of labor, the result of which is the integral index of complexity, - is the sum of evaluations by individual factors. Using this approach allows comparing the complexity of various, technologically unrelated works with a sufficient level of accuracy.

Each of these groups is divided into lower level factors that have a verbal description. To provide an objective assessment of the labor complexity, it is necessary to formalize the result in a digital form, taking into account the criteria of complexity for each factor, and their influence.

The methodology involves a combination of research methods and strategies, as well as certain hypotheses and ideas that need to be clarified and confirmed by relevant research:

1. It is assumed that in any profession it is possible to identify and evaluate a set of common factors that describe the main functional areas in its content, which will ensure the requirement for universality of the model of activity.
2. In principle, it is possible to allocate the minimum and sufficient number of its structural elements to ensure the adequacy of the model.
3. It is assumed that presentation of professional activity in the form of a graph (graphic model) will allow to explore it as a system of interconnected operations and to calculate their weight characteristics.
4. It is assumed that the use of fuzzy set theory methods to describe the weakly structured elements of the model (factors, characteristics), will allow to ensure its universality by extending the boundaries of modeling.

The proposed hypotheses meet the requirements of the ability, in particular explain all the phenomena and processes for which they have been used; can describe a broader class of phenomena and processes (new types of professional activities) and are fundamentally simple.

An analytical evaluation of professional activity is based on the analysis and evaluation of clearly formalized characteristics of operations (tasks) performed by the employee within their responsibilities. Characteristics of operations (tasks) are formalized exclusively with the help of structural modeling with further detailing of the main attributes within the functional-logical (informational) model, the main assumption during the development of which is given by the hypothesis 2.

Consider the structural model of the field of knowledge. Functional-logical (information) model (Fig. 3) - model of the research object, presented in the form of information describing the structural elements and variables of the object essential for this consideration, the characteristics of the elements, the connections between them, the inputs and the outputs of an object, which allows, through the input of information on the change of input values, to model the possible states of the object, that is to classify the type of professional activity and carry out its evaluation using analytical methods [7 - 9]. Thus, the conceptual structure of the subject area (Fig. 3 – 5) can be represented by a plurality of structural elements, each of which is described by the basic characteristics.

2.1 Technological factors

Depending on the labor process mechanization level, the influence of technological factors on its complexity varies significantly, as the degree of contact between the worker and the subject of work also changes. On the other hand, since the growth of mechanization leads to complicated equipment management and the complexity of the technological process and requires higher qualifications, the complexity of labor is greatly increased. Technological complexity factors are divided into components: the complexity of managing tools, the complexity of labor objects, the complexity of technological processes (Fig. 3).

2.2 Organizational factors

Organizational factors characterize the employee's autonomy in the process of performing the work and the breadth of performed works set (Fig. 4).

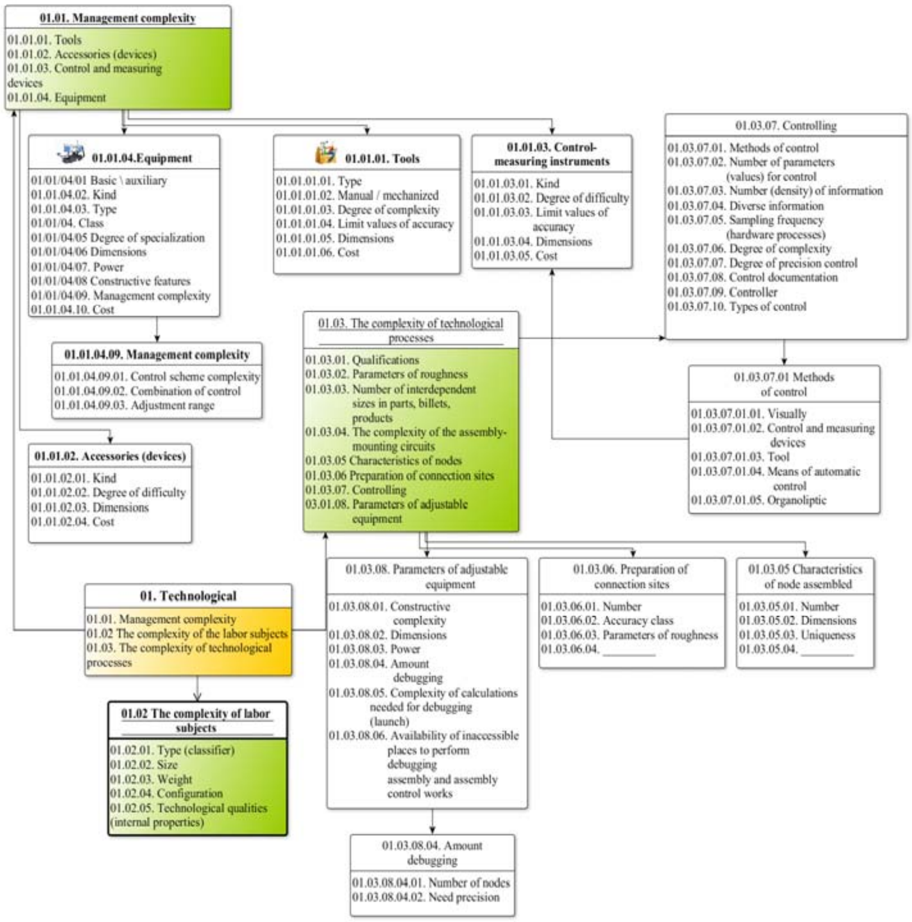

Fig. 3. Technological factors of the activity model.

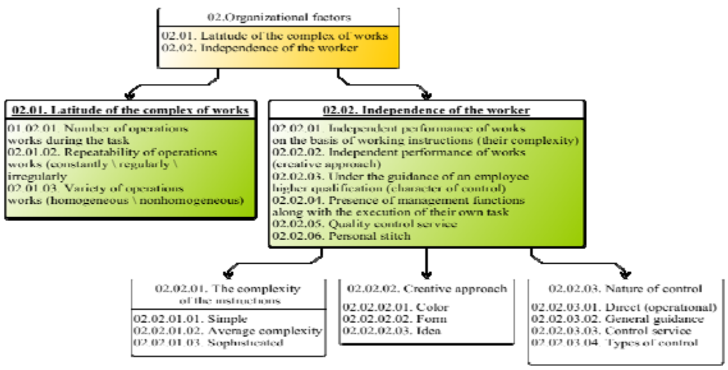

Fig. 4. Organizational factors of the activity model.

2.3 Factors of responsibility

The factors of responsibility allow us to consider work from the point of view of several types of responsibility (Fig. 5): for safety of others and one's own life, for the final result (work completion) and its influence on other units (employees) and the enterprise as a whole, as well as the place of work (its significance) in the technological process. The significance of the work characterizes the degree to which the employee is aware of its significant impact on the organizational system, the organization as a whole, and possibly on society. Completeness means that it requires and allows the completion of an entire and explicit cycle of operations, operations or work from beginning to end with a visible (understandable) result.

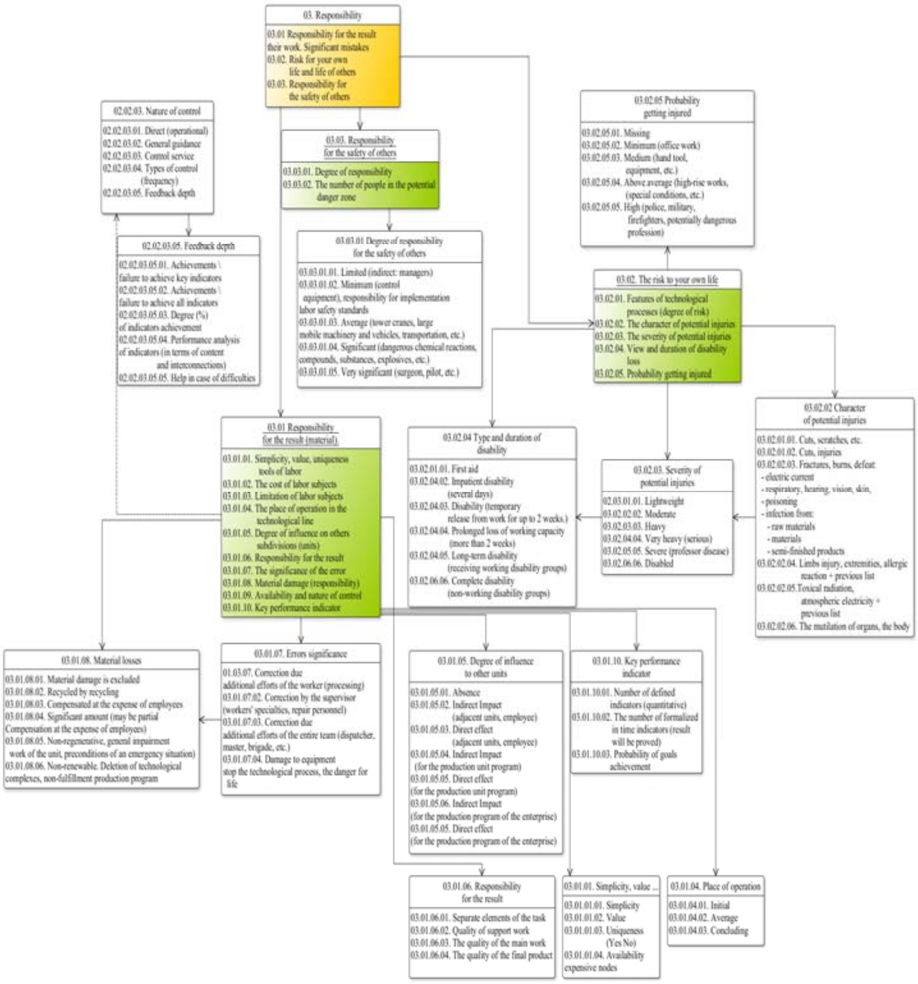

Fig. 5. Factors of responsibility in the model of activity.

3 Indicator of the work motivation potential

The F.Gerzberg's theory of the work characteristics addresses five main factors that determine the motivation and satisfaction of the employee in the work: variety (VAR), completeness (end result, COM), significance (degree of influence, SIG), independence (IND), feedback (control, FDB). All these factors and their attributes were considered in the models (Fig. 3-5).

In practice, using the procedure for diagnostic evaluation of the work characteristics, indicators related to the five mentioned aspects are combined and a single indicator – motivational potential indicator (MPI) is received.

$$MPI = \left(\frac{VAR + COM + SIG}{3} \right) \times IND \times FDB \tag{1}$$

The variety of the operation (work) is described by aspects of 02.01.02 and 02.01.03, which are evaluated by the corresponding ordinal scales (Table 1, 2).

Table 1. Repeatability of operations (works), k_1

Attribute value	*Scores*
Constantly	1
More regularly than constantly	2
Regular	3
Regularly with variable schedule	4
Irregularly	5

Table 2. Variety of operations (works), k_2

Attribute value	*Scores*
Monotonous homogeneous	1
Monotonous heterogeneous	2
Varied homogeneous	3
Varied heterogeneous	4

Completeness of work is determined by aspects of 03.01.04., 03.01.06. (Table 3, 4). The coefficient of diversity is used together with the index of homogeneity of the profession, which is determined by the coefficient of clustering k_{kl} of the work graphic model [10 - 11].

Table 3. The location of the operation in the technological line, k_3

Attribute value	*Scores*
Initial	1
Average	2
Concluding	3

Table 4. Responsibility for the result, k_4

Attribute value	*Scores*
Separate elements of the task	1
Quality of support work	2
The quality of the main work	3
The quality of the final product	4

The significance of the work is presented by aspects of 03.01.05., 03.01.07., 03.01.08. (Table 5-7).

Table 5. Degree of influence on other units (employees), k_5

Attribute value	*Scores*
Missing	0
Indirect impact on adjacent units (employees)	1
Direct influence on adjacent units (employees)	2
Indirect impact on the production program of the unit	3
Direct impact on the production program of the unit	4
Indirect impact on the production program of the enterprise	5
Direct impact on the production program of the enterprise	6

Table 6. Error significance, k_6

Attribute value	*Scores*
Correction due to additional employee efforts (processing)	1
Correction by the supervisor	2
Correction due to additional efforts of the whole team (dispatcher, master, brigade, etc.)	3
Damage to the equipment, stopping of the technological process, danger to life	4

Table 7. Material damage, k_7

Attribute value	*Scores*
Material damage is excluded	0
Recovery due to recycling	1
Compensation at the expense of the employee	2
Significant amount (compensation is possible partly at the expense of the employee)	3
Non-recoverable (violation of the general work of the unit, precondition of the emergency situation)	4
Non- recoverable (failure of process equipment, failure of production program)	5

Independence of work is determined by aspects of the factor 02.02. (Table 8,9).

Table 8. Independence at work, k_8

Attribute value	*Complexity*	*Scores*
Under the direction of the head of the highest category (leader)	------	1
Independently based on working instructions (complexity of instructions)	simple	2
	medium complexity	3
	complex	4
Independently (creative approach)	color	5
	form	6
	plan (idea)	7
Presence of management functions	------	8

Table 9. The nature of control, k_9

Attribute value	*Scores*
Direct (urgent)	1
General management (subdivision)	2
General control (functional direction)	3
Operations management (enterprise), statement of general objectives	4

The feedback is determined by the aspects included in the 02.02.03 factor. (Table 10, 11)

Table 10. Depth and volume of feedback, k_{10}

Attribute value	*Scores*
Achievement \ not achievement key indicators	1
Achievement \ not achievement of all indicators	2
Degree (%) achievement of all indicators (by periods)	3
Analysis of the indicators performance (in terms of content and interconnections)	4
Help in case of difficulties	5

Table 11. Types of control, k_{11}

Attribute value	*Scores*
Finish	1
Selective	2
Operative	3
Constant	4

Using the assessment scales (Table 1-11), the formula (1) can be submitted (2):

$$\overline{MPI} = \left[\frac{\left(\frac{k_1 + k_2 * k_{kl}}{2}\right) + \left(\frac{k_3 + k_4}{2}\right) + \left(\frac{k_5 + k_6 + k_7}{3}\right)}{3} \right] \times \left(\frac{k_8 + k_9}{2}\right) \times \left(\frac{k_{10} + k_{11}}{2}\right) \quad (2)$$

The value of the motivational potential of work is theoretically in the range of 1 - 100%, however, there is practically no work with motivational potential that accepts minimum and maximum values. The practical application of evaluating the motivational potential of the work consists in the development of recommendations for the improvement, reorganization of some aspects of work in order to improve the indicators of these factors (Table 1 - 10), since their degree of manifestation determines the probability of obtaining high results of work both in personal and organizational sense.

4 An expert system for work complexity assessing

The existing methodology involves evaluating the factors and their characteristics using a grading scale, which somewhat complicates the evaluation itself, as many factors can't be described in digital form. That is why the task of developing the concept of a knowledge-based information system was solved and a prototype expert system for the task evaluation of complexity of work was developed. This approach involves reviewing expert assessments of the task significance in terms of the fuzzy sets theory and the use of expert knowledge.

Formalization of expert's knowledge is related to the description of qualitative characteristics, which are usually not structured and can't be unambiguously interpreted. In addition, in problems solved with the help of intelligent systems, it is necessary to use inaccurate knowledge that can't be accurately interpreted as true or false, for example, the importance of the operation, its implementation time - the characteristics that determine the weight of each operation.

Using the conceptual apparatus of fuzzy logic, linguistic variables were introduced, which are part of the models of professional activity. Linguistic variable is a variable whose value is determined by the set of verbal characteristics of some property [12].

Each value of a linguistic variable is defined as a fuzzy set, which, in turn, is described by the base ordinal scale X and by the membership function μ (x).

The main tasks within the development of an expert system for the analytical evaluation of professional activities are the task of developing an appropriate knowledge base, mechanisms for its filling and integrating the work memory block with the module of algorithms for working with entities. The terminology of CLIPS [13 - 15] is used in the presentation of the material in connection with the free distribution of its code and the syntax typical of many common programming languages of expert systems.

The main elements of the expert system are represented by facts, production rules and rules within the framework of IT development of professional activity analytical evaluation. Within the scope of the study, a field of knowledge was defined - a model of knowledge about the subject field, that is, the transition from structured knowledge to its formalization was carried out. Production model N_p of knowledge (products) filed is presented by cortege (3):

$$N_p = \left(S_{p_d}; R_{a_p}; A^r \to A^s; R_{b_p}\right), \tag{3}$$

where S_{p_d} – description of the situations class; R_{a_p} – the condition under which the products are activated; $A^r \to A^s$ – the products core (3); R_{b_p} – condition (action) to be performed after the core is implemented (4):

$$P_t = \bigwedge_{r=\overline{1,r}} A^r \to \bigwedge_{s=\overline{1,s}} A^s, \quad (4)$$

where P_t – production designation; *t* – number of products in the production model; A^r – variable predicate (fact) from *r* variables, which is called parcel; A^s – variable terminal predicate from *s* variables, which is called the conclusion.

Input variables predicates that describe the current state of the model of professional activity and are part of the production model solely as parcels (5):

$$A^r\left(\left[a_{ij}\right]_1, \left[a_{ij}\right]_2, ..., \left[a_{ij}\right]_r\right). \quad (5)$$

The terminal predicates that determine the new states of the model parameters and are part of the production model solely as conclusions (6):

$$A^s\left(\left[a_{ij}\right]_1, \left[a_{ij}\right]_2, ..., \left[a_{ij}\right]_s\right). \quad (6)$$

Using the conceptual apparatus of fuzzy logic, fuzzy sets are introduced that describe the input and terminal predicates defined by the membership function. Linguistic variables with the help of sets of standardized functions are given slightly structured parameters of the professional activity model. The templates for presentation of knowledge in the expert system taking into account (3-6) and the syntax of the productive programming language CLIPS [16] are presented as designs (7):

$$P_t = \begin{pmatrix} defrule\left\langle N_p \right\rangle \left[S_{p_d}\right] \\ \begin{pmatrix} \left(R_{a_p}\right) \\ \left(\left\langle a_{ij} \right\rangle \left\langle value \right\rangle\right) \\ (...) \\ \left(\left\langle a_{ij} \right\rangle \left\langle value \right\rangle\right) \end{pmatrix} \\ \Rightarrow \\ assert\left(\left\langle a_{ij} \right\rangle \left\langle value \right\rangle))\right) \\ R_{b_p} \end{pmatrix} \quad (7)$$

The rule header defines conditional elements (CE), or LHS-rule - Left Hand Side - the left side of the rule or the input predicates (5). If the rules templates do not conflict with the active facts and the condition is fulfilled R_{a_p}, the core of the product is activated and moved from the knowledge base to the working list of rules of the machine of logical output [16]. Terminal (6) part of the rule is given by a list of actions (RHS-rule - Right Hand Side), which must be executed when the rule is activated with the assert operator.

The generalized syntactic structure of the knowledge field, realized within the expert system, is given by the expression:

$$F_k = \langle A, M, E \rangle,$$

where $A = \langle A, A_a, B \rangle$ – the structure of the input data to be interpreted in the system; $M = \langle S_k, S_f \rangle$ – data interpretation model; S_k – conceptual structure of the subject area; S_f – a functional structure that simulates the scheme of reasoning during the interpretation; $E = \langle E_o, E_a \rangle$ – output data structure.

The conceptual structure S_k is based on the revealed conceptual structure of the subject industry with the help of the conceptual analysis paradigm and the principles of hierarchy of concepts constructing. S_k represented by a structural model of professional activity developed within the framework of the research. S_f is presented in accordance with the information model and rules of the knowledge base, the mechanisms of its filling and integration of the working memory block with the module of algorithms for working with entities, that is, the integration of data and algorithms implemented on different bases: imperative and declarative programming languages.

Knowledge-based expert system [17] provides for the activation of relevant rules for the determination and calculation of numerical estimates of factors.

5 Conclusions

1. Patterns of weak structural characteristics of professional activity model structural elements (facts) and rules of the knowledge using the syntax of the declarative programming language CLIPS, which provided the opportunity for practical implementation of program modules, taking into account the characteristics of structural and information models of professional activity are developed.

2. The description of the model's structural elements with the help of the knowledge base developed rules, allowed to expand the boundaries of modeling, which was a significant disadvantage of existing systems and to practically implement the model data within the production information systems.

3. The developed templates of the basic rules allowed to determine the characteristics of the structural elements of the professional activity model and the weight of each operation in terms of linguistic variables, which required the transition to numerical estimates in order to ensure interaction with the calculation module for the evaluation of all activities implemented through object-oriented programming languages.

4. The issue of restrictions on the use of models requires additional research, but the preliminary results give grounds for claiming that they can be used for a wide range of occupations, due to the compliance of the developed model with the requirements of universality.

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